

CAMBRIDGE

INTERACTIVE
TEXTBOOK
INCLUDED



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Cambridge
science
for Western Australia



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How to use this resource

Elements in the print book

You will see the following types of boxes throughout this book.

Glossary

definitions of key terms are provided next to where the key term first appears in the chapter.

Learning goals

These are descriptions of what the student will learn throughout the section.

Explore!

Students are encouraged to conduct research online to find and interpret information.

Did you know?

These are short facts that contain interesting information.

Quick check

These provide quick checks for recalling facts and understanding content. These questions are also available as Word document downloads in the Interactive Textbook.

Science as a human endeavour

These are recent developments in the particular area of science being covered. They may also show how ideas in science have changed over the years through human discovery and inventions.

Section questions

Question sets at the ends of sections are categorised under the following headings: Remembering, Understanding, Applying, Analysing and Evaluating. Action verbs have been bolded. These questions are also available as Word document downloads in the Interactive Textbook.

Hands-on activities

Try this

Classroom activities help explore concepts that are currently being covered.

Practicals

Classroom or laboratory activities and investigations help consolidate student understanding. These activities are also available as Word document downloads in the Interactive Textbook.

End-of-chapter features

Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked question	Check
2.1 I can explain the reasons for classifying living organisms.	5	
2.1 I can group organisms on the basis on their similarities and differences.	8	
2.2 I can use and interpret keys to identify organisms.	11	
2.2 I can explain how biological classification has changed over time.	12	
2.2 I am able to classify using a hierarchical system.	1	
2.1 I can describe the differences between the classification systems used by Aboriginal and Torres Strait Islander peoples and those used by Western science.	6	
2.2 I can use scientific convention when naming species.	4	
2.3 I can recall the six kingdoms.	2	

Data questions

Use the following diagrams to answer the questions.

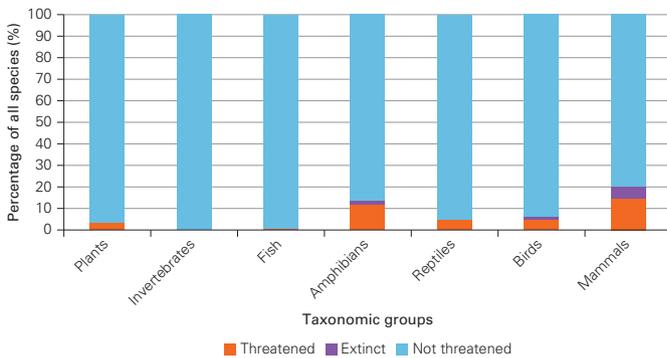


Figure 2.69 The conservation status of different taxonomic groups in Australia

Chapter checklists help students check that they have understood the main concepts and learning goals of the chapter.

Chapter review question sets are categorised under the following headings: Remembering, Understanding, Applying, Analysing and Evaluating. Action verbs have been bolded. These questions are also available as Word document downloads in the Interactive Textbook.

Data questions help students apply their understanding, as well as analyse and interpret different forms of data linked to the chapter content. These questions are also available as Word document downloads in the Interactive Textbook.

STEM activity: Applying biomimicry to solve a human problem

Background information

Engineering is a varied and exciting industry. Engineers often work with designers and architects to use the natural world as inspiration for solving engineering problems and to develop new products that improve our lives. Some examples of biologically inspired designs include Velcro® based on those prickly seeds that stick to your socks on a bush walk, adhesives that mimic the sticky feet of geckos, and solar navigation technology (inspired by the navigation abilities of bees).

This new area of science is called 'biomimicry', which means to imitate life or to learn from nature. Because biomimicry copies nature, it often reflects possibilities for technologies due to the almost endless number of animals, plants and insects. Consider some of the challenges that we face as humans. The natural world faces these challenges too. Therefore engineers can study the way plants, animals and insects approach these challenges and then improve their own designs. For example, the water lenses in water treatment plants are designed to act like animal cell membranes, which let certain substances pass through while others are kept out. In addition, studying a leaf and how it captures the Sun's energy allowed for the creation of more effective solar cells by engineers.

Research and feasibility

- 1 Discuss and agree on a human problem to study with your group. Start by researching the issue by making a list of all the main ideas of the human problem and the effects they have. An example is given below for the issue of road traffic.

Major cause of traffic	Effects	What would animals do here?
Too many cars on the road causes traffic jams.	Too many cars on the road causes traffic jams.	Acts have specialised patterns of movement as they encounter traffic. They actually move faster but add additional lanes.
Blockages on the roads.	Traffic comes to a complete stop.	If there is anything blocking an ant's path, an ant will remove it, which allows the other ants to move past without interference.

- 2 Explain the human problem in a statement and the cost on society (this is not just monetary, but includes environmental, social, and psychological costs, among others).

Design

- 3 Identify your plant, insect or other animal and its scientific name, and briefly describe why mimicking the organism could help with a progressive solution to the human problem.
- 4 Describe the unique features of your organism. Are these characteristics linked to its classification?
- 5 Describe how you mimic the material, colour and structure of the organism to design something new.
- 6 List the materials and their physical properties required to realise your design (remember that you do not need to build your design, so think about all possibilities).
- 7 Describe how each material was used and for what purpose. You may wish to use a table.

Materials	Physical properties	Purpose of material

Create

- 8 Search for ideas within your group, and note on which uses biomimicry to solve the human problem the best.
- 9 Create a scale drawing of your invention, including a front view and side view of your invention.
- 10 Describe your design by listing the special features of the design and which aspect of your organism inspired those features.

Evaluate and modify

- 11 Evaluate your design and its ability to solve the problem you identified. What improvements would you make?

Design brief: Applying biomimicry to solve a human problem

Activity instructions

In teams, you will become design engineers who will use the biomimicry of plants, insects or other animals to develop and design a sustainability-related invention that solves a human problem. Examples of problems you may like to look at could be transportation building design, lighting.

Suggested materials

- A3 and A4 paper
- pens, pencils
- ruler

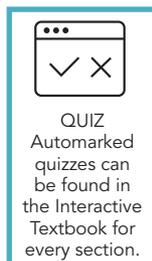
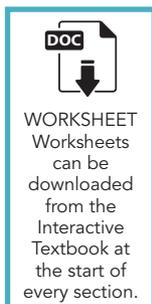
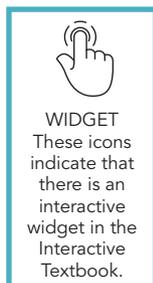
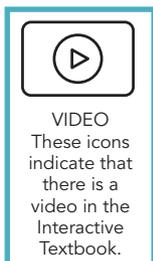
Design brief: Applying biomimicry to solve a human problem

Including water can. Your team will not only draw a detailed and labelled diagram of your design, but also describe your design by listing the special features and which plant, insect or other animal inspired those features. Remember to ask yourselves throughout the process: 'What would nature do here?'

Figure 2.32 A simple shell could be your inspiration for an efficient sustainable house.

STEM activities encourage students to collaboratively come up with designs and build solutions to problems and challenges.

Links to the Interactive Textbook



Overview of the Interactive Textbook (ITB)

The **Interactive Textbook (ITB)** is an online HTML version of the print textbook powered by the Edjin platform. It is included with the print book or available as a separate digital-only product.

Definitions pop up for key terms in the text.

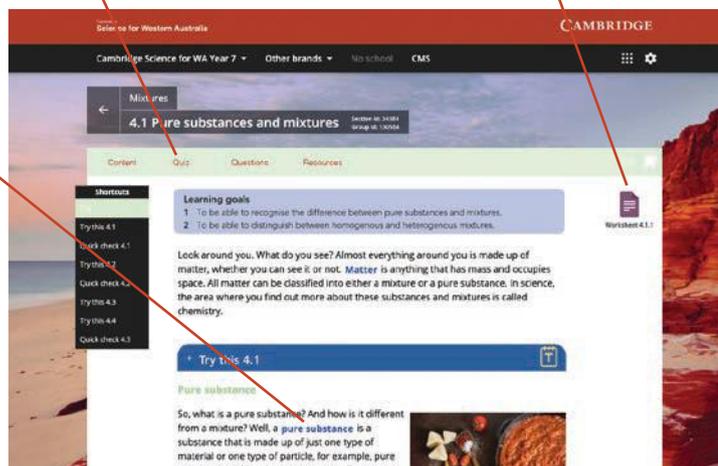
Quizzes contain automarked questions that enable students to quickly check their understanding.

Worksheets are provided as downloadable Word documents.

Videos summarise, clarify or extend student knowledge.

Widgets are accompanied by questions that encourage independent learning and observation.

Practicals are available as a Word document download, with sample answers and guides for teachers in the Online Teaching Suite.



Practical 2.1

Observing *Euglena*

Aim
To observe a single-celled organism under the microscope.

Materials

- *Euglena* sample
- pipette
- compound microscope
- dimple slide
- coverslip
- sharp pencil
- plain paper
- glycerol (optional)

Method

- 1 Set up the microscope on your bench.
- 2 Place a small drop of the *Euglena* sample into the dimple on the slide. One drop of glycerol can be added to slow the movement of the *Euglena*.
- 3 Lower the coverslip on an angle over the drop to protect the sample.
- 4 Place the slide onto the stage of the microscope and focus, using the lowest power magnification first.
- 5 Draw a scientific drawing of the *Euglena* you observe. Use a sharp pencil.
- 6 Use the internet to research the structure of *Euglena*. Label your scientific drawing.

Discussion

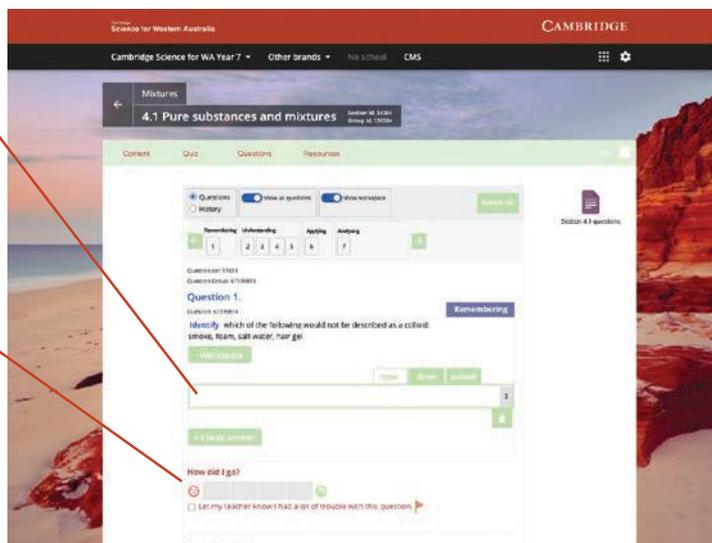
Euglena can make sugars like plants can, but they also have a simple 'eye' spot (sensitive to light, not a true eye). *Euglena* can also move, as you have observed. From your observations, justify whether you believe *Euglena* is more similar to animals or plants.

Be careful

Ensure proper microscope handling and use is observed.

Workspaces enable students to enter working and answers online and to save them. Input is by typing, handwriting and drawing, or by uploading images of writing or drawing.

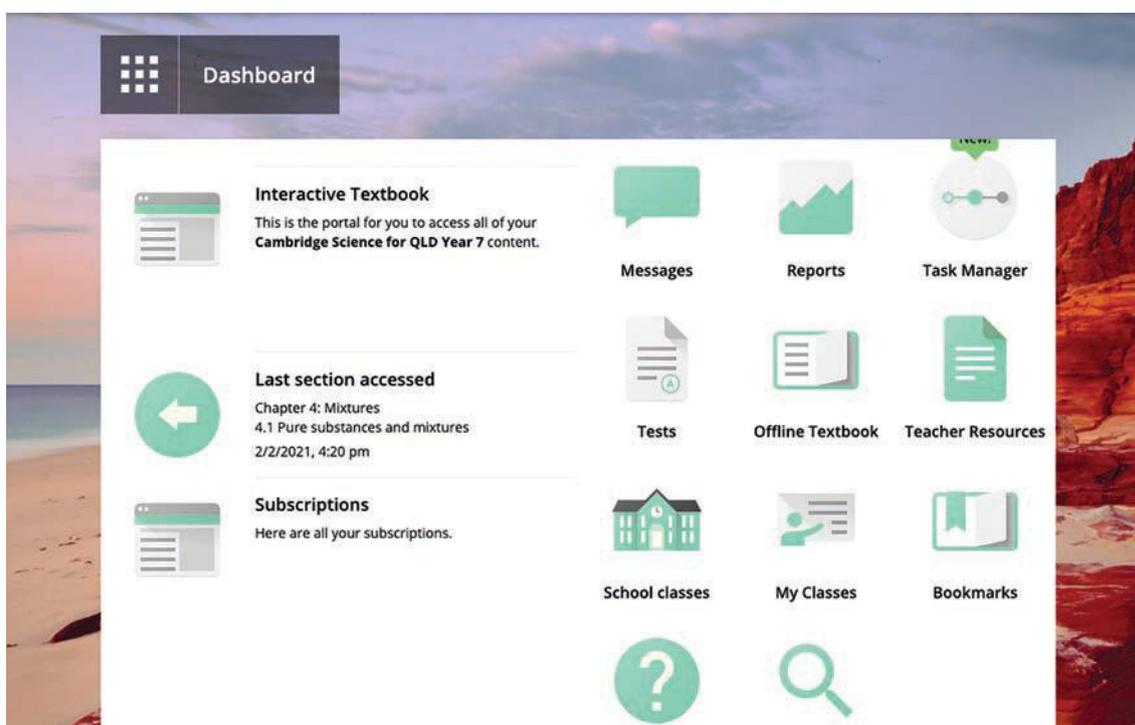
Self-assessment tools enable students to check answers, mark their own work, and rate their confidence level in their work. This helps develop responsibility for learning, and communicates progress and performance to the teacher. Student accounts can be linked to the learning management system used by the teacher in the Online Teaching Suite.



Overview of the Online Teaching Suite (OTS)

The Online Teaching Suite is automatically enabled with a teacher account and is integrated with the teacher's copy of the Interactive Textbook. All the assets and resources are in one place for easy access. The features include:

- **The Edjin learning management** system with class and student analytics and reports, and communication tools
- Teacher's view of a **student's working and self-assessment**
- **Chapter tests** and **worksheets** with answers as PDFs and editable Word documents
- Editable **curriculum grids** and **teaching programs**
- **Teacher notes** for Practicals, Try this, Explore! and STEM activities.



Chapter 1

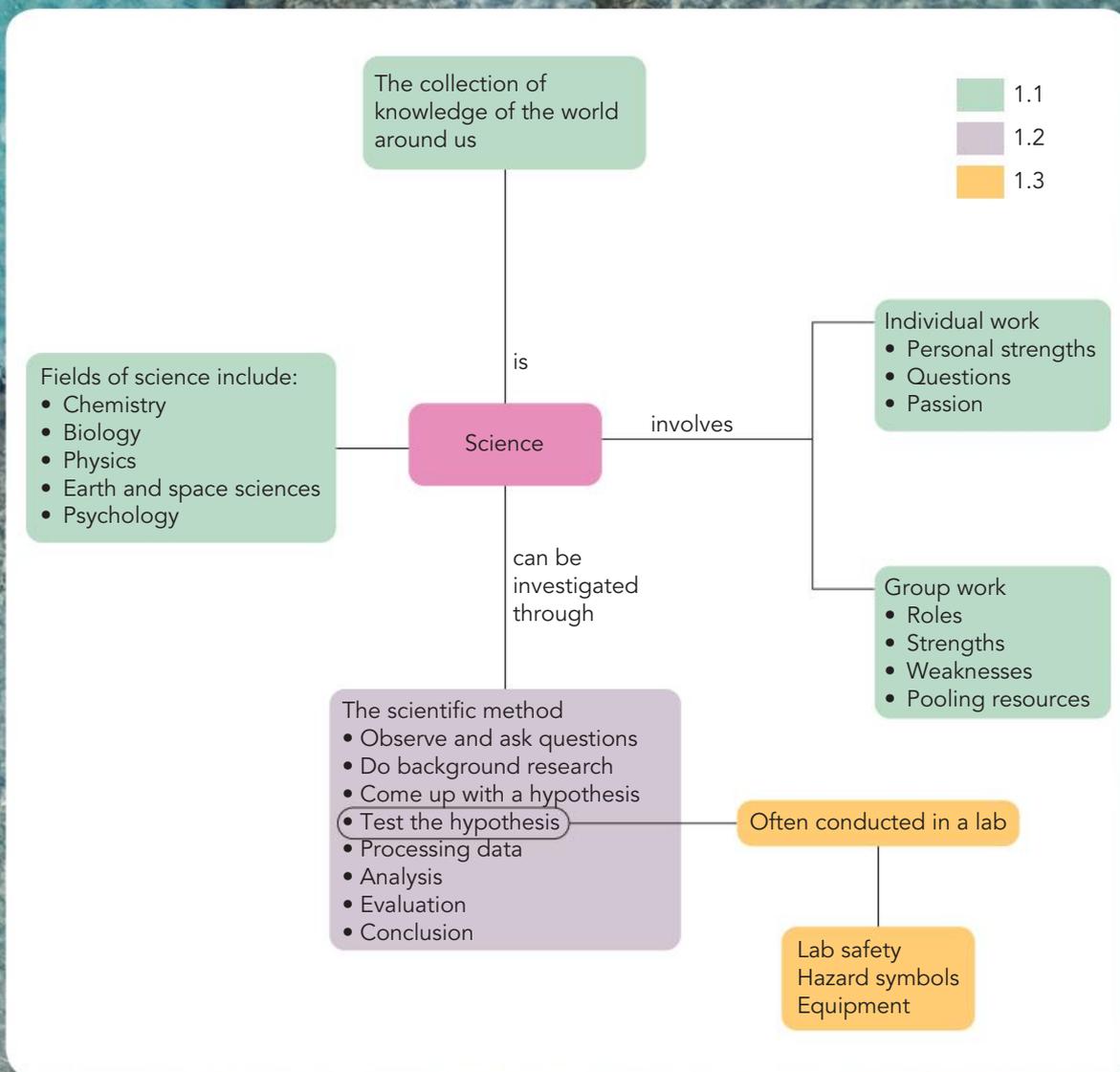
Science skills



Chapter introduction

Although you might not have realised it at the time, you would have studied aspects of science in primary school. Science is a field of study that tries to make sense of the world around us. In this chapter, you will learn more about what scientists do, who they work with, and the rules and principles that govern their work. It is important that all scientists have a set of similar processes that they follow to make sure their findings are valid.

Chapter map



1.1 What is science?



Learning goals

- 1 To be able to recognise four fields of science.
- 2 To explore the roles of group members in a team of scientists.

knowledge

the understanding of information

experiment

a controlled situation where data is gathered to answer a question

data

facts or statistics gathered to answer a question or for further analysis

The word for 'science' comes from the Latin word for '**knowledge**', *scientia*. Science is the study of our surroundings through experiment and observation. We can use scientific knowledge to answer questions about how things work, solve problems and create amazing new technologies.

In science, we are constantly asking questions about the universe, how things work, why they work that way and what happens if we change things. By collecting and analysing information about the world around us, scientists can produce answers about each question asked.

For example, you might be trying to grow broccoli. Your plants are looking great, and then, all of a sudden, they are filled with holes. You wonder why this is happening, so you watch your plants and observe that white moths are landing on the leaf. By analysing

this data, you realise that the moths are laying eggs on your plants. These eggs are hatching into caterpillars that are eating your plants! You then place a net over your plants to reduce the impact of the moths. This is science in action!

Scientists often use **experiments** to collect data in a controlled way. **Data** is the term used to group together anything observed during an experiment. The data generated from observations and experiments allows scientists to draw conclusions, make recommendations and create models that explain the world around us.

Aboriginal and Torres Strait Islander perspectives in science

Aboriginal and Torres Strait Islander peoples have been asking scientific questions and collecting observational data on the Australian continent for thousands of years. Knowledge of Country/Place is extremely helpful in understanding the unique location that is Australia.

For example, over thousands of years, Aboriginal and Torres Strait Islander peoples have developed a deep understanding of:

- the unique seasonal cycles which occur not only in Western Australia but also across the entire continent
- moon phases, and solar and lunar eclipses
- the use of native Australian plants for food and medicine
- the local Australian ecosystems and how they are affected by invasive species
- land and water resource management to protect flora and fauna biodiversity.



Figure 1.1 Caterpillars eating a broccoli plant

Aboriginal and Torres Strait Islander peoples also have a deep understanding of Country/Place and this knowledge has been used to construct a protocol for scientists to respectfully conduct experiments on traditional lands.

Some of these examples will be presented further throughout this text, with particular reference to Western Australian Aboriginal peoples. If you would like more information at any time, you can start a link with your local Aboriginal community by contacting either the Local Aboriginal Land Council (LALC) or the Local Aboriginal Education Consultative Group (AECG).

Fields of science

Just as there are many types of questions, there are many fields of science. The main areas of science that are covered in Years 7 to 10 Science are biology, chemistry, physics and Earth and space science.

Biology is the study of all living things. A person who studies biology is known as a biologist. Within the field of biology, there are many smaller specialised fields, such as zoology (study of animals), botany (study of plants), ecology (study of

ecosystems), biotechnology (study of how organisms can be used to create products of value to society), and anatomy and physiology (study of the structure and functions of living things).

These are some questions a biologist might ask:

- How do plant roots work?
- How can the number of koalas be increased in an area?
- What animals eat this plant?

Chemistry is the interaction of substances with each other and with energy. These substances make up matter and are called chemicals from the term *chemistry*.

A person who studies chemistry is known as a chemist. Branches of chemistry include organic chemistry (study of carbon-based chemicals such as those found in fossil fuels) and medicinal chemistry (the design and development of medicines).

These are some questions a chemist might ask:

- What will happen if I heat this substance?
- Will I get a new chemical if I mix this one with that one?
- What are the chemicals in this liquid?



Figure 1.2 Biologists taking samples from the ocean



Figure 1.3 A chemist in action

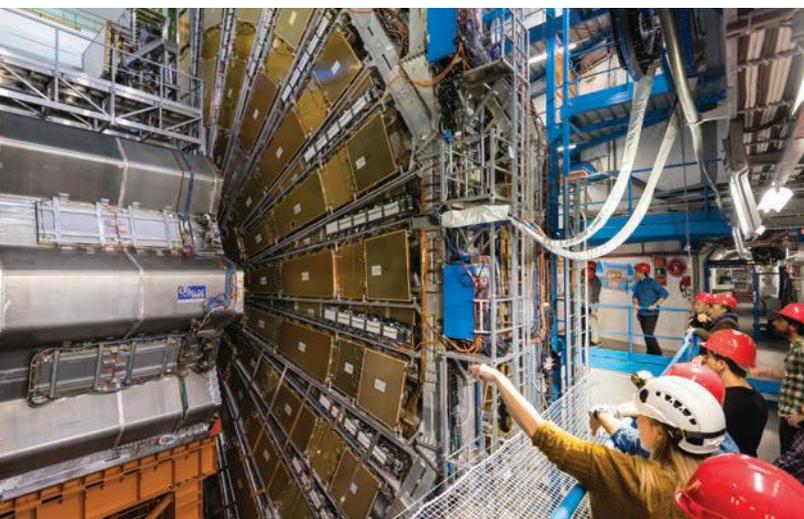


Figure 1.4 Physicists working on the Large Hadron Collider in Geneva

Physics is the study of forces, energy and matter (excluding the interactions studied in chemistry). People who become experts in physics are known as physicists and can specialise in many fields such as atmospheric physics (study of weather and climate), atomic physics (study of atoms) and astrophysics (study of space).

These are some questions a physicist might ask:

- What forces are acting on an aeroplane?
- Does light travel at a constant speed?
- What types of energy are safe to use?

Earth and space science is the study of Earth and space. These scientists study rocks, stars, volcanoes and the non-living resources around us. Geology, astronomy and climatology are just some of the many fields people can specialise in.

These are some questions an Earth and space scientist might ask:

- Where does lava come from?
- What are asteroids made of?
- Where is gold likely to be found?

There is often a lot of overlap between different fields in science. For example, both physics and chemistry are involved in the study of matter, and both biology and chemistry are involved in food science. Biology and Earth and space science are involved in the study of sending astronauts into space, and very many different sciences are involved in agricultural science.



Figure 1.5 Geologists mapping an area

Explore! 1.1

Careers in science

Although biology, chemistry, physics, and Earth and space science have been discussed in this chapter, there are many more fields of science in the world. There is basically a branch of science in whatever you are interested in! **Psychology** is a field of science that you can choose to study during Years 11 and 12. Psychology deals with the brain and investigates things such as emotions, dreams, mental processes, behaviours and mental health conditions.

What other fields of study in science are there? What jobs can these fields of study lead to?

Conduct research to find five other scientific specialist areas or careers that have not been mentioned in this chapter.

Quick check 1.1

- 1 Recall the definition of 'science'.
- 2 State the name given to information gathered in science.
- 3 Name the controlled situation used in science to gather data.
- 4 Identify the field of science that would study:
 - a an endangered animal
 - b the distribution and origin of rocks
 - c the composition of a new drug.

Science as a human endeavour 1.1

Careers in science

All scientists, regardless of their field, have common tasks that they conduct. These tasks include working collaboratively, classifying objects into groups of smaller things, and making observations and **inferences**. All these tasks can be demonstrated by scientists who study red-tailed black cockatoos (*Calyptorhynchus banksii*).

One of the most exciting parts about being a scientist is making a new discovery. This is exactly what happened when scientists from the University of Sydney, Australian Museum, University of Edinburgh and CSIRO worked together to identify a sixth subspecies of the red-tailed black cockatoo. This new species found its home in the south-western Wheatbelt region of Western Australia.

The team of researchers compared the genetic components of the **DNA** for red-tailed black cockatoos from all over Australia. Analysis of DNA can allow scientists to **predict** if a species will have a different morphology (size, shape, colour, etc.) to another.

The scientists used laboratory equipment to **analyse** the genetic components for different red-tailed black cockatoos and found that there were differences in the DNA sequence for the five known subclasses of the bird. Remarkably, the scientists were able to discover a new, sixth species of the bird, which was genetically different to the others, living in the Wheatbelt region of Western Australia. The scientists called the bird, *Calyptorhynchus banksii escondidus*, where 'escondidus' refers to the bird being 'hidden' right in front of us. The life of a scientist can be very exciting when making discoveries like this.



Figure 1.6 A male and female *Calyptorhynchus banksii* pair sitting together on a branch. The female characteristically has yellow spots on the head and an orange tail, while the male has a red marking on the tail.

inference

applying a reason or explanation to an observation, based on past experiences and known facts

DNA

deoxyribonucleic acid, a chemical present in cells of living things that carries genetic information

predict

to make an estimate about a possible future event or outcome

analyse

examine something in order to find meaning, what it is made of or a relationship with other things

Quick check 1.2

- 1 Describe what you think of when you think of a scientist at work.
- 2 Identify what fields of science might be involved with studying animal behaviour.
- 3 Explain why scientists from different countries need to work together.

Who do scientists work with?

Scientists can work individually or in groups. They may work for themselves or might work for large multinational companies. When you conduct experiments in science class, you will often be working in groups. In the real world, these groups are made up of experts from many different fields to bring their strengths together.

Working in groups:

- is an important part of life
- requires cooperation between team members
- requires sharing ideas and resources
- means team members need to understand their role in finding a solution to a problem being investigated.



Figure 1.7 Roles in groups

A good group has:

- a clear understanding of everybody's roles
- equal sharing of responsibilities between all members
- the ability to communicate and resolve problems
- the ability to complete the tasks assigned in a timely manner
- members who listen to each other.

Roles in groups

Figure 1.7 on page 8 shows some descriptions of possible roles in groups. Often people take on

multiple roles in groups, but it is important that everyone in a group knows their role, focuses their effort on the things they are good at and contributes equally. It is also a good idea to try different roles occasionally as you may find that you have a skill you did not know about.

It is important to never get stuck in the same role too many times. Even though you might feel more comfortable in certain roles in groups, you should always try out new positions and develop skills that you may not be naturally strong in.

Quick check 1.3

- 1 Name some qualities about yourself that are strengths when you do group work.
- 2 Identify what roles you would be good at.
- 3 State a role that you do not think you would be good at and explain why.
- 4 Identify three goals that would allow you to be better at the roles you stated in Question 3.

Try this 1.1

Produce a paper tower

You will work in groups. Each person in the group chooses at least one role from Figure 1.7. Your group will act as a team of consultant engineers, working towards finding a solution to a challenge.

First, brainstorm solutions together. Remember these rules:

Rules for brainstorming

Focus on quantity: Come up with as many ideas as you can.

Encourage wild ideas: Don't criticise ideas that are wild. They may lead to innovative designs.

Record all ideas: Have one student be the 'scribe' and write everything down.

Combine and build ideas: Discuss and elaborate on the ideas of other students.

Focus: Stay on topic.

Challenge

You are to design and create a newspaper tower that can support this textbook at least 20 cm off a table.

Criteria

- 1 The tower must not be taped to the table and cannot be supported by any other item.
- 2 Your teacher will set a time limit for the task.

continued...

...continued

3 The group can only use the following materials:

- two pieces of newspaper
- scissors
- 50 cm sticky tape

Process

- 1 Allocate a role to each person in the group as discussed in the chapter.
- 2 Brainstorm all possible solutions to the problem, including drawings of your design.
- 3 Create and test a prototype.
- 4 Improve your prototype.
- 5 Discuss the process you followed.

Evaluation

Present your designs to the rest of the class.

- 1 Explain the process of how you came up with your design.
- 2 Identify the roles each group member played.
- 3 Discuss how you would approach the research and design process the next time you conduct a similar task.

Section 1.1 questions



Remembering

- 1 **State** a research question that a biologist might ask.
- 2 **State** what a physicist would study.
- 3 **Recall** how scientists collect data.

Understanding

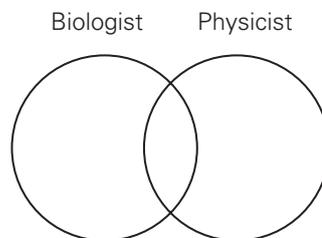
- 4 **Explain** how science has affected your day so far.

Applying

- 5 A scientist studies an asteroid in space. **Describe** how this study would fit into the fields of chemistry or physics.

Analysing

- 6 **Compare** the work of a biologist to that of a physicist. You may use a Venn diagram.



Evaluating

- 7 Some fields of science can overlap. **Explore** the fields of science a biochemical engineer might study.

1.2 What do scientists do?

Learning goals

- 1 To be able to describe each step of the scientific method.
- 2 To be able to identify the different types of variables in a scientific experiment.
- 3 To be able to recognise the difference between quantitative and qualitative data, as well as random and systematic errors.



Science can be thought of as a systematic way of investigating. It involves making observations, asking questions, making predictions, conducting experiments, collecting and analysing data and forming conclusions. However, one scientist may not be involved in every step of the process.

For example, the Government of Western Australia want to investigate the possibility of coral bleaching on Ningaloo Reef. Here is one example of how different scientists might work together.

A marine scientist could review related knowledge and provide a summary of background scientific research. The scientist might ask the **research question** 'what factors cause coral to bleach?' Then, the scientist can create a possible **hypothesis** about the cause of coral bleaching.

Environmental scientists could then design an experiment to test whether the hypothesis is supported or not supported. They could gather data about the temperature or pH readings of the ocean.

A marine chemist or physicist could join the team to **observe** the experimental procedure, and gather, analyse and evaluate the data. The results could then be communicated back to the Government of Western Australia or written in a scientific journal.

Sometimes, researchers begin their work due to someone making a **claim**, which is sometimes a statement that has no accompanying evidence but may be worthy of study. Researchers can evaluate a claim by collecting further evidence by procedures like the above. What a scientific team effort!

The scientific method

The process referred to above is known as the scientific method.

The steps in the scientific method also provide a good framework for how you should report on your findings. Each step in the process can be documented in a practical report that allows other people to understand your findings and repeat the experiment.

research question

a question that can be answered practically through scientific investigation or through research to evaluate a claim

hypothesis

a proposed explanation or prediction of an event (e.g. an experiment) based on research and current knowledge

observe

use senses and tools to gather information/data

claim

a statement with no evidence provided that is evaluated and then either supported or not supported by the collection of thorough evidence

The scientific method may differ slightly from one area of science to another, but will start with observing the world around you. Here is a basic outline of how the scientific method works.

1 Observe and ask questions

This is something you can do every day! You might notice the cactus on the window sill is looking unwell. You might ask yourself some questions based on the observation. For example, 'How much water does a cactus need to survive?' This would be your research question.

8 Conclusion

Finally, you can ask yourself what the data means and use it to answer your original research question. You can also ask yourself if the hypothesis has been supported or not. Your hypothesis about overwatering cacti has been supported.

Your conclusion may lead you to ask more questions. For professional scientists, if their experiment is published in a journal, this will make the experiment available for other scientists to think about and further the findings through asking even more specific questions. Can you think of what else you might want to find out?

7 Evaluation

You then evaluate your experiment. You may talk about how reliable your data is and suggest improvements if you found there were any problems.

6 Analyse data

You then analyse the data that you have gathered to find any trends, patterns or relationships, and then summarise what you have found, including any problems with your data. Three of the overwatered cacti looked pale and shrunken, while all the cacti watered correctly produced side shoots (pups).

5 Processing of data

You then record and present the results. For example, you may keep track of how the cacti are doing every day. You might want to record the colour and shape of the cacti or measure how much the cacti grow each week. The results can be presented in tables and graphs.

Figure 1.8 The scientific method

Observe and ask questions

The first step in the process is often based on an observation. Scientists continually observe the world around them to gather information. These observations come from using our senses: sight, hearing, smell, taste and touch.

You use some senses for gathering information more than others. Sight is very important for making observations. However, you often use several senses together.

peer-review
to read, check, and give an opinion about something that has been written by another scientist or expert working in the same subject area

2 Do background research

You might head to the internet to try to find suggestions to answer your questions. Professional scientists generally use **peer-reviewed** journal articles to see what other scientists in the past have found out and experiments that have been done. You may find out that plants can die from too much water!

3 Hypothesis

You then come up with a prediction that can be tested. For example, 'If cacti (plural for cactus) are watered five times the recommended amount, then they will not do well'.

4 Test the hypothesis

This involves developing a series of steps that can test the hypothesis and is called the method. You need to formulate a method that is safe, allows the collection of data and is carried out in such a way that there is no other explanation possible for the outcome except the one you are interested in. You may need to use 10 cactus plants of the same variety, placed on the same window sill, and continue the experiment for one month. You may find a method that you need to modify to suit your own experiment.

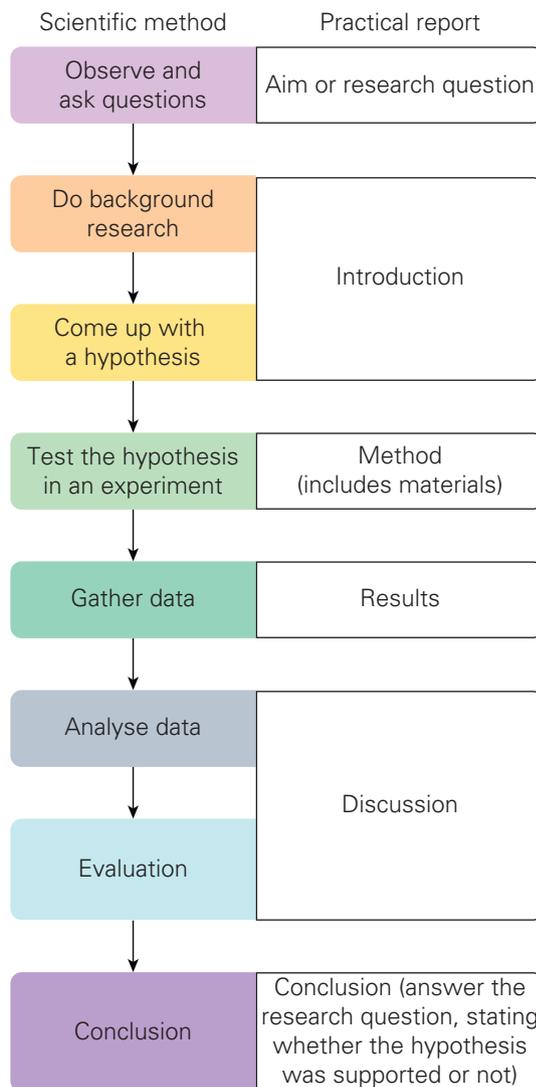


Figure 1.9 The scientific method matched to sections of a lab report

infer

to link an observation with past knowledge and assign meaning to the observation

variable

a component of an experiment that changes or can be changed

independent variable

the variable that is changed during an experiment

dependent variable

the variable that is tested or measured during an experiment (as it responds to the independent variable)

controlled variable

the variable or variables that are kept the same during an experiment

fair test

an experiment where the independent variable is changed, and other variables are controlled

qualitative

a form of data that is a descriptive measurement

quantitative

a form of data that is a numerical measurement

What is an observation?

Observations are statements about information gathered from your senses. An observation does not include predictions or assumptions about what is being observed.

These are some examples of observations:

- The sky is blue.
- The pool water is cold.
- The food smells nice.

What is an inference?

After a scientist has made an observation, they often make an inference to explain the observation. This is like a conclusion or possible explanation they can form, based on observation and their past experiences and knowledge.

Here are some examples. The first part of the sentence is an observation; the second part is an inference.

- Trent beat Lewis in a race; you **infer** that it is because he trains more.
- The ice cream melted quickly; you infer that it was a hot day.

These observations and inferences allow research questions to be asked. These questions should be able to be investigated scientifically. For example:

- Do more training hours improve race performance?
- What effect does temperature have on the melting time of ice cream?

Independent, dependent and controlled variables

Once an observation has been made and a research question generated, the next step is often to conduct an experiment. Experiments are conducted in controlled situations that a scientist creates to test only one thing. This allows the scientist to measure the effect that changing this one thing will have. The things that will be changed are called **variables**.

For example, a boy wants to see if changing the place where a towel is placed after a shower affects the time it takes to dry. Will laying it on the ground or hanging it on a rack decrease the drying time?

In this example, the boy is:

- changing the place where the towel is left. This is the **independent variable**.
- measuring the time it takes for the towel to dry. This is the **dependent variable**.

Both the independent and dependent variables may need to be measured in an experiment. In an experiment, we would predict that a change in the independent variables causes a change in the dependent variable.

To show that only the position of the towel changes the time it takes to dry, all other factors must be kept the same, such as the temperature of the room, amount of water on the towel and the towel used. These are the **controlled variables**. These variables are controlled to ensure that the experiment is a **fair test**.

Collecting data: Types of data

When something is observed, the information can be split into two types of categories. These categories are **qualitative** and **quantitative** observations.

Quick check 1.4

- 1 Define the term 'inference'.
- 2 State three observations about the room you are in.
- 3 Sally observed that the plants in her garden that grew the most were closest to the sprinkler. State an inference that Sally might make based on this observation.

Data type	Qualitative	Quantitative
Definition	Qualitative observations are descriptive and usually come from our senses. They refer to a type, which might be represented by a name, letter or number code. For instance the swimmers may be called Ali and Tom, or A and B, or Lane 1 and Lane 2, etc.	Quantitative observations are numerical values or counts that are expressed as numbers and are often measured with tools such as thermometers, measuring cylinders or stopwatches.
		
Example	Ask who is a better swimmer or ask observers to rate their swimming style on a scale of Poor / Fair / Excellent.	Record the times of the swimmers in seconds using a stopwatch.
Accuracy	This description could be very detailed but each person who watched the race might give a slightly different description and so qualitative descriptions are hard to compare. They are subjective (open to interpretation or opinion).	This may be a more reliable piece of data as a number is objective (not open to interpretation or opinion). It can be easily compared to other observations, for example, the next time they race each other, even if a different person is collecting the data. Repeated measurements are also helpful to check that the same thing happens each time.

Table 1.1 Comparing qualitative and quantitative observations

Quick check 1.5

- 1 State the kind of observation that is gathered using measurement tools.
- 2 State the kind of observation that is descriptive, or a type, and not a numerical value or count.
- 3 Describe the possible strengths of using qualitative data.
- 4 Explain why it is useful to make repeated observations.

Try this 1.2**Quantitative data versus qualitative data**

Pair up with someone else in the class. Try to describe your partner both qualitatively and quantitatively. Some ideas have been suggested in the table below, but you may have your own ideas.

Feature	Qualitative observation	Quantitative observation
Hair		
Height		
Eyes		
Pets		
Siblings		

After you have completed the activity, share your findings with the rest of the class.

- 1 Identify which features were easiest to describe qualitatively.
- 2 Identify which features were easiest to measure quantitatively.
- 3 State a reason why a scientist would use qualitative measurements.

Practical 1.1: Investigation**Vitamin C in fruit juices****Aim**

To develop observations and inferences based on a simple task.

Research question

Do citrus fruits contain a higher concentration of vitamin C than other types of fruit?

Materials

- cornstarch
- beaker × 2
- test tubes – enough to test each variety of juice
- pipette
- hotplate
- iodine
- water
- various fruit juices (e.g. orange, lemon, pineapple, tomato, apple, blueberry, kiwi)

Be careful

Ensure appropriate signage is displayed during and after hotplate usage.

No food is to be consumed in the lab.

Planning

- 1 You need to provide some background information to the investigation. Complete some research and write a brief paragraph to explain the importance of vitamin C in a balanced diet.
- 2 Identify the independent variable in this investigation.
- 3 Identify the dependent variable in this investigation.
- 4 Identify the controlled variables in this investigation.

Method

- 1 Add 1 tablespoon of cornstarch to a beaker.
- 2 Mix with enough water to make a paste-like consistency.
- 3 Add 250 mL of water to the beaker and bring to the boil on a hotplate. This is your starch solution.
- 4 Add 75 mL of distilled water and 10 drops of starch solution to another beaker.

continued...

...continued

- 5 Add drops of iodine to this solution until it turns a dark blue-black. This is now your vitamin C indicator.
- 6 Add 5 mL of the indicator solution to a test tube.
- 7 You can now add the different fruit juices drop by drop to the indicator solution. The more vitamin C present in the juice, the lighter the colour of the indicator solution. Count the number of drops of each type of juice that it took to cause a colour change.
- 8 If time permits, repeat each experiment once or twice. Do you get the same results?
- 9 Now make inferences to explain each observation based on your prior knowledge or experience.

Results

Complete the results table.

Juice	Number of drops taken to cause a colour change			
	Trial 1	Trial 2	Trial 3	Average

Discussion

- 1 Plot a column or bar graph of the number of drops vs. type of fruit juice.
- 2 Describe any trends in your results. Is there any pattern between the type of fruit (e.g. citrus vs non-citrus) and the number of drops needed for a colour change? Or is there another pattern present, such as the colour of the fruit?
- 3 Another variation is to add the same volume of juice to each test tube and count the number of indicator drops required to change the colour of each. Using your results from the drop-wise experiment, predict what you think the results of that experiment would be.
- 4 Evaluate your method and suggest any improvements that you could make if you were to do it again.

Conclusion

Answer your research question, using data from the experiment to support your statement.

Collecting data: Measuring tools

When scientists use tools to collect data, it is important that the results are accurate.

Accuracy is the closeness of a measurement to the true value and there are many pieces of equipment available to help increase this. The choice will depend on the size of the object that you want to measure.

Length

You can use rulers to measure the length of a straight object. You can also use measuring tape for a non-straight object or even a trundle wheel for large distances.

It is important to use the most **precise** tool and unit when measuring. For example, if you are measuring the size of a snail, you would use a ruler and millimetres. If you are measuring the size of a person, you would use a measuring tape and centimetres, and if you are measuring the length of the school grounds, you would use a trundle wheel and metres.

The ruler has smaller markings and greater precision than the trundle wheel.

Some professions use a laser distance measuring tool. This tool uses a laser to make even more precise distance measurements.

accuracy
how close a measurement is to the true value

precision
how close measurements are to each other

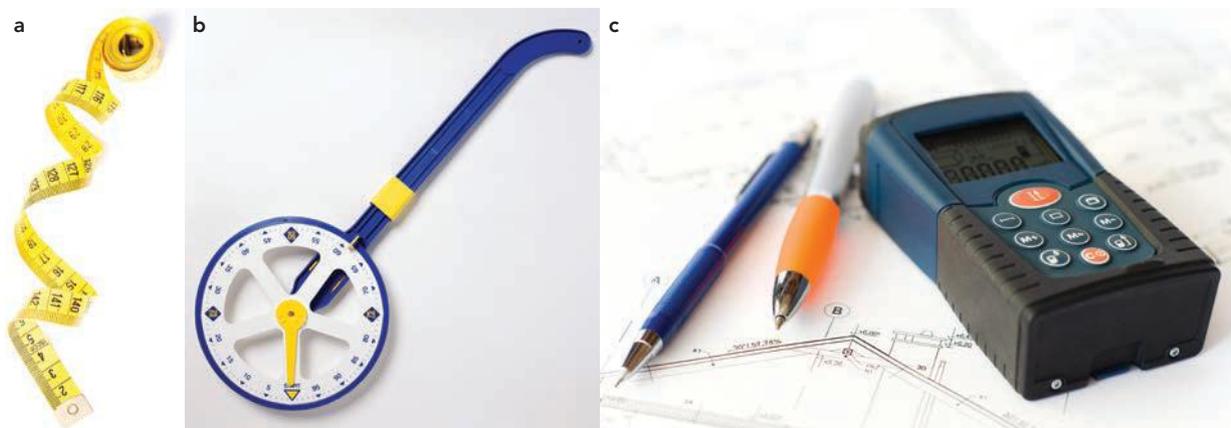


Figure 1.10 (a) A measuring tape, (b) a trundle wheel and (c) a laser distance measure for precise distances. Generally, to measure the length of an object, you use the unit millimetre (mm), centimetre (cm), metre (m) or kilometre (km).

Volume

Volume is measured in cubic units such as cubic millimetres (mm^3), cubic centimetres (cm^3) or cubic metres (m^3). Volume of a liquid is measured using different-sized measuring cylinders in millilitres (mL) and litres (L).

Figure 1.11 (a) A measuring cylinder and (b) a scientist using a pipette for dispensing a volume of liquid



Analytical scientists that require a high degree of accuracy and precision in volume measurements could also use a pipette. This piece of laboratory equipment is commonly used when a very small, but accurate, amount of liquid is required.



Figure 1.12 A data logger probe

Temperature

Digital thermometers, liquid in glass thermometers and data logger probes are used to measure the temperature of different objects. The unit of degrees Celsius ($^{\circ}\text{C}$) is used to measure temperature. Thermometers generally have a maximum temperature of around 110°C and a minimum temperature of -10°C ; however, it would be extremely rare that you would conduct an investigation in school where temperatures exceed these numbers.

Time

Stopwatches are an accurate way of gathering data about time. The units of seconds (s) and



Figure 1.13 The liquid in the glass thermometer shown uses the measurement unit Celsius ($^{\circ}\text{C}$), but in some parts of the world, degrees Fahrenheit ($^{\circ}\text{F}$) is used.

milliseconds (ms) are used most in science; however, minutes, hours and days could also be recorded for long-term experiments.

Practical 1.2

Reading equipment

Aim

To practise taking readings using specific pieces of equipment.

Materials

Station 1

- spring balances 100 g, 500 g, 1 kg, 5 kg
- different masses

Station 2

- 3 sugar cubes
- electronic balance

Station 3

- 2 ice cubes
- 50 mL water
- beaker
- thermometer

Station 4

- stopwatch

Station 5

- ruler
- A4 sheet of paper

continued...

...continued

Method

In groups of three, rotate through the stations, taking individual readings and filling out the results table. Alternatively, you could work alone and collect results from two other people.

Station 1

- 1 Place the mass onto each spring balance and measure the mass in grams.
- 2 Copy and complete the table shown in the results section.

Station 2

- 1 Measure the mass of one sugar cube using the electronic balance.
- 2 Keep the sugar cube on the electronic balance and zero the balance.
- 3 Add two more sugar cubes and record the mass.

Station 3

- 1 Place 50 mL of water into a 250 mL beaker.
- 2 Use the thermometer to measure the initial temperature.
- 3 Add two ice cubes, wait for 30 seconds and then measure the temperature.
- 4 Record the results in your table.

Station 4

- 1 Attempt to stop the stopwatch at exactly 2 seconds.
- 2 Record the results from three attempts.

Station 5

- 1 Measure the diagonal length of the A4 sheet of paper.
- 2 Measure the width of the A4 sheet of paper.
- 3 Measure the length of the A4 sheet of paper.
- 4 Record the results from three attempts.

Results

Station	Person 1 reading	Person 2 reading	Person 3 reading	Mean
1: 100 g balance (g)				
1: 500 g balance (g)				
1: 1 kg balance (g)				
1: 5 kg balance (g)				
2: initial (one cube) (g)				
2: (zero)				
2: (two cubes added) (g)				
3: (°C) initial				
3: (°C) final				
4: first try (s)				
4: second try (s)				
4: third try (s)				
5: diagonal (mm)				
5: width (mm)				
5: length (mm)				

continued...

...continued

Discussion

- 1 Station 1: Decide when each of the spring balances would need to be used in an experiment.
- 2 Station 2: Explain why it is important to zero the electronic balance before each use.
- 3 Station 3: Propose a reason why it is important to think about time when measuring temperature.
- 4 Station 4: Explain why it is important to do multiple trials and average the results.
- 5 Station 5: Discuss why millimetres were used for units to measure the paper, rather than metres.
- 6 If there were differences in the temperatures recorded by different people at station 3, suggest possible reasons for the differences.

Mass

Electronic balances and spring balances are used to measure mass in science. Electronic balances can give an extremely precise mass reading. The units of milligrams (mg), grams (g) and kilograms (kg) are used to measure mass. Larger masses can be measured in tonnes (1 tonne = 1000 kg).

Minimising error

Errors are differences between the values we observe and what is actually true. Errors can cause results that are inaccurate, or even completely false. **Random errors** are unpredictable and are caused by factors that cannot be easily controlled by the experimenter. **Systematic errors** are consistent and may be caused by faulty equipment or a problematic method.

Meniscus

When you try to measure liquid in a container, you will notice that the sides of the liquid are curved. As discussed earlier, it is important to take accurate measurements in science, so you need to know how to measure the curve of the top of the liquid in the container. This curve is called the **meniscus** and it can go up at the sides of the container, making a **concave** shape, or down at the sides of the container, making a **convex** shape.

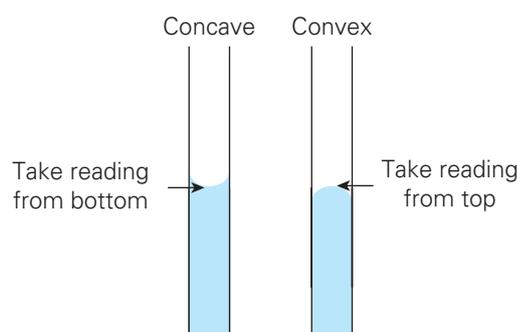


Figure 1.14 Reading a meniscus

Concave and convex meniscus

Water and water-based fluids, such as milk, produce a concave meniscus. This is because the particles of fluid are more attracted to the container than they are to themselves. A convex meniscus is formed when fluid particles are more attracted to themselves than the container they are in. This happens to mercury when placed in glass.

It is important to take the reading of the meniscus from the lowest part of the curve when the curve is concave and the highest part of the curve when the curve is convex.

If you ensure that your readings are from the correct part of the meniscus each time, you will increase the accuracy and precision of the data you are gathering.

random error

an error that is random and caused by factors that cannot be easily controlled by the experimenter

systematic error

an error that causes measurements to differ from the true result by a consistent amount, often due to faulty or uncalibrated equipment

meniscus

the surface of a liquid in a container

concave

a surface that curves inwards

convex

a surface that curves outwards

parallax error

an error caused by not reading liquid measurements at eye level, which leads to measurements being too high or too low

trend

a pattern in data that shows the general direction/shape of the relationship between the independent and dependent variables

Parallax error

When taking a reading from the meniscus of a liquid, you can also encounter a problem known as **parallax error**. This happens when the measurement is different from the true value because of your eye being positioned at an angle to the measurement markings. If you are looking at the measuring line from above, you will not be able to accurately measure the meniscus as you need to be at eye level or parallel with the line you are measuring. This also happens when you are using other instruments such as thermometers.

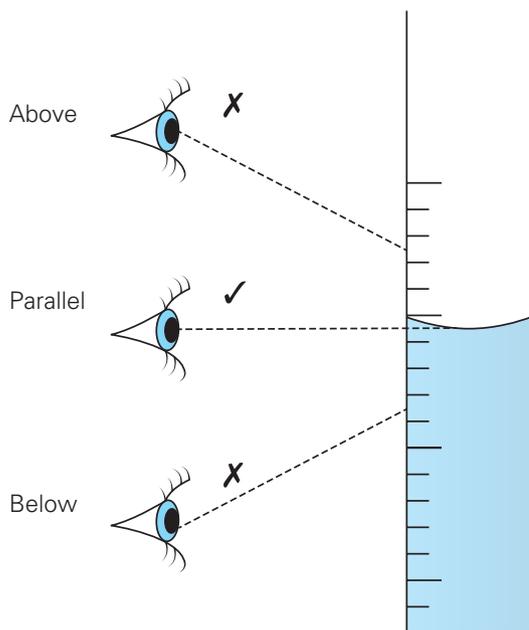
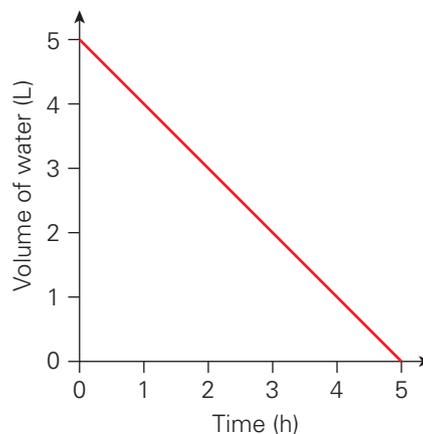


Figure 1.15 Example of parallax error

Describing patterns in data

When you have collected your data, it can be presented in tables and graphs. These are helpful to see any patterns in your data. We refer to patterns in graphs as **trends**. They show a relationship between the independent variable and the dependent variable. The graph in Figure 1.16 shows how you could describe a trend.



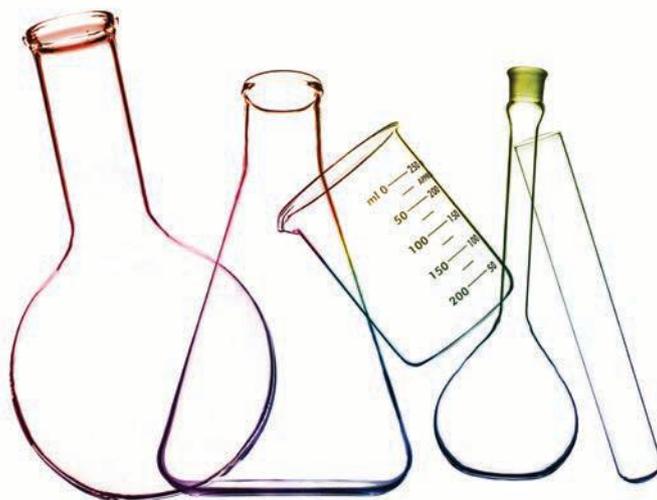
Graph to show how time affects the volume of water in a tank

Figure 1.16 This graph shows a steady decrease. You could describe this by saying, 'As time (in hours) increases, the volume of water in the tank (in litres) decreases'.

Evaluation

The evaluation section of your report is where you outline any problems you faced during the experiment and offer suggestions that will improve your method. Any suggested improvements should include the following information:

- A brief description of the problem encountered
- A description of how you could improve your experimental method (e.g. use different equipment or change the order of the steps).



Conclusion

A conclusion is a short paragraph in a scientific report and should include the following ideas:

- A statement that answers your research question
- Evidence that supports this answer
- An explanation of whether the data supports or disproves the hypothesis.

Worked example 1.1

Suppose that you were watching a race, and you noticed that the racer named Trent beat the one named Lewis. This was an observation of the world around you. If you were interested in why that happened, you might carry out further research by the following procedure.

Section	Example	Explanation
Research question	Do more training hours improve race performance?	The question needs to be able to be investigated scientifically and answered safely. The question has an independent and dependent variable which are easily measured.
Background research	Runners who train for more than four hours per week reduce their race time by an average of ten minutes. Runners who add three days of strength training to their weekly program increase their leg strength and improve race performance.	This is your background information. You need to use the internet and books to find scientific information that provides information about what you're studying. Make sure you use reputable websites and give a reference link for anything you use. The sentences shown are an example of what could be included.
Hypothesis	An increase in training hours will increase race performance.	This is where the research question is changed into a prediction that can be tested.
Method	<p><u>Variables</u> Independent variable: number of training hours per week. Dependent variable: time taken to finish a 10 km race. Controlled variables: participants are the same age, same athletic abilities and receive the same amount of training. The same race distance is used for all participants.</p> <p><u>Risk assessment</u> All runners must wear suitable footwear during the race.</p> <p><u>Method</u> Eighteen 12-year-old males will complete a logbook, noting down the time spent training and the type of training they did. On race day, the time taken for each participant to finish the race will be recorded.</p>	<p>This is where you design your investigation. You need to consider the variables (i.e. what you will change and what you will measure), a risk assessment and a method. (Risk assessment will be covered more in the next section.)</p> <p>The number of training hours is the independent variable because it is the variable that we change to see what effect it has on the dependent variable.</p> <p>The time taken to finish a 10 km race is what we predict will change as a result of the training hours change. This makes time taken to finish a 10 km race the dependent variable.</p>

continued...

...continued

Section	Example	Explanation														
Results	<table border="1"> <thead> <tr> <th>Number of training hours per week (hours)</th> <th>Time taken to finish a 10 km race (minutes)</th> </tr> </thead> <tbody> <tr> <td>4</td> <td>102</td> </tr> <tr> <td>7</td> <td>92</td> </tr> <tr> <td>10</td> <td>86</td> </tr> <tr> <td>15</td> <td>80</td> </tr> <tr> <td>21</td> <td>72</td> </tr> <tr> <td>32</td> <td>59</td> </tr> </tbody> </table>	Number of training hours per week (hours)	Time taken to finish a 10 km race (minutes)	4	102	7	92	10	86	15	80	21	72	32	59	You need to present your results in tables and graphs.
	Number of training hours per week (hours)	Time taken to finish a 10 km race (minutes)														
4	102															
7	92															
10	86															
15	80															
21	72															
32	59															
Analysis	As the number of training hours increases, the time taken to finish the race decreases.	You need to look at your data and identify any trends, patterns or relationships.														
Evaluation	<p>The investigation only considered 18 male runners completing one 10 km race. Although the participants were all 12 years old, they were all different heights and had different diets. Their training also varied. Some purely completed running training, whereas others also swam or did strength training.</p> <p>To improve the investigation, a bigger sample size of participants is required. Each participant should eat the same diet and complete the same type of training.</p> <p>The investigation could be extended by also considering female runners, or looking at different race distances.</p>	<p>This section is where you consider any issues with your method and suggest potential improvements for any future investigation.</p> <p>If the data is inconclusive, it could mean that there are more variables that need to be controlled.</p>														
Conclusion	In conclusion, the results show that more training hours improve race performance. This is shown by the data: runners who only trained for four hours completed their race in an average of 102 minutes, whereas the runners who trained for 32 hours finished their race in an average of 59 minutes. The hypothesis of 'an increase in training hours will increase race performance' is supported. The data could also be used to improve race performance in teen boys.	You need to answer your research question, justifying it with data that you collected. This will allow you to accept or reject your hypothesis.														

Quick check 1.6

- 1 Define the term 'meniscus'.
- 2 Explain why measurements are taken from either the top or the bottom of the meniscus.
- 3 Explain how a concave meniscus forms.
- 4 Describe how you would minimise parallax error.

Section 1.2 questions**Remembering**

- 1 **Recall** how an observation is different from an inference.
- 2 **Define** qualitative data and quantitative data.

Understanding

- 3 **Classify** the following pieces of data as qualitative or quantitative.
 - a Tami scored 74% on the test, Aidan scored 90% on the test.
 - b Teachers rated their students' behaviour for 'Submits work on time' as Rarely, Sometimes, Often, Always.
 - c Students mixed two chemicals and recorded what they saw. Aaron wrote down, 'The mixture went blue'. Hannah wrote down, 'The mixture went a dark greenish-blue. The test tube felt warm to the touch. Small bubbles appeared.'
 - d A scientist recorded the number of times a gorilla ate in a 24-hour period.

Applying

- 4 A tennis ball is dropped off a 10 m tower in the Western Australian town of Gin Gin. A student measures the time taken for the tennis ball to hit the ground with a stopwatch. The experiment was repeated three times and the time values recorded fluctuated randomly around the correct time measured by scientists. **Describe** why this fluctuation is due to random error and not systematic error.

Analysing

- 5 A scientist undertook the following experiment.

Step 1: Observed that a pot plant seems to grow better the closer it is to a window.

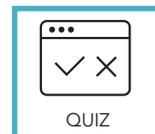
Step 2: Conducted an experiment where a flowering plant was placed in the window and a cactus was placed in a dark room. The flowering plant was watered, and the cactus was not. The flowering plant was also given fertiliser but the cactus was not.

Step 3: Collected the data and concluded that plants grow better when they are exposed to more sunlight.

 - a **Identify** a mistake in the scientist's method.
 - b **Describe** whether this was a fair test.

Evaluating

- 6 For the pot plant experiment detailed in Question 5, **describe** the changes to the experiment required to ensure the experiment is fair.
- 7 **Propose** what a meniscus would look like if the molecules of a liquid inside a container were equally attracted to themselves and the container.



1.3 Where do scientists work?



Learning goals

- 1 To be able to identify hazard symbols in a science laboratory.
- 2 To be able to draw common laboratory equipment.
- 3 To be able to describe how to safely light a Bunsen burner.

Exploring the laboratory

Not all scientists work in laboratories, of course! Depending on the area of science, they may work ‘in the field’ such as out and about in the natural environment, on land or in the sea, and they can work in organisations like zoos, private companies or for the government. Now that you are studying science, you will get to participate in many exciting scientific experiments in the laboratory.

Lab safety basics

The laboratory can be a very dangerous place if you do not follow the safety rules, or if you misuse the equipment or forget to use safety gear. Throughout your science career in school, you could get burned, be exposed to dangerous chemicals or cut yourself on broken equipment. Therefore, it is extremely important to know some core rules.

Referring to Figure 1.18 on page 27, spot the differences between the students who are ignoring the rules (top image) and those following the rules (bottom image). The class in the top image is making seven dangerous mistakes. Suggest what they might be (the answers are on page 28.)



Figure 1.17 It is important to wear appropriate personal protective equipment at all times when working in a lab environment.





Figure 1.18 Good lab safety is essential.

Spot the difference: did you find all the lab safety issues in Figure 1.18? Answers:

- Always wear safety glasses over your eyes (not on top of your head) when you are handling chemicals or glassware. Chemicals and broken glass can be damaging to your eyes.
- Always wear a lab coat that can protect your school uniform from stains and your skin from harmful chemicals.
- If you are given rubber gloves by your teacher, wear them at all times. These will protect your hands from harmful substances. Always wash your hands after you have removed your gloves to be extra safe. Sometimes, safety glasses, lab coats and gloves are grouped together and called personal protective equipment, or PPE for short.
- Always wear enclosed footwear to make sure that nothing can fall onto your feet and hurt you.
- Use a safety mat/heatproof mat whenever you are using a Bunsen burner to

prevent damage to the bench and other equipment.

- Always follow your teacher's instructions.
- Never eat or drink in a lab.

It is important to be observant in the lab and be on the lookout for any potential hazards. Common hazards in the lab are something that you could trip or slip on, or cut or burn yourself on. If you see a hazard, it is important to make your teacher aware of it as soon as possible, so they will be able to stop anyone from getting hurt.

Hazard symbols

Each time you conduct an experiment in science, there are many potential hazards to be aware of.

How do you know what chemicals are dangerous? When you use chemicals, you will see that there are often symbols on the label of the bottle. These symbols tell you the possible dangers when handling any chemical.

Type of hazard	Risk	Assess	Control
Glass 	There are many pieces of glass equipment in the lab.	Glass can get hot, form sharp edges that can cut if broken and can also be heavy.	Always place glassware in the centre of the bench on a flat surface. Allow to cool before handling. Inform your teacher of breakages and avoid any broken glass.
Biological 	Biological material, such as organs for dissection, bacterial cultures, microbes or plants are studied in the lab.	Any living or dead specimen could contain microorganisms that can make you ill.	Make sure you wash your hands thoroughly. Wear gloves when your teacher tells you to. Dispose of all biological material in the correct way.
Chemical 	You will use many chemicals for experiments.	Some of these can be toxic, corrosive or irritate your skin.	Make sure you always wear gloves and goggles, and wash your hands. NEVER get any chemicals in your mouth or eyes.

Table 1.2 Risk assessment table

Name of hazard	Symbol	Meaning	Examples
Corrosive	<p>Symbol: Corrosion</p> 	This chemical causes skin corrosion/burns or eye damage on contact, or is corrosive to metals.	Sodium hydroxide Sulfuric acid
Health hazard/ Hazardous to the ozone layer	<p>Symbol: Exclamation mark</p> 	This chemical will cause immediate skin, eye or respiratory tract irritations.	Many acids and alkalis
Flammable	<p>Symbol: Flame</p> 	This chemical will catch fire easily.	Ethanol Propanone
Hazardous to the environment	<p>Symbol: Dead tree and fish</p> 	The chemical will cause damage to all living things if it enters the waterways.	Copper sulfate
Explosive	<p>Symbol: Exploding bomb</p> 	This chemical is an explosive at risk of exploding, even without exposure to air.	Potassium Lithium

Table 1.3 Chemical hazard symbols

Name of hazard	Symbol	Meaning	Examples
Oxidising	Symbol: Flame over circle 	These chemicals produce oxygen, which causes other substances to burn more.	Potassium permanganate Nitric acid
Acute toxicity	Symbol: Skull and crossbones 	This substance will cause severe illness or death if it enters the body.	Mercury Lead
Serious health hazard	Symbol: Health hazard 	This chemical can cause serious long term health hazards such as damage to organs, cancer or genetic defects if it is swallowed or enters airways.	Turpentine Petrol
Gas under pressure	Symbol: Gas cylinder 	These gases are stored under pressure and may leak causing fire, poisoning, corrosion, suffocation or 'ice burns'.	Ammonia Liquid nitrogen

Table 1.3 (Continued)

Quick check 1.7

- 1 State the correct initial response if you see a hazard in the science lab.
- 2 State when you should wear a lab coat.
- 3 Recall the name of the safety equipment that will protect your eyes.
- 4 Describe how your school labels hazardous chemicals that are being used in an experiment. Ask your teacher for an example and record how it is labelled.

Get to know your equipment

All experiments need to be safe, fair and exact. One of the ways to ensure that this happens is to choose the correct equipment for each task. This might sound obvious, but there are several pieces of equipment that can be used for even the simple task of holding a liquid. In Table 1.4 are several pieces of equipment used to hold and work with liquids, and their purpose.

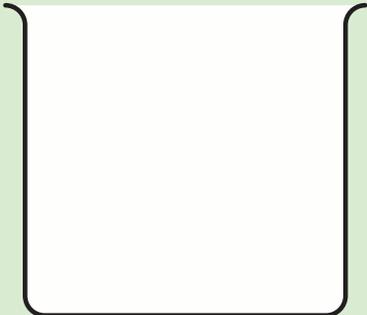
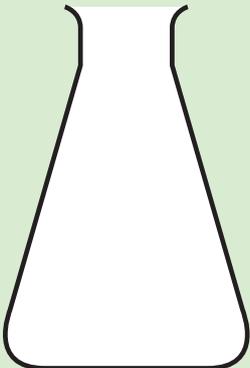
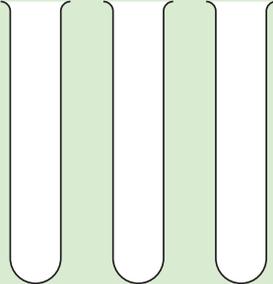
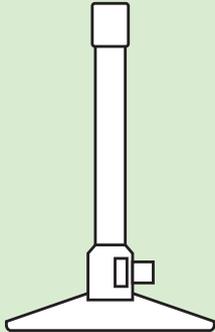
What it is used for	How it looks	How it is drawn
<p>A beaker is a common piece of equipment found in most labs. It comes in many sizes and is generally used for holding, mixing and heating liquids.</p>		
<p>A conical flask is similar to a beaker but the shape of its neck is different to reduce the likelihood of liquid spilling. It can be used to swirl liquids and prevent hot liquids from boiling over.</p>		
<p>Test tubes are used for holding small amounts of liquids. As they do not have a flat bottom, a test-tube rack is used to hold them.</p>		
<p>A measuring cylinder is used to accurately measure specific volumes of liquids. It must not be used to mix or heat liquids.</p>		
<p>A Bunsen burner is a common device used to add a controlled amount of heat to an object.</p>		

Table 1.4 Some common lab equipment

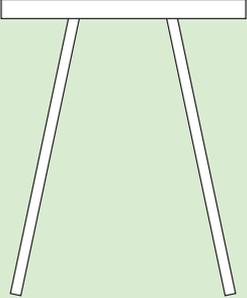
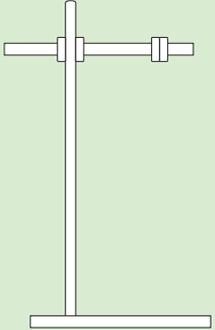
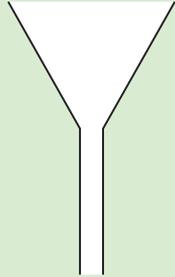
What it is used for	How it looks	How it is drawn
A tripod is used to hold an object above a Bunsen burner flame while it is being heated. A wire gauze mat usually sits on top of the tripod.		
A retort stand and bosshead clamp are used to hold objects in place while testing.		
A funnel can be used to separate mixtures or make it easier to transfer liquids from one container to another.		
An evaporating dish is used to heat up and evaporate small amounts of liquid.		

Table 1.4 (Continued)

You may have noticed that next to each image of the equipment in Table 1.4, you will see a two-dimensional drawing. Two-dimensional, or 2D, drawings show the dimensions of length and width but do not show depth. All 2D drawings are made up of shapes. These are called scientific drawings and you use these drawings when you draw the set-up for an experiment. Use the following rules when creating a scientific drawing:

- Use a sharp pencil.

- Use a ruler to draw a straight line (no freehand).
- Only draw in 2D.

Heating equipment

In many of the experiments you will conduct in your science classes, you will need to heat different objects. This can be done using a water bath, hotplate or microwave oven, but one of the most common heating tools in the lab is the Bunsen burner.

The Bunsen burner

A Bunsen burner is a heating tool that uses gas and a flame of controlled intensity. Although not all Bunsen burners look the same, they all have the same parts, as shown in Figure 1.19

Be careful

Remember these important safety points when using a Bunsen burner.

- Tie long hair back and secure loose clothing such as school ties.
- Roll up sleeves if they are too long.
- Never leave the Bunsen burner unattended.
- Turn the Bunsen burner to a yellow safety flame when not heating.
- Place the Bunsen burner on a heatproof mat.
- Wait for all equipment to be cool before handling.

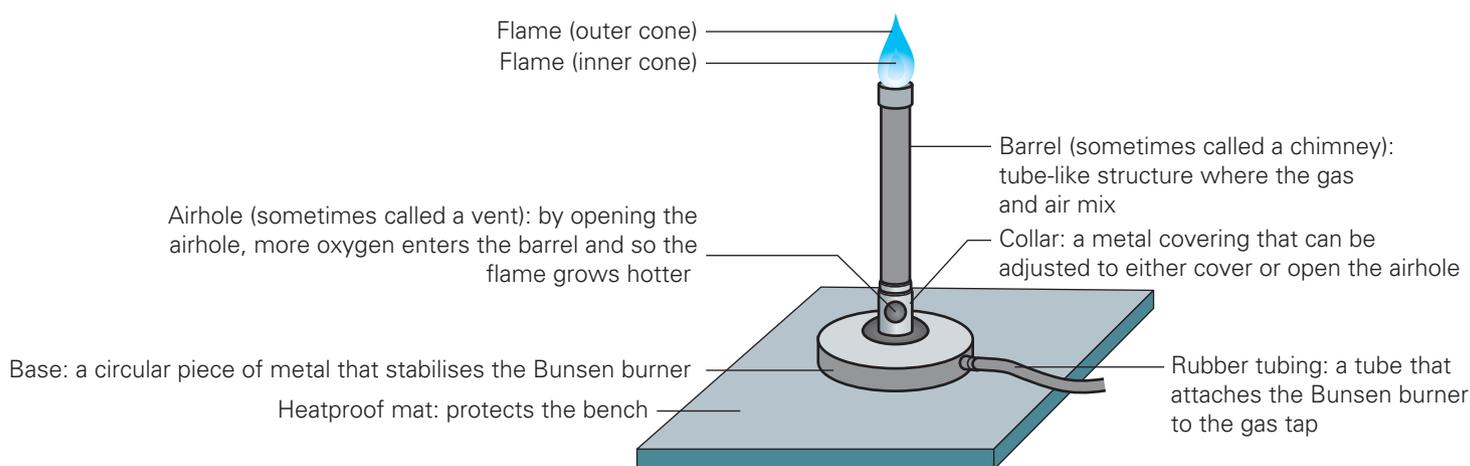


Figure 1.19 Components of a Bunsen burner

Controlling the flame

You can control the type of flame and the temperature of the Bunsen burner by changing the size of the airhole. The airhole size is adjusted by twisting the collar, or by turning the knob if your Bunsen burner is like the one in Figure 1.20.

When you first light a Bunsen burner, you must close the airhole to produce a bright yellow 'safety flame'. This yellow flame is not as hot and can be easily seen. The flame is yellow because the gas does not mix in the barrel with oxygen from the air when the airhole is closed. Oxygen is necessary to produce a more intense flame. When the collar is turned and the airhole is open, more oxygen can mix with the gas and so this produces a much more powerful blue flame.

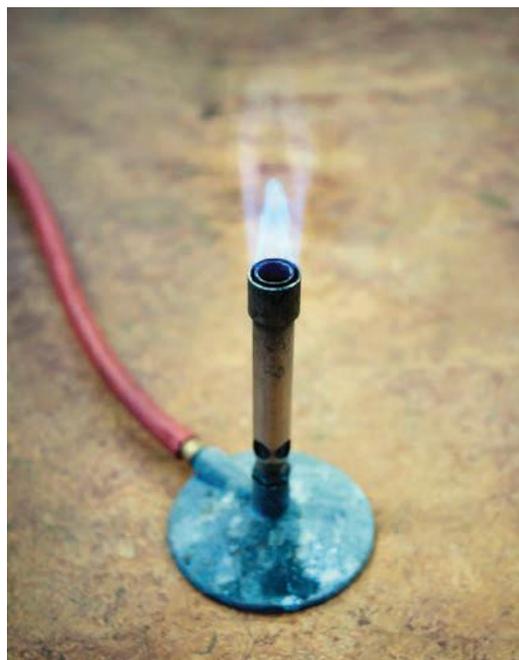


Figure 1.20 Blue flame, or roaring Bunsen flame, is produced when the airhole is fully open. It allows oxygen from the air to mix with the gas in the barrel.

Practical 1.3

Using a Bunsen burner

Aim

To practise the safe procedure for lighting a Bunsen burner.

Materials

- Bunsen burner
- matches
- heatproof mat

Method

- 1 Place the Bunsen burner on a heatproof mat.
- 2 Attach the Bunsen burner rubber tubing to a gas tap.
- 3 Ensure the Bunsen burner hole is closed to give a safety flame.
- 4 Strike a match away from your body.
- 5 Turn on the gas.
- 6 Bring the match up towards the tip of the barrel mouth to light the flame.
- 7 Shake out the match and place on the heatproof mat.
- 8 When heating anything, twist the collar to open the airhole and produce a blue flame.
- 9 When the Bunsen burner is not being used for heating, twist the collar to close the airhole and produce a safety flame.
- 10 Ensure the gas is turned off at the end of any Bunsen burner practical.

Planning

Consider the following questions while doing your risk assessment:

- 1 Explain why the airhole is closed before turning on the Bunsen burner.
- 2 Explain why the match is struck away from the body.

Be careful

Ensure that you follow measures to ensure general fire safety.

Practical 1.4

Heating water

Aim

To identify and use the appropriate equipment for heating water.

Materials

- 250 mL beaker
- boiling tube (large test tube)
- evaporating dish
- stopwatch
- Bunsen burner
- tripod
- gauze mat
- heatproof mat
- test-tube tongs
- 250 mL measuring cylinder

Planning

Read the following method and create a risk assessment for this experiment.

Be careful

Ensure general fire safety measures are observed.
Ensure appropriate personal protective equipment is used when handling hot equipment.

continued...

...continued

Method

The diagrams in Figure 1.21 show how to set up your equipment for each test.

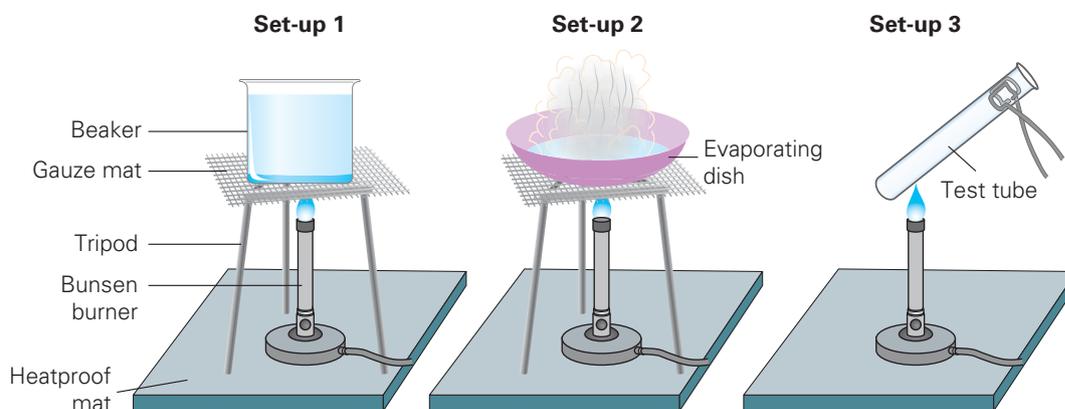


Figure 1.21 Experimental set-ups

Set-up 1

- 1 Add 50 mL of water to a beaker.
- 2 Place the beaker on the gauze mat over the tripod.
- 3 Light the Bunsen burner and measure the time taken for the water to reach boiling point.

Set-up 2

- 4 Fill the evaporating dish with water and pour into the measuring cylinder. Record the volume of water it can hold.
- 5 Repeat steps 1–3, replacing the beaker with an evaporating dish.

Set-up 3

- 6 Fill the evaporating dish with water and pour into the measuring cylinder. Record the volume of water it can hold.
- 7 Add 50 mL of water to a large test tube.
- 8 Hold the test tube over a blue flame using wooden tongs. Point the test tube opening away from yourself and anyone else and move it in a circular motion above the flame until the water boils.
- 9 Record the time it takes for the water to boil.

Results

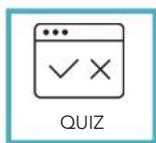
Copy and complete the following results table.

Container	Maximum volume of equipment (mL)	Time taken to reach boiling point
Beaker		
Evaporating dish		
Test tube		

Discussion

- 1 Describe any trends in your results.
- 2 Identify the best piece of equipment for holding and heating a small sample of substance.
- 3 Identify the best piece of equipment for removing some of the water.
- 4 Identify any limitations in the method.

Section 1.3 questions

**Remembering**

- 1 **List** three pieces of personal protective equipment you might use in the lab.

Understanding

- 2 **Outline** the steps involved in safely lighting a Bunsen burner.

Applying

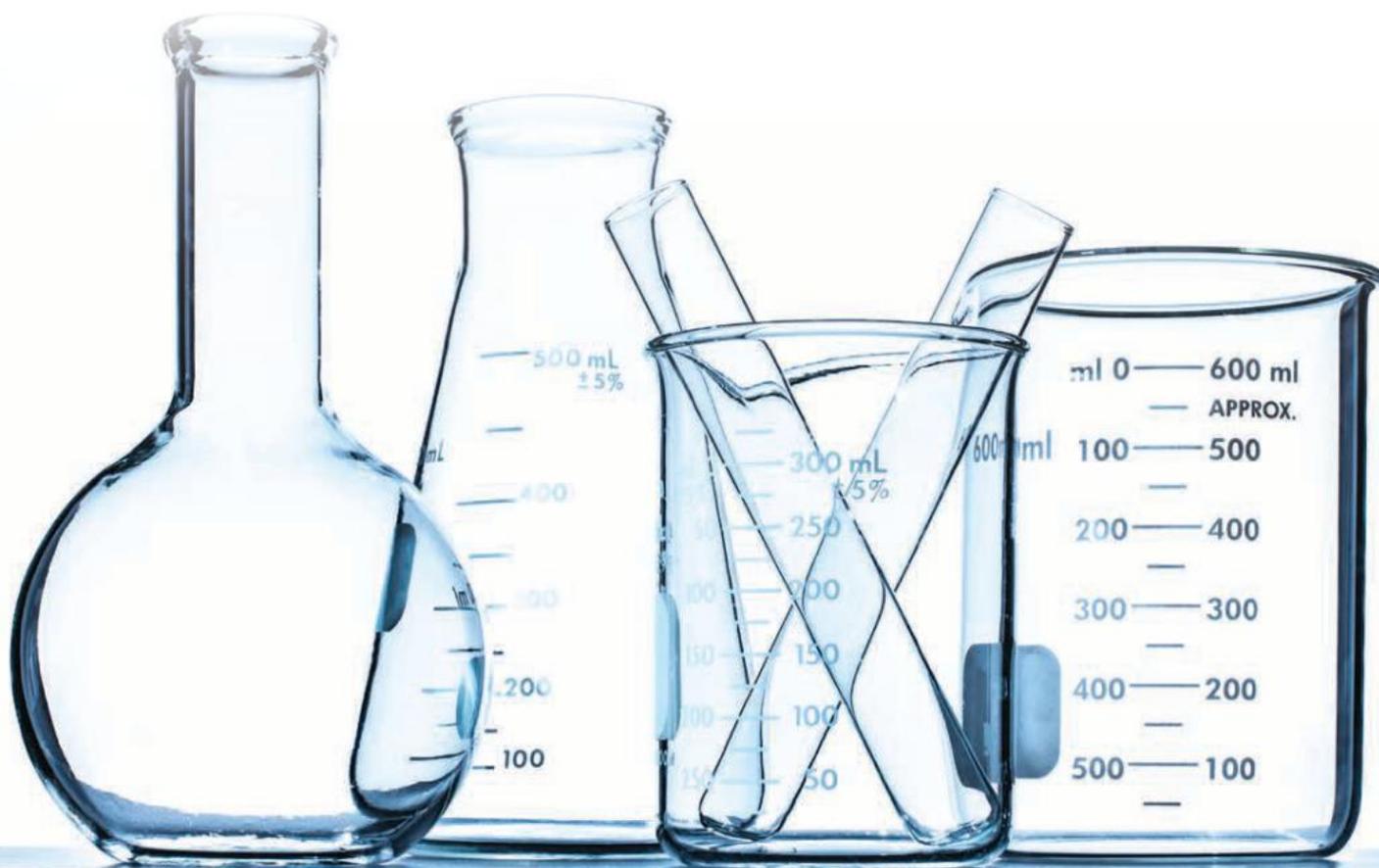
- 3 **Organise** the lab equipment featured in this chapter into categories: containers; heating equipment; measuring tools; and others.

Analysing

- 4 **Compare** the use of a conical flask and a beaker.

Evaluating

- 5 **Create** a risk assessment and an equipment list for a possible experiment to test the absorbance of different paper towels.



Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked question	Check
1.1 I can name different fields of science and what is studied in them.	4	
1.2 I can describe each stage of the scientific method or sections of a lab report.	12	
1.2 I can identify independent, dependent and controlled variables.	10 a	
1.2 I recognise the difference between quantitative and qualitative data.	10 c	
1.2 I can select the most appropriate piece of measuring equipment when collecting data.	2	
1.2 I recognise the difference between systematic and random errors.	8	
1.3 I can describe some common safety issues in the science lab.	1	
1.3 I can identify hazard symbols in the science laboratory.	13	
1.3 I can identify and draw common lab equipment.	3	
1.3 I can summarise the instructions for safely lighting a Bunsen burner.	11	

Review questions

Remembering

- 1 **Recall** three science safety rules.
- 2 **List** two pieces of equipment used to measure length.
- 3 **Draw** the following laboratory equipment: beaker, measuring cylinder, Bunsen burner.
- 4 **State** the name of four different fields of study in science.

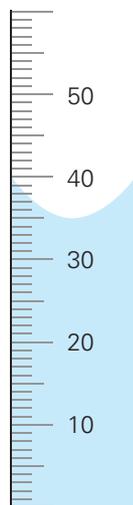
Understanding

- 5 **Explain** why it is important to choose the best piece of measuring equipment for a task.
- 6 **Describe** how a convex meniscus is formed.
- 7 **Identify** a piece of equipment and unit of measurement that could measure:
 - a the length of an ant
 - b the weight of a Bunsen burner
 - c the volume of liquid in a cup of coffee.



Applying

- 8 A depiction of a measuring cylinder is shown below.
- a **Identify** the amount of liquid in the container and explain your answer, with reference to the meniscus. The graduations are in mL.



- b A student measured 20 mL of water from a measuring cylinder 10 times, and when weighed the samples of water fluctuated above and below the 20 g mark. **Describe** whether this fluctuation is due to random or systematic error in the measurement.
- 9 **Explain** a reason why mercury forms a convex meniscus in a test tube.

Analysing

- 10 A student set out to test paper-plane wing size and the distance the plane travels.
- a **Identify** the variable she is changing (testing) and how it might be measured.
- b The student notices that planes with larger wing sizes appear to float higher, and she yells out to her laboratory partner, 'They must capture more wind!'. **State** whether this is an observation, an inference or both.
- c The student records distance flown in metres, using a tape measure. **Deduce** if this is qualitative or quantitative data.
- d The laboratory partner remarks that the testing is not fair as they took it in turns to fly the planes and he is a better thrower. **Analyse** the method and describe how the students could improve this experiment to make it more fair.
- 11 **Explain** the reason the airhole of a Bunsen burner is closed when it is not in use.

Evaluating

- 12 **Create** a flow chart showing the stages of the scientific method.
- 13 A bottle of arsenic acid requires hazard symbols to warn scientists of the risk of using the substance. Arsenic acid is corrosive, acutely toxic, a health hazard and an environmental hazard. **Sketch** the hazard symbols that are required on the bottle of arsenic acid. Use Table 1.3 to aid your response.

Data questions

You can measure 100 mL of water in a measuring cylinder by filling the glassware to the 100 mL line and making sure that the water level is read correctly from the bottom of the meniscus. Some Year 7 students measured out 100 mL of water in a measuring cylinder and weighed the amount of water on an electronic balance. They repeated this experiment 10 times and the results are shown in Table 1.5.

Measuring cylinder	Mass of water (g)
1	100.0
2	96.5
3	100.0
4	100.0
5	99.7
6	100.8
7	100.3
8	99.9
9	99.7
10	104.2

Table 1.5 Mass of 100 mL of water measured in a measuring cylinder and weighed on an electronic balance

- 1 The experiment was conducted at a temperature at which 1 mL of water has a mass of 1 g. Use this information to **determine** what should be the accurate value for the mass of 100 mL of water.
- 2 **Identify** two results which are considered furthest away from the accurate value.
- 3 Use the data in Table 1.5 to **describe** the differences in the collected results.
- 4 **Deduce** whether the differences in results identified in Question 3 could be from the measuring cylinder or the electronic balance or both.
- 5 **Infer** why there might be considerable differences in the collected data.
- 6 If the students were to repeat this experiment 10 more times, **predict** to what extent the results would change.



Chapter 2

Classification

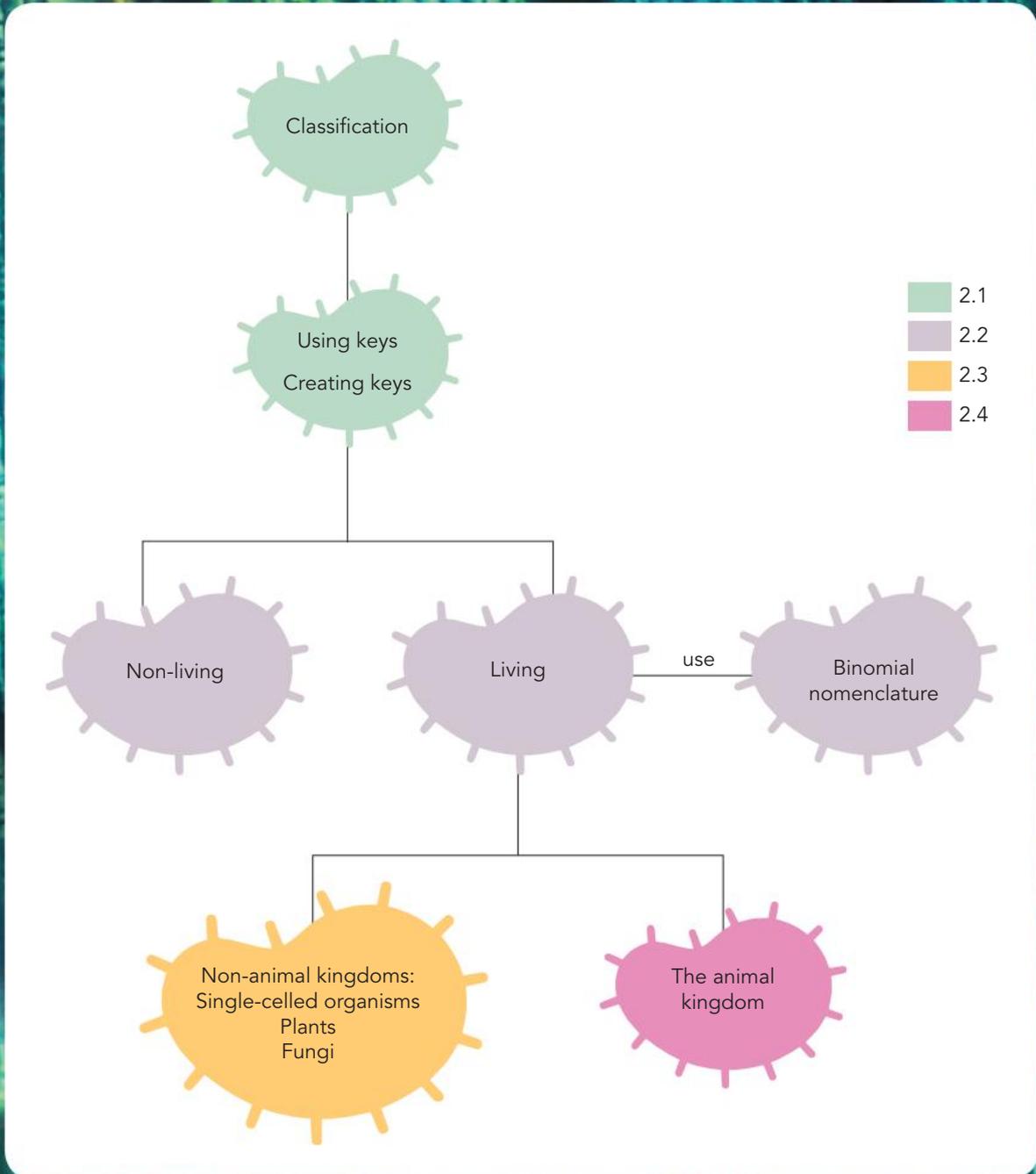


Chapter introduction

Whether you are answering questions about what food you would like to eat, what music you like or what movies you want to watch, you are unknowingly grouping many things together based on similarities. This process is called classification.

In this chapter, you will explore the way scientists use classification systems to share their knowledge and group all of the living organisms on Earth.

Chapter map



2.1 Classification and keys



Learning goals

- 1 To be able to understand how classification is useful to identify living organisms.
- 2 To be able to interpret and construct a dichotomous key.
- 3 To explore classification systems used by many Aboriginal and Torres Strait Islander peoples.

classification
the grouping of similar objects or organisms together

genre
a category used to group media such as music, art or books

You do it all the time!

Classification is the process of arranging similar things into groups. You do this every day without even thinking about it.

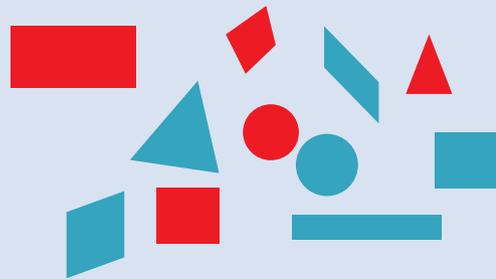
When you are looking for a show on a streaming platform, you automatically scroll through different **genres** such as comedy, drama, family or sci-fi to find what you want. Just imagine if all the shows that are available to you were just placed online in no particular order. It would be next to impossible to find what you were looking for. This is why classification is necessary.

People are also classified in many different ways. How many times have you been asked your year level, school name or date of birth? These are all ways that people can gather information about you and place you into a group.

Try this 2.1

Classification

Take a look at the image below.



- 1 Decide how many groups are in the picture.
- 2 Justify your answer.
- 3 Compare your answer with other people in your class.
- 4 Discuss why different people may have different answers.

Figure 2.1 Supermarkets are a place where classification is really important; otherwise, how would you be able to run in and out in five minutes to get your microwave popcorn for movie night?



Communication is key

In science, it is important to be able to share and develop ideas with people all over the world. To do this, scientists across different fields need to create a universal language that everyone understands and agrees on. If universal classification systems were not put into place, biologists, for example, would not know if an organism they had discovered was new and one chemist would not know if another chemist was talking about the same substance as them.

To be able to classify, you must first make detailed observations about the characteristics of the things being classified, then you can group the things with the most similarities together. Consider the robots in the following picture. What are their observable

characteristics? How could you classify or group them? Which robots are most similar and should be grouped together?

characteristic
a feature or quality of something

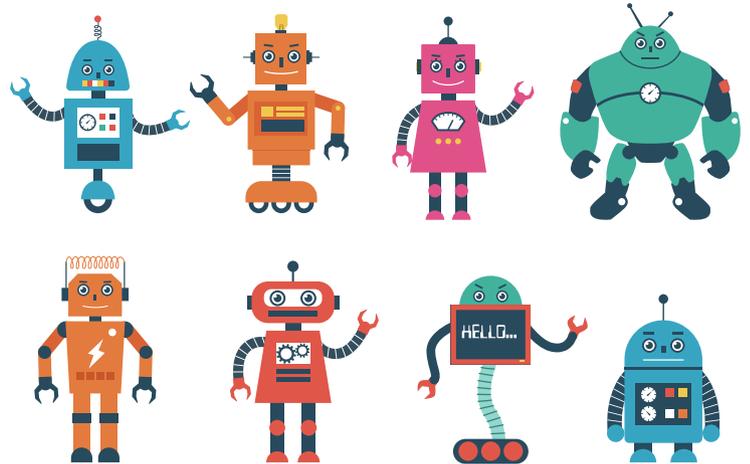


Figure 2.2 Even robots can be classified based on their observable characteristics.

Try this 2.2

Let's practise observing the different characteristics or features of living things. Describe the features you see in each animal. Compare your observations with your classmates. Did you observe the same features?



Did you know? 2.1

Not actually a panda

Although the red panda shares many similarities with the giant panda, with which it shares its name, it also shares many characteristics with raccoons. Since it fits in with neither, it has been classified in a unique group of its own.



Figure 2.3 Red panda (*Ailurus fulgens*) in the wild

Quick check 2.1

- 1 Define the term 'classification' in your own words.
- 2 Name three examples of classification systems that you named in Try this 2.2 and explain how they demonstrate classification.
- 3 Explain why it is important that scientists all use the same language of classification.

Aboriginal and Torres Strait Islander classification systems

Aboriginal and Torres Strait Islander peoples classify organisms in different ways. Often living things are not seen in isolation but rather in terms of how they connect with other things. For example, living things may be classified based on their:

- use (e.g. medicines, tools, clothing)
- edibility (i.e. can it be eaten?)

- observable features (e.g. wings, fins)
- habitat (e.g. aquatic, land, coastal)
- life stage (e.g. a living thing may be classified differently depending on which stage in the life cycle it is at).

Different peoples will have different complex classification systems. This demonstrates their deep knowledge of an organism's connections with other living things and the environment.

Explore! 2.1

Totemic systems

Many Aboriginal and Torres Strait Islander peoples also use totemic classification where animals hold significant totemic relationships with individuals. For example, in Noongar culture (peoples from the South West region of Western Australia), children are given a spiritual totem animal. A person with a *weitj* (emu) totem is to protect and preserve that totem. Research the significance of totems to Aboriginal and Torres Strait Islander peoples, and focus your exploration on totems in your local Aboriginal culture.

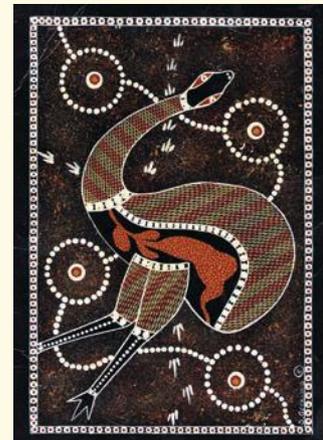


Figure 2.4 Aboriginal art showing an emu, or *weitj* in Noongar language

Unlocking classification

Before you explore some different types of classification systems, it is important that you understand how to use **keys**. You usually think of a key as something that unlocks a door, but in science, the term is also used when you are ‘unlocking’ or sorting out a group of items

into an order that makes sense. Keys allow you to follow a series of steps and identify objects that have already been classified. Figure 2.5 shows four different marsupials found in Western Australia. You can use the key in Figure 2.6 to determine their names.

key
a tool used to identify organisms

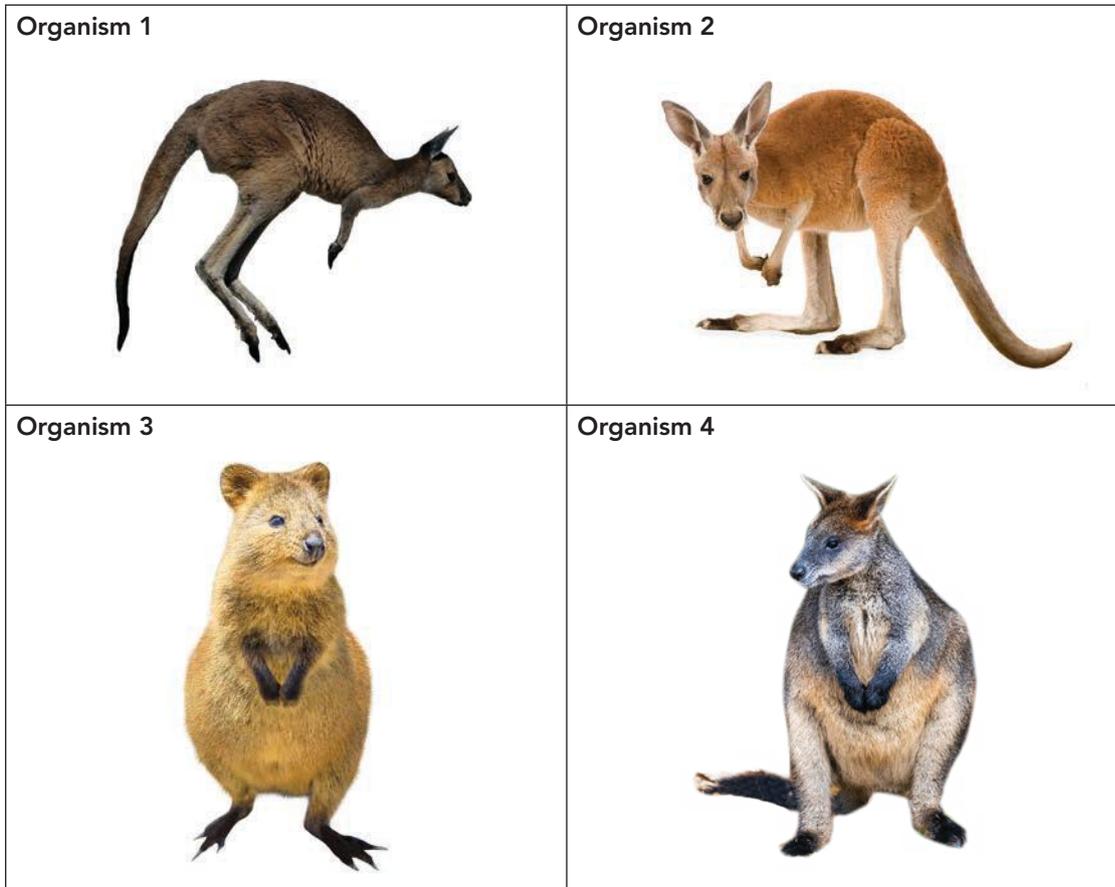


Figure 2.5 Some marsupials found throughout Western Australia and neighbouring states

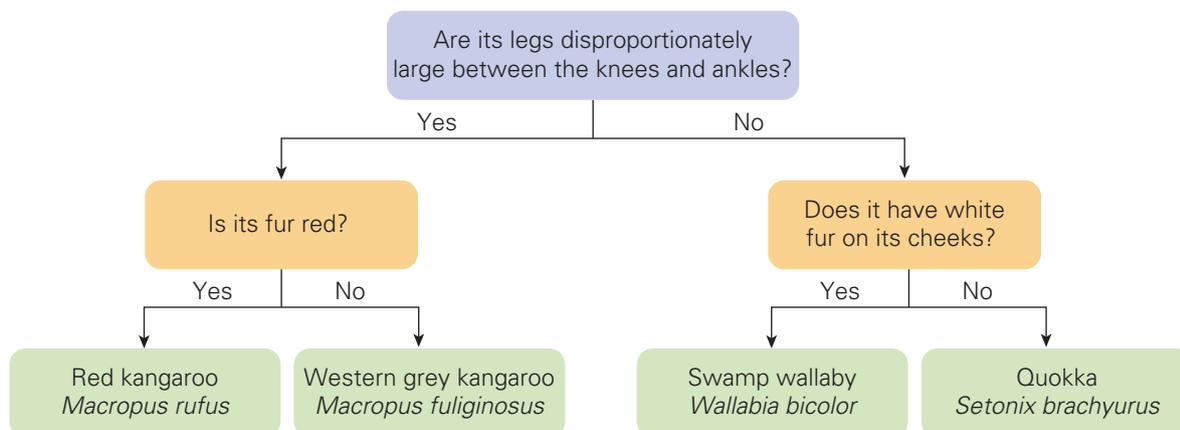


Figure 2.6 A branching dichotomous key for classifying some Western Australian marsupials in Figure 2.5

Using keys

Imagine you are a scientist wanting to focus your research on the quokka. You have been sent a photo of Organism 3 as shown in Figure 2.5 but are not sure if it is the quokka. To determine if you have the correct organism, you must use the key in Figure 2.6.

Can you work out whether the name of Organism 3 is the quokka? Start at the top and at each step in the process, make a yes/no decision.

dichotomous key

a tool for scientists to identify an organism from a series of choices between two characteristics

The key that you just used is known as a **dichotomous key**. A dichotomous key is an organised set of couplets

of mutually exclusive characteristics of biological organisms (in other words, an organism will always be one or the other, but not both items in each level of the key). The word dichotomous literally means 'to cut in two'. At each stage, it gives you just two options based on the organisms you are looking at, allowing you to narrow down the possible choices. If the organism falls into one category, you go to the next indicated couplet. There is no right or wrong way to start a key, as long as it has two options and is specific. A key can also be drawn as a table. Test whether you get the same answer using this key in Table 2.1 as you do when using the branching key in Figure 2.6.

1a	Large legs	Go to #2
1b	Small legs	Go to #3
2a	Red fur	Red kangaroo
2b	No red fur	Western grey kangaroo
3a	White fur on cheeks	Swamp wallaby
3b	No white fur on cheeks	Quokka

Table 2.1 A dichotomous key in table format to identify some Western Australian marsupials

Quick check 2.2

- 1 Explain the purpose of a key.
- 2 Define the term 'dichotomous key' and describe how it works in your own words.
- 3 Use the dichotomous key of Western Australian marsupials in Table 2.1 and Figure 2.6.
 - a List the characteristics of the red kangaroo.
 - b Identify marsupials **1–4** in Figure 2.5.



WIDGET
Classifying
Australian
animals

Try this 2.3

Making a branching dichotomous key

As a class, discuss some ways that a deck of cards can be grouped by listing the different characteristics. Create groups of similar cards based on these characteristics. Are there different ways you could classify or group the cards? Challenge a classmate to find a certain card using one of the grouping methods you come up with. Perhaps they could race your teacher who is trying to find the same card but in a shuffled and ungrouped deck of cards. What can you conclude?

Now try to make a branching dichotomous key based on one of the ways you chose to group your cards. Test it on a classmate to see if it works.

Creating a key

Here are some things to think about when creating a key.

Will the characteristics change over time?

Grouping organisms based on what they look like considers a creature's **morphology**. However, some characteristics, like colour, size and shape, are not so useful for making a key as these characteristics can change over time, or with the seasons. For example, think about your hair colour – was it the same colour when you were born? Will it change as you get older? Another example from the animal world is the stoat (Figure 2.7). It has a white winter coat that offers it camouflage when there is snow



Figure 2.7 This is an image of a stoat with its winter coat (white) and summer coat (brown). It seems like it could be two different animals!

on the ground, while in summer it completely changes colour to brown!

Are the characteristics specific?

You might have noticed that the Western Australian marsupial key on page 46 focused on specific observable characteristics of each creature at each stage of the key.

This is very important to remember when constructing a key, otherwise scientists could become confused and get different answers when they use the same key. If you were to design a key based on the three adult females shown in Figure 2.8, you might be tempted to describe their height as short, medium and tall. This would not be a dichotomous classification as it is very subjective – what someone else calls short may be different from what you call short! The term **qualitative** is used when a characteristic is described in this way. Starting your key with 'Is the adult female taller or shorter than 160 cm?' would be better as there are only two options to choose from in this case, and the answer is clear. The term **quantitative** is used when a characteristic is measured or described using numbers.



VIDEO
How quickly do these animals change appearances?

morphology
the study of the size, shape and structure of organisms

qualitative
a form of data that is a descriptive measurement

quantitative
a form of data that is a numerical measurement



Figure 2.8 Height can be described (qualitative) or measured (quantitative), but to classify, you need to make sure the characteristic is clear and measurable (i.e. quantitative) where possible.

Narrowing down the choices

You need to make sure that the features of the object you are choosing are unique to that object or at least different from a few of the other options. If you were to classify the animals shown in Figure 2.9, you could not use 'striped' as a defining feature.

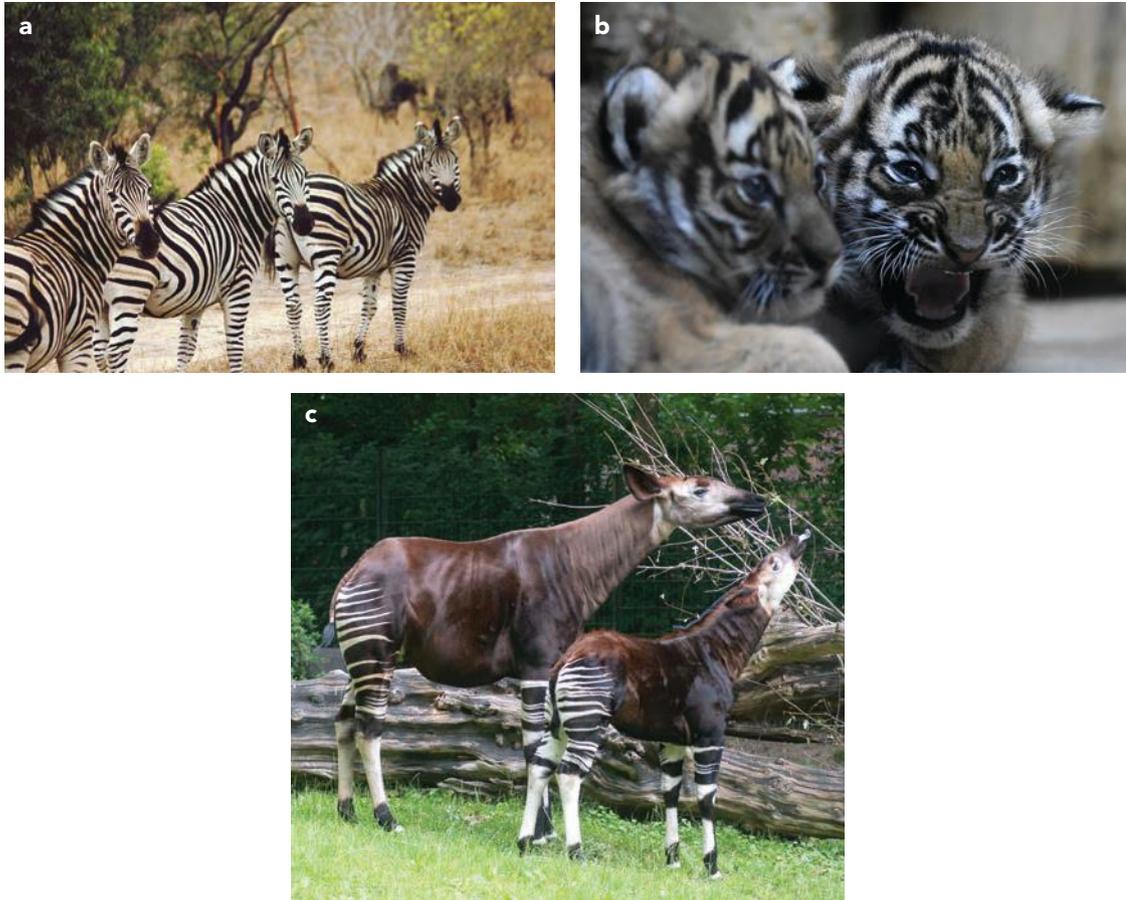


Figure 2.9 Can you name these striped animals?

Quick check 2.3

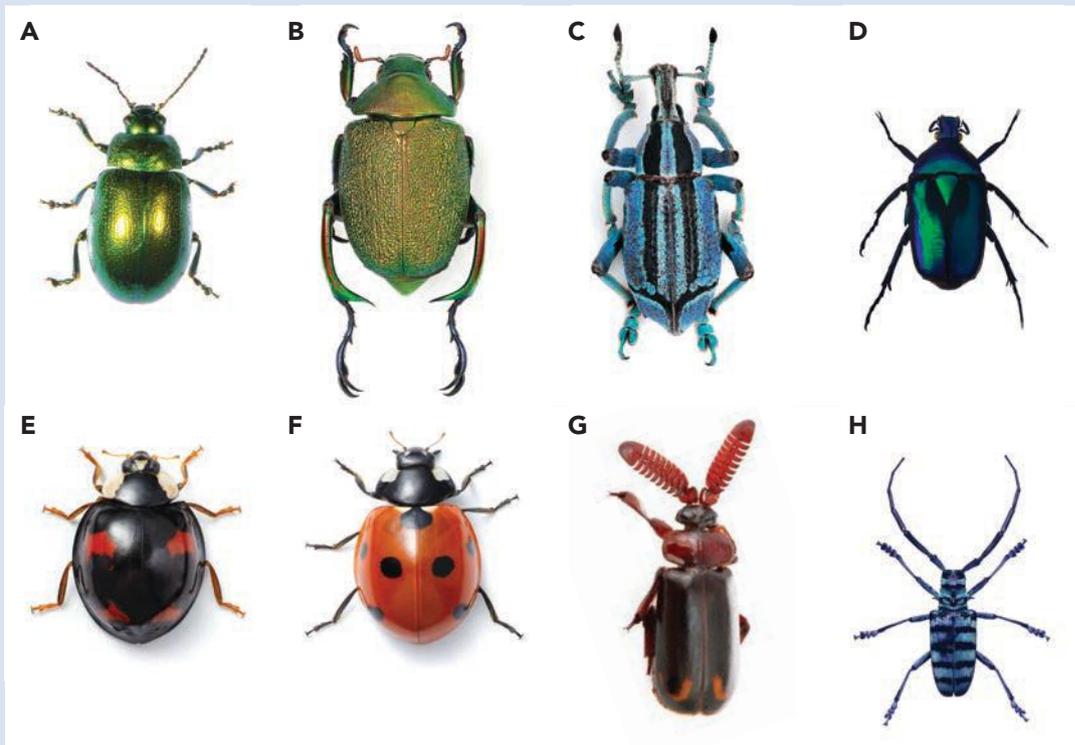
- 1 Summarise the key points to remember when selecting characteristics to create a key.
- 2 Define the terms 'qualitative' and 'quantitative' in your own words.
- 3 When making a key, discuss whether the characteristics need to be qualitative or quantitative.
- 4 In the table below, identify an example of a quantitative description that would match each qualitative description for the characteristics.

Characteristic	Qualitative	Quantitative
Height	Tall	
Legs	Many	
Fur length	Short	
Wing size	Big	

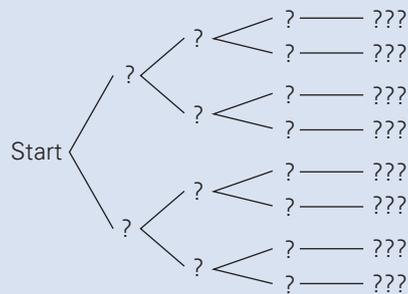
Try this 2.4

Creating a key for some insects

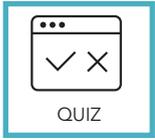
The diagram below shows eight different beetles (A–H).



- 1 Observe the different insects and describe their main differences.
- 2 Use the main difference between the insects to separate them into two groups. Create and label a tree diagram, shaped like the example on the right on a piece of paper to show these divisions.
- 3 Separate each group into two further groups, and then continue until there are eight individual insects on the final level of the tree diagram.
- 4 Use the differences you have identified to construct a dichotomous key for the insects.
- 5 Pass the key to a classmate and get them to use it on your insects to make sure it is easy to follow. In other words, your classmate should arrive with the eight insects in the same categories at the bottom of the diagram, as you intended.
- 6 After you have tested the key, make any alterations that you need to in order for it to work.
- 7 Explain the main difficulties you faced when you constructed your key.
- 8 Discuss the reason for any changes you made after testing the key with a classmate.



Section 2.1 questions

**Remembering**

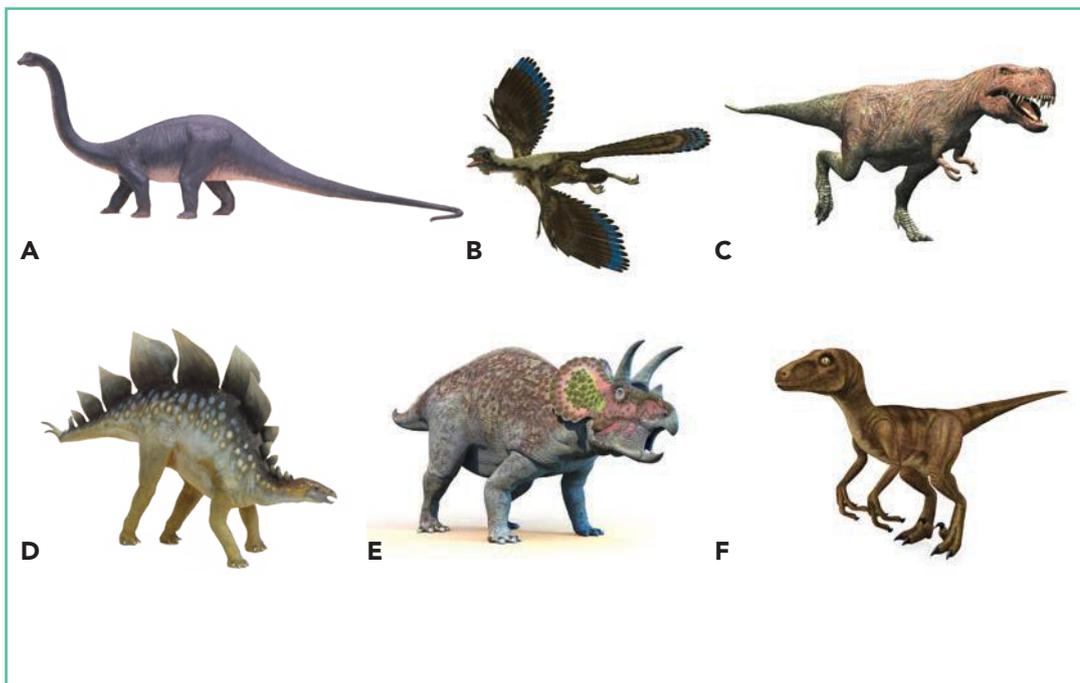
- 1 **Define** the term 'classification'.
- 2 **Explain** why scientists need to classify things.
- 3 **Recall** the term given to a key that has two possible options at each stage.

Understanding

- 4 Which of the following characteristics would be best to use when making a classification key for birds? **Explain** your choice.
 - A Where the bird was last observed
 - B What food the bird likes to eat
 - C The number of birds in your suburb
 - D Colour markings on the bird's wings
- 5 **Explain** why the shape of an animal may not be the best defining feature to focus on when creating a key. Suggest some features that would be useful.

Applying

- 6 **Determine** which of the following features would be useful when creating a key to identify types of plants (there may be more than one correct answer).
 - A Short leaves vs long leaves
 - B Smooth leaves vs spiny leaves
 - C Tall vs short
 - D 1 m average height vs 0.2 m average height
 - E Pink spots on leaf vs no pink spots
 - F Dark green colour vs light green colour
- 7 **Determine** the identity of each dinosaur (A–F) using the following images and dichotomous key.

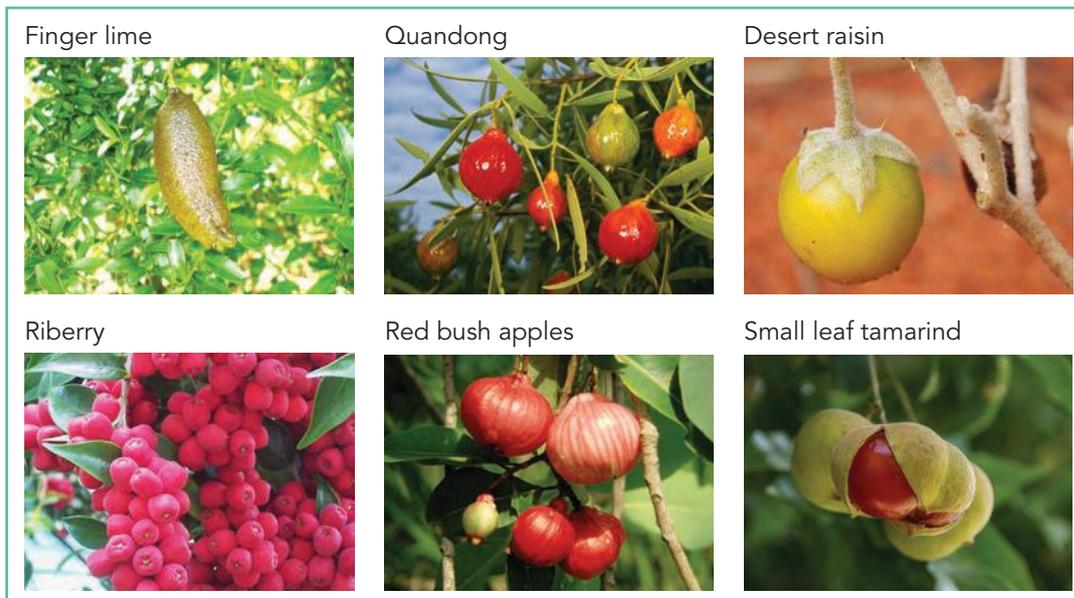


Dinosaur dichotomous key:

- | | | |
|---|--|--------------------------|
| 1 | Has four legs | Go to #2 |
| | Has two or fewer legs | Go to #3 |
| 2 | Has horns or plates | Go to #4 |
| | Has no horns or plates | <i>Diplodocus</i> |
| 3 | Has wings | <i>Archaeopteryx</i> |
| | Has no wings | Go to #5 |
| 4 | Has horns | <i>Triceratops</i> |
| | Has plates on back | <i>Stegosaurus</i> |
| 5 | Arms less than half the length of the legs | <i>Tyrannosaurus rex</i> |
| | Arms longer than half the length of the legs | <i>Velociraptor</i> |

Analysing

- 8 **Distinguish** between qualitative characteristics and quantitative characteristics.
- 9 Aboriginal and Torres Strait Islander peoples use many endemic plants for medicinal purposes. Some of these are shown below.



- a **Classify** the native fruits into two groups based on a specific characteristic. Outline the features of each fruit that led you to your classification.
- b Now use the images again to **classify** these native fruits but this time into three groups. Outline the features of each native fruit that led you to your classification.
- c Ask to see the groups your classmates came up with and **compare** with yours.

Evaluating

- 10 **Decide** whether the features are good or weak descriptors to use in a dichotomous key for humans and **justify** your choices.
- Blue or brown eyes
 - Long hair
 - 150–160 cm tall
 - Likes cats
 - Size 6 shoe

2.2 Classifying living things



Learning goals

- 1 To be able to classify a living organism.
- 2 To be able to use conventions to name organisms.



Is it alive?

One of the most basic classification groupings that can be used is 'living' or 'non-living'. The characteristics of living things are often summarised using the acronym MRS GREN. Can you work out what these characteristics are, based on this acronym? The flow chart in Figure 2.10 will give you some clues. It is important to keep in mind that when a thing is described as non-living, it does not mean the same thing as dead. Something that is dead used to exhibit all the characteristics of living things, while something that is non-living never exhibited them.

The first characteristic, movement, needs some explanation. Movement from one location to another – locomotion – is easy to see, but the characteristic also refers to movement while staying in the same place, which may be difficult to observe, partly because it could be so slow. Examples are a change in orientation (e.g. plants moving leaves to catch sunlight); moving parts of the organism in relation to the whole (e.g. flowers opening and closing, or spores being released); internal movement, such as movement of sap; or movement seen inside cells with a microscope.

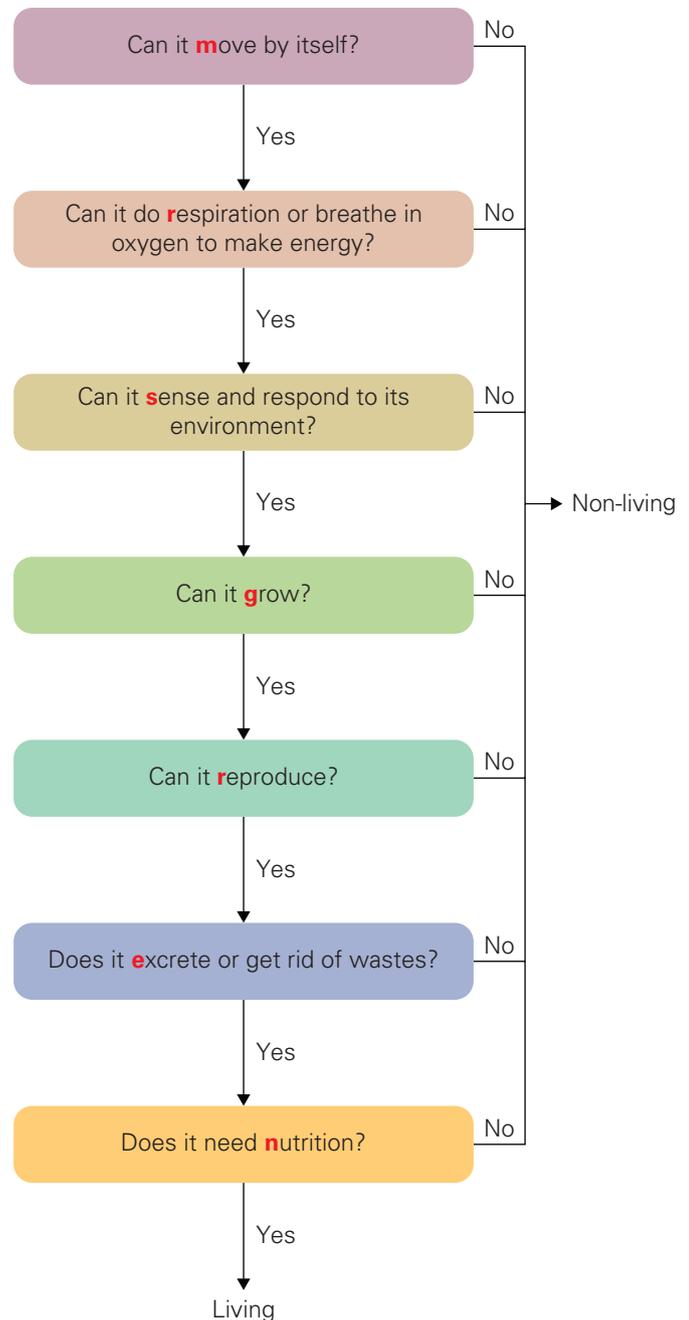


Figure 2.10 Unless all seven criteria are met, a thing cannot be classified as 'living'.

Explore! 2.2

Search online for information on how crystals grow. Would you classify crystals as living things? What about an aeroplane? The Sun? Justify your answers by listing which criteria they meet and which criteria they do not meet.

Quick check 2.4

- 1 State the characteristics that all living things share and describe an example for each (plant/animal/insect).
- 2 Explain what non-living means.
- 3 Distinguish between non-living and dead.
- 4 Copy and complete the table below.
 - Tick if the characteristic is present.
 - Classify the object as living, non-living or dead.

Object	Tick if the characteristic is present							Living? Non-living? Dead?
	M	R	S	G	R	E	N	
Fire								
Dolphin								
Yeast								
Car								
Squashed fly								
Paper								
Cactus								

Did you know? 2.2

Are you related to a banana?

Every living organism on this planet has evolved from a common ancestor. Scientists have discovered this by studying the similarities in **DNA**. DNA is found in every living cell and basically gives the cell or organism instructions on how to grow and function. Humans share about 60% of our DNA with chickens. This is not too surprising as we both have eyes, hearts, legs and many other similarities. However, we humans also share about 60% of our DNA with bananas. This does not imply relation, however, rather similarities in cell processes such as cell division, the cell cycle and DNA replication. Can you see how classifying by DNA might not be the only answer?



Figure 2.11 Humans and bananas are quite different!

Taxonomy

So far, you have learned why it is important to classify things and about the tools that help do that. Now you are going to look at how biologists use these systems to classify

all living things or **organisms**. The branch of science that classifies organisms is known as **taxonomy**. Taxonomy is just like a magical filing system for the 8.7 million different living things that exist in our world!

DNA
deoxyribonucleic acid, a chemical present in cells of living things that carries genetic information

organism
a living thing

taxonomy
a branch of science that groups organisms

There is not always a clear way to classify each organism and sometimes whole groups of organisms get so big that they then must be broken down into smaller groups. This means that the detailed classification is constantly changing as new organisms are found and added to it. The basic structure of the system has been around for about 250 years and is widely accepted as the standard system to use in all countries.



Figure 2.12 Taxonomists maintain collections of living things to study their features and DNA for classification.

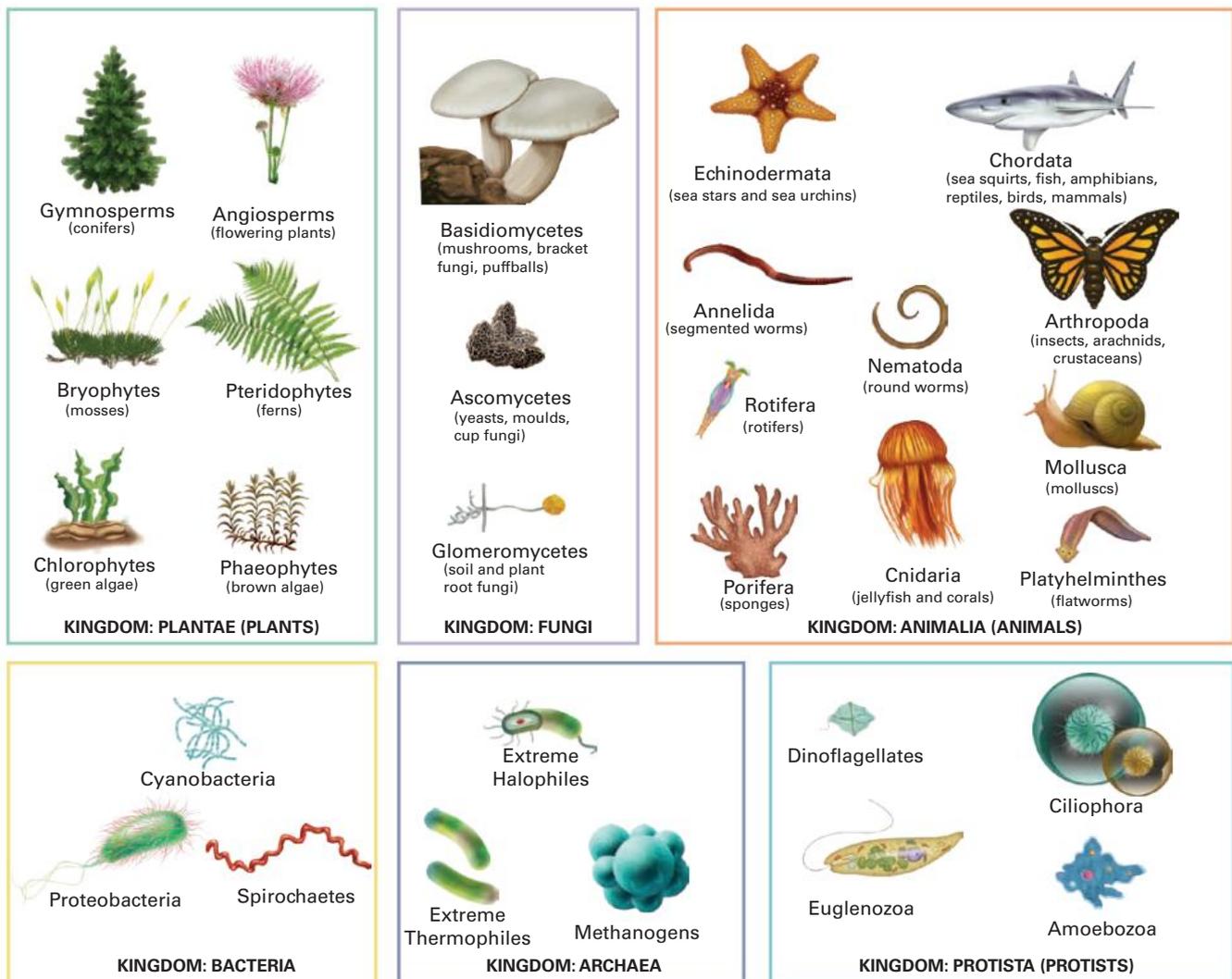


Figure 2.13 The six-kingdom classification of living organisms, with some representative groups within each. Note that there are many more groups than the ones shown, especially in the kingdoms Bacteria, Archaea, Protista and Fungi.



Figure 2.14 Linnaeus on a scientific expedition

Carl Linnaeus

Carl Linnaeus was a Swedish **botanist** born in 1707. He realised quite early on in his career that the classification system used at the time was not working. For example, the scientific name for a tomato plant during his time was: *Solanum caule inerme herbaceo foliis pinnatis incisae racemis simplicibus* – what a mouthful! Linnaeus noticed that as new organisms were discovered, the names for each got longer and longer, so the current naming system was going to have to change.

Try this 2.5

The order and names of Linnaeus' different levels of classification can be remembered by using a mnemonic device such as **Keep Pond Clean Or Froggy Gets Sick**, or **Kids Prefer Cheese Over Fried Green Spinach**. Try to make up your own mnemonic to remember each level.

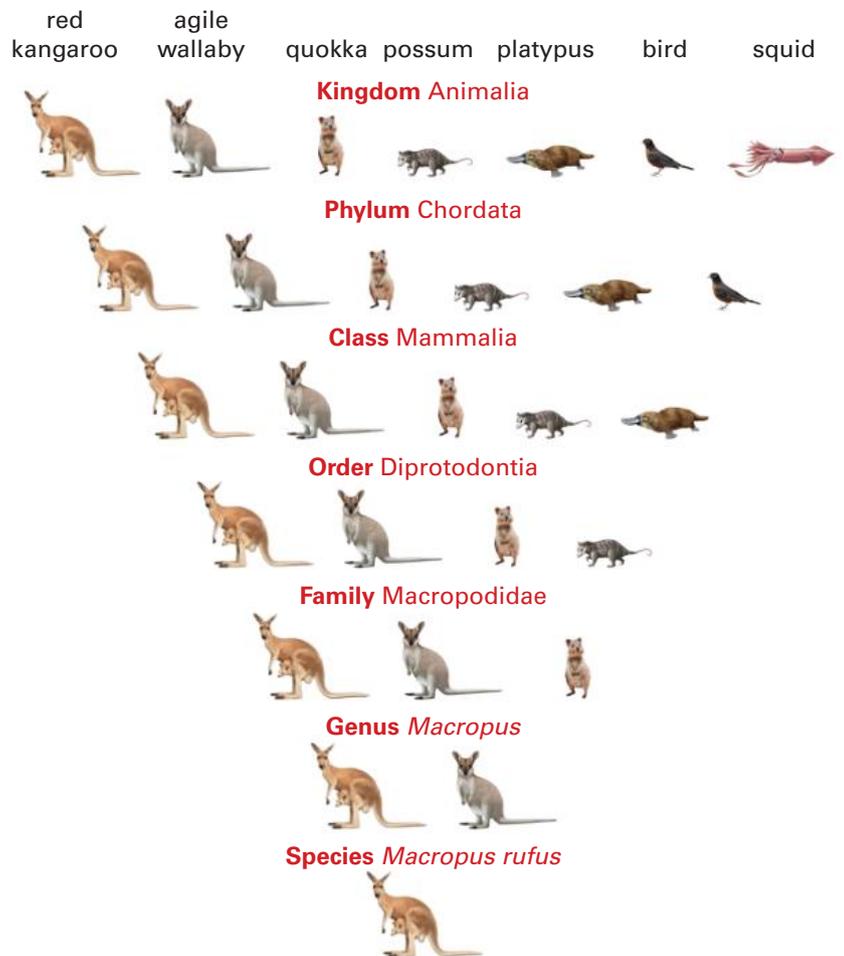


Figure 2.15 Linnaeus' classification hierarchy: at each level as you go down the organisms share more characteristics and are more similar.

Linnaeus was responsible for sorting living things or organisms into groups based on their physical similarities. He called the largest group 'kingdom' and the smallest group 'species'. The levels of classification that he developed were **kingdom, phylum, class, order, family, genus** and **species**. He managed to classify over 10 000 organisms during the course of his life and his work forms the basis of the current classification system.

botanist

a scientist who studies plants

kingdom

the highest classification on the Linnaean taxonomic rankings and the most broad

phylum

the taxonomic ranking below kingdom and above class

class

the taxonomic ranking below phylum and above order

order

the taxonomic ranking below class and above family

family

the taxonomic ranking below order and above genus

genus

the taxonomic ranking below family and above species

species

the most specific taxonomic ranking below genus

microbiologist

a scientist who studies very small living things like bacteria

domain

the highest taxonomic rank above kingdom and even more broad

Carl Woese

In addition to the original levels that Linnaeus suggested, a higher, broader level was proposed by Carl Woese (a **microbiologist**) in 1990. This level is called **domain** and it consists of Bacteria, Archaea and Eukarya. The domain Eukarya includes the kingdoms you are most likely familiar with, such as animals, plants and fungi.

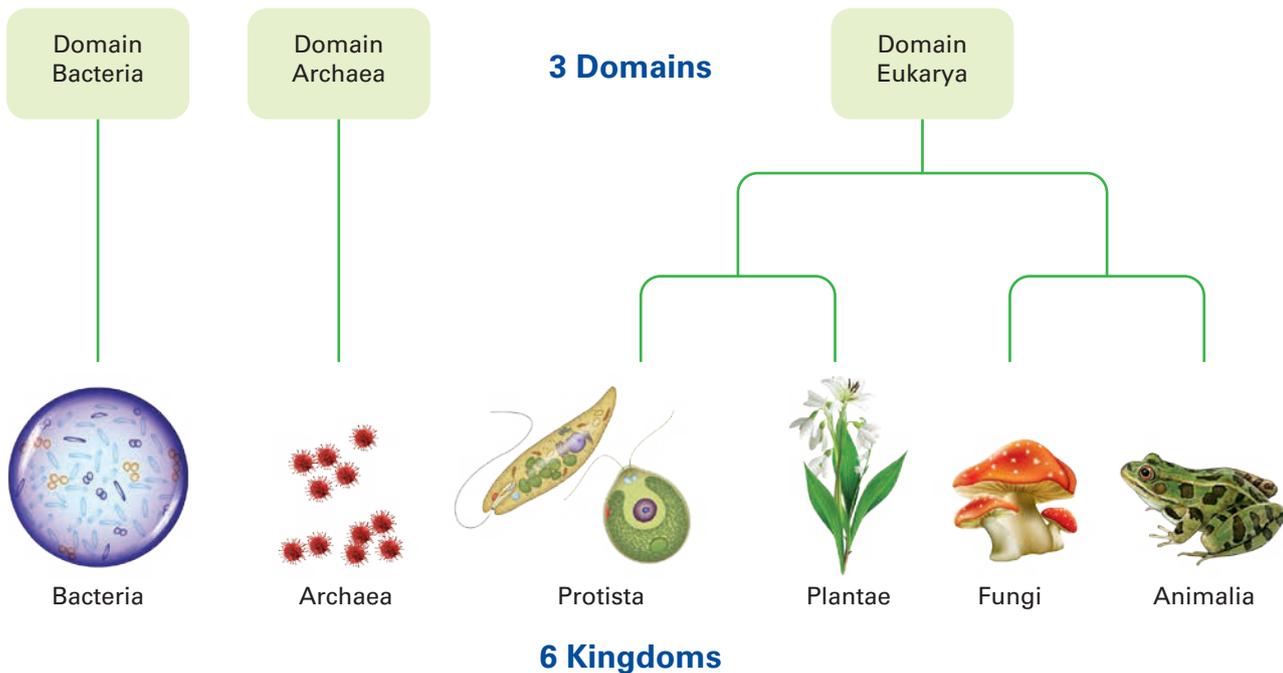


Figure 2.16 The links between Woese's domains and kingdoms

Explore! 2.3**Changes in classification**

New advances in technology have allowed us to learn that certain organisms are more closely grouped than we thought. By analysing DNA, we can see that even things which don't look alike can be classified together! Research online the link between the whale and hippo; the elephant, manatee and hyrax; and the horse and rhino.

Quick check 2.5

- 1 Define the term 'taxonomy' in your own words.
- 2 Explain why the classification system is constantly being updated.
- 3 Recall the names of the six kingdoms.
- 4 Discuss how Woese's proposal changed the way organisms are classified.

Binomial naming

Linnaeus is also responsible for the two-part naming system described next, which is known as **binomial nomenclature**. This replaced much longer names such as the one for the tomato plant given on page 55. Linnaeus renamed it *Solanum lycopersicum*. Earlier in this chapter, you learned about the importance of a universal language in science. Scientists usually use a form of Latin or Ancient Greek to name an organism, which is why it sometimes can sound like a spell from a *Harry Potter* book – ‘*Macropus fuliginosus!*’ – (that’s a western grey kangaroo!).

	Common name	Western grey kangaroo
	Kingdom	Animal
	Phylum	Chordate
	Class	Mammal
	Order	Diprotodon
	Family	Macropod
	Genus	<i>Macropus</i>
	Species	<i>fuliginosus</i>
	Scientific name	<i>Macropus fuliginosus</i>

Table 2.2 *Macropus fuliginosus* on a beach, and its classification

How to write the names

You might have noticed that when writing an organism’s scientific name, there are a few rules that need to be followed:

- The first part of the name (genus) is written with a capital letter.
- The second part of the name (species) starts with a lowercase letter.
- If you are typing a name, italics should be used.
- If you are writing the name, you should underline the name.

For example, *Hippocampus colemani*, *Hippocampus zebra*, *Hippocampus angustus* and *Hippocampus histrix* are all different types of seahorse found around Australia. The genus name (first part of the name) for all these species, *Hippocampus*, is from the words *hippos* meaning ‘horse’ and *campe* meaning ‘sea monster’. As you can see from Figure 2.17, they share many similarities but are all unique. That is why the species (the second part of the name) is also used to identify specific organisms.

binomial nomenclature
a system of naming in which two names are used to identify an individual genus and species of an organism



Figure 2.17 (a) *Hippocampus colemani*, (b) *Hippocampus zebra*, (c) *Hippocampus angustus*, (d) *Hippocampus histrix*

Try this 2.6

Classifying Australian animals

Find three similar Australian organisms, for example, three snakes or three parrots, and draw up a table like Table 2.2. Find out their classifications and scientific names. How similar are the three organisms? List some characteristics they share. How different are they? List some characteristics that are unique. At what level do you notice they are different? What does this mean about how closely related they are?

Did you know? 2.3

In recent years, instead of using names derived from meaningful Latin or Greek words, scientists have started using made-up Latin-sounding names as more species are discovered every day. Some scientists are using the world of *Harry Potter* for inspiration! They have named a new species of crab, *Harryplax severus*, after both Harry Potter and his potions teacher Severus Snape. They also named a species of wasp, *Ampulex dementor*, after the spooky prison guards.



Figure 2.18 (a) *Harryplax severus*, (b) *Ampulex dementor*

Why are scientific names important?

In everyday life, it is quite rare to use the Latin names of plants and animals because the words are often hard to pronounce and remember. If you were asked to identify the organisms in Figure 2.19 as *Phascolarctos cinereus*, *Callistemon citrinus* or *Cracticus tibicen*, you probably would not be able to. However, if you were to use their common names – koala, bottlebrush and magpie – it would be easy.



Figure 2.19 (a) koala (*Phascolarctos cinereus*), (b) crimson bottlebrush (*Callistemon citrinus*), (c) Australian magpie (*Cracticus tibicen*)

You may ask, why can't you just use the common name? Well, some common names for animals are repeated all over the world, but they are not the same species. For example, the Australian magpie is a completely different species from the British magpie (Figure 2.20). In fact, they are not even in the same family! It is likely that the name originated from European colonial settlers, who saw a black and white Australian bird and named it after the most common black and white bird from their country of origin.



Figure 2.20 British magpie (*Corvus pica*)

Science as a human endeavour 2.1

The animal that would not fit the mould

Whenever there is a rule, there is a rule breaker, and the platypus is one of the biggest rule breakers of the living world. In 1799, scientists in Australia sent a sample of a platypus back to the British museum for cataloguing. The creature they received was so different from anything they had ever seen they had no idea how to classify it. In fact, they believed that the scientists in Australia had sewn together several different animals to play a prank on them! This is because the platypus displays features that are similar to mammals, birds and reptiles all in one creature.

It was not until 2008, more than 210 years later, that scientists finally had definite proof that the platypus is most closely related to mammals but also has some close links to birds and reptiles.

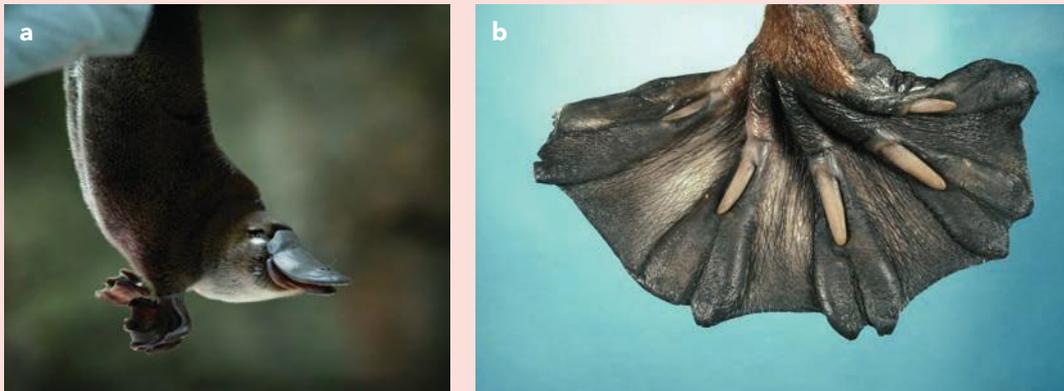


Figure 2.21 (a) Platypus young displaying their duck-like bill (b) Webbed platypus foot

Explore! 2.4

Australia once had lions!

In 2017, Australian scientists discovered a new species of extinct marsupial lion that roamed Australia around 19 million years ago! New species are discovered all the time, and that includes extinct organisms known only from fossils. Research and describe the process by which scientists determine whether an organism belongs to a new or existing species.

Quick check 2.6

- 1 Define the term 'binomial nomenclature' in your own words.
- 2 When looking at a list of scientific names, state how you would know which organisms were most similar.
- 3 Discuss some of the difficulties scientists would experience if they only used the common names of organisms.

Try this 2.7**Taxonomy exercise**

Draw up a table for the kingdom, phylum, class, order, family, genus, species and scientific name of the platypus. Then in a table, list the characteristics of a mammal in one column, a bird in another column and a reptile in a third column. This task will require you to do some research into the characteristics of these classes of animals. Now use your table and highlight which characteristics the platypus shares with mammals, birds and reptiles.

Try this 2.8**Creating an animal**

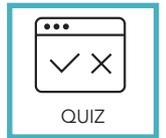
In this activity you will create a new animal. You may draw it or use an online app.

- 1 Obtain sketch paper and pencils or search for 'make new animals' on the internet.
- 2 Draw your animals or use an online animal building tool to create a new animal with features of many different types of animals (e.g. Switchzoo).
- 3 Take a screenshot of your creation and then create a description of the animal.
Your description should include:
 - Name of animal
 - Habitat: aquatic, terrestrial, both
 - Behaviours
 - Diet
 - How it uses the features you have chosen
 - Warm blooded or cold blooded
 - How its offspring are born
 - How long it lives
- 4 Classify your animal into a group (insects, birds, mammals, reptiles, etc.).
- 5 Using your description, justify why you classified your new animal as you did.

Section 2.2 questions

Remembering

- 1 **Name** the person who is called the 'father' of modern taxonomy.
- 2 **Recall** the names of the six kingdoms of organisms.
- 3 **State** the seven characteristics of living things.
- 4 **List** the eight levels of classification, from general to specific.



Understanding

- 5 The scientific name for the Australian common bluetail damselfly is *Ischnura heterosticta*. **Identify** the country or countries where this name applies.
- 6 **Outline** the main problems with the classification system that was used before the Linnaeus system.
- 7 **Describe** how the genus and species names are used to construct a scientific name of a living organism.



Figure 2.22 Male common bluetail damselfly

Applying

- 8 Imagine you saw a platypus in the wild for the first time. **Describe** how you would classify it and why. In your response, discuss the physical features of the platypus.

Analysing

- 9 Freshwater crocodiles (*Crocodylus johnstoni*) are endemic to Northern Western Australia. They are reptiles that most commonly eat fish, and female crocodiles burrow in sand to lay eggs, which later spawn offspring. Use this information to **classify** *Crocodylus johnstoni* in one of the six kingdoms.

Figure 2.23 *Crocodylus johnstoni* in the Lennard river in the Windjana Gorge National Park, Western Australia

Evaluating

- 10 **Predict** how closely related the fish in Figure 2.24 are with the clownfish on the bottom left based on physical characteristics.



Figure 2.24 Tropical fish

2.3 Non-animal kingdoms



Learning goal

- 1 To be able to distinguish the six kingdoms of living organisms.

Single-celled organisms

Most of life on Earth is **unicellular**, meaning it only is made up of one cell. You might not instantly get excited about single-celled life, but some of these organisms can thrive in places that no other living creature could survive, like in a 300°C hot pool or freezing Antarctica!

Until recently, archaea and bacteria were grouped together in a kingdom called

Monera. Due to the work of Carl

Woese referred to previously, they

are now split into two domains or kingdoms. Although both groups are ancient, have no nucleus and are protected by a cell wall, scientists discovered that archaea and bacteria are genetically distinct, and archaea have some genetic similarities to the Eukarya, the domain that includes plants and animals.

unicellular
consisting of one cell



Figure 2.25 Unicellular organisms have only one cell, which performs all the cellular functions.

Archaea

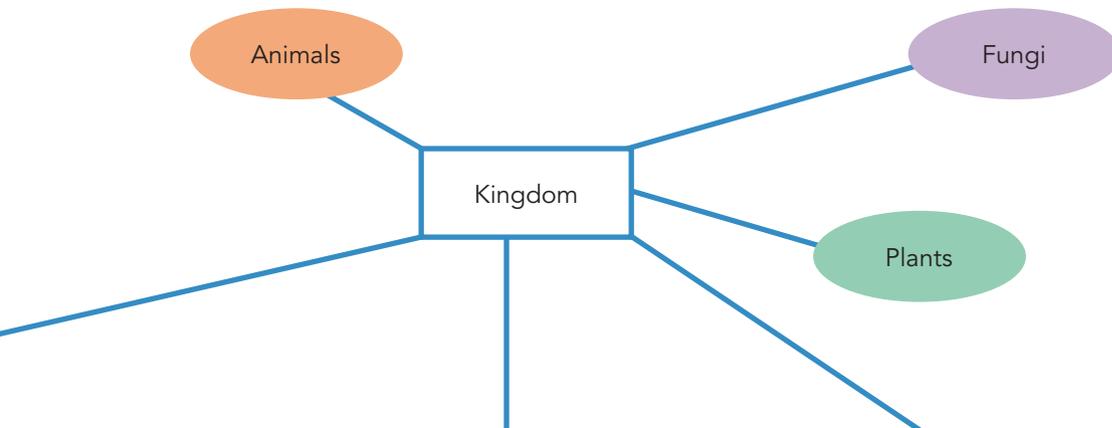
- Simple single-celled organism
- Oldest form of life on Earth
- Date back to 3.5 billion years ago
- Found in the most inhospitable and extreme environments on Earth
- Common in oceans
- Used in treatment of sewage
- Found in the gut, especially of ruminants and termites.



Figure 2.26 Archaea can be found in inhospitable (harsh) environments like these geothermal hot springs or even toxic oil wells.

Did you know? 2.4

We have one kind of archaea in our bodies. It is called a methanogen because it produces methane gas. So, you can blame the archaea next time you expel methane from your body!



Bacteria

- Simple single-celled organism
- Nearly as ancient as Archaea, appeared about 2.5–3 billion years ago
- Vital for digestion in animals, including humans
- Decompose wastes
- Create fertile soil, vital for agriculture
- Used to produce food (cheese, yoghurt) and industrial materials
- Some are harmful, causing infectious diseases.



Figure 2.27 Bacteria adapt quickly to threats, which is a problem doctors are facing as some harmful bacteria become antibiotic resistant.

Protista

- Complex single-celled organism
- Single cells like bacteria and archaea but complex in comparison
- Do not always have a cell wall and can be varied in size
- Organisms that do not fit into the other kingdoms get placed in the Protista kingdom
- Appeared in the fossil record about 1.7 billion years ago
- Most live independently but some form small colonies
- Some can cause disease but most are harmless to humans
- Most phytoplankton and many algae are protists, responsible for a huge proportion of photosynthesis
- Digest cellulose in the guts of ruminants and termites
- They also break down wastes and help make fertile soils.

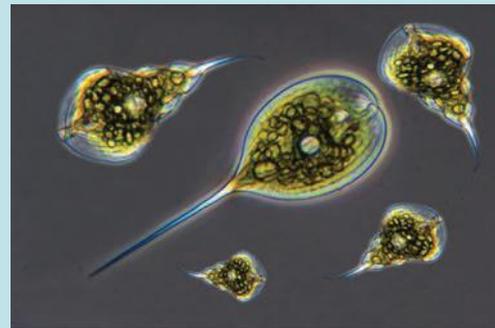


Figure 2.28 These *Phacus* euglenoids can swim and make sugars by a process called photosynthesis, just like plants can.

Quick check 2.7

- 1 Name the kingdoms that contain single-celled organisms.
- 2 Define the term 'microscopic' in your own words.
- 3 Summarise the key characteristics of bacteria.
- 4 Name an organism in the Protista kingdom.
- 5 Explain whether all single-celled organisms are harmful.



VIDEO
What are
protists?

autotroph

an organism that produces its own food from light, carbon dioxide, water or other chemicals

non-vascular

not containing veins or specialised fluid vessels

vascular

containing veins or specialised fluid vessels

spore

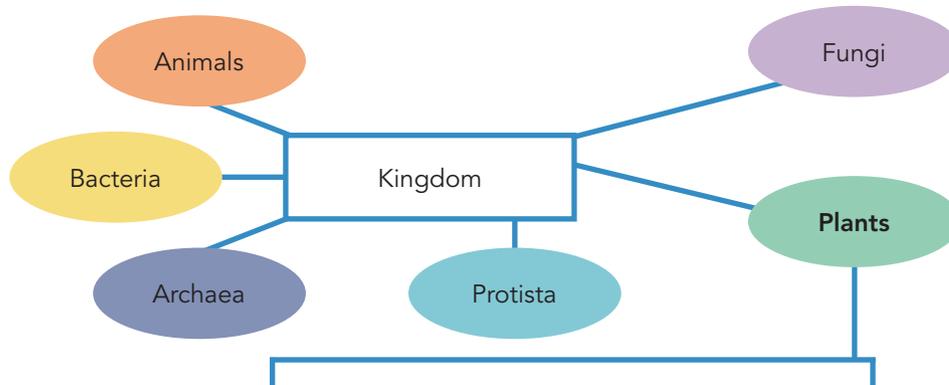
a single-celled reproductive unit

Plants

Plants do incredible things for us. They turn the greenhouse gas carbon dioxide into oxygen, the very useful gas that allows us to stay alive. Plants have been on Earth for millions of years longer than animals, and have spent that time transforming the atmosphere into one that contains oxygen and can support life.

Plants are producers because they produce the primary food source for all life on land. This happens because they are **autotrophs** capable of converting the energy from the Sun into useful sugars that can be digested.

Figures 2.29 to 2.33 show how the plant kingdom is divided, based on whether they have vascular tissue and if they produce seeds.



Non-vascular

Non-vascular plants do not have any specialised cells in their roots and stems to transport water and nutrients from one part of the plant to another. All the plants in this division share some common characteristics:

- Cannot grow very large or tall
- Often found spread across rocks or the ground in cool, moist, shaded areas
- Reproduce using **spores** (a single-celled reproductive unit)
- Include mosses, liverworts and hornworts, and some algae.



Figure 2.29 Mosses can take in water and nutrients through their leaves. They do not need to have roots, therefore they can grow on hard surfaces. They also reproduce using spores, which are single-celled and hence smaller than seeds.

Vascular

Vascular plants have a specialised vascular system; that is, roots and stems for transporting water and nutrients around the plant. The veins that you normally see on leaves are special pathways for water and nutrients to flow called xylem (for water transport) and phloem (for sugars and nutrients). Ferns, non-flowering plants and flowering plants all have these transport systems.



Figure 2.30 Veins that you see on leaves are special pathways for water and nutrients to flow.

Flowering plants

- Use brightly coloured flowers and sweet nectar to lure insects, birds and other animals to the flower
- Rely on animals, wind and water to help spread the flowers' pollen to produce seeds
- Develop seeds inside the 'fruit', which in botany includes pods, capsules and all 'fruiting bodies'
- Can have fruit that is edible and attractive, so when animals eat the fruit, they spread the seeds over large distances
- Vary in size from small to very large
- Can grow in a wide range of environments.



Figure 2.31 Flowering plants are the most advanced form of life in the plant kingdom.

Ferns

- Have been on Earth about 360 million years
- Are vascularised
- Can grow to large sizes
- Reproduce through spores
- Like moist, humid, shaded areas
- Do not have seeds.



Figure 2.32 Ferns mainly grow in moist, humid areas.

Non-flowering plants

- Include cycads and conifers
- Reproduce using seeds, which is complex as seeds contain multiple cells rather than one. These cells are protected by a waterproof layer, much like the hard shells of reptiles and birds, which prevents the seed from drying out.
- Include conifers that produce cones that are male (they contain pollen) or female (they contain seeds)
- Rely on wind to move the pollen from the male cone to the female cone.



Figure 2.33 The Wollemi Pine is an ancient non-flowering, seed-producing plant that is only found in Australia.

Quick check 2.8

- 1 Define the terms 'vascular' and 'non-vascular'.
- 2 Recall if organisms in the plant kingdom are single-celled or multicellular.
- 3 Recall the groups of plants that produce seeds.
- 4 Copy and complete the following table to summarise the characteristics of different plant groups.

Characteristics	Non-vascular	Vascular		
		Ferns	Non-flowering	Flowering
Roots and stems				
Maximum height				
Spores or seeds				
Flowers or no flowers				
Examples				

Practical 2.1

Observing *Euglena*

Aim

To observe a single-celled organism under the microscope.

Materials

- *Euglena* sample
- pipette
- compound microscope
- dimple slide
- coverslip
- sharp pencil
- plain paper
- glycerol (optional)

Method

- 1 Set up the microscope on your bench.
- 2 Place a small drop of the *Euglena* sample into the dimple on the slide. One drop of glycerol can be added to slow the movement of the *Euglena*.
- 3 Lower the coverslip on an angle over the drop to protect the sample.
- 4 Place the slide onto the stage of the microscope and focus, using the lowest power magnification first.
- 5 Draw a scientific drawing of the *Euglena* you observe. Use a sharp pencil.
- 6 Use the internet to research the structure of *Euglena*. Label your scientific drawing.

Discussion

Euglena can make sugars like plants can, but they also have a simple 'eye' spot (sensitive to light, not a true eye). *Euglena* can also move, as you have observed. From your observations, justify whether you believe *Euglena* is more similar to animals or plants.

Be careful

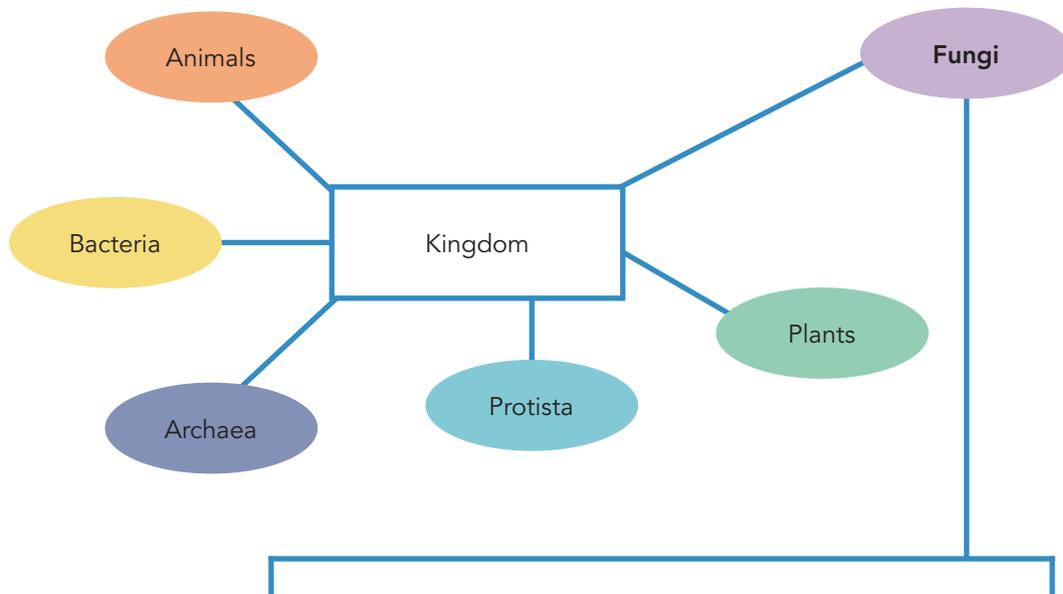
Ensure proper
microscope handling
and use is observed.

Fungi

Fungi have traits that are similar to both plants and animals, but they are different enough to form their own kingdom. Fungi, like animals, cannot produce their own food as plants do. They absorb their nutrients from organic matter including dead organisms in their environment, or as parasites growing on or in living organisms. Unlike animals, most are **sessile**, meaning that they cannot move around too much. The fungi kingdom ranges from microscopic single-celled organisms, such as yeast, to multicellular organisms, such as mushrooms. Fungi can reproduce by releasing spores, which are single-celled fungus organisms, or by 'budding', whereby a new fungal organism is created by an outgrowth on the original fungus.

sessile

an organism that is fixed in its location and does not independently move but may move its body parts



Single-celled fungi

Yeast is a single-celled fungus used to make bread rise and in the manufacture of beer.



Figure 2.34 Yeast cells seen under a microscope

Multicellular fungi

Fungi are the source of some medicines. For example, the antibiotic penicillin, which is used to fight bacterial diseases, is prepared from the mould *Penicillium chrysogenum*.



Figure 2.35 *Penicillium chrysogenum* growing in a petri dish

Fungi (as well as some bacteria, archaea and protists) have one of the most important roles on Earth. They feast on the deceased – they eat and break down all dead organisms, allowing nutrients to be recycled in the circle of life. Nutrient recycling is important. If there were no decomposers, life on Earth simply could not exist, as the nutrients that organisms take from soil or water would never return.



Figure 2.36 Fungi recycling a fallen tree

However, some fungi are deadly. *Batrachochytrium dendrobatidis* is a fungus that causes the deadly disease chytridiomycosis in frogs. When the disease enters a frog population, it kills all of them! This disease was first discovered in Australia in 1993, but it is thought to have been in Australia since the 1970s. Currently, it is found in all states and territories except the Northern Territory. The disease is believed to have been the cause of at least four recent frog extinctions and ten rapidly declining frog species in Australia. Currently, there is no cure or method of controlling this disease in the wild.



Figure 2.37 Dead Lesueur's frog, *Litoria lesueurii*, in a river

Some fungi are just plain weird! *Ophiocordyceps unilateralis* is sometimes referred to as the zombie fungus. This fungus can infect ants, take control of their bodies and force them to leave their nests and climb a nearby plant. The fungus then bursts out of the ant's head and spreads its spores to other ants in the colony.



Figure 2.38 Fungi sprouting out of the brain of an ant!

Explore! 2.5

Can trees talk?

Surprisingly, they can! Research how scientists believe trees communicate with each other using fungi and what things this communication can accomplish.

Quick check 2.9

- 1 Recall the characteristics of fungi.
- 2 State the characteristics that plants and fungi have in common.
- 3 Do some research and identify some examples of fungi that can be both beneficial and dangerous to humans.
- 4 State the conditions that are best for mould or fungi to grow.

Practical 2.2: Investigation

Spores are all around us

Aim

To design a method to fairly investigate how different factors affect the growth of mould on bread.

Time period

Approximately 1 week

Prior understanding

Fungal spores are in the air all around us every minute of the day. You inhale these spores with every breath you take, and they try to grow in your lungs. Luckily, humans have a brilliant immune system that can fight them off. The food we store at home, on the other hand, does not have an immune system, so fungi that land on it can grow very easily. Most of the fungi that grows on food is known as mould. It is important to store food in an environment that slows down mould growth as much as possible, such as a cool pantry or a fridge or freezer. This keeps the food edible for longer.

Materials

- 9 slices of bread, or 3+ pieces per *independent variable* group, which are near or past their 'best before' date and preferably with no preservatives
- 9 zip-lock bags
- paper towels
- sticky labels
- permanent markers
- sticky tape

Planning

- 1 Read the prior understanding section and identify what environmental factor affects the growth of mould on food at home.
- 2 Create a research question that can be easily and safely investigated.
- 3 Identify one independent variable to test, based on your research question. Describe the different groups that you will set up for the experiment.
- 4 Identify the dependent variable and how you will measure it.
- 5 Identify the controlled variables and describe how these will be managed.

Method

- 1 After a few minutes exposed to air to pick up some spores, place each piece of bread into a zip-lock bag and seal the end well.
- 2 Cover the seal with a layer of sticky tape to prevent anyone opening it. **DO NOT OPEN AGAIN** – This is a safety issue as breathing in mould can be dangerous.

continued...

Be careful

Make sure you do not open or puncture the bag once growth has begun.

Ensure that growing conditions remain under 30°C for safety considerations.

...continued

- 3 Label each bag with the following information:

Group number:

Description:

Date:

Student/s name:

- 4 Set up three bags for each independent variable group that you planned in the planning section.
- 5 Monitor each group for 5–7 days.
- 6 If any part of the set-up is changed over that period of time, then note the reason for this.
- 7 Collect each bag. *DO NOT OPEN for safety reasons.*
- 8 Measure the amount of fungal growth for each independent variable group and record the results in a table. Your teacher may direct you to create your table on a spreadsheet.

Results

- 1 Calculate the mean growth measurement for each independent variable group.
- 2 Calculate the range for each independent variable group on the table.
- 3 Graph the mean of each group's data on paper. Your teacher may direct you to create your graph on a spreadsheet.

Discussion

- 1 Describe any trends, patterns or relationships in your results table.
- 2 Identify any **anomalous** results that you found.
- 3 Analyse how much variation was observed between the measurements within each group.
- 4 Describe how the set-up or method was adjusted, if at all, once the experiment was started.
- 5 Critique your management of the controlled variables. Were they managed properly to ensure they did not change and affect the measurements?
- 6 Were there any obvious sources of error or parts of the procedure that caused the data to be less accurate than it could have been? Describe any changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

- 1 Propose a valid conclusion that can be drawn from these results.
- 2 Justify this conclusion using data from your results.

anomalous
an outlying result
that does not fit in
with the pattern of
the other results

Try this 2.9

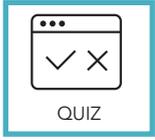
Classification super-challenge!

To check if you know the key characteristics of the different kingdoms, try this super challenge! Read the description, see if you can identify the kingdom the organism belongs to and then find a picture of a possible organism that fits the description.

Description	Kingdom	Picture
I am a single-celled organism. I live in the large intestine of mammals like humans to help food break down. I reproduce very quickly.		
I am a multicellular organism that uses sunlight to make my own food. I grow flowers to produce seeds inside of fruits.		
I cause dead animals to really reek when I slowly digest their tissues, producing methane. I am a single-celled organism with no nucleus in my cell.		
I am a unicellular organism that can move and live in pondwater. My body is covered with little hairs to help me move and I can swim very fast. I eat bacteria.		
I make my own food using the sunlight and I am multicellular. I get my nutrients from insects I can catch in my folding leaves.		



Section 2.3 questions

**Remembering**

- 1 **List** three examples of fungi.
- 2 **Define** 'vascular plant'.
- 3 **State** the kingdom that *Penicillium* mould belongs to.

Understanding

- 4 **Explain** the benefits of a seed compared to a spore.
- 5 **Describe** two ways in which seeds can spread.

Applying

- 6 **Distinguish** between unicellular and multicellular organisms.
- 7 **Identify** why animals depend on bacteria and fungi.

Analysing

- 8 **Classify** each of these species into the correct kingdom.
 - a *Streptococcus pneumoniae* is an organism that can make you very sick. It belongs to the second oldest kingdom and is made up of single cells.
 - b *Trypanosoma evansi* is a single-celled organism that needs to eat other organisms to survive. Its cells have specialised structures inside of them.
 - c *Osmunda regalis* is an organism that uses the Sun to make sugars and reproduces using spores. This organism has specialised vascular tissue.
 - d *Tremella fuciformis* is an organism that reproduces using spores and is a parasite of other organisms to gain food.
 - e *Haloferax volcanii* is a single-celled organism that can survive in extreme environments that no other organism could survive in.
- 9 In the past, fungi were part of the plant kingdom. **Propose** reasons why this might have been the case.

Evaluating

- 10 Suzi discovered that a piece of bread left in a zip-lock bag had developed a black fuzzy mould like substance. She decided to investigate the factors affecting mould growth. She used the same brand of bread and zip-lock bags. She placed the sealed bags in different temperatures.
 - a **Identify** the variable she was changing or testing (independent variable).
 - b **Identify** the variable she was measuring (dependent variable).
 - c **Determine** some examples of variables she kept the same or controlled.
 - d **Provide** two other variables she could test with a similar experiment assessing the growth of mould.



2.4 The animal kingdom

Learning goals

- 1 To be able to describe the difference between invertebrates and vertebrates.
- 2 To be able to recall seven classes of chordates.

When you think of an animal, your first thought is most likely of a large and probably charming creature such as a sloth or penguin. What you probably do not think of is a sponge or coral. It might surprise you to know that most of the animals on our planet are microscopic and look nothing like the animals you first thought of. All organisms that are placed in the animal kingdom share some defining features that set this kingdom apart from the others.



Figure 2.39 A tardigrade is an example of a microscopic animal.

All animals:

- are multicellular (made up of more than one cell working together)
- have cells that contain special structures inside of them
- are **heterotrophs**, meaning they eat other organisms or their secretions, excretions or remains to gain energy
- can independently move their location (they are motile) or their body parts if they stay in one location (if they are sessile)
- can digest food inside their body (the majority) or in some cases outside their body.

Animal phyla

There are more than 35 phyla in the animal kingdom, but you are going to just focus on the nine key ones, as shown in Table 2.3. Often, scientists will talk about **vertebrates** or **invertebrates**. A vertebrate is an animal with an internal backbone or endoskeleton, while an invertebrate is an animal with no internal backbone. Instead, invertebrates may have a hard outer casing called an exoskeleton. However, despite vertebrate and invertebrate being important terms to know and understand, they are not used as an official level in the classification system. The nine key phyla are summarised in Table 2.3. Note that while all the phyla represent invertebrates, chordates include both invertebrates and vertebrates.



heterotroph

an organism that cannot make its own food, instead relying on other organisms for energy

vertebrate

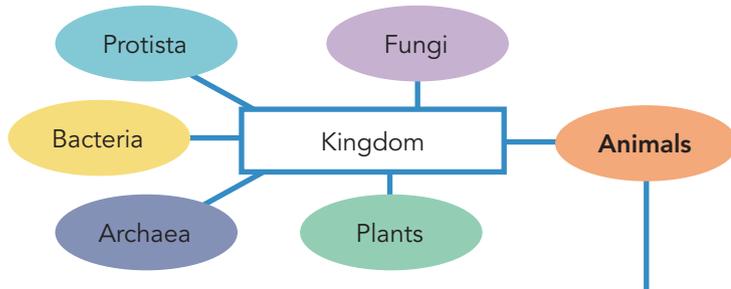
has a backbone

invertebrate

does not have a backbone

ANIMAL KINGDOM		
Phyla (scientific name in brackets)	Examples	Invertebrate or vertebrate
Poriferans (Porifera)	Sponges	Invertebrates (they have no backbone)
Cnidarians (Cnidaria)	Jellyfish, sea anemones, coral	
Platyhelminths (Platyhelminthes)	Flatworms	
Nematodes (Nematoda)	Roundworms	
Annelids (Annelida)	Earthworms	
Molluscs (Mollusca)	Shelled animals	
Arthropods (Arthropoda)	Insects, spiders, crustaceans	
Echinoderms (Echinodermata)	Sea stars, sea urchins	
Chordates (Chordata) (not all chordates have backbones)	Fish, amphibians, reptiles, birds, mammals	

Table 2.3 Summary of the nine key phyla in the animal kingdom



Figures 2.40 to 2.48 illustrate the nine key animal phyla used in the classification system.

Poriferans

(pron. *pore-if-er-ans*)

- 'Pore-bearers', have holes
- Use filters to obtain food
- No organs
- Sessile
- Simple animal, no specialised organs
- Include sponges.



Figure 2.40 A sponge with its simple tube form for filtering water

Cnidarians

(pron. *nigh-dare-ee-ans*)

- 'Stinging nettle'
- Soft, hollow body
- Fires stinging spine at target like a harpoon
- One opening for food and waste
- Include anemones, coral and jellyfish.



Figure 2.43 The box jellyfish, whose venom is strong enough to kill humans, can be found in the Northern Territory and northern Queensland.

Platyhelminthes

(pron. *plat-ee-helm-in-thees*)

- 'Flat worms'
- No segmentation, unlike Annelids
- Have a simple brain and eyes
- Can be cut in half and they will continue to live
- Many are decomposers – they recycle waste, or are parasites living in other organisms
- Include all flatworms.



Figure 2.41 Flatworms display many vibrant colour combinations.

Nematodes

(pron. *nee-ma-toads*)

- An unsegmented worm found in soil, water and the bodies of other organisms as **parasites** and pests
- Also known as roundworms
- Most are very small or microscopic
- Widespread and very numerous.



Figure 2.44 Many nematodes are parasites.

parasite
an organism that lives in or on another organism and takes its food from its body

Annelids

(pron. *an-e-lids*)

- 'Ringed worms', meaning have ringed body segments
- Soft bodies
- One hole for food, one for waste
- Need a moist environment, can survive on land
- Include earthworms.



Figure 2.42 The tiger worm is named so because of its stripes.

Molluscs

(pron. *mol-usks*)

- Second largest of all of the phyla, second only to Arthropods
- Have a muscular foot and soft body
- Have a mantle (a cover or outer layer like a cloak), and for some it forms a shell
- Have a radula, a scraping device for eating
- Include squid, snails, slugs, octopuses and oysters.



Figure 2.45 A snail taking a ride on another snail

Arthropods

(pron. *arr-throw-pods*)

- ‘Jointed foot’, means their limbs are made of jointed segments
- Exoskeleton
- Contain 80% of all animal species
- Found in every habitat, in the air, in fresh and salt water, and underground
- Have complex sensory organs such as compound eyes and antennae for hunting and detecting threats
- Include insects, spiders, scorpions, millipedes, crustaceans (crabs, lobsters, prawns) and many more.



Figure 2.46 Spider wasps paralyse spiders and drag them to their nests where they lay an egg on the spider. When the young hatches, it will eat the spider.

Echinoderms

(pron. *eeek-ine-o-derm*)

- ‘Spiny skin’
- Found in the ocean, not freshwater
- Have specialised organs, but no brain and no blood
- Most have radial symmetry
- Include sea urchins, sea cucumbers, brittle stars.



Figure 2.47 When a sea star loses a limb, it can grow back.

Chordates

(pron. *core-dates*)

- Have a spinal cord: a long nerve that connects the brain to the rest of the body
- In most species, called vertebrates, the spinal cord is protected by bones called vertebrae
- Include humans, all other mammals, fish, reptiles, amphibians and birds.



Figure 2.48 The little penguin (*Eudyptula minor*), found on Penguin Island in Rockingham, is an example of a chordate.

Explore! 2.6

Some scientists believe they have found an immortal jellyfish (*Turritopsis dohrnii*). Research how the scientists explain this immortality and propose whether the same biological trick could ever be used by humans.

radial symmetry

organism is symmetrical around a line drawn through the centre in more than one position

bilateral symmetry

organism can be divided into two symmetrical halves

Symmetry

When classifying animals into their correct phyla, their symmetry is also used as a structural feature to help classify it. **Radial symmetry** means you can draw an imaginary line in several

directions through the centre of the animal and you will get identical halves. **Bilateral symmetry** means you can only draw an imaginary line in one position to get identical halves. As seen in Figures 2.49, 2.50 and 2.51, some animals are not entirely symmetrical.



Figure 2.49 The sea star shows radial symmetry.



Figure 2.50 The eastern osprey (*Pandion cristatus*), common to Rottneest Island, shows bilateral symmetry.

Explore! 2.7

Most but not all animals have symmetrical body shapes. Investigate and find examples of animals that do not have symmetrical bodies.

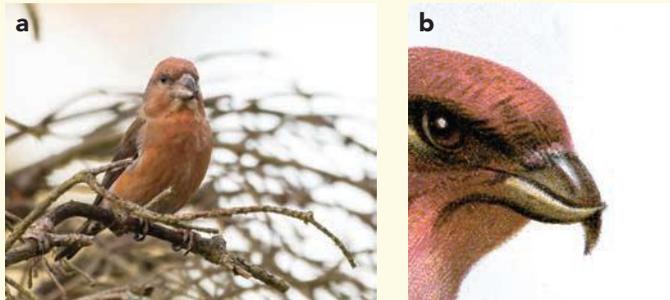


Figure 2.51 (a) A male crossbill; (b) Close up of its crossed bill

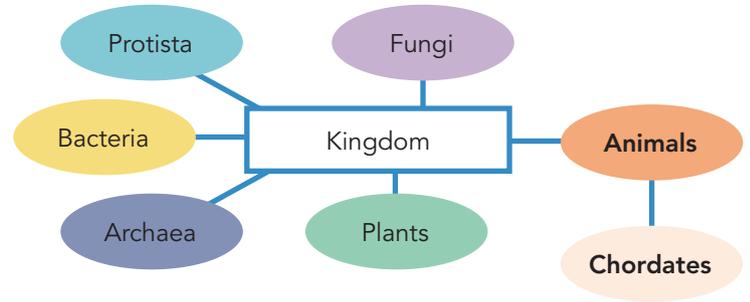
Try this 2.10

Look at each of the following animals then decide whether they show radial symmetry, bilateral symmetry or no symmetry.



Animal classes

Kingdoms are divided into phyla, and the next grouping down after phylum is class. You will now take a closer look at seven classes of chordates: Agnatha, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia (Figures 2.52 to 2.61).



Agnatha (jawless fish)

(pron. *ag-na-tha*)

- Flexible
- Often parasites or scavengers
- Oldest chordates
- Include all jawless fish.



Figure 2.52 The hagfish is extremely flexible.

Chondrichthyes (cartilaginous fish)

(pron. *con-drik-thees*)

- Have cartilage (softer and more flexible than bone)
- Have fins on the sides of their bodies (lateral fins) and on their backs (dorsal fins)
- Very manoeuvrable and fast swimmers
- Efficient hunters
- Include sharks, skates and rays.



Figure 2.54 The great white shark is a fearsome hunter.

Osteichthyes (bony fish)

(pron. *ost-ee-ick-thees*)

- Bony fish with a skeleton of ridged bone (not as flexible as cartilage but offers more protection of organs)
- Include salmon, tuna, eels, trout and clownfish
- **Ectothermic** (cold-blooded) – the

ectothermic
a cold-blooded organism that cannot regulate its internal temperature

temperature inside their bodies is controlled by the temperature of their environment.



Figure 2.53 A salmon swimming upstream to spawn

Amphibia (amphibians)

- Can live in and out of water
- Always need a water source nearby to lay their eggs
- Their eggs do not have a waterproof shell
- Develop from an egg and then into a tadpole or larvae
- Undergo **metamorphosis** (a change in form, in this case from a tadpole with gills and a tail to having lungs, legs and no tail)
- Use their moist skin and lungs to take in oxygen from the air
- Include toads, frogs, newts and salamanders.

metamorphosis
the process of transformation from an immature form to an adult form



Figure 2.55 The White's tree frog is found in Australia.

Explore! 2.8

Chordata is the only phylum that contains vertebrate animals. Most, but not all, chordates are vertebrates. Search on the internet for a chordate that is not a vertebrate.

Reptilia (reptiles)

- Have waterproof scales as covering
- Most lay eggs, but the shells are more leathery than those of amphibian eggs, and they do not dry out
- Ectothermic
- Have lungs for breathing
- Include snakes, lizards, turtles and crocodiles.



Figure 2.56 A thorny devil (*Moloch horridus*) sits in the sun to warm up.

Aves (birds)

(pron. *ah-vays*)

- Have feathers covering their body
- Lay eggs with hard shells
- Beak for feeding
- Winged, but not all birds can fly
- **Endothermic** – they can control the internal temperature of their bodies and do not have to rely on their environment to remain warm
- Control of internal temperature – allows birds like penguins to live in freezing cold places such as Antarctica where reptiles would never be able to survive
- Include all living birds.

endothermic

a warm-blooded organism that can regulate its body temperature



Figure 2.59 Birds such as emus and cassowaries have grown too large to fly and have adapted to a life on the ground.

Mammalia (mammals)

- Feed their offspring on milk produced by the mother
- Have a covering of hair or fur
- Endothermic
- Have three subclasses based on how they produce offspring: placentals, monotremes and marsupials.



Figure 2.57 Dogs are not only very good friends, they are also placental mammals like us!



Figure 2.58 The bilby (*Macrotis lagotis*) is an endangered marsupial found in Western Australia.

The class Mammalia is divided into three subclasses based on how they produce offspring.

Placentals nourish their young inside the mother's body until the offspring is fully developed. The young is attached by a cord to the mother's placenta, which supplies their food. Most mammals are placental mammals and include mice, horses, dingoes, whales and humans, among others.

Monotremes lay eggs just like reptiles, in leathery shelled eggs. They include echidnas and platypuses; in fact these are the only monotremes that exist now.

Marsupials have offspring that live in a pouch from a very early stage in development. The offspring latch onto their mother's nipple inside the protective pouch and remain there until they are fully developed. They include kangaroos, wombats, possums and koalas. Marsupials are only found in Australasia, South America and, in smaller numbers, in Central America and North America.



Figure 2.60 A mother giraffe with her newborn offspring



Figure 2.61 Echidnas use their long nose to hunt for termites.

Did you know? 2.5

How mosquitoes hunt

If you have ever been out on a warm summer night near water, you may have been bitten by a mosquito. Mosquitoes are found in the phylum Arthropoda. They have many specialised sensory organs that allow them to detect the presence of food, in your case, blood. In fact, it is only the female mosquito that feeds on blood as they need it to develop their eggs. You are an easy target as you do not have a thick layer of fur to protect your skin. Mosquitoes can sense the carbon dioxide that you breathe out from up to 50 metres away and will follow it, knowing that a human is nearby, until it leads to their target. When they are less than one metre away, they will then use both their vision and a special thermal sensor to detect their prey.

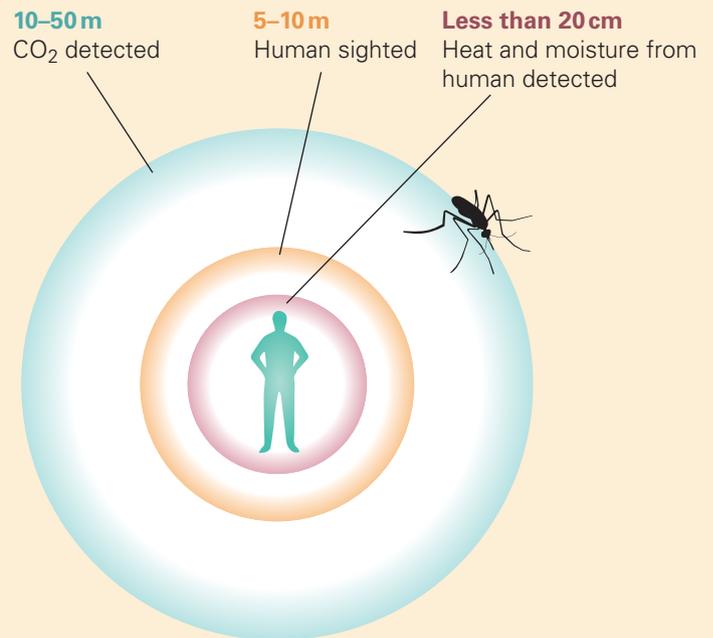


Figure 2.62 Zones of human detection for mosquitoes

Practical 2.3

Dissecting a squid**Aim**

To explore the anatomy of the squid and observe its simple organ system.

Materials

- 1 squid
- dissection tray (plastic chopping board)
- dissection scissors
- probe
- newspaper
- 11 toothpicks
- 11 sticky labels
- gloves
- lab coat
- Optional: dissection microscope
- Recommended: Laminated copies to Squid Internal and External Anatomy for reference during dissection.

Be careful

Ensure that disposable gloves and a lab coat or apron are worn when the squid is being handled.

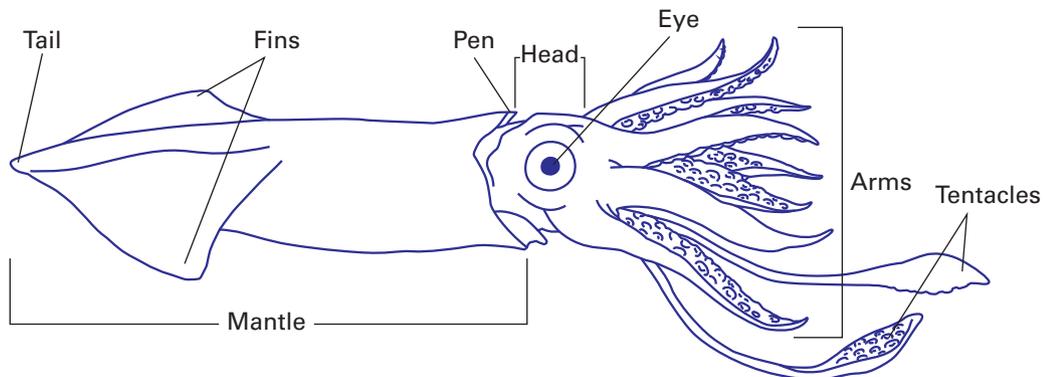


Figure 2.63 External anatomy of the squid

continued...

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Method

- 1 Create 11 toothpick label flags with the toothpicks and sticky labels, by folding the labels over like a flag at the top of each toothpick. Add each of the following to the labels: heart, ink sac, gills, tentacles, arms, eyes, mantle, pen, fins, siphon, gonads.

External anatomy

- 2 Place the squid on the dissecting tray and lay it out flat.
- 3 Study the external anatomy diagram in Figure 2.63. Place your toothpick labels to identify all the external parts of your squid.
- 4 Count the number of arms the squid has. Arms are different from the tentacles, as they are shorter and have suction pads all the way along them.
- 5 Count the number of tentacles the squid has. Tentacles are longer than the arms and only have suction pads at the end.
- 6 Pick up the squid and hold the mantle like an ice-cream cone. Allow the arms to spread backwards over your hand. This will expose the mouth of the squid.
- 7 Locate the beak of the squid. It will be hard and brown.

Internal anatomy

- 8 Place the squid back on the dissecting tray and use the scissors to cut the mantle upwards from the tentacles to the top.

Be careful to cut away from the centre of the squid so you don't damage its organs.
- 9 Open up the mantle of the squid, like opening a book.
- 10 Locate the gills, ink sac, heart and gonads and label them using your toothpicks.

Be careful not to puncture the ink sac at this point, as it will spill all over the squid.
- 11 Once you have labelled all the internal parts of the squid, try to remove each organ very carefully and place around the dissecting tray.

Optional

- 12 Locate and remove the pen. The pen is a hard, transparent part of the squid's internal anatomy. It is the remains of a shell and offers support for the squid when moving. It is located in the centre of the mantle. Once you locate the pen, you should be able to peel it away from the surrounding tissue using your fingers.
- 13 Remove the ink sac from the squid. Place it on a dish to catch any mess, and try popping it with a toothpick. Use the pen of the squid or the toothpick to write your name on a piece of paper.
- 14 If you have successfully located and removed the beak and radula, observe these structures under a dissecting microscope.

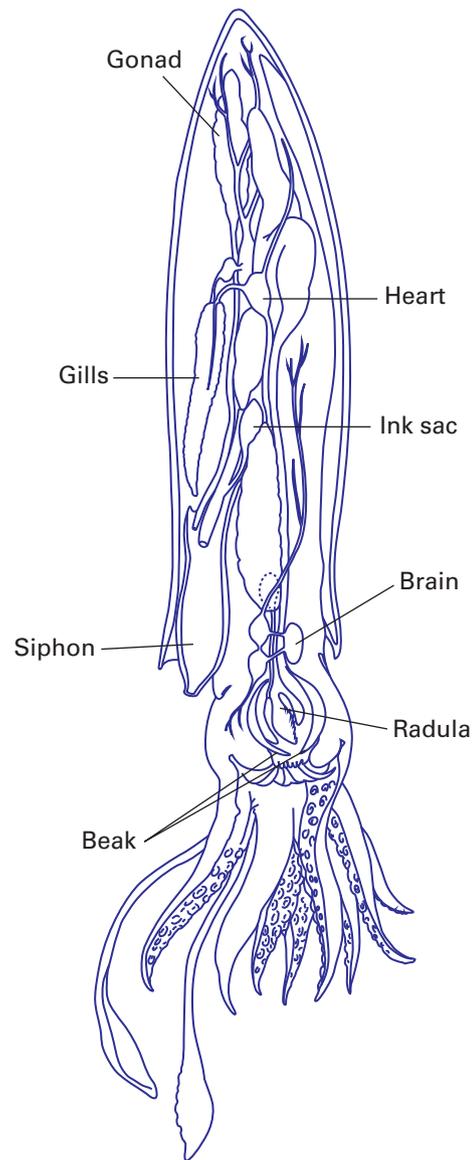


Figure 2.64 Internal anatomy of the squid

continued...

...continued

Results

Develop a table to record the following:

- a Main features identified (see method)
- b Number (how many times was this feature observed)

Discussion

- 1 Squids are classified in the class of Cephalopoda, which comes from the Greek words for 'head-foot'. Discuss how this name relates to the squid's anatomy.
- 2 Squids are classified in the phylum of Mollusca, which includes all shellfish. Discuss a probable reason for why the squid is classified this way when it does not have a shell.
- 3 Propose a reason why it would be beneficial for a squid to be able to produce ink.

Did you know? 2.6

Reptile roadkill

When you drive through the countryside, you often see reptiles as road kill. This is because the tarmac that the road is made from holds the day's heat better than the sandy soil around it. At night, reptiles seek out warm rocks to keep themselves warm but, unfortunately, vehicles drive on that warm tarmac as well.



Figure 2.65 Reptiles looking for warmth may often be run over.

Quick check 2.10

Which phylum?

Use the information about each of these species to decide which phylum they should belong to.

- 1 *Asaphus kowalewskii* is an extinct member of the largest phylum. All the members of this phylum had an exoskeleton, segmented body and jointed limbs.
- 2 *Ailurus fulgens* has a long tail and a nerve cord that runs down its back. This nerve cord is protected by hard bones.
- 3 *Monanchora arbuscula* is an animal that obtains food by filtering sea water through pores on its body.
- 4 *Pseudoceros susanae* is a colourful animal that is completely flat. It has bilateral symmetry and can be cut in half and survive.
- 5 *Cassiopea andromeda* has a soft body and a specialised cell called a nematocyst (pron. *nee-ma-toe-sist*) that fires a stinging spine at its target like a harpoon.
- 6 *Pisaster ochraceus* has radial symmetry and cannot survive in fresh water. It digests its prey by pushing its stomach out of its mouth.

Quick check 2.11

- 1 Describe two differences between amphibians and reptiles that allow reptiles to live away from water.
- 2 Identify the difference between birds and reptiles that allows birds to survive in more environments than reptiles.
- 3 Recall how an amphibian gets oxygen from the air.
- 4 Name two members of the Osteichthyes class.

Did you know? 2.7

Wombats have developed a pouch that faces in the opposite direction from the pouches of other marsupials to protect their young from dirt when the mother is digging a burrow.



Figure 2.66 Australia is home to three existing species of wombat: the common wombat (shown above), the southern hairy-nosed wombat and the northern hairy-nosed wombat.

Quick check 2.12**Identify the chordate class**

- 1 *Pseudonaja textilis* is an ectotherm with a skin made of waterproof scales. This animal lays leathery eggs that do not need to be submerged in water.
- 2 *Vulpes lagopus* is an endotherm that is covered in fur. It gives birth to fully developed young and feeds them on milk.
- 3 *Trichoglossus moluccanus* is a colourful animal that is an endotherm. It possesses several adaptations including wings and feathers, which allow it to fly.
- 4 *Litoria caerulea* can survive on land but will always be found near a body of water as it needs to keep its skin moist, and can only lay its eggs in water.
- 5 *Thunnus albacares* is a marine animal that has specialised fins, a jaw with teeth and a bony skeleton.

Try this 2.11**Exploring the animal kingdom**

Use your preferred web browser to research any four living species that you want. Your choices should each be from a different phylum.

Make a cue card for each one. Print out a small picture of the species, and include the following information for each one.

- Common name
- Scientific name
- Phylum

continued...

...continued

- Characteristics of the phylum
- Three features of this species
- Three interesting facts about it

Now you have gathered information on your animals, it is time to play 'Two truths, one lie' with a partner.

- 1 Choose two facts about each of your chosen species and create one lie about the species.
- 2 Read the two truths and one lie out to your partner to see if they can correctly guess the lie.
- 3 Swap after each animal to give your partner a chance to trick you.
- 4 When you have played this game with your partner, swap partners and play again.

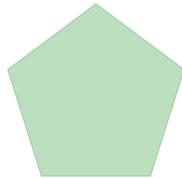
Section 2.4 questions

Remembering

- 1 **Recall** where you would find living sponges.
- 2 **Name** three examples of an arthropod.

Understanding

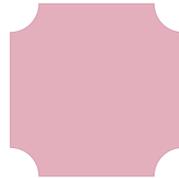
- 3 **Identify** the characteristics you would use to differentiate between the following animals:
 - a jellyfish and earthworm
 - b kookaburra and koala
 - c frog and tuna.
- 4 **Identify** whether each of the following shapes has bilateral or radial symmetry:



a



b



c



d

Applying

- 5 **Describe** the difference between a vertebrate and an invertebrate.
- 6 **Explain** why reptiles can live in deserts whereas amphibians need a moist environment.

Analysing

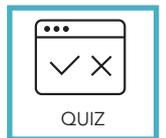
- 7 The sea pig (*Elpidiidae scotoplanes*) is an unusual animal that lives on the bottom of the ocean. It can only survive in salty water. It has feeding tentacles and five to seven pairs of feet. Its body has bilateral symmetry and is soft. **Identify** the phylum that the sea pig belongs to and provide an explanation of your choice.



Figure 2.67 A sea pig

Evaluating

- 8 **Discuss** the reason why many animals that live in water are ectotherms rather than endotherms.
- 9 **Compare** animals found in the Amphibia and Aves classes.



Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked question	Check
2.1 I can explain the reasons for classifying living organisms.	5	
2.1 I can group organisms on the basis on their similarities and differences.	8	
2.2 I can use and interpret keys to identify organisms.	11	
2.2 I can explain how biological classification has changed over time.	12	
2.2 I am able to classify using a hierarchical system.	1	
2.1 I can describe the differences between the classification systems used by Aboriginal and Torres Strait Islander peoples and those used by Western science.	6	
2.2 I can use scientific convention when naming species.	4	
2.3 I can recall the six kingdoms.	2	
2.4 I can describe the different characteristics of a vertebrate and an invertebrate.	7	
2.4 I can recall seven classes of chordates.	3	

Review questions



Remembering

- 1 **Recall** the term used to describe the most general group of living things.
- 2 **List** the kingdoms in the Linnaean taxonomy.
- 3 **Identify** seven classes of chordates.
- 4 **Recall** the correct way to write the genus and species name of the domestic cat. *Hint*: the unformatted name is felis catus.

Understanding

- 5 **Outline** why it is useful to classify organisms and give them a unique universal name.
- 6 **Discuss** how Aboriginal and Torres Strait Islander peoples classify living things.
- 7 **Explain** the different characteristics of vertebrates and invertebrates. Use examples of an emu (*Dromaius novaehlloandiae*) and a garden snail (*Cornu aspersum*) to aid your response.

Applying

- 8 **Organise** the following objects into three groups and give each group a name that best describes the objects you have placed in that group.
skateboard pen spoon scissors pencil bicycle car paint plate
- 9 **Construct** a dichotomous key to classify the contents of your pencil case.
- 10 Moss and fungi both produce spores. **Describe** two differences between these organisms.

11 Each step of the key below can be used to describe an organism. Use it to **describe**:

- a a Tibetan terrier
- b an Italian greyhound.

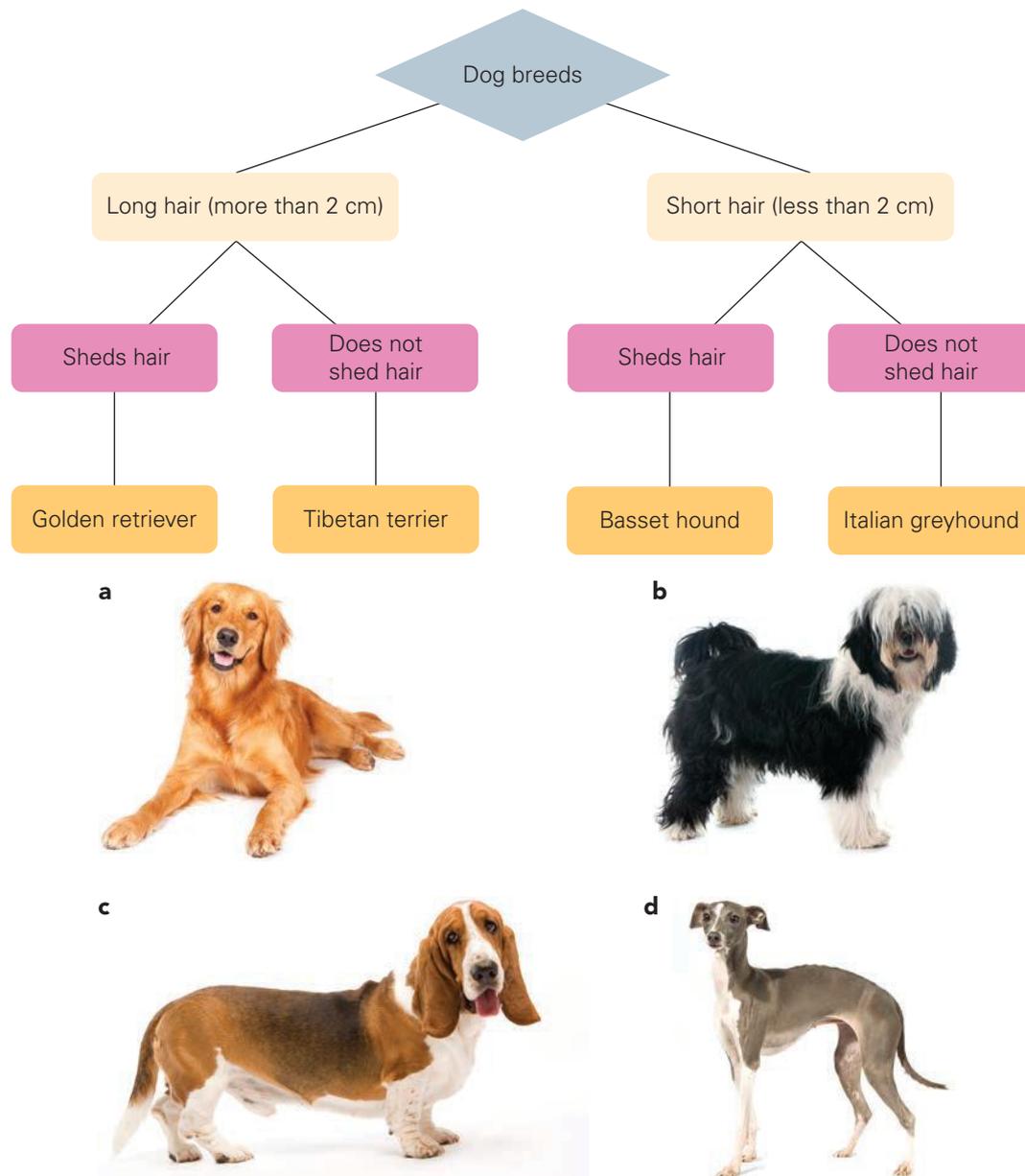


Figure 2.68 (a) Golden retriever; (b) Tibetan terrier; (c) Basset hound; (d) Italian greyhound

Analysing

- 12 The number of kingdoms has changed over time as more information is gathered about the natural world. **Explain** why it is likely that the levels of classification will continue to change.
- 13 **Predict** what would happen if all the decomposers in the world were suddenly to die out.

Evaluating

- 14 *Euglena* are single-celled organisms that can detect light, can swim and are able to photosynthesise. **Discuss** why it would be difficult to classify this organism.
- 15 Scientists used to classify all life as plants or animals. **Justify** which kingdom (plants or animals) you would place fungi, based on what you have learned in this chapter.

Data questions

Use the following diagrams to answer the questions.

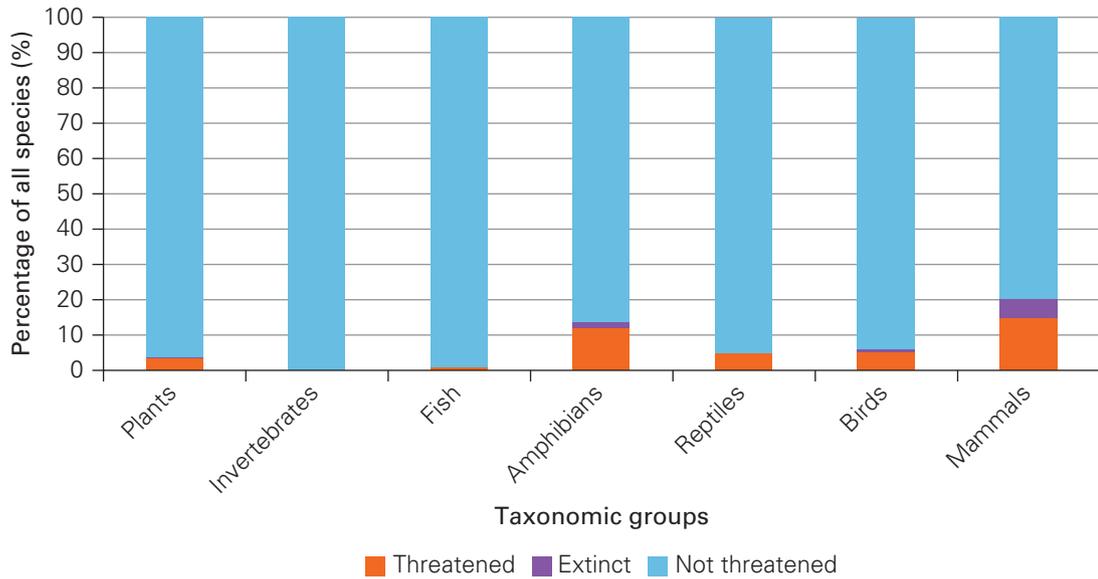


Figure 2.69 The conservation status of different taxonomic groups in Australia

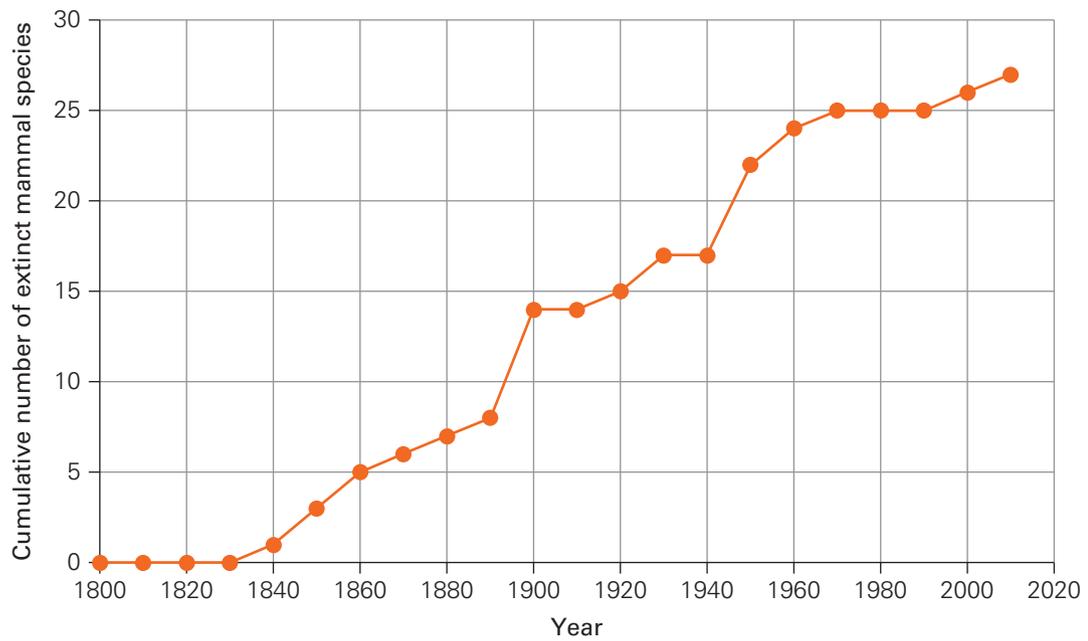
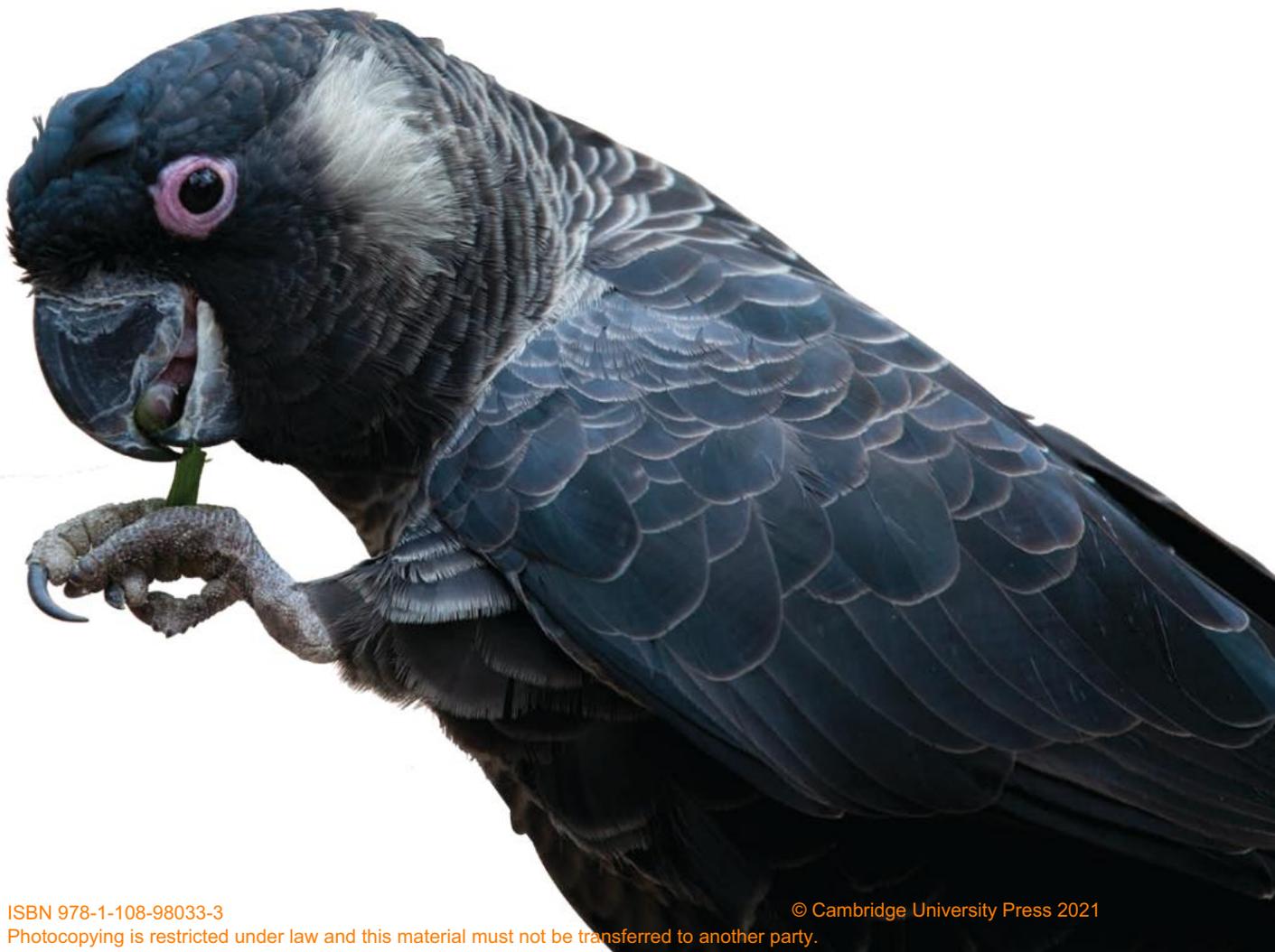


Figure 2.70 The cumulative number of extinctions of mammal species in Australia since 1800

- 1 **Identify** the taxonomic group that is under the least threat using Figure 2.69.
- 2 There are 828 bird species in Australia. 6% of these species are considered as threatened.
Calculate the number of species of birds that are considered as threatened.
- 3 **Calculate** the average rate of mammal extinctions per year from 1800–1920 using Figure 2.70.
- 4 **Organise** the taxonomic groups in the graph from most threatened to least threatened using Figure 2.69.
- 5 **Contrast** the number of extinct and threatened species in mammals with the number of extinct and threatened species in amphibians in Figure 2.69.
- 6 **Predict** the number of extinct Australian mammal species in the year 2020, using Figure 2.70.



STEM activity: Applying biomimicry to solve a human problem

Background information

Engineering is a varied and exciting industry. Engineers often work with designers and architects to use the natural world as inspiration for solving engineering problems and to develop new products that improve our lives. Some examples of biologically inspired designs include Velcro® (based on those pesky prickly seeds that stick to your socks on a bush walk), adhesives that mimic the sticky feet of geckos, and sonar navigation technology (inspired by the echolocation abilities of bats).

This new area of science is called 'biomimicry', which means to imitate life or to learn from nature. Because biomimicry copies nature, it offers millions

of possibilities for technologies due to the almost endless number of animals, plants and insects.

Consider some of the challenges that we face as humans. The natural world faces these challenges too, therefore engineers can study the way plants, animals and insects approach these challenges and then improve their own designs. For example, the water filters in water treatment plants are designed to act like animal cell membranes, which let certain substances pass through, while others are kept out. In addition, studying a leaf and how it captures the Sun's energy allowed for the creation of more effective solar cells by engineers.



Figure 2.71 Bobsled outfits were designed to mimic shark skin. They are made from a woven ribbing fabric that reduces drag while still allowing movement.

Design brief: Applying biomimicry to solve a human problem

Activity instructions

In teams, you will become design engineers who will use the biomimicry of plants, insects or other animals to develop and design a sustainability-related invention that solves a human problem. Examples of problems you may like to look at could be transportation, building design, lighting,

landscaping, water use. Your team will not only draw a detailed and labelled diagram of your design, but also describe your design by listing the special features and which plant, insect or other animal inspired those features. Remember to ask yourselves throughout the process: 'What would nature do here?'

Suggested materials

- A3 and A4 paper
- pens, pencils
- ruler

Research and feasibility

- 1 Discuss and agree on a human problem to study with your group. Start to research the issue by making a list of all the main ideas of the human problem and the effects they have. An example is given below for the issue of road traffic.

Major causes of traffic	Effects	What would animals do here?
Too many cars	Too many cars on the road causes traffic jams.	Ants have specialised patterns of movement as they encounter traffic. They actually move faster but add additional lanes.
Blockages on the roads	Traffic comes to a complete stop	If there is anything blocking an ant's path, an ant will remove it, which allows the other ants to move past without interference.

- 2 Explain the human problem in a statement and the cost on society (this is not just monetary, but includes environmental, social, and psychological costs, among others).

Design

- 3 Identify your plant, insect or other animal and its scientific name, and briefly describe why mimicking the organism could help with a prospective solution to the human problem.
- 4 Describe the unique features of your organism. Are these characteristics linked to its classification?
- 5 Describe how you mimic the material, colour and structure of the organism to design something new.
- 6 List the materials and their physical properties required to realise your design (remember that you do not need to build your design, so think about all possibilities).
- 7 Describe how each material was used and for what purpose. You may wish to use a table.

Materials	Physical properties	Purpose of material

Create

- 8 Sketch out ideas within your group, and vote on which uses biomimicry to solve the human problem the best.
- 9 Create a scale drawing of your invention, including a front view and side view of your invention.
- 10 Describe your design by listing the special features of the design and which aspect of your organism inspired those features.

Evaluate and modify

- 11 Evaluate your design and its ability to solve the problem you identified. What improvements would you make?



Figure 2.72 A simple shell could be your inspiration for an ethically sustainable house.

Chapter 3

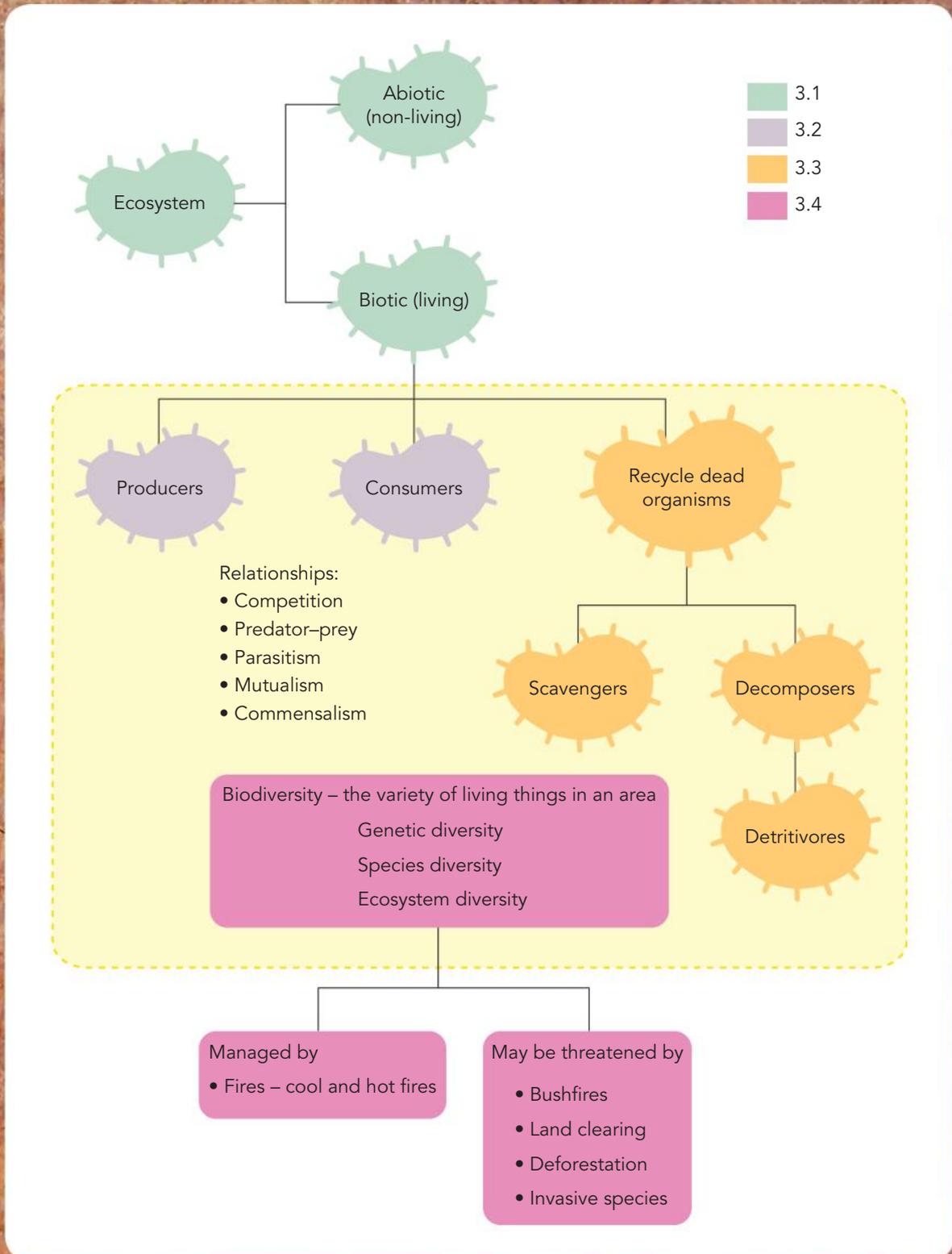
Interactions in ecosystems



Chapter introduction

Congratulations! You are at the top of your food chain. In fact, you are at the top of many food chains. Whether you are eating a pancake or a steak, the last organism that will use the energy stored in that food is you. But what would happen if all the pancakes disappeared? Would you go hungry or would you find another food source? In this chapter, you will look at how the interaction of organisms and their environment are linked together. You will also explore the long-reaching effects that just a few small changes to an environment can cause.

Chapter map



3.1 Ecosystems



Learning goals

- 1 To be able to recognise the difference between biotic and abiotic factors in an ecosystem.
- 2 To be able to state the various levels of organisation in an ecosystem.
- 3 To be able to describe five different species interactions in an ecosystem.

ecosystem

the living and non-living components of a specific area and their interactions

biotic

relating to the living things in an ecosystem

abiotic

relating to the non-living things in an ecosystem

environment

the biotic and abiotic conditions that affect an organism in its location

Ecosystems are all the living and non-living parts of a particular area. All parts of an ecosystem are linked and even the smallest of changes can produce massive results. Deserts, forests, coral reefs and grasslands are among the many ecosystems found on Earth.

Describing ecosystems

When scientists discuss ecosystems, they are referring to all the living (**biotic**) and non-living (**abiotic**) features within an area and how they interact. The **environment** of an ecosystem includes the biotic and abiotic conditions that affect an organism in its location.

Some examples of the biotic and abiotic features of an environment are listed in Table 3.1.

Biotic	Abiotic
Animals	Water
Trees	Rocks
Fungi	Weather
Food	Temperature
Diseases	Light

Table 3.1 Some examples of biotic and abiotic features of ecosystems

If you are trying to decide whether a feature of an environment is biotic (living) or abiotic (non-living), you may like to remind yourself of the life processes displayed by all living things that you learned about in Chapter 2.

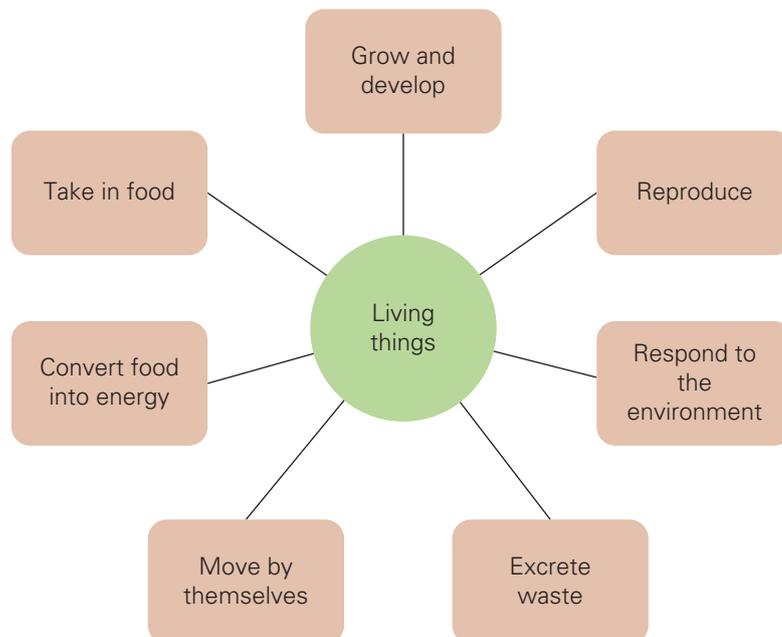


Figure 3.1 All living things demonstrate these processes.

Try this 3.1

Coral reefs

A coral reef is an example of an ecosystem. List as many biotic (living) and abiotic (non-living) features of this type of ecosystem as you can. The images in Figure 3.2 may help to inspire you. After you have tried on your own, chat with your classmates to see what other ideas they had that you can add to your two lists.



Figure 3.2 Images of the beautiful ecosystem that is our Great Barrier Reef (left) and Ningaloo Reef (right)

Explore! 3.1

Antarctica

In the 4th century BC, Aristotle hypothesised that a landmass could exist in the southern hemisphere. He used the Greek word 'Antarktikos' (meaning the opposite of the arctic) to describe it. In 1775 during his second voyage, Captain Cook described the existence of such a polar continent as 'probable'. The continent was largely neglected for the remainder of the 19th century due to its inhospitable environment, isolation and lack of resources.

In 1820, at least four explorers from various countries saw the coastline of the continent of Antarctica. The year 1821 was possibly the first time any humans ever put a foot on the shores of Antarctica, but many historians dispute this claim. The first recorded confirmed landing was in 1895 by a Norwegian-Swedish whaling ship (Antarctica). Starting in the late 1890s, adventurers from different countries raced to reach the geographic South Pole. Many of them failed until Roald Amundsen, a Norwegian, succeeded in 1911.

Since then, a number of governments have built permanent research stations in Antarctica. Scientists are excited to learn as much as they can about the unique Antarctic ecosystem. The international Antarctic Treaty of 1959 required that Antarctica should be used for peaceful and scientific reasons only, and many nations participate in conferences to discuss ongoing agreements about the details of this. Between one thousand and four thousand international scientists are usually on Antarctica, depending on the season.

Research a project that is taking place at one of Antarctica's transnational research stations. Present a summary to your classmates.



Figure 3.3 An adult Weddell seal (*Leptonychotes weddellii*) is pictured in front of the Mawson Station, one of several permanent research stations in Antarctica maintained by the Australian Antarctic Division. The red vessel behind the seal is *Aurora Australis*, which was the Australian icebreaker ship until March 2020.

Habitats

habitat

the natural home of an organism

community

a group of animals or plants that live or grow together

population

all organisms of a particular species or group who live in one area

abundance

the number of individuals of a species within a community or ecosystem

Imagine an emperor penguin in a desert. He is surrounded by sand as far as the eye can see, no water, and it is extremely hot. This penguin is not very happy and that is because he is not in his natural **habitat**.

He does not have any of the things near him that he needs to survive like water, fish and other penguins.

The same could be said for a

desert snake in Antarctica. All organisms have a specific set of needs that will allow them to thrive, and the area in which they live that provides these needs for them is called their habitat.

Some examples of these needs that make up an organism's ideal habitat include:

- food
- water
- shelter

- space to live
- environmental conditions, like temperature and light intensity
- other similar organisms for reproduction.

A habitat has specific living and non-living conditions within it. For example, the Daintree River ringtail possum lives high up in the canopy of rainforest trees, where it can keep cooler than organisms living lower down. Their habitat suits their needs perfectly. Each ecosystem is made up of many individual habitats that are the perfect places for specific organisms to survive.

Levels in an ecosystem

When scientists discuss an ecosystem, they can also describe the biotic (living) organisation at different levels from large to small: **community**, **population** and individual. Table 3.2 summarises each level.

Try this 3.2

Ecosystems

In groups of five, come up with five different ecosystems and write them down. Then as a class, list them on the board, avoiding any repetitions. Discuss whether some areas can be further broken down into several habitats.



Figure 3.4 An example of many habitats in one area

Level of organisation	Description
Individual	One living organism.
Population	A group of the same species of an organism living in the same area. For example, there is a population of the western grey kangaroo living in the John Forrest National Park. Their total number is called their abundance .
Community	A group of different organisms that live in the same area. For example, Rottneest Island consists of a community of living organisms including plants, snakes, frogs and quokkas.

Table 3.2 The levels of organisation in an ecosystem

Quick check 3.1

- 1 Define these terms in your own words: ecosystem, biotic, abiotic, habitat.
- 2 Name four different types of ecosystem.
- 3 Name three examples of biotic and abiotic factors in an ecosystem.
- 4 Discuss what it is that makes a habitat a home for a particular organism.

Try this 3.3

Demonstrating the organisation of ecosystems

Select an Australian organism you find interesting. Some examples are wombats, bilbies and turtles. On a piece of A3 paper, put the name of this organism in a small circle in the centre of your page – this is your individual. You may like to include a picture of your organism. Now draw a larger circle around your individual. This will be your population. List or draw what would be in your organism's population. Continue to add examples of each level of organisation as you work all the way up to biosphere.

If you study a community, you might observe how a bird eats the fruit from a specific plant. However, a scientist studying an ecosystem would also study the effects of a bushfire on an entire habitat, which would include many living and non-living features.

Explore! 3.2

Look at Figure 3.5. It illustrates how the different levels of organisation of an ecosystem are related and can be demonstrated. But there are two levels you have not looked at yet. Use your preferred browser to research the following questions:

- 1 Define what a biome is. What does it include?
- 2 Define what a biosphere is. What does it include?

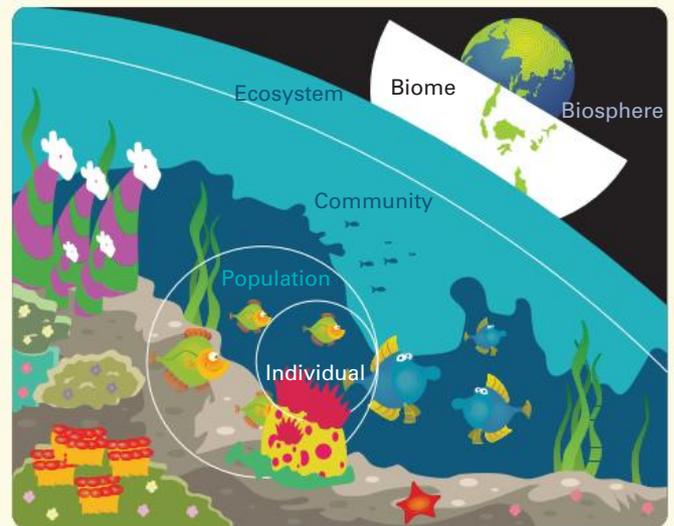
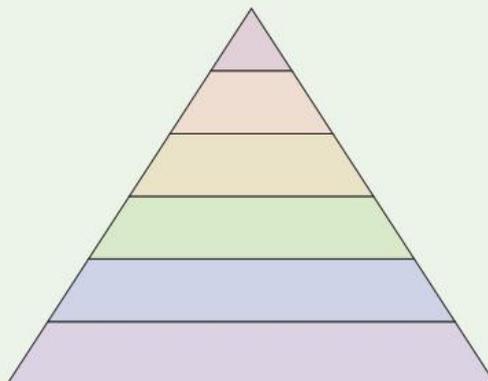


Figure 3.5 Levels of organisation

Quick check 3.2

- 1 Define the terms 'environment', 'community' and 'population' in your own words.
- 2 Name a specific habitat and propose a community, population and individual that would be found in that habitat.
- 3 Sequence the following terms to demonstrate the levels of organisation: individual, ecosystem, biosphere, biome, population, community. You may draw a pyramid similar to the image shown.



Science as a human endeavour 3.1

Ecosystem case study: Saving the Great Barrier Reef



Figure 3.6 Aerial photo of a small section of the magnificent Great Barrier Reef

The Great Barrier Reef is the largest coral reef on Earth with an area of 344 400 square kilometres. That is almost 70 million football fields! The water temperature in the reef can range from 24–30°C throughout the year. Owing to the clean waters, light can penetrate to a depth of around 20 metres.

The reef structure is composed of and built by billions of living organisms called coral polyps. It is home to around 1625 species of fish, 133 species of sharks and rays and 600 types of corals. There are also hundreds of reptiles, mammals and birds found around the reef.

One example of a reptile found at the reef is the green turtle. There are around 16 000 green turtles on the reef. These turtles can carry **barnacles** and **algae**, which some fish in the community feed on.

barnacle

small sea creature with a shell that sticks to rocks and the bottom of boats

algae

small protist organisms (see Chapter 2) without leaves or roots; a valuable food source in aquatic ecosystems



Figure 3.7 A healthy reef contains hundreds of species of fish and coral of many wonderful colours.



Figure 3.8 A green turtle supports a community of other living things.

continued...

...continued

In 2016 and again in 2017, the Great Barrier Reef suffered mass coral bleaching. This was the first case of back-to-back mass bleaching on the reef. Coral bleaching is when, because of global warming or pollution, the water gets too warm or dirty for the algae that live in the coral. Then the stressed algae move out of the coral. Algae provide up to 90 per cent of the coral's energy. This means the coral loses its major source of food and eventually starves to death. In 2016, the result was a 30% loss of coral, and a further 20% loss in 2017.



Figure 3.9 A coral that has undergone coral bleaching

In September 2017, there was good news from Southern Cross University. Australian scientists working in the Philippines had been working with a team to repair their damaged reefs by encouraging the reproduction of coral larvae in special tanks to then be released. This is not always successful, but these amazingly talented scientists have now been the first in the world to successfully re-establish a breeding coral population from larvae directly on a reef. This means there is hope that the Great Barrier Reef may be saved.

Interactions in an ecosystem

Organisms do not live by themselves – they live in communities and are constantly interacting with other species. Some interactions help both species, some help just one of the species, and some can be negative for one or both species. All these interactions are needed to maintain balance in an ecosystem. Competition, predator–prey and

symbiotic relationships are all examples of different types of interactions between organisms. Symbiosis means ‘to live together’, and it happens when two species have a close relationship with each other. Interactions that fall under the category of symbiosis are mutualism, parasitism and commensalism. These interactions are summarised in Table 3.3.

symbiotic
a relationship between two types of living things that helps at least one of them survive



Figure 3.10 Examples of (a) an Australian parasite, (b) a mutualistic relationship and (c) commensalism



VIDEO
Interactions
explained

Interaction	Species 1	Species 2	Definition	Example
Competition	Harm	Harm	When two organisms (same or different species) compete for the same resource (shelter, food).	Humans compete with all species for space.
Predator–prey	Benefit	Harm	One species kills and eats another species.	Small fish on the Great Barrier Reef predate on coral polyps.
Parasitism	Benefit	Harm	One species is the parasite (benefits), which lives in and feeds on a host species (harmed).	Kangaroos are susceptible to ticks which suck their blood. The kangaroo is harmed and the tick gets food and shelter.
Mutualism	Benefit	Benefit	Both species benefit.	Cape sugarbirds feed on the nectar from the king protea flower. As they reach the nectar, pollen gets stuck on their beak, so helping to pollinate the flower.
Commensalism	Benefit	No effect	One organism benefits and the other is unaffected.	The remora, also called a sharksucker or suckerfish, rides sharks by using a flat, oval sucking-disk structure on its head.

Table 3.3 Summary of some of the different interactions that occur in an ecosystem. The three bottom-most interactions are symbiotic interactions.

Try this 3.4

What is the interaction?

Look at each of the following images and with a little research, decide which type of interaction is being demonstrated.



Figure 3.11 Examples of different types of interactions between organisms: (a) echidna eating ants, (b) lichen and algae on a rock and (c) two adult seals fighting

Section 3.1 questions

Remembering

- 1 **List** the components of an ecosystem, from largest to smallest.
- 2 **Identify** two abiotic features found at the Great Barrier Reef in Queensland.
- 3 **Identify** three biotic features of the Ningaloo Reef in Western Australia.
- 4 **Define** the terms 'parasitism', 'mutualism' and 'commensalism'.



Understanding

- 5 **Name** a population in the Great Barrier Reef.
- 6 **Define** the term 'habitat'.
- 7 The common kangaroo tick (*Amblyomma triguttatum*) feeds on the blood of a western grey kangaroo (*Macropus fuliginosus*). The kangaroo is harmed, and the tick is provided food and a home. **Deduce** whether the association between the kangaroo and tick is parasitism, mutualism or commensalism.

Applying

- 8 Using what you have learned about interactions in ecosystems, **provide** an example of each of the following interactions in which humans are involved.
 - a mutualism
 - b parasitism
 - c commensalism
 - d competition
- 9 Look at Figure 3.12 and **identify** parts of the ecosystem such as communities, abiotic and biotic factors, populations, and habitats.



Figure 3.12 A rich ecosystem

Analysing

- 10 **Compare** the terms 'ecosystem' and 'environment'.
- 11 **Compare** the abiotic and biotic factors in an ecosystem. You may use a Venn diagram.

Evaluating

- 12 Environmental conditions are changing in ecosystems every day. **Propose** the changes in abiotic factors that occur in a desert ecosystem over the course of a day and how these changes would affect the biotic parts of the ecosystem.
- 13 'All populations living together within a community interact with one another and with their environment to survive and maintain a balanced ecosystem.' **Justify** your position on this statement.

3.2 Food chains and food webs



Learning goals

- 1 To be able to define the terms 'producer' and 'consumer'.
- 2 To be able to interpret a food chain and food web to show feeding relationships.
- 3 To be able to describe how energy flows through a food chain.

energy

the ability to do work by producing heat or motion

cellular respiration

the chemical process by which cells release energy from food

Energy

We have a lot in common with all the living creatures around us, such as dogs and fish and even slugs, but the main similarity is that we all eat. We all need

to gain **energy** from eating other organisms to live. In humans, we use this energy to grow, move, reproduce, repair and stay warm. Even plants need energy, but because they do not have mouths to eat, they do it differently, they make their own food. They then do what we do, and use this energy to grow, move, reproduce and repair.

Plants make their own food and animals eat ready-made food that they find. Once an organism has acquired food, it needs to turn this food into energy. It does this at a cellular level by using the glucose produced in the digestion of food, in a process called **cellular respiration**.

The energy produced in cellular respiration is used for all the processes in each living organism. A common mistake is to think that plants do not perform cellular respiration because they make their own food. In fact, they must do cellular respiration, otherwise the food they produce would never get turned into energy, so they would never be able to grow.

Quick check 3.3

- 1 Define the term 'energy' in your own words.
- 2 Explain what energy is needed for.
- 3 Explain why cellular respiration is a necessary process carried out by all living things including plants and animals.
- 4 Name the inputs and outputs of the process of cellular respiration.

This is the cellular respiration word equation: glucose + oxygen → energy + carbon dioxide + water

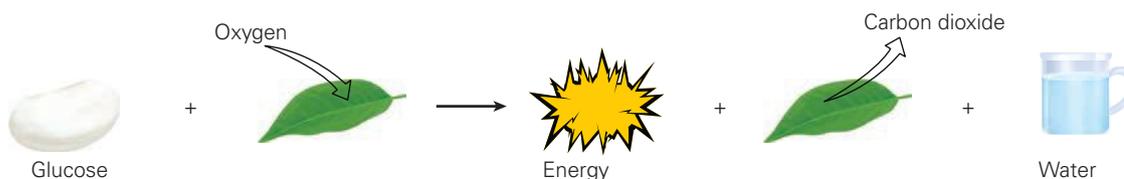
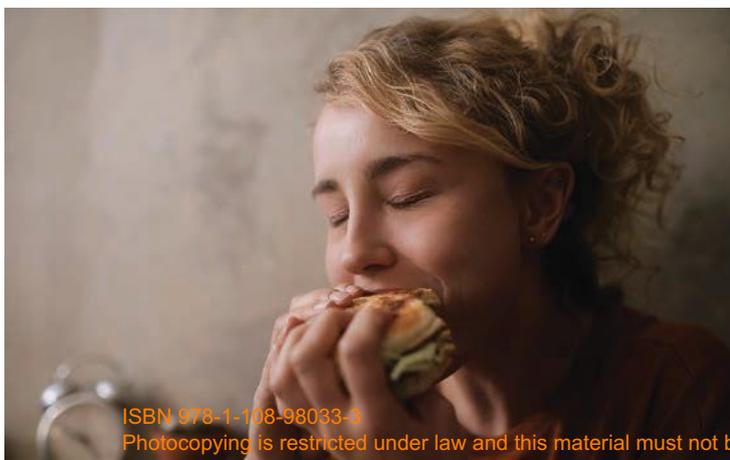


Figure 3.13 The process of cellular respiration

Figure 3.14 We all need to eat.



Producers

Think about your garden at home or at school. How are the plants kept alive? You would probably say that someone has to make sure the plants have access to sunlight and are watered every so often. You are right, plants use the water in soil along with the light energy from the Sun and carbon dioxide in the air to

form sugars called glucose in their leaves. This process is known as **photosynthesis** and it is how plants make their own food. This is the reason that plants are also called **producers** – they produce or make their own food.

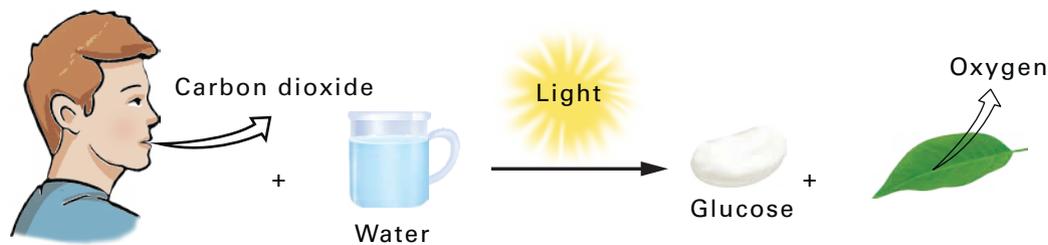
This is the word equation for photosynthesis:

carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen

Plants then break down these sugars in their bodies just like you do and use these sugars for energy. They use energy to grow, reproduce and repair themselves.



Figure 3.15 Green leaves absorb light energy from the Sun to make food.



photosynthesis
the process by which a plant uses the energy from the light of the Sun to produce its own food

producer
an organism capable of producing food from photosynthesis

Figure 3.16 Photosynthesis

Practical 3.1: Investigation

Observing photosynthesis

Aim

To investigate the effect of changing light intensity on photosynthesis.

Time period

Approximately 2–3 days

Prior understanding

Photosynthesis uses carbon dioxide (CO₂), water and light energy to make glucose and oxygen. Aquatic plants extract dissolved carbon dioxide from the water to photosynthesise. A way to measure the amount of dissolved carbon dioxide in the water is to add the indicator bromothymol blue. Water will appear yellow when a high concentration of carbon dioxide is present and turn to blue as the concentration of dissolved carbon dioxide is reduced.

Materials

- aquatic plant
- bromothymol blue solution (acts as an indicator to show if photosynthesis is occurring)
- 4 small conical flasks
- 500 mL beakers
- large measuring cylinder
- straws
- balloons
- aluminium foil or stopper

Be careful

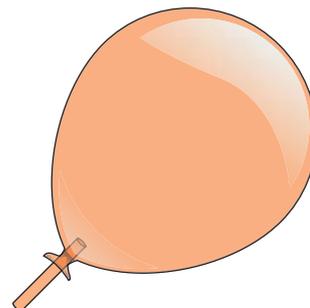
Bromothymol blue can be harmful when inhaled. Blow into the balloon, and then use the balloon to bubble carbon dioxide into the water. Do not blow directly into the solution. Ensure the room is well ventilated and wear appropriate personal protective equipment.

continued...

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Method

- 1 Pour 320 mL of water into a 500 mL beaker.
- 2 Add enough drops of bromothymol blue solution to turn the water a pale blue colour.
- 3 Blow up a balloon and insert a straw into the end of it as shown, pinching it shut to hold in the air.
- 4 Dissolve carbon dioxide into the water by inserting the straw into the beaker and *gently* releasing the air into the solution causing it to bubble through for approximately 1 minute until the water turns pale yellow.
- 5 Label each conical flask with the following information:



Group 1: Control	Group 2: Light	Group 3: Control	Group 4: Dark
Description: No plant in light	Description: Plant in light	Description: No plant in dark	Description: Plant in dark
Date:	Date:	Date:	Date:
Student/s name:	Student/s name:	Student/s name:	Student/s name:

- 6 Measure out 80 mL of bromothymol blue + water solution from step 4 and pour it into one of the four conical flasks. Repeat this for each of the three remaining flasks.
- 7 Add a 7 cm piece of the aquatic plant to the Group 2 and Group 4 flasks. Use the straw to gently push the plants into the water to make sure they are submerged.
- 8 Cover each flask with aluminium foil or a stopper.
- 9 Copy the table shown in the results section into your science book.
 - Label the independent variable and its groups in the table.
 - Label the dependent variable in the table.
- 10 Record the initial colour of the water in each flask.
- 11 Position the flasks as described on the label.
 - Group 1 and Group 2 flasks next to a window.
 - Group 3 and Group 4 flasks in a cupboard away from any light.
- 12 Observe the flasks after 2–3 days. Has the colour changed?

Results

Independent variable	Dependent variable		
	Initial water colour	Final water colour	Change in dissolved carbon dioxide? <ul style="list-style-type: none"> • None • Some reduction • Substantial reduction
Group 1 _____			
Group 2 _____			
Group 3 _____			
Group 4 _____			

continued...

...continued

Discussion

- 1 Identify any trends, patterns or relationships in your results.
- 2 Explain what a change of colour means in terms of whether photosynthesis is occurring in the plant. What does it mean when the solution is yellow? What does it mean when the solution is blue?
- 3 Discuss if there was any change in the control flasks. Explain why you think that is.
- 4 Explain the importance of having flasks with no aquatic plants.
- 5 Did you have any errors during this experiment that you could have minimised? Propose any changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

State a conclusion about the relationship between light and photosynthesis in plants.



Figure 3.17 A koala (*Phascolarctos cinereus*, top) and a goat (*Capra aegagrus hircus*, bottom) are shown consuming producers.

Quick check 3.4

- 1 Discuss why plants are called producers.
- 2 Name the inputs and outputs of the process of photosynthesis.

Consumers

Humans do not have the ability to photosynthesise, so we, and other animals, need to eat plants or other organisms to gain their sugars (glucose) to turn it into energy. You might think, ‘why don’t humans have the ability to photosynthesise?’ The fact is, we need a lot more energy in our everyday lives compared to plants. If we could photosynthesise, we would need massive sails of skin and to spend every minute outside to produce even a fraction of the energy we would need. This would not give us much time to do anything else!

The fact that animals eat food that is ready-made, means that we are all considered to be **consumers**.

consumer
an organism that obtains food from consuming other organic material

Try this 3.5

Producers and consumers

Look at the pictures of Australian organisms in Figure 3.18 and organise them into producers and consumers.



Wattle



Quokka



Fruit bat



Eucalyptus



Platypus



Bottlebrush



Kangaroo paw



Kangaroo

Figure 3.18 Australian organisms

Did you know? 3.1

Life deep under the sea



Figure 3.19 Examples of life around a deep-sea hydrothermal vent

Up until around 35 years ago, scientists believed that all life relied on energy gained from the photosynthesis process. However, with specialised deep-sea submarines, scientists discovered ecosystems deep down in the ocean, much further down than light can penetrate. These ecosystems are gathered around hydrothermal vents that produce large amounts of heat and expel chemicals and minerals. The producers in these hydrothermal habitats use these chemicals and minerals to produce chemical energy in a process known as chemosynthesis and are known as **chemotrophs**. This discovery has led scientists to believe that we may find life in places such as Europa (a moon of Jupiter) that has a liquid water ocean under a thick layer of ice that light cannot penetrate.

Types of consumers

In every ecosystem, there are many different types of animals that eat a wide variety of things. Usually we do not eat the same food for every meal of every day. The types of food that we eat, or consume, place us into special groups. If you eat only plants, you are called a **herbivore**, if you eat both plants and animals, you are known as an **omnivore** and if you only eat other

chemotroph

an organism that obtains energy through chemical processes in its environment

herbivore

an animal that eats only plants

omnivore

an animal that is naturally able to eat both plants and meat

carnivore

an animal that eats only meat

animals, you are called a **carnivore**. The one thing that all these groups have in common is that they are all consumers.

Most herbivores, carnivores and omnivores display similar features to others in their group. These features allow biologists to identify their eating habits without observing them eating. For example, one of the main tools biologists can use to identify the diet of a mammal is to look at its teeth.

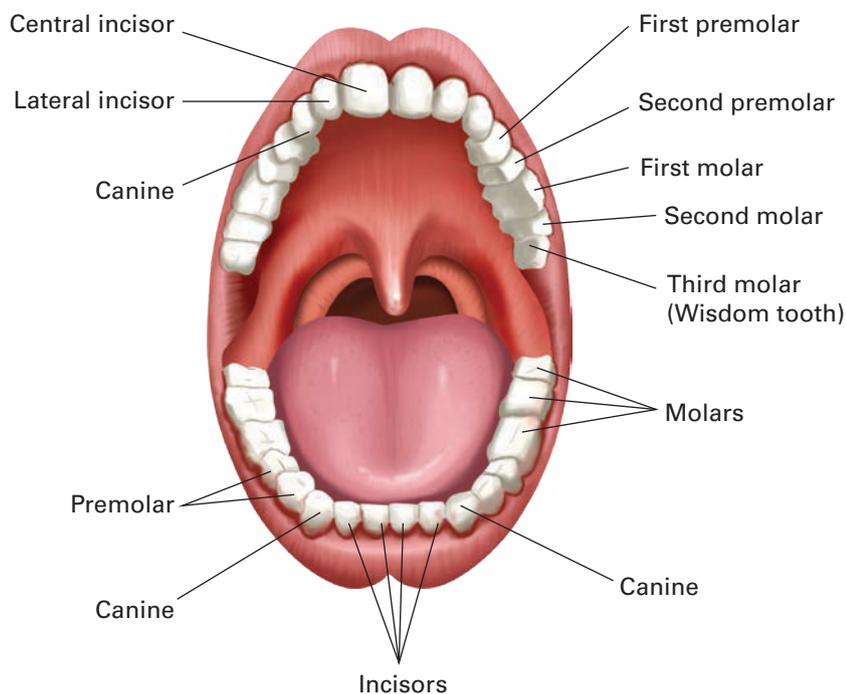


Figure 3.20 Human teeth identify us as omnivores.

Humans are natural omnivores, which means that we have evolved to eat both plant and animal products. Because of this, we have a range of different teeth in our mouths. Starting at the front are the incisors. These are sharp, flat, cutting teeth, like scissors. They are used to bite off pieces of food. Herbivores use these teeth to nibble away at plants and, as they are used constantly, they tend to wear down. To combat this, the incisors of some animals, such as rabbits and wombats, continue growing throughout their lives.

The long, sharp, pointed teeth next to incisors are called canines. They are near the

front of the mouth and are used to hold and tear at food. Carnivores have large well-developed canines that they use to catch and kill their prey. Many herbivores lack canines as they do not hold and tear at the food they eat.

The flat teeth at the back of your mouth are known as molars. These teeth are for chewing and grinding and are found in herbivores, carnivores and omnivores. Herbivores have large, almost flat molars that allow them to grind plant material into very small pieces before swallowing.

Figure 3.21 A rabbit's incisors keep growing throughout its life.

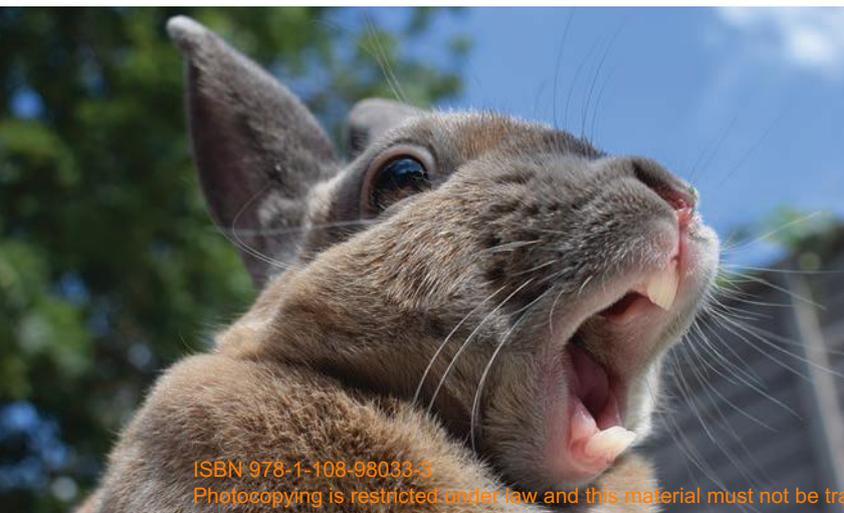


Figure 3.22 This leopard is showing off her impressive canines.

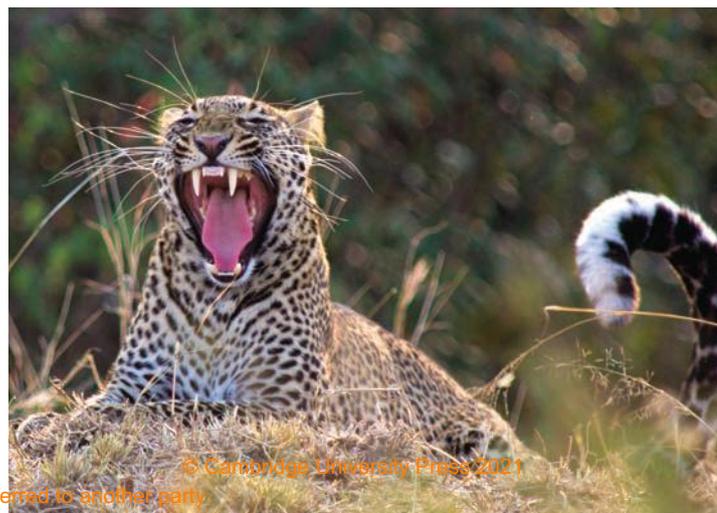




Figure 3.23 A cow using her molars to chew some grass

Try this 3.6

Animal teeth

Ask your teacher if you can view a random selection of animal skulls and look at their teeth. Do they have incisors, canines or molars? Can you confirm what the animal might eat? Tabulate your observations and compare with your classmates to provide evidence of what species each animal might be.

Quick check 3.5

- 1 Define the term 'consumer' in your own words.
- 2 There are three main types of consumer.
 - a Name the three types.
 - b State what each group eats.
- 3 Examine the images in Figure 3.24 and for each determine:
 - i the type of teeth
 - ii the structure and function
 - iii the animal types in which those kinds of teeth are found.

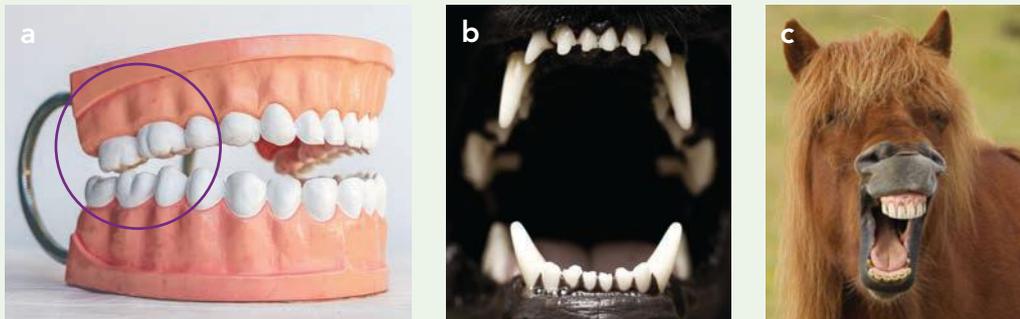


Figure 3.24 Images of different types of teeth



Food chains: What eats what?

In an ecosystem, it is important to know what eats what. This allows scientists to follow the flow of energy starting from the Sun, to the producers and making its way through the consumers. This flow of energy is known as a **food chain**.

An example of a simple food chain would be:

grass → mouse → hawk

The direction of the arrow in a food chain indicates the flow of energy through the chain. The food chain in Figure 3.25 introduces some new terms, which are explained in Table 3.4.

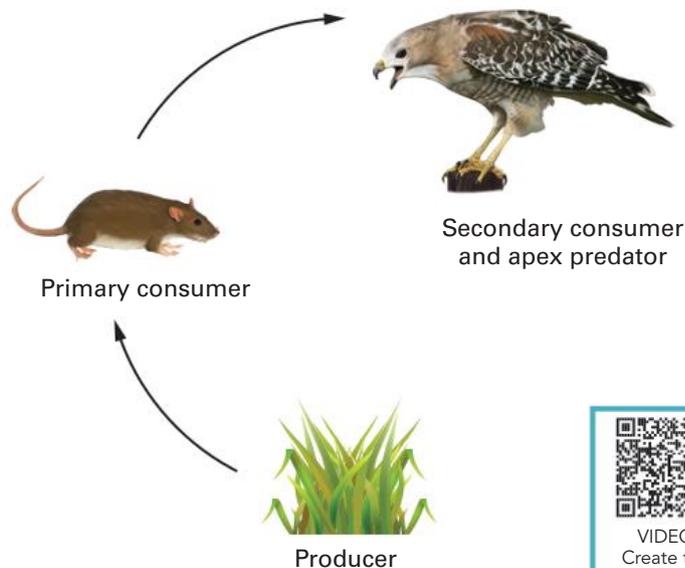


Figure 3.25 A hawk is an example of an apex predator as it has no natural predators.



Term	Definition	Example
Primary consumer	The first consumer in the food chain that eats the producer and is therefore always a herbivore.	Termites eat a wattle tree (producer)
Secondary consumer	A consumer that eats the primary consumer or herbivore. Usually carnivores, but can be omnivores.	Echidna eats the termites (primary consumer)
Tertiary consumer	A consumer that eats the secondary consumer.	Dingo eats the echidna (secondary consumer)
Apex predator	A consumer at the top or end of the food chain that usually only has humans as a possible predator.	Dingo

Table 3.4 Consumers can be classified into these groups, based on their position in a food chain.

food chain
the flow of food energy through an ecosystem passing from plants and bacteria to consumers

primary consumer
an animal that eats plants

secondary consumer
an animal that eats other animals

tertiary consumer
an animal that eats secondary consumers

apex predator
a predator at the top of a food chain

As you learned at the start of this chapter, you are at the top of your food chain. You are an apex predator. But you are not just at the top of one food chain, you are at the top of many. You are at the top of the broccoli food chain and also the burger food chain.



Figure 3.26 Broccoli food chain

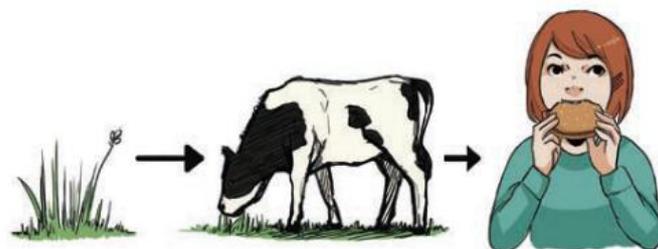


Figure 3.27 Burger food chain

Try this 3.7

What food chains can tell us

Consider the food chain in Figure 3.28 to answer the questions.



Figure 3.28 What does this food chain tell us?

- 1 State what the arrows show the flow of.
- 2 Identify where all the energy originally comes from.
- 3 Identify the producer, first consumer, second consumer, tertiary consumer and apex predator.
- 4 Identify the herbivore.
- 5 Predict what would happen if:
 - a fairy penguins moved into the area and ate all the krill before the fish could get to it
 - b a local commercial fishing company over-fished the area
 - c chemicals running off farmland killed all the phytoplankton.

Quick check 3.6

- 1 Define the term 'food chain' in your own words.
- 2 Recall where the Sun should go in a food chain and why.
- 3 Identify the producer, primary consumer, secondary consumer, tertiary consumer and apex predator out of these organisms in a food chain: termite, dingo, echidna, eucalyptus tree.
- 4 Recall what sort of information you can find out from looking at a food chain.

Food webs

food web
a group of interweaving
food chains

There are many different types of organisms in any habitat. There are also many food chains that are interlinked. These interlinked food chains are known as a **food web**.

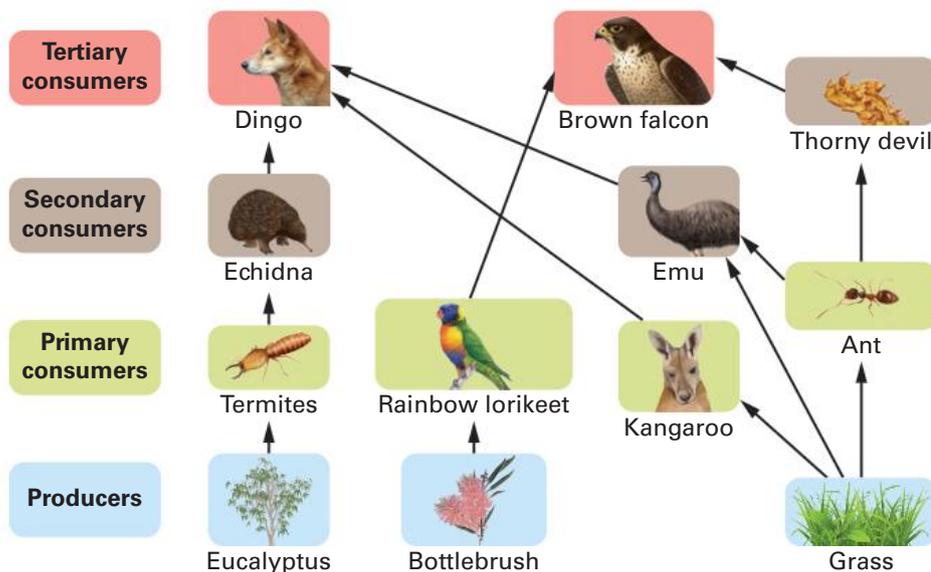


Figure 3.29 An example of an Australian food web

If you look at the food web in Figure 3.29, you can see the interaction between many Australian organisms found in an ecosystem. You might notice that although there are many food chains displayed in this particular example, there is a maximum of four organisms in each food chain. This is because energy is lost from each **trophic level** of the food chain as it passes from the Sun to the producer and consumer. Generally speaking, only 10% of the energy is passed on to the next level. This is the **10% rule**. Each organism uses up most of the energy it consumes in the following ways:

- through carrying out processes like growing, moving and reproducing
- as heat loss when the organism uses the food to fuel its living processes such as respiration
- in bodily waste as the organism does not digest and use all the food it eats.

This means that there can only be a limited number of animals at the top of the food chain as less energy is getting to them. Figure 3.30 shows this loss of energy. Note that kilojoules (kJ) is a unit of energy. One kilojoule is equal to 1000 joules.

trophic level refers to an organism's level or position in a food web. It is based on an organism's feeding habits, where producers occupy the first trophic level, primary consumers the second trophic level, and secondary consumers the third trophic level, etc.

10% rule when energy is passed from one trophic level to another, only 10% of the energy will be passed on

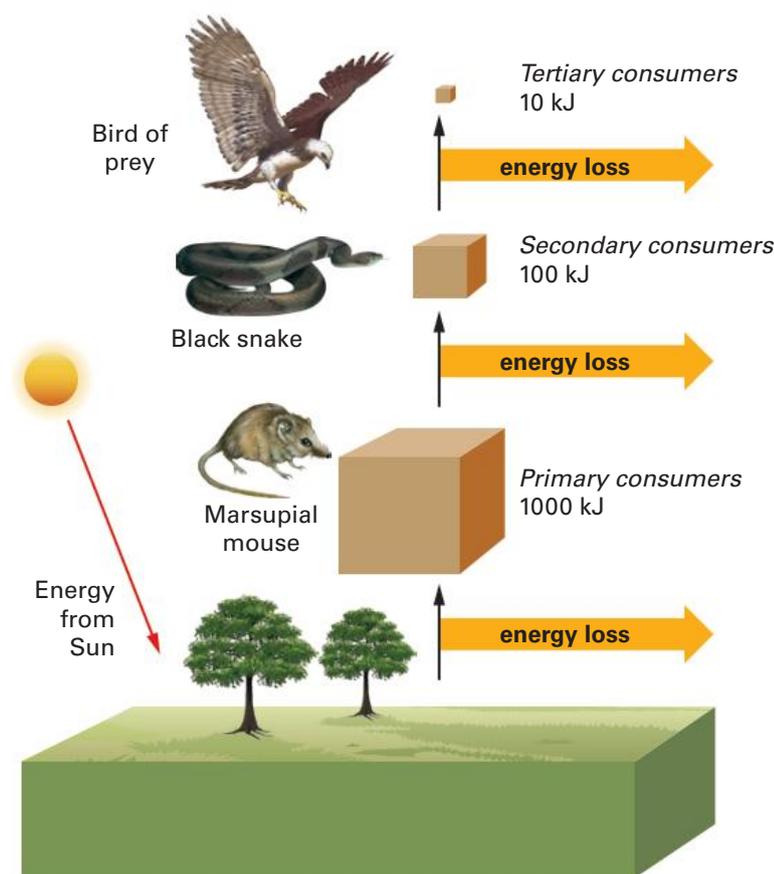


Figure 3.30 The energy flow and loss through a food chain

Worked example 3.1

Use Figure 3.30 to answer the following questions.

- If the snake consumes 350 kJ of energy, and it is eaten by the eagle, calculate how much energy would be available to the eagle.
- Calculate how much energy was originally available to the mouse from the producers.

continued...

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Working	Explanation
<p>a energy for eagle = $10\% \times 350 \text{ kJ}$</p> $= \frac{10}{100} \times 350 \text{ kJ}$ <p>OR $0.1 \times 350 \text{ kJ}$</p> $= 35 \text{ kJ}$	<p>By the 10% rule, only ten per cent of 350 kJ will be available to the eagle.</p> <p>10% is equivalent to $\frac{10}{100}$ or 0.1.</p>
<p>b $350 \text{ kJ} = \frac{10}{100} \times \text{energy for mouse}$</p> $\text{energy for mouse} = \frac{100}{10} \times 350 \text{ kJ}$ $= 10 \times 350 \text{ kJ}$ $= 3500 \text{ kJ}$	<p>If the snake had 350 kJ available, and that was 10% of what was available to the mouse, then the mouse would have had 3500 kJ available to it.</p>

Quick check 3.7

- 1 Explain what a food web is.
- 2 Recall what organisms need energy for.
- 3 Describe how energy is lost from an organism or a food chain.
- 4 Summarise what you notice about the amount of energy (kJ) that is passed on from the producers to the primary consumers and from the primary consumers to the secondary consumers.
- 5 *Challenge question:* Using Figure 3.30, calculate how much energy is passed on as a percentage of the original amount of kJ.

Try this 3.8

Food web model

Model the flow of energy in food webs from producer to consumers using the following materials:

- photos of producers, primary consumers, secondary consumers, tertiary consumers and apex predators, in the normal ratio of these types of organisms in the wild
- different coloured balls of wool
- scissors

Instructions

- 1 Each student will be allocated a photo.
- 2 Stand in a circle as a class. A student with a photo of a producer will take the end of the piece of wool. The piece of wool will represent the flow of energy along the food chain.
- 3 The producer should choose what primary consumer it wishes to be eaten by, and pass that person the ball of wool. (The producer should keep hold of the end of the wool.)
- 4 The primary consumer will then choose the secondary consumer they wish to be eaten by, and pass them the ball of wool.
- 5 Repeat this process with the secondary consumer.
- 6 When the wool reaches the apex predator, cut it, but each person in the chain should keep hold of it.

continued...

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- 7 Take a photo each time a food chain is made, so that the development of the web can be seen.
- 8 Start a new chain, by starting a new piece of wool in a different colour. Try to pick different organisms at first, but you can also re-use organisms. Repeat this process many times, starting with different producers.
- 9 A complex web will form between you and your classmates.
- 10 Discuss the complex nature of the food web you have produced as a class.
- 11 Ask one organism in the food web to 'die' by dropping the string. Discuss as a class the effect that the loss of that organism from the ecosystem would have on the remaining organisms.

Discussion

- 1 Follow one of the threads of wool and write down a food chain.
- 2 Describe the effect that removing a producer from this food web would have.
- 3 Explain why an ecosystem with many types of organisms would be able to cope with the loss of one species.
- 4 Critique whether your model of a food web accurately depicts a real ecosystem.
- 5 Propose one way in which this model could be improved.

Explore! 3.3

How wolves changed the course of a river

Yellowstone National Park is in the USA. Wolves were once one of the apex predators found in the park, but the population was wiped out by the government in the 1920s.

Although other predators such as grizzly bears and cougars remained, the park was left without wolves for 70 years. They were reintroduced into the area in 1995 to help control a growing elk population.

This reintroduction gave biologists a unique opportunity to study how the return of an apex predator affects an ecosystem. The results showed a bigger change than the scientists ever thought possible.

Without wolves, the elk population in Yellowstone grew unchecked. This meant that they consumed too much food such as willow trees that were needed by other species. This included beavers, whose numbers then started to drop.



Figure 3.31 Grey wolf in Yellowstone National Park



Figure 3.32 Elk crossing a river

continued...

...continued

To help restore the population of beavers, 129 beavers were released into drainages. When park-wide aerial surveys began in 1996, there were 49 beaver colonies. When the wolves began reducing the elk population, the number of beaver colonies had risen to around 100 in 2015.

Beavers are famous for building dams and that is exactly what they have done. There are now many more dams found in Yellowstone, which can help control water flow when storms hit and provide cold, shaded water for fish. As there are more willows, there are more trees to provide habitats for birds.



Figure 3.33 Loss of habitat for beavers

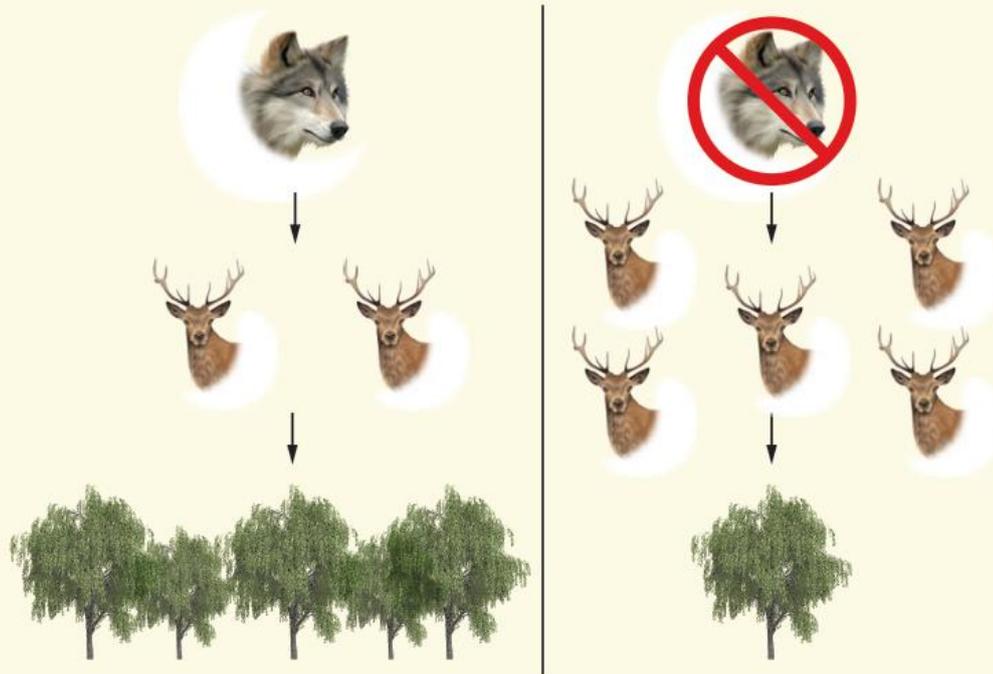


Figure 3.34 A pictorial representation of how the wolves have brought balance back to Yellowstone National Park

Research this amazing change brought about by the reintroduction of wolves.

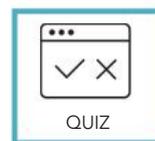
- 1 Name four organisms that were affected by the presence of wolves.
- 2 Draw as many food chains as you know to exist in Yellowstone Park.
- 3 Explain how the reintroduction of wolves saved the Yellowstone Park ecosystem.
- 4 'The impact of producers on an ecosystem is greater than that of apex predators.' Evaluate this statement and give your opinion.



Section 3.2 questions

Remembering

- 1 **State** how the flow of energy is represented in a food chain.
- 2 **State** the process by which plants produce their own food.
- 3 **Name** the components plants need to make food.



Understanding

- 4 **Define** the following terms:
 - a carnivore
 - b herbivore
 - c omnivore.
- 5 **Explain** why all food chains must contain a producer.

Applying

- 6 Look at the food web in Figure 3.35.
 - a **Identify** three food chains in the food web.
 - b **List** the producers and apex predators based on the diagram.
 - c **State** the organisms that dingoes eat.
 - d **Identify** any organisms that are secondary and tertiary consumers.
 - e **Describe** the impact on this ecosystem if a fungus killed all the grasses.

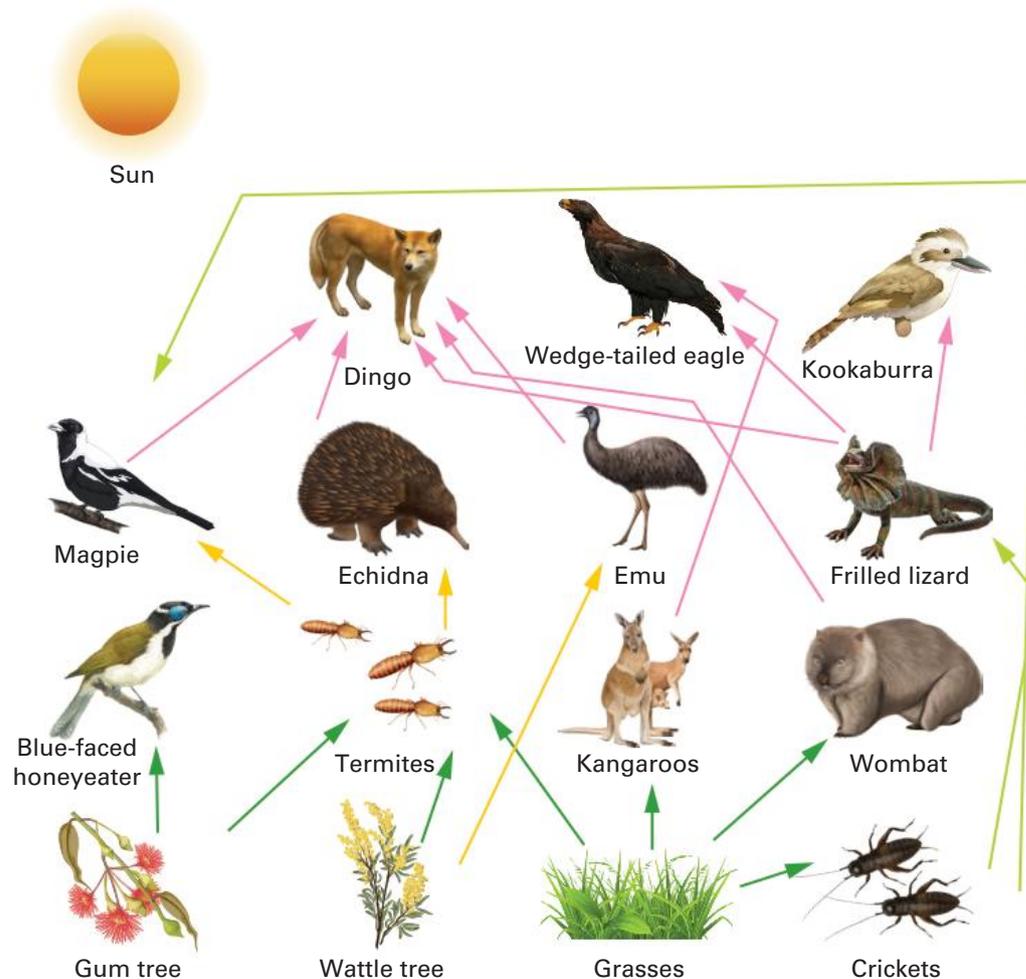


Figure 3.35 A food web

Analysing

- 7 **Compare** a herbivore and an omnivore.
- 8 **Distinguish** between food chains and food webs and then determine why food webs are more useful to scientists.
- 9 Look at the ecosystems in Figure 3.36 and **decide** which one is more likely to survive an environmental disaster. Explain your choice.

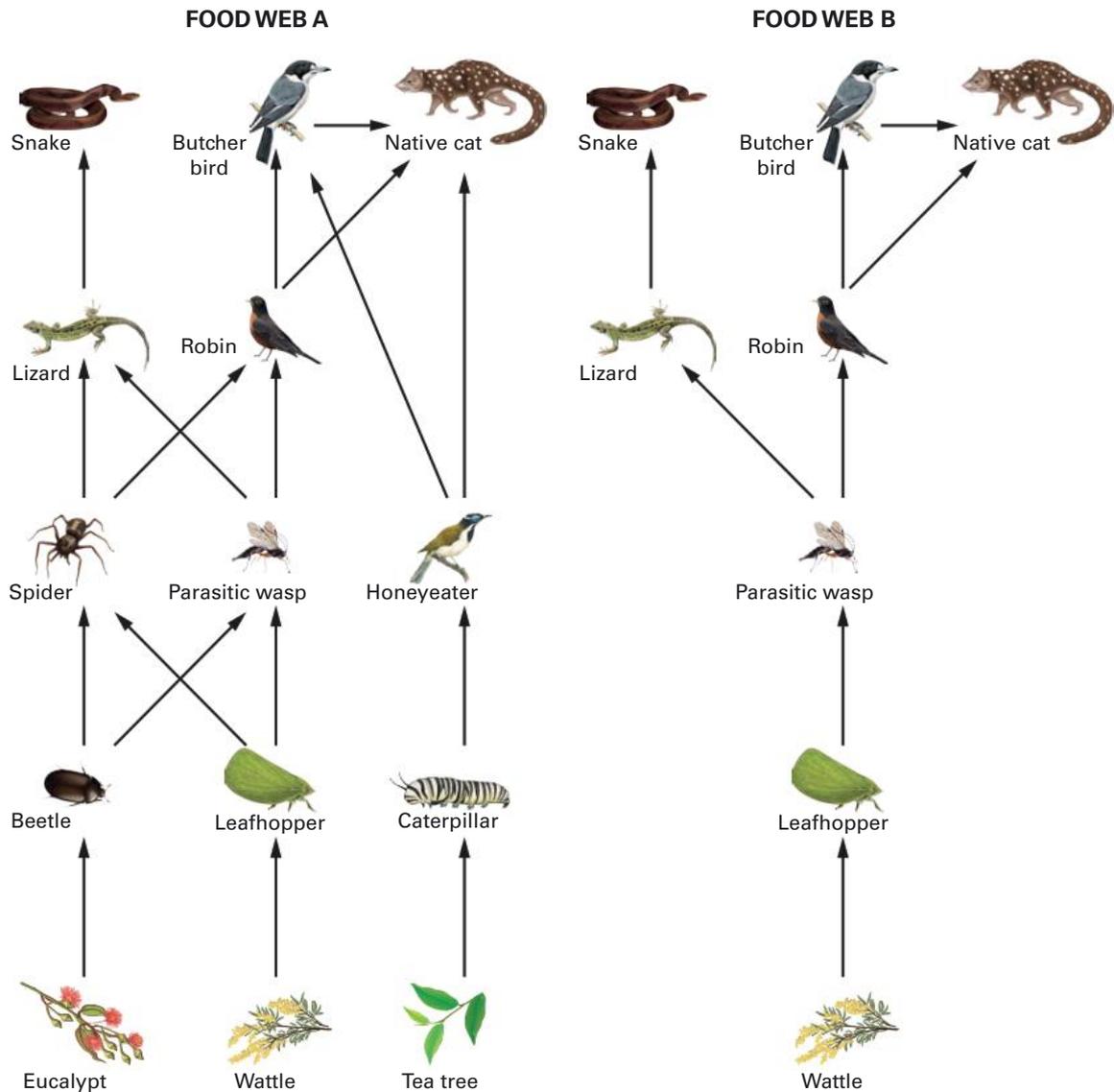


Figure 3.36 Two different ecosystems support these two food webs.

Evaluating

- 10 **Propose** a reason that a herbivore would not be able to eat meat easily.
- 11 **Predict** two effects of removing a predator from a food web.

3.3 Recycling in ecosystems

Learning goal

- 1 To be able to explain the importance of microorganisms in food chains and food webs.

All living things within an ecosystem fall into one of three categories:

- organisms that make their own food (producers)
- organisms that eat other living organisms (consumers)
- organisms that contribute to recycling dead organisms (**scavengers**, **decomposers** and **detritivores**).

Scavengers

Scavengers start the recycling process of dead and decaying animals. They can be found anywhere in the world – on land and in marine environments. In Australia, they include monitors (carnivorous lizards), spotted-tail quoll, dingoes and crows. The role of scavengers is vital for any ecosystem as they contribute to the decomposition process. Decomposers and detritivores, which you will learn about shortly, are responsible for completing the process of breakdown and returning the nutrients to the ecosystem. Scavengers do not use energy to kill their prey, but they use their sense of smell to find their food.

Figure 3.37 Scavengers: Torresian crows (*Corvus orru*) and dingoes (*Canis lupus dingo*) in Australia



Decomposers

Decomposers gain their energy by breaking down already dead organisms. Bacteria and fungi are examples of decomposers. They secrete chemicals called enzymes that break down the dead organisms. They then absorb the broken down substances.

When decomposers break down dead organisms, the decay returns much needed nutrients back into the soil, which plants then use to grow. This makes them a vital part of the circle of life.



Figure 3.38 Decomposers and detritivores hard at work



scavenger

an organism that feeds on dead animals that it has not killed itself

decomposer

an organism such as a bacterium or fungus that makes dead plant and animal material decay

detritivore

an organism that feeds on dead or decaying organic matter

microorganism

a living thing that on its own is too small to be seen with the naked eye

Most decomposers on Earth are **microorganisms** – organisms so small that they can only be seen with a microscope. Microorganisms are around us all the time, floating through the air or lying on a surface. Most of these microorganisms are harmless and only begin to grow and spread when an organism dies.



Figure 3.39 Bacteria are an example of a microorganism, in this case, growing on agar in a Petri dish.

Detritivores

Detritivores are also involved in recycling nutrients. They have mouthpieces which help speed up decay by ingesting and digesting **detritus** (dead and decaying material). The detritus is excreted as smaller sized pieces which

detritus

waste or debris

Did you know? 3.2

Echinoderms like sea urchins, sea stars and sea cucumbers hunt for their own food, but they are also detritivores. They can move around and consume decaying organic matter.

Some sea worms such as the Christmas tree worm, *Spirobranchus giganteus*, even have feathery appendages that can spread out in the water to collect this matter.



Figure 3.40 Christmas tree worm (*Spirobranchus giganteus*)

increases the surface area available for decomposers like bacteria and fungi to feed off. Detritivores include beetles, flies, slugs, snails and earthworms. Marine detritivores include crabs, lobsters, sea stars and sea cucumbers.

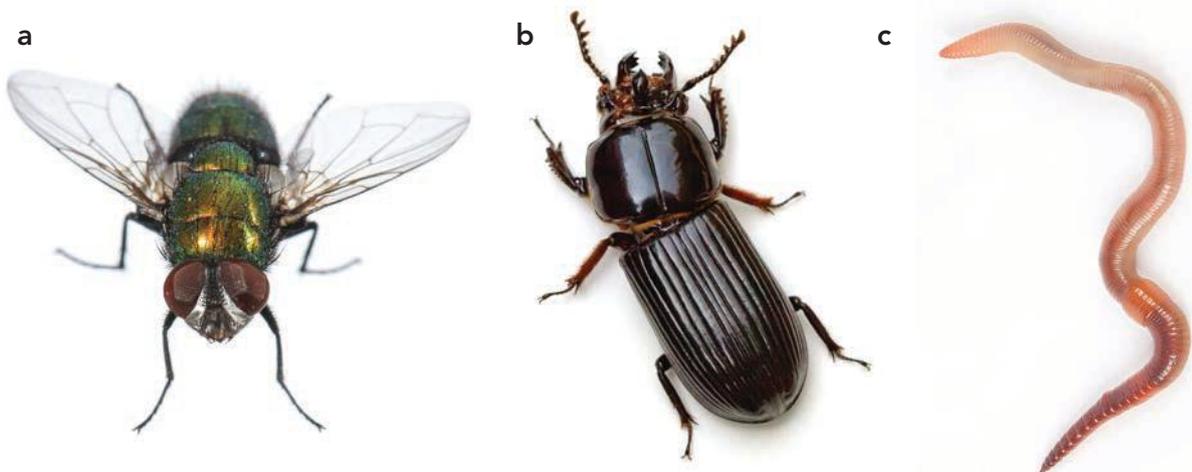


Figure 3.41 Examples of detritivores: (a) flies, (b) beetles and (c) earthworms

Quick check 3.8

- 1 Define the terms 'scavenger' and 'decomposer' in your own words.
- 2 Define the term 'detritivore'.
- 3 Explain why plants rely on decomposers.
- 4 Distinguish between detritivores and decomposers.

Practical 3.2: Investigation**Friendly bacteria****Aim**

To design a method to investigate how different types of yoghurt affect the growth of harmful bacteria.

Time period

Approximately 1.5 weeks

Prior understanding

Pathogenic bacteria are in the air and on all surfaces around us. Raw food, such as fruits bought at the grocery store, can be contaminated by pathogenic bacteria due to handling. These **pathogens** do not usually cause a problem: when the fruit is consumed, the bacteria are destroyed either by the acidic environment of the stomach or by the good bacteria that live in each person's intestine. However, some bacteria evade these immune defenses and cause food poisoning.

pathogen
an organism that can cause illness

It is recommended that fruits be washed well before consuming to avoid food poisoning. However, this is not easily done with soft fruits such as strawberries. Another option has been presented and requires investigation. Could covering fruit with yoghurt (which contains cultures of good bacteria) be used to disinfect soft fruit before consumption?

Materials

- different types of cultured yoghurt (3 is recommended)
- 1 strawberry or another type of soft fruit
- 4 sealable food containers
- 1 small paint brush

Be careful

Do not open the experimental container once the experiment begins. Do not consume any food products in the lab. Ensure all materials are disposed of in the appropriate manner.

Planning

- 1 Develop a research question for this investigation.
- 2 Identify the dependent variable and state how it will be measured.
- 3 Identify the independent variable and describe the different groups that will be set up for the experiment.
- 4 Develop a hypothesis by predicting how a change to the independent variable will affect the dependent variable.
- 5 Identify the controlled variables and describe how these will be managed to prevent any controlled variables from affecting the measurements.

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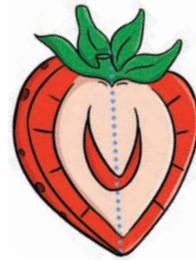
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Method

- 1 Label each container with the following information:

Group number:
Type of yoghurt:
Date:
Student/s name:

- 2 Cut each strawberry into four pieces vertically as shown.
- 3 Leave one piece of strawberry untouched to use as a control (comparison) and paint each of the three remaining pieces with a different type of yoghurt.
- 4 Place each piece of strawberry in a separate container labelled with the yoghurt type.
- 5 Seal the container by placing the lid on tightly.
- 6 Monitor the experiment for 9 days, recording observations and taking photographs of each container, every 3 days.
- 7 If any part of the set-up is changed, note the reason for this.



Results

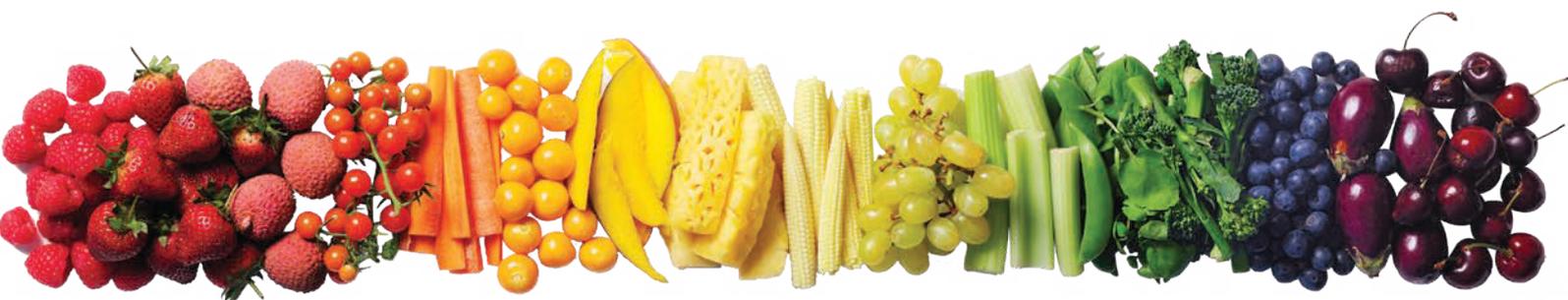
- 1 Collect each container but DO NOT OPEN for safety reasons.
- 2 Measure the amount of bacterial growth (in terms of area) for each group and record the results. Your teacher may direct you to create a table and graph on a spreadsheet or on paper.
- 3 Calculate the mean measurement for each *independent variable* group.
- 4 Calculate the range for each *independent variable* group on the table.
- 5 Graph the mean of each group's data.

Discussion

- 1 Describe any trends, patterns or relationships in your results.
- 2 Describe how much variation was observed between the measurements within each group.
- 3 Discuss whether the controlled variables were managed properly to ensure they did not change and affect the measurements.
- 4 Describe changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

Discuss which yoghurt (if any) could best be used to disinfect soft fruit instead of washing it. Justify your answer by discussing your experimental results.



Brown food chain

Consumers get their energy from producers or other consumers, and producers get their energy from the Sun. You also know that producers use this light energy along with carbon dioxide and water, to form glucose through the process of photosynthesis. Green

plants form the base of the green food chain, but not all parts of a plant may be available to eat. For example, the woody parts or some roots may be inaccessible. So what happens to all the energy stored in this plant material that does not get eaten? It becomes detritus (waste or debris) and forms the base of the brown food chain.

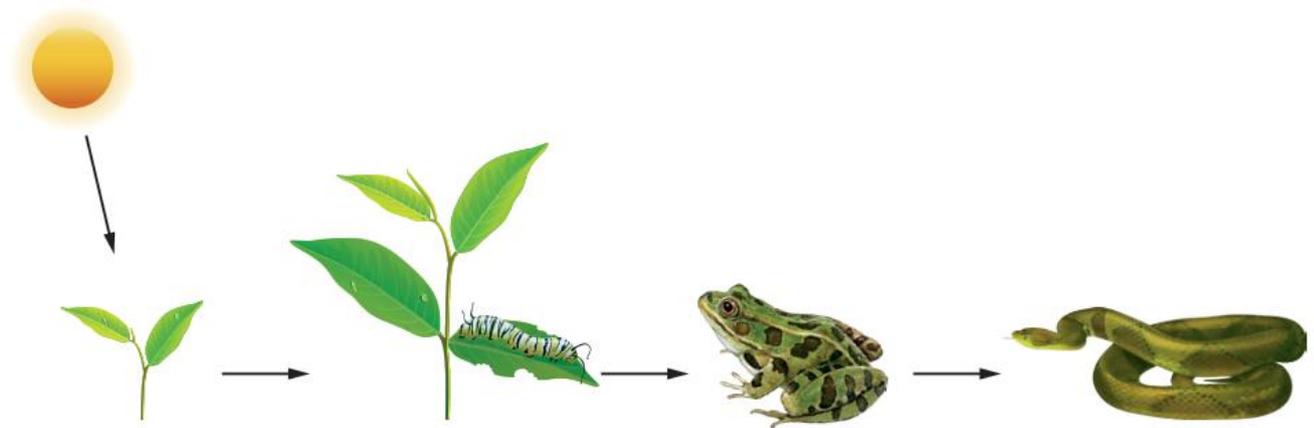


Figure 3.42 Green food chain

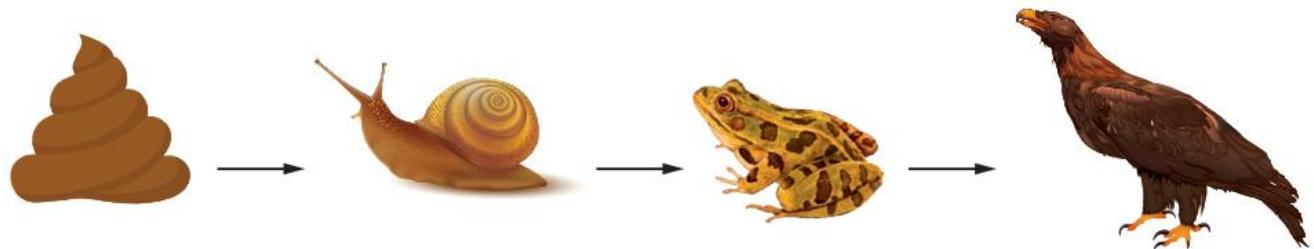


Figure 3.43 Brown food chain

All other dead organisms add to this brown food chain, as well as all the waste they excrete throughout their lives. As humans, eating waste can make us very sick. However, many organisms on Earth get at least some of their energy directly from detritus. Species within the Lagomorpha family such as rabbits and hares produce a hard and a soft type of faeces. These animals will reingest their soft faeces to extract more nutrients.

The brown food chain is directly linked to the green food webs found in every ecosystem. When detritus is included in a food web diagram, it shows the complex and important interaction that decomposers have in an ecosystem.



Figure 3.44 Pikas (*Ochotona daurica*, shown here), rabbits and hares are part of the Lagomorpha order. They can produce a different kind of faecal matter called 'caecal matter' that is soft, full of nutrients and can be eaten again.

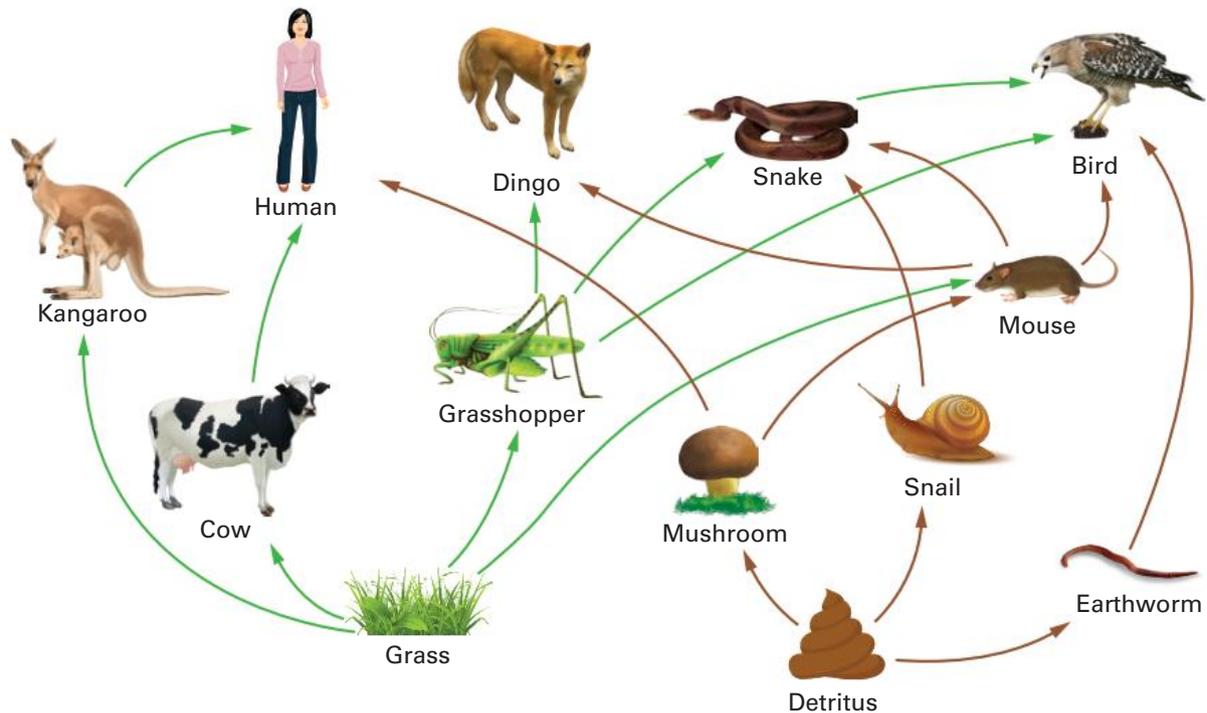


Figure 3.45 Combined green and brown food webs

Section 3.3 questions



Remembering

- 1 **State** the name of a detritivore in the brown food chain.
- 2 **List** three examples of decomposers.

Understanding

- 3 **Describe** why decomposers are an important part of an ecosystem.
- 4 **Describe** what could happen to the world if scavengers and decomposers did not exist.

Applying

- 5 **Construct** a brown food chain that could be found on a coral reef.
- 6 **Classify** each of the organisms in the food chain you have created as decomposer, first order consumer or second order consumer.
- 7 **Explain** the role that scavengers can play in an ecosystem.
- 8 Look at Figure 3.46 and, using your knowledge of decomposers, **describe** what is happening.



Figure 3.46 A decomposer in action

Analysing

- 9 **Compare** the role of a producer with the role of detritus.
- 10 **Distinguish** between a decomposer and a detritivore.

Evaluating

- 11 **Propose** a reason why decomposers can be found wherever there is life.
- 12 **Predict** how a food web would change if all the decomposers in an ecosystem died. Give reasons for your decisions.

3.4 Human impact on ecosystems

Learning goals

- 1 To be able to describe the different types of biodiversity.
- 2 To be able to describe the human impact on ecosystems.



Biodiversity

When scientists look at all the different types of animals found in an area, they start to talk about **biodiversity**. Biodiversity refers to the variety of all living things found in a specific area. There are three different types of biodiversity:

- **Genetic diversity.** This is the number of differences within one species. Humans are very genetically diverse, as people have many shapes, sizes and abilities. If a

species is very genetically diverse, it is thought to be healthy.

- **Species diversity.** This is the variety and abundance (total number) of different species found in an area. Places like coral reefs and rainforests are said to be extremely biodiverse because many different species live in a small area.
- **Ecosystem diversity.** This is the variety of ecosystem types found in an area.

biodiversity

the number and types of plants and animals that exist in an area



Did you know? 3.3

Ninety per cent of the bananas that you buy from the supermarket are identical! Even though there are around 1000 species of banana in the wild, the one that may be squished at the bottom of your school bag is probably a clone of the Cavendish variety. Cavendish accounts for 47% of the bananas grown worldwide and 99% of all bananas sold commercially for export to developed countries. This variety grows fast, stays fresh for weeks and has no seeds, which makes it great for eating. However, as they are all clones, if the plant were attacked by a disease, a large supply of bananas could be wiped out very quickly.

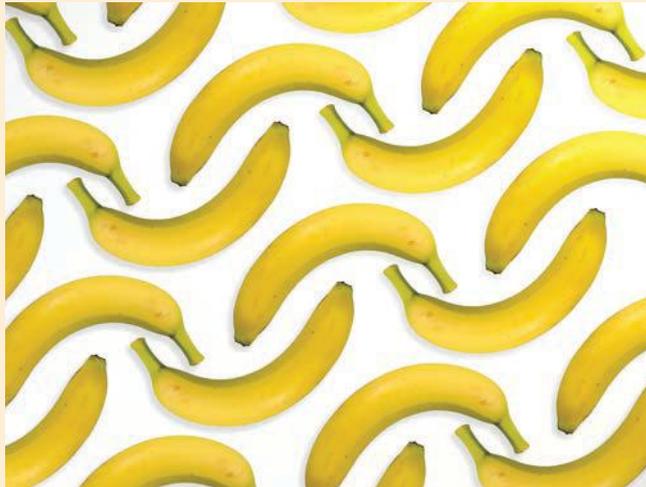


Figure 3.47 Many bananas are clones.

As we discovered in the classification chapter, all life on Earth is categorised into six kingdoms. These kingdoms indicate the species biodiversity on our planet. It is estimated that there are more than 8 million species on Earth, and that number is growing as new species are discovered. About

76% of all species have been classified into the animal kingdom. This means that the animal kingdom is the most diverse of all the kingdoms. Within the animal kingdom, the phylum Arthropoda is by far the most diverse and within this phylum, the class Insecta makes up about 73% of all animal species.

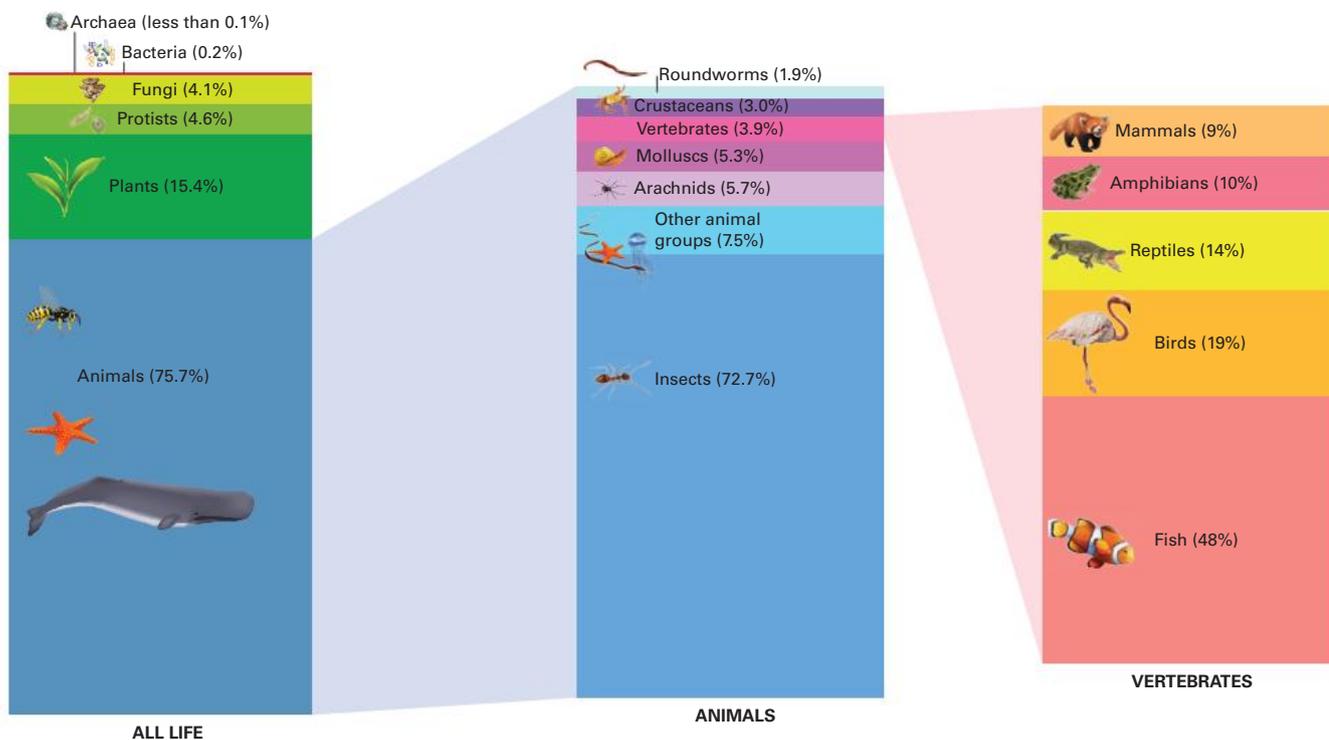


Figure 3.48 Species biodiversity on our planet (approximate percentages shown)

Threats to biodiversity

It is important to be able to measure the biodiversity of ecosystems and habitats in order to monitor the number of species and individuals found there. The more biodiverse

an area is, the more likely it will be able to recover from natural or human-caused threats such as disease, fire, habitat loss or introduced species. Therefore, when an area is extremely biodiverse, it is healthy.

Practical 3.3: Investigation

Assessing biodiversity at your school

Aim

To compare the biodiversity of two different areas in the school grounds.

Prior understanding

Biodiversity is a measure of how many *different* species live in an area *and* whether these species are equally abundant in numbers, or does one species dominate the others with a comparatively larger number of individuals. Healthy habitats have a higher biodiversity index.

One biodiversity index that can be used is called the Menhinick index. It can be calculated using the following equation. Higher numbers indicate higher levels of biodiversity.

$$\text{biodiversity index} = \frac{\text{number of species in survey area}}{\sqrt{\text{total number of individuals}}}$$

For example, in a survey recording 26 individual invertebrates belonging to five different species, the biodiversity would be

$$\text{biodiversity index} = \frac{5}{\sqrt{26}} = 0.98$$

Be careful

Try to avoid insects that might bite or sting.

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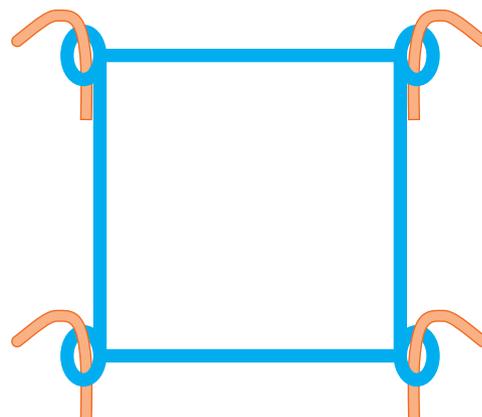
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Materials

- Invertebrate Identification Key
- magnifying glass
- quadrats, if available, or if they are unavailable: four tent pegs and 4.5 m of fine string-line with loops tied every metre (the tent pegs must be able to fit through the loops). A one metre quadrat can be created by pegging out the string-line into the shape of a square. Push the tent pegs through each loop to pin the corners to the ground.

Method

- 1 Choose two different survey areas to assess within the school grounds, such as a grassy area and a garden.
- 2 Take all equipment to the first survey area.
- 3 Randomly choose a spot to place your quadrat.
- 4 Take photos of any invertebrates you record. This will help you to later identify any species you cannot name.
- 5 Repeat steps 3 and 4 in another four random spots.
- 6 Move to the second survey area and repeat steps 3–5.



Results

- 1 Develop a table to record the data from each survey area. Include a place to record survey area, type of invertebrate and number of individuals.
- 2 Identify any unknown invertebrates using an Invertebrate Identification Key. Record this data in the table.
- 3 Count the number of each invertebrate. Record this data in the table.
- 4 Calculate the total number of individual invertebrates found in each survey area.
- 5 Calculate the Menhinick biodiversity index (how biodiverse an area is) for each survey area by using the equation on the previous page. Show your working for each area.
- 6 Record the level of biodiversity for each survey area in the table.

Discussion

- 1 Contrast the Menhinick biodiversity index results for the two areas.
- 2 Identify the survey area that would be considered more biodiverse.
- 3 Discuss the reasons for any differences found when comparing the two survey areas.
- 4 Swap your data with another group to give each other feedback on how easily the table can be used to compare the two survey areas. Your feedback should discuss the following:
 - how well the table is organised to compare the two survey areas
 - how clearly the biodiversity calculations have been written
 - any other suggestions to improve the quality of the data presented in the table.
- 5 After receiving feedback, make alterations to the table to address the identified issues and write up a final copy to present to the class.
- 6 Compare the level of biodiversity calculated by each of the other groups. Determine how much variation was found between different group results.
- 7 Compare the different types of species found in each survey area with other groups. Identify species that were not found consistently in each survey area.
- 8 Discuss if the biodiversity of the two survey areas can be reliably compared, based on your response to the previous question.

continued...

...continued

- 9 Decide upon some changes that could be made to the method to improve the quality of the data in future experiments.
- 10 The equation only takes into account the number of different species, instead of the number of different species and their abundance. Complete some research to find a better equation that can be used to determine the level of biodiversity.

Aboriginal land management

Bushfires are common in Australia. In our dry climate, they are one of the most dangerous and threatening events that can happen to an ecosystem. However, many Australian ecosystems rely on occasional bushfires to encourage biodiversity.

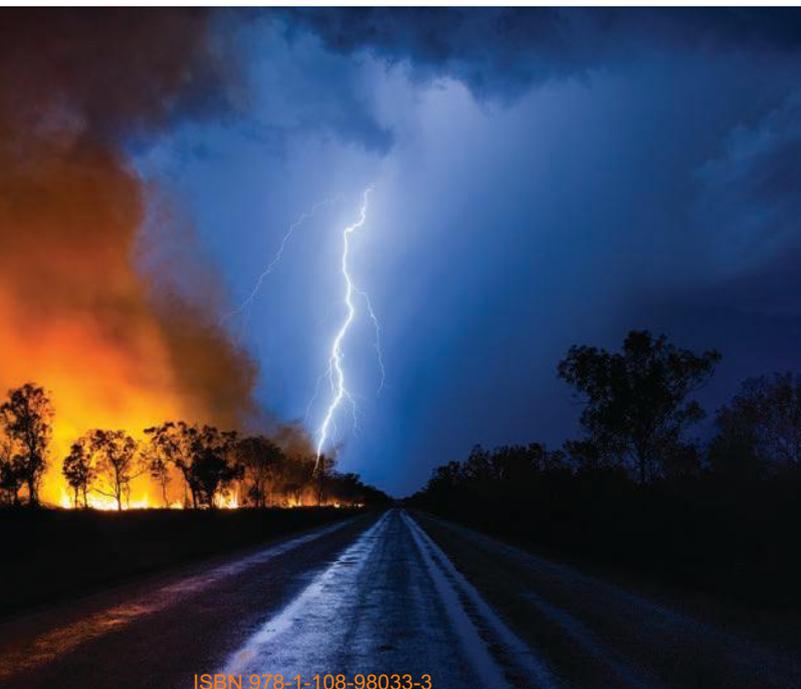
firestick farming

the burning of areas of bush in stages, by the application of firesticks, to encourage new growth

Bushfires can occur naturally or can be human induced. Some of the natural causes of bushfires are dry conditions, high temperatures, low humidity, strong winds and lightning. Spontaneous combustion due to extremely hot temperatures can also start bushfires, but this is less common than lightning. Humans can light fires either deliberately or accidentally.

Aboriginal and Torres Strait Islander peoples have a deep understanding and connection to the land. They have thrived in a particularly

Figure 3.49 Lightning naturally starting a bushfire



harsh environment using techniques passed down from Elders to young over many generations. The use of fire is one of the most important techniques that they have used to gather food, shape the landscape and regenerate ecosystems.

Firestick farming

Firestick farming involves the controlled burning of vegetation. Aboriginal and Torres Strait Islander peoples have known for thousands of years that this will promote plant growth, attract new animals to an area and cause any animals hiding in burrows to come out into the open. With animals no longer in their burrows and less vegetation for them to hide behind, people were able to hunt easily. By burning areas of bush, they made room for new plants and activated seeds stored in the ground, which provided new sources of food for animals in the area.

Figure 3.50 Regrowth of plants after a bushfire. The plant shown is an Australian grass tree (*Xanthorrhoea australis*).



Two types of fires are used for firestick farming:

- **Cool fires.** These are low intensity fires that are carried out regularly to clear the undergrowth. They do not damage the larger plants and are used to clear paths and promote the growth of native plants for both humans and grazing herbivores. This is important because Aboriginal and Torres Strait Islander peoples use many **endemic plants** for both culinary and medicinal purposes.
- **Hot fires.** These are used more sparingly as they burn areas of thick vegetation including trees and shrubs, which are important habitats for animals. These fires are very



Figure 3.51 A devastating hot fire

dangerous and destructive, killing everything in their path. Because of this, they are only used in overgrown areas where vegetation is struggling to thrive so as to revitalise the area.

endemic plants
plants found widely
throughout specific regions

Quick check 3.9

- 1 Propose some causes of fire in Australia before Aboriginal and Torres Strait Islander peoples arrived.
- 2 Recall three main uses of firestick farming.
- 3 Describe how firestick farming helped to promote new plant growth.
- 4 Contrast the two types of fire used in firestick farming.
- 5 Currently, we use controlled burns in winter to reduce natural bushfires in summer. Predict a problem with disrupting this natural event.

Science as a human endeavour 3.2

Firefighting in virtual reality

Researchers at Deakin University in Australia have created a virtual reality training simulator for firefighters. It is called FLAIM Trainer. The simulator creates a training scenario that uses a touch technology feedback system. The trainee is required to wear a heavy uniform, breathing apparatus and protective clothing that heats up to make the experience extremely realistic.

Thanks to this technology, firefighters will now be able to practise key skills and knowledge in a safe and more cost-effective environment. This makes it safer for a firefighter to do their job and more likely that they can save lives and the environment.



Figure 3.52 A helicopter used for fighting fires in Western Australia

Land clearing for palm oil

Rainforests are one of the most important ecosystems. Up until very recently, they stretched like a band around the equator of Earth where climate conditions are perfect for their growth. Rainforests are often referred to as the lungs of Earth, as the high volume of plants photosynthesise and produce huge amounts of oxygen. They are also like air filters because they take in carbon dioxide during photosynthesis and store it internally. This is especially important, considering the large amount of carbon dioxide humans are producing and the warming effect it has on our planet. Rainforests are also biodiversity 'hotspots' with more than 50% of the world's species living there.

What are we doing?

Unfortunately, humans are cutting down vast areas of rainforest every day. In fact, each year an area bigger than the whole state of Victoria is destroyed. Some of the biggest rainforests closest to Australia can be found on the island of Sumatra in Indonesia and the island of Borneo. These rainforests contain some of the world's last remaining Borneo pygmy elephants (*Elephas maximus borneensis*), Sumatran tigers (*Panthera tigris sumatrae*), Sumatran rhinoceroses (*Dicerorhinus sumatrensis*) and Bornean and Sumatran orangutans. The main threat to these species and the rainforests is palm oil farming.



Figure 3.53 Orangutans are treated as pests by farmers in Borneo and Sumatra.



Figure 3.54 Areas of land like this are often cleared for palm oil farming.

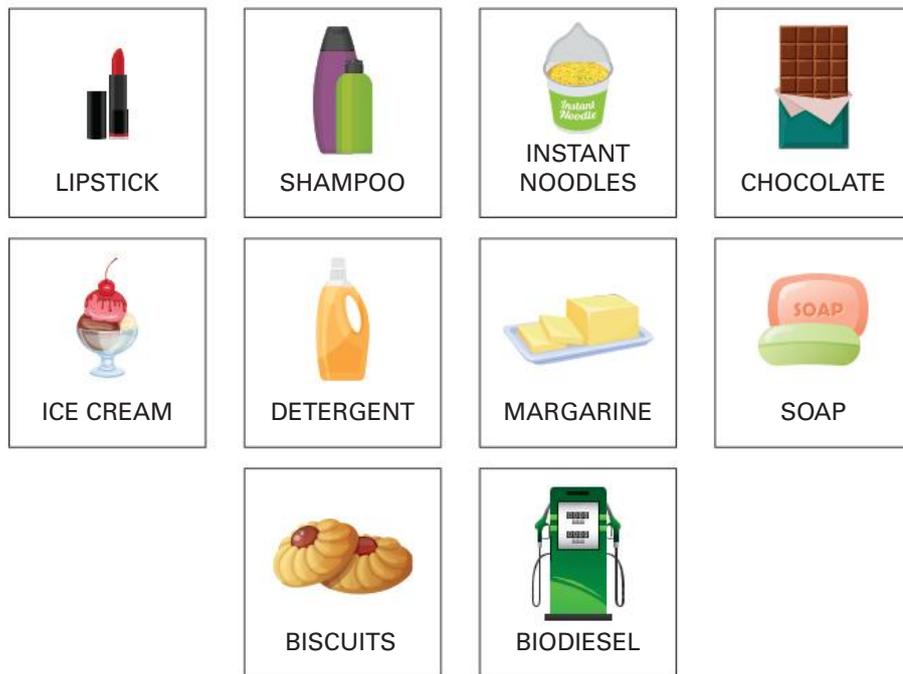


Figure 3.55 These everyday products are likely to contain palm oil.

You may not know it, but you probably eat or use palm oil daily. That is because it is found in many of the products you buy at the supermarket, from shampoo to pizza dough. Palm oil is used by many companies because it is cheap and so the global need for palm oil is growing rapidly. The Borneo and Sumatran rainforests are perfect environments for palm oil trees to grow fast, even though they are originally from West Africa. Many of the citizens in these countries are very poor, so palm oil farming is crucial for jobs and the economy of these countries.

Why is it a problem?

As the demand for palm oil increases, more and more areas of rainforest are being cut down to make way for palm oil farms. This means less and less room for already endangered species such as the orangutans, elephants and tigers. Not only are these animals forced out of their homes, but if they wander onto the farms they are treated like pest species and killed.

In an attempt to protect the small numbers of Sumatran tigers left, the government of Indonesia opened the Gunung Leuser National Park wildlife reserve in 1934. It was established as a national park in 1980. The Gunung Leuser National Park itself was put on UNESCO's danger list in 2011 due to the 'threats posed by poaching, illegal logging, agricultural encroachment, and plans to build roads through the site'.

Many people blame the palm oil sector as a main offender in the degradation of the protected areas.

Figure 3.56 Sumatran tiger (*Panthera tigris sumatrae*)





Figure 3.57 Dangerous clearing fires

Deforestation is also a threat to the environment of these areas. By removing plants and their roots, the thin layer of soil found in rainforests is easily washed away, meaning that nothing will grow in that area again. The pesticides and herbicides used to promote palm oil growth can pollute local waterways.

deforestation
clearing a wide area of trees or natural land

Much of the clearing that is occurring in the rainforests to produce palm oil tree farms is done using fire. This kills the local wild life, including many animals. It also releases massive amounts of stored carbon into the air, which contributes to global warming.

What can we do?

All this information can be upsetting and it might feel like the problem is too big for you to do anything about, especially as you are still in school. Here are a few things that you can start to do that will help the situation:

- Be aware if your product contains palm oil. Palm oil can be called many things on an ingredient list including the items seen in Figure 3.58.
- Encourage friends and family to buy products with sustainable palm oil. This is palm oil that has been grown by companies that promise to protect the environment. Look for products with the logo in Figure 3.59.



Figure 3.58 Can you spot the various things palm oil may be labelled under?

All of them can be manufactured using palm oil.



Figure 3.59 The Roundtable on Sustainable Palm Oil logo

Quick check 3.10

- 1 Explain why rainforests are referred to as 'Earth's lungs'.
- 2 Name five products that contain palm oil.
- 3 Identify why palm oil is widely used in many products.
- 4 Explain why using palm oil is a problem.
- 5 Be aware of how palm oil is labelled in ingredient lists. Encourage friends and family to buy products that use sustainable palm oil. Download the POI palm oil barcode scanner and do a home audit. Identify products you use that contain palm oil.

Science as a human endeavour 3.3**Palm oil farming**

Scientists are currently studying different practices to make palm oil farming more environmentally friendly and sustainable. By collecting data from plantations, they can study the effects of cropping practices, such as fertiliser application and sowing of legume cover crops. This information will help growers make decisions that improve yield and productivity, meaning that forests do not need to be cleared to create land for farms.



Figure 3.60 Palm oil seeds



Explore! 3.4

Deforestation in Australia

Queensland's Brigalow Belt is one of Australia's most significant biodiversity hotspots. Named after the brigalow tree (*Acacia harpophylla*) that was once commonly found in this region, the belt extends for over 36.4 million hectares. Since the 1850s, 90% of Brigalow Forest has been cleared, leading to a massive loss of habitat for a number of species. Some ecologists say that there should be a new national park in this region. This would mean a loss of jobs from local logging and agricultural industries, but it might mean a boost in tourism.



Figure 3.61 (a) Pristine brigalow trees and (b) deforestation of native vegetation by land clearing in the Brigalow Belt

Your task is to research the benefits and limitations of creating this new national park and present a balanced argument to the Minister for Environment.

You should include the following points:

- Explain how the national park will increase biodiversity in the area.
- Include a named animal or plant that will benefit from the national park.
- Present a map of the area.
- Explain how the national park could be both good and bad for local residents.
- Suggest solutions for any problems the national park will cause.
- Give your opinion based on your research.



Figure 3.62 The bridled nail-tail wallaby (*Onychogalea fraenata*)

invasive species

an organism that is not native to an environment and causes harm to native organisms

biological control

the practice of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

Invasive species

An **invasive species** is an organism that has been introduced to a new ecosystem by humans. This is usually done by accident but sometimes it is done on purpose. Australia has many invasive species such as foxes, rabbits,

goats, and feral cats and pigs. All these species were introduced by European colonists for hunting, farming or to make Australia feel more like Europe. Sometimes invasive species are introduced to help control the numbers of another organism. This is an example of a **biological control**.

Explore! 3.5

Rabbit-proof fences

Rabbits are considered a major pest in Australia. In fact, while it is normal to own a pet rabbit in Western Australia, it is illegal in Queensland! In 1995, the **calicivirus** was introduced as a biological control, to reduce the massive rabbit population. However, some rabbits were immune to the virus, and foxes (another pest) had now lost a food source and so were eating native wildlife instead.

calicivirus
a disease that damages a rabbit's internal organs and can cause bleeding

Go online to investigate the following:

- 1 Find out about the rabbit-proof fences built in Western Australia in the 1900s, as shown in Figure 3.63. Report on how they were used to try to limit the spread of plagues of rabbits.
- 2 Find out about the myxoma virus and its release in Australia in 1950 in an attempt to control the rabbit population. Summarise your findings.



Figure 3.63 Rabbit-proof fences were built to try to limit the devastation caused by rabbits.

Disastrous control

The cane toad originally comes from Puerto Rico but was brought to Australia to try to manage beetles that were eating sugar cane crops. The cane toad had been introduced to Hawaii for the same purpose and had done a great job. However, after they were released in the sugarcane plantations of north Queensland in 1935, their population exploded, and they quickly became a huge pest. Cane toads have many ecological impacts such as competing with native species for food and space. They are also poisonous and so kill any predatory native species such as quolls, snakes and crocodiles that eat them.

Cane toad populations are growing throughout Australia and were said to have arrived at the border of Western Australia and the Northern Territory in 2009. The Government of Western Australia has implemented a long-term cane toad management plan.



Figure 3.64 A cane toad (*Rhinella marina*)

Effective control

Not all examples of biological control have gone wrong. European settlers brought a cactus known as the ‘prickly pear’ to Australia to use as a food source for a beetle. This was not just any old beetle, as it produced a red dye for the production of soldiers’ uniforms. The cactus thrived in Australia and soon covered an area larger than Victoria. The cactus moth (*Cactoblastis cactorum*), which eats only the prickly pear was then introduced as a

biological control to help slow down the spread of the cactus. Another benefit of the moth is that when there is no cactus left, it dies off because the cactus is its only food source. Several years after the introduction of the moth the cactus population was under control, even though it is still around today in smaller numbers. Aboriginal and Torres Strait Islander peoples may use cool fires to control the growth of invasive species such as African lovegrass (*Eragrostis spp.*) and lantana (*Lantana camara*).



Figure 3.65 Prickly pear (genus: *Opuntia*)

Figure 3.66 Cactus moth larvae feeding on prickly pears



Try this 3.9

Find the PestSmart website online and use it to research three pest animals in Australia. Record your findings in a table like this one.

Name	Areas found	Main problems caused	Control measures

Section 3.4 questions

Remembering

- 1 **Name** the three types of biodiversity.
- 2 **List** four examples of an invasive species in Australia.

Understanding

- 3 **Define** the following terms:
 - a species diversity
 - b genetic diversity
 - c ecosystem diversity.
- 4 **Describe** the use of the 'firestick' by Aboriginal and Torres Strait Islander peoples.

Applying

- 5 **Identify** which phylum in the animal kingdom is most diverse.
- 6 **Explain** why some introduced species are classified as pests.
- 7 **Explain** why the cactus moth is referred to as an effective biological control.
- 8 **Provide** two examples of the impact that humans are having on oceanic ecosystems.

Analysing

- 9 **Compare** the use of 'hot fire' and 'cold fire' burning techniques by Aboriginal and Torres Strait Islander peoples.
- 10 Go online and research the work a group is doing to counteract the impact humans are having on biodiversity loss. Try to choose a group that you may find interesting. An example might be the Orangutan Foundation. **Report** your findings.

Evaluating

- 11 Bushfires naturally occur in Australia and many organisms have adapted to cope with this. Natural bushfires may occur around once every 5–10 years; however, many areas undergo controlled burns yearly to prevent wildfires. **Predict** how this might damage the ecosystem.
- 12 **Create** a pros and cons list on the role of invasive species.



Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked questions	Check
3.1 I can recognise the difference between abiotic and biotic factors in an ecosystem.	10	
3.1 I can describe species interactions within ecosystems.	8	
3.2 I can classify organisms according to their position in a food chain.	14	
3.2 I can construct a food chain to show feeding relationships in habitats.	2	
3.2 I can construct and interpret a food web to show relationships.	13	
3.2 I can explain the 10% rule for energy transfer in food chains.	6	
3.3 I can explain the importance of microorganisms in food chains and food webs.	15	
3.4 I can describe the concept and importance of biodiversity.	7	
3.4 I can explain the impact of human activity on local habitats.	1	
3.4 I can describe how living things can cause changes to the environment and impact other living things.	17	
3.4 I can describe the impact and management of invasive species that can affect food webs that are of importance to Aboriginal and Torres Strait Islander peoples.	9	

Review questions



Remembering

- List** two natural and two human threats to an ecosystem.
- Identify** the food chain that contains grass, a grasshopper, a snake and an eagle.
- State** what incisors are used for.
- Recall** the characteristics of all living things.

Understanding

- Define** 'community' in an ecosystem.
- Describe** how energy is lost along a food chain.
- Explain** how high biodiversity might be a sign of a healthy ecosystem.
- Summarise** the five key interactions between species in an ecosystem. For each interaction, provide an example not mentioned in the text.
- Describe** one way Aboriginal and Torres Strait Islander peoples use cool fires to maintain endemic plant resources.

Applying

- Provide** an example of an organism that affects the abiotic features of an environment.
- Consider** a reason why palm oil farmers treat local wildlife as pests.

- 12 A producer is always part of a food chain. **Explain** how a producer fits into the brown food chain.
- 13 Using the pictures of organisms in Figure 3.67, **create** a food web.

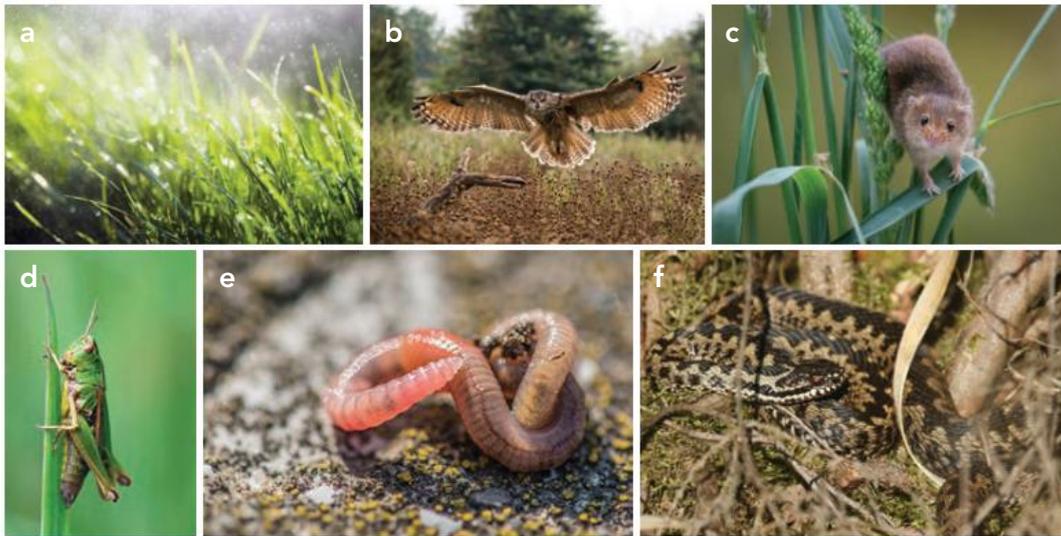


Figure 3.67 Organisms in an ecosystem

Analysing

- 14 Copy Figure 3.68 into your notebook.
- a Use arrows to **illustrate** the interactions between each organism.



Figure 3.68 Various organisms

- b **Classify** each organism as producer, consumer and decomposer. Each organism may have more than one label.
- c **Categorise** (if any) the herbivores, carnivores, omnivores or detritivores.
- 15 **Contrast** the roles of decomposers and consumers.

Evaluating

- 16 A grassland ecosystem changes dramatically throughout the year. **Propose** several abiotic and biotic changes that may occur in a grassland ecosystem during summer and winter.
- 17 Look at the food web in Figure 3.69. **Predict** what would happen if the mouse was removed from the food web.

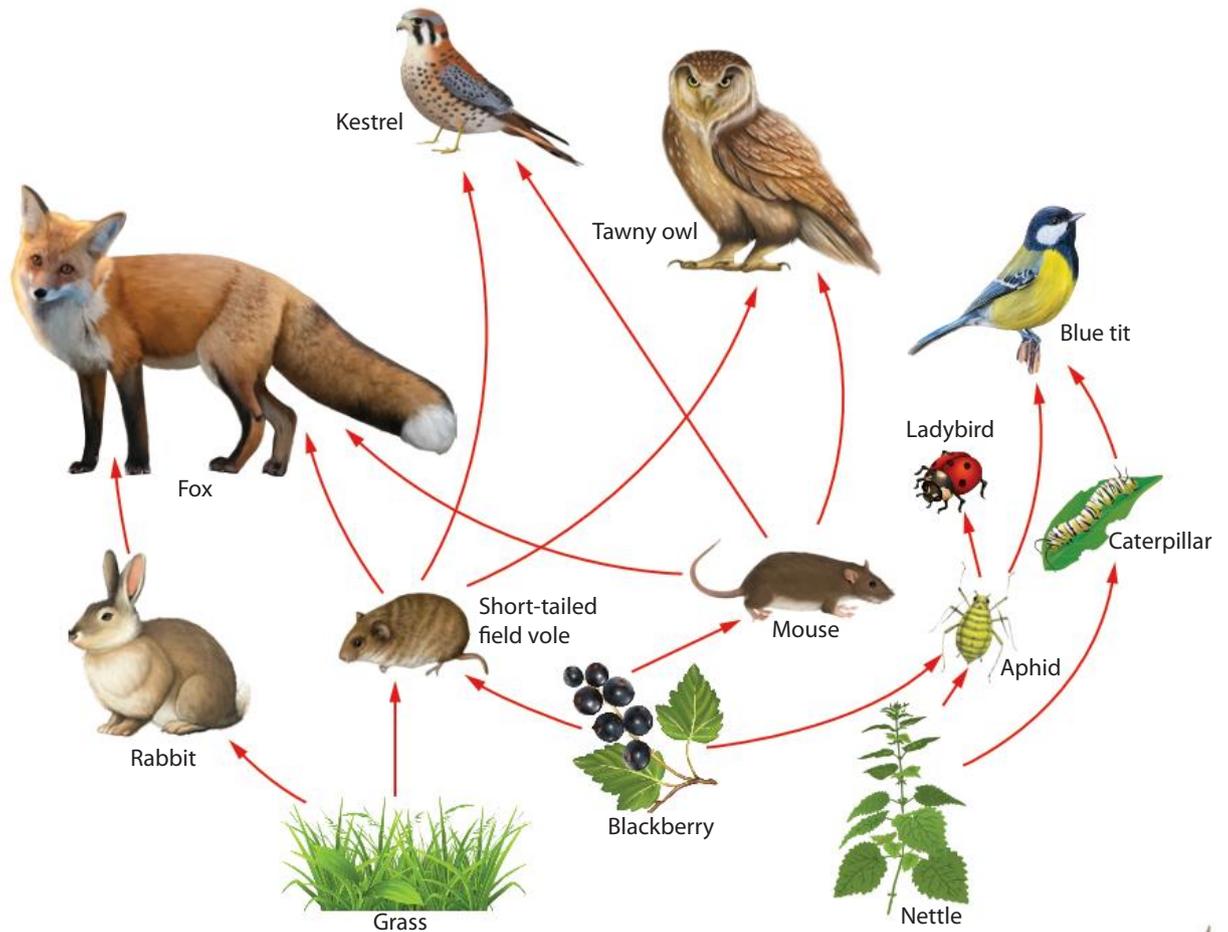


Figure 3.69 A food web

Data questions

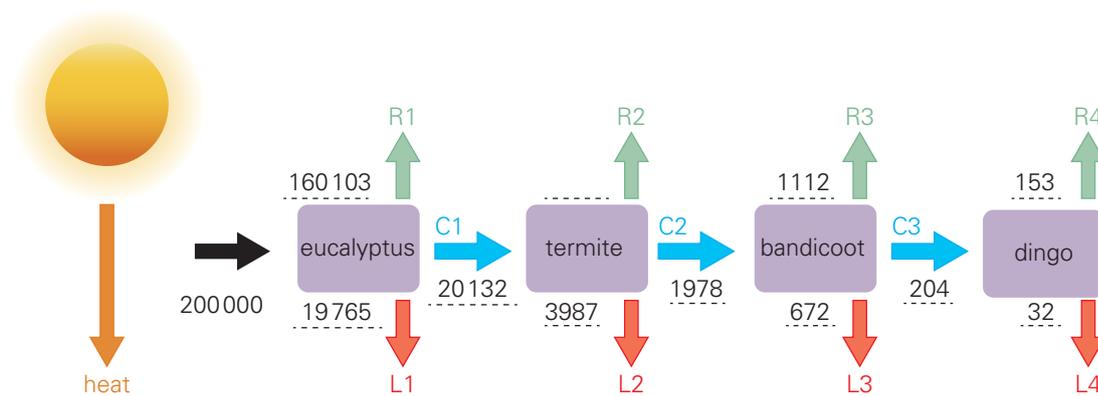


Figure 3.70 Energy transfer in an Australian food chain. All values are in kJ. Blue arrows (C1–3) represent energy transferred through the food chain; green arrows (R1–4) represent energy lost as heat and through respiration; and the red arrows (L1–4) represent the energy lost as detritus (dead organic matter and waste).

- Identify** the secondary consumer in Figure 3.70.
- Calculate** the R2 value.
- Calculate** the efficiency of the energy transfer through the termite in Figure 3.70.
- Organise** the efficiency of energy transfers (C1, C2 and C3) from highest to lowest, using Figure 3.70.
- Deduce** why the food chain does not extend further than the dingo.
- Geckos will also eat termites. They are far smaller than a bandicoot. **Predict** if the gecko's L3 value would be higher or lower than the bandicoot's L3 value in Figure 3.70.
- Justify** your answer to Question 6.



STEM activity: Designing a cane toad trap

Background information

Australia is home to many beautiful amphibians, but the cane toad is not one of them. It is classified as both an amphibian and a pest. Cane toads were introduced to Queensland in 1935 to control cane beetles, and the toads adapted quickly to the Australian environment. In 2009, they arrived in Western Australia, and programs were implemented to track and limit the spread.

Cane toads are gluttonous feeders and can significantly reduce the population of native creatures. They have a toxic venom in their skin, which protects them from predators. Cane toads have no natural predators and are a threat to native animal species. Only human intervention can control and reduce the population.

Design brief: Create a prototype of a device that can be used to reduce the population of cane toads humanely.

Activity instructions

In this task, you will investigate the different ways you can track the cane toad population. Then you will design and construct a prototype device that could be used by individuals and government organisations to trap cane toads or their tadpoles. You will need to consider the following information and design constraints:

- 1 The design and construction must be cost-effective.
- 2 The prototype must be constructed so that no animal (including the cane toad) is harmed.
- 3 The prototype must be able to be left in a way so that curious people cannot injure themselves from touching the device or possibly touching a captured cane toad/tadpoles.
- 4 The prototype device must be able to be transported for safe removal of toads/tadpoles.

Figure 3.71 A cane toad



Suggested materials

- recyclable materials such as plastic bottles, containers, boxes
- duct tape
- scissors
- ruler
- balls the size of cane toads

Research and feasibility

- 1 Identify other animal species that live in the same ecosystem as cane toads. If necessary, research this information.
- 2 Research and explain what 'humane' means, and discuss in your group why your prototype design must be humane.
- 3 Research the lifecycle and identify why the cane toad has become such a pest in Australia.
- 4 Research and identify the ways that the cane toad population can be controlled.

Design

- 5 Decide in your group the method you are going to use to reduce the population of cane toads. You may want to use a table like this one to list the positives and negatives of each method.

Method of control	Positive	Negative
Adult toad trap		
Tadpole trap		
Barrier		

- 6 Design your prototype device and label the key components of the design. How do the components of the design help your invention to be humane, safe, effective and affordable?

Create

- 7 Construct your prototype device using the available materials.
- 8 Test your prototype device for durability and get other groups to test how well it works.

Evaluate and modify

- 9 Discuss in your group how well your prototype device worked, and reflect on how effective you think it will be.
- 10 Evaluate if you now think that other methods of controlling the population would be more effective. Would you like to make any changes to your prototype?
- 11 Present your prototype to the class and ask your peers how effective the prototype would be where they live, and what suggestions they can offer to improve it.

Chapter 4

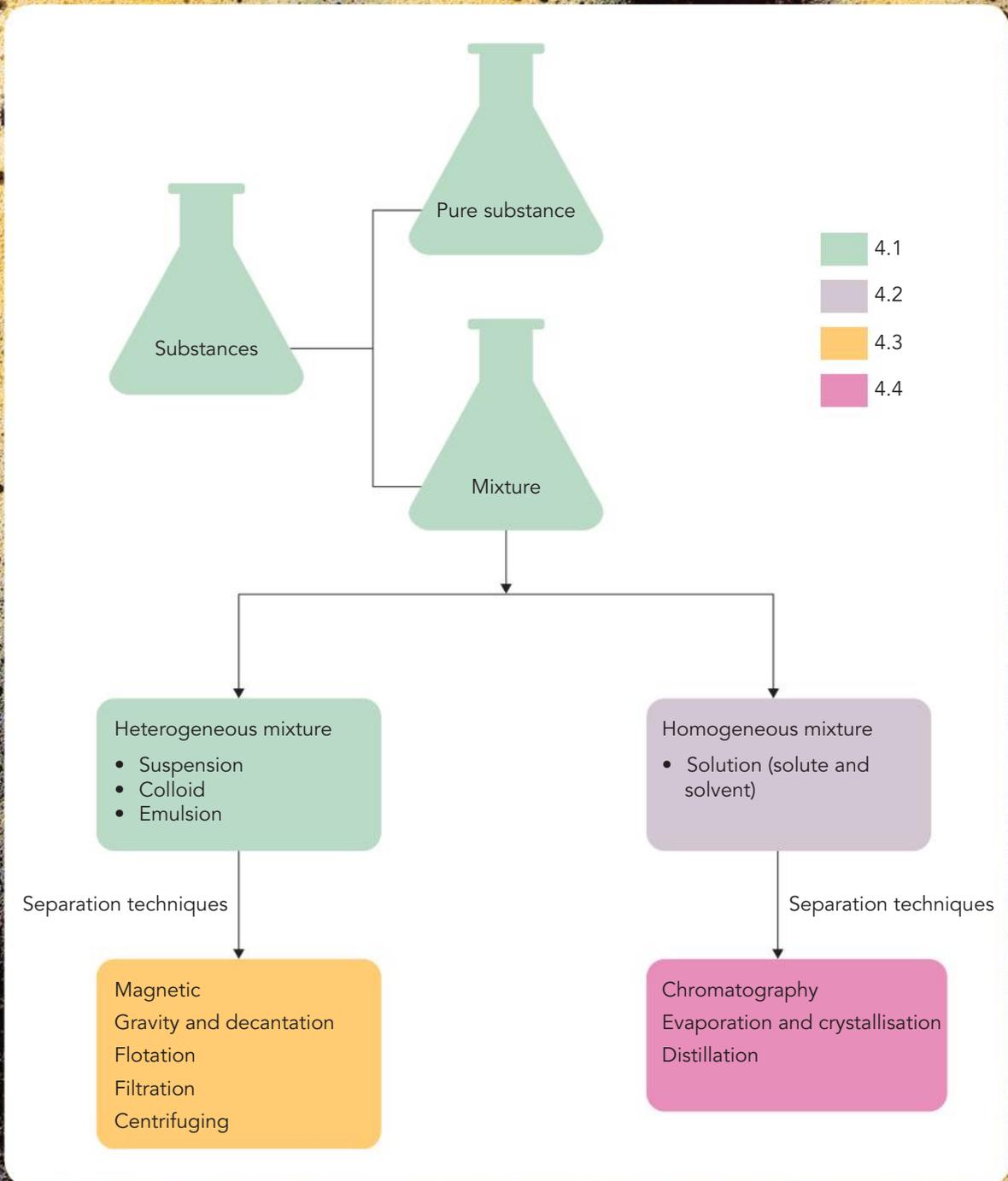
Mixtures



Chapter introduction

Our world is an amazing place. It is made up of many different substances, such as wood, food, metal, fibres, air, glass, plastic and ceramics. Some of these substances are pure substances, while others are mixtures. This chapter will help you understand how to identify pure substances and mixtures and the differences between them, and the role of chemistry in helping us separate mixtures into their parts. You will also look at mixtures and their separation in your home, as well as how people in different occupations use separation techniques.

Chapter map



4.1 Pure substances and mixtures



Learning goals

- 1 To be able to recognise the difference between pure substances and mixtures.
- 2 To be able to distinguish between homogeneous and heterogeneous mixtures.

Look around you. What do you see? Almost everything around you is made up of matter, whether you can see it or not. **Matter** is anything that has mass and occupies space. All matter can be classified into either a mixture or a pure substance. In science, the area where you

find out more about pure substances and mixtures is called chemistry.

matter

anything that has mass and occupies space

pure substance

material that is made up of just one type of particle

physical property

measurable property such as density, size, colour, magnetism, mass, melting point or texture

mixture

material made up of two or more different substances that are mixed together

dissolve

cause to become mixed in a substance so that it cannot be seen

Try this 4.1

What is this?

Gather some everyday substances such as tea, milk, cheese and peppercorns. List their unique physical properties in a way that your classmates could guess the substance from the physical description.

one type of material or one type of particle, for example, pure water, pure gold and pure oxygen gas. Every pure substance has unique **physical properties** such as different states, densities, size, magnetism, colour, mass, melting points, boiling points and texture. Scientists need an understanding of these different physical properties to be able to distinguish one type of material from another.

Mixtures

Mixtures are substances made from two or more different substances that are mixed together but can be physically separated. Mixtures can be separated because they are not combined in a chemical way. Some examples of mixtures that you may be familiar with include soft drinks (a mixture of sugar, water, carbon dioxide, flavours and colouring), a cup of tea (a mixture of tea leaves and water), tap water (a mixture of water and chlorine and salts **dissolved** from groundwater), spaghetti bolognese (a mixture of pasta, beef, tomatoes, and other vegetables, herbs and spices such as garlic, chillies and thyme) and healthy fruit salad (a mixture of kiwi fruit, apples, bananas and raspberries).

Pure substance

So, what is a pure substance? And how is it different from a mixture? Well, a **pure substance** is a substance that is made up of just



Figure 4.1 Spaghetti bolognese sauce is a mixture you may love to eat.

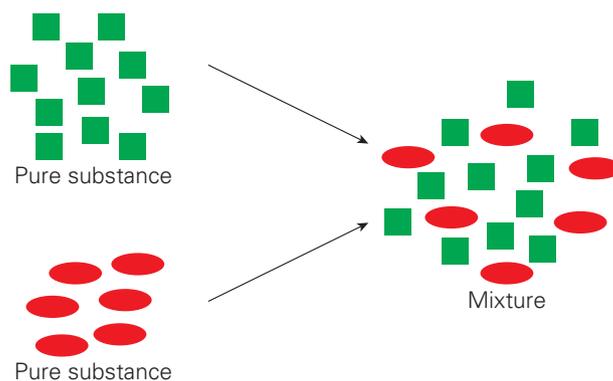


Figure 4.2 A mixture is made of two or more substances.

Quick check 4.1

- 1 Define the terms 'pure substance' and 'mixture' in your own words.
- 2 Classify the following substances as pure substances or mixtures.

smoke	pen ink	iron
soft drink	aluminium foil	cough medicine
trail mix	margarine	tap water
hand cream	chocolate milk	jelly
salt water	ice cream	cheese
oxygen	carbon dioxide	blood

Types of mixtures

Mixtures can be classified into different types based on their properties and the way they behave. The following table introduces the four main types of mixtures: **solutions**, **suspensions**, **colloids** and **emulsions**.



Try this 4.2

Identifying mixtures

Have a look at a glass of vinegar (a solution). Look at it closely and try to identify the characteristics mentioned in Table 4.1. For example, solutions are usually transparent or see-through. Then observe an example of a suspension, a colloid and an emulsion and practise identifying the characteristics that define them.

solution

a mixture where one substance is evenly dissolved in another

suspension

a mixture where one substance will eventually settle out of the solvent

colloid

a mixture where particles of one substance will not dissolve but remain distributed through another substance

emulsion

a colloid of two or more liquids

Type of mixture	Definition	Examples
Solution	A type of mixture that is formed when one substance (solute) dissolves evenly into another (solvent). It is usually transparent.	Vinegar (a mixture of water and acetic acid) Lemonade Cordial
Suspension	A type of mixture that is formed when a substance does not dissolve in a liquid and will separate and settle to the bottom if left to stand. They are usually cloudy only after mixing.	Muddy water Snow domes
Colloid	A type of mixture that is formed when you have a suspension that does not separate or settle. The larger particles of one substance stay distributed through the other substance.	Whipped cream (the gas air is distributed throughout the liquid cream) Hair gel (thickeners and polymers distributed in water) Wet paint (a solid pigment distributed in liquid)
Emulsion	A type of mixture that is formed when a colloid of two or more liquids are spread evenly through one another.	Salad dressing only when shaken together (the liquid oil is spread out throughout the liquid vinegar) Milk (an emulsion of fat droplets and oils in water)

solute

the component of a solution being dissolved

solvent

the component in a solution capable of dissolving another substance

Table 4.1 Types of mixtures

Quick check 4.2

Copy and complete the following table and select the correct mixtures from Figure 4.3 for the 'Examples' column.

Type of mixture	Transparent or cloudy?	Separates/settles when left to stand?	Examples
Solution			
Suspension			
Colloid			
Emulsion			



Figure 4.3 What type of mixtures are illustrated in these images? What are they mixtures of?

1. milk – emulsion of fat in water; 2. vinegar – solution of acetic acid and water; 3. whipped cream – colloid of air in cream; 4. tea – solution of tea and water; 5. wet paint – colloid of solid pigment distributed in liquid; 6. salad dressing – when mixed it is an emulsion of oil in vinegar; 7. fog – colloid of water in air; 8. snow globe – suspension of plastic and water; 9. muddy water – suspension of mud and water.

Did you know? 4.1**Milk used to come with cream!**

In days gone by, milk in glass bottles with little foil caps used to be delivered by a milkman to your home. Those bottles had a layer of cream at the top, because the fresh cow's milk, when left in the fridge, would separate into skim milk and a layer of fatty cream that floated to the surface.

Nowadays, the process of homogenisation forces hot milk, under high pressure, through small nozzles so that the creamy fat globules become so small that they remain evenly dispersed throughout the milk. As the fat does not separate out any more, the milk is an emulsion of two liquid colloids (the fat and the milk).



Figure 4.4 A milkman delivering bottles of unhomogenised milk (in the 1950s) and a bird feeding off the cream at the top of the unhomogenised milk



Figure 4.5 Milk homogenisation machinery

Separating mixtures

Mixtures are not chemically combined, so this means they can be separated into their components based on the physical properties of the substances in the mixture, for example, by sorting, filtering or evaporation. Remember, physical properties are how a substance looks (size, mass, texture, shape, volume) or how it behaves around other substances (magnetism, density, solubility).

Sorting recycling

Your weekly recycling is sorted using a variety of different separation techniques because of the different properties of the substances you recycle, like paper and cardboard, plastics, glass, steel cans and aluminium drink cans. This includes manual sorting, the use of sieves, magnets and machines that sort by

mass, followed by more manual sorting. The separated elements are then taken to their respective recycling companies.



Figure 4.6 Your weekly recycling is sorted using a variety of different separation techniques that use the different properties of the substances.

Try this 4.3

Creating a photo essay or blog post

Note: You need a camera for this activity.

Create a time sequence photo essay or blog post. To do this you will need to take photos of each stage of this activity and save them into a Word file or similar document.

- 1 With your parent/guardian's permission, take a small bowl and make a mixture of some chickpeas (or beans), uncooked rice, paperclips, small leaves from the garden and water. Remember, this is a photo essay so take a photo each time you add a substance to your bowl. Stir the substances together.
- 2 Your job is to now try to separate the five substances. What are the properties of the different substances? What tools do you have in the kitchen you could use? What should you remove first? What will you do? Consider your steps of action and then begin. (There is no right answer so enjoy investigating).
- 3 Document each step of the separation by taking a photo of what you do and any tools you use.
- 4 Share your photo essay with your classmates and teacher, or publish your blog to the internet. Did you all separate the substances in the same way and in the same order using the same tools? What were the properties of the components of the mixture that allowed them to be separated?

homogeneous mixture

a mixture where components are evenly distributed

heterogeneous mixture

a mixture that can be separated into its parts, and those parts retain their original properties

Classifying mixtures

Mixtures can be broadly classified into two categories: **homogeneous mixtures** and **heterogeneous mixtures**. You need to understand

these terms because they help you determine the properties of mixtures, and you need to know these before you can even attempt to separate a mixture into its components.

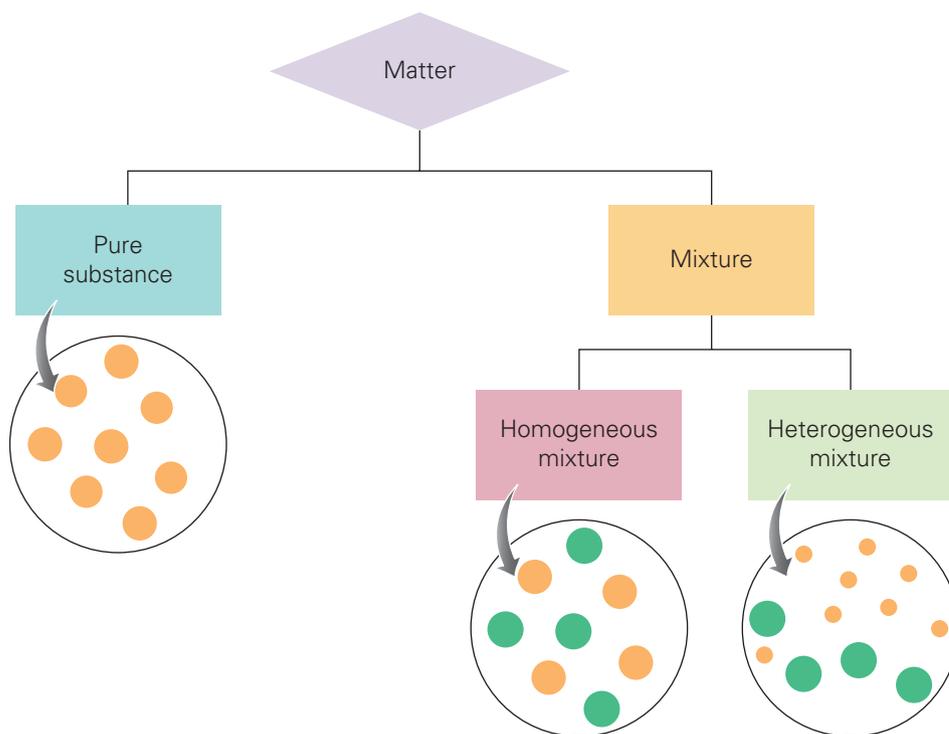


Figure 4.7 How particles may be organised in a heterogeneous mixture and a homogeneous mixture

Homogeneous mixtures are mixtures where you cannot tell that two or more substances have been mixed together as they don't settle or separate out when left to stand. The components of the mixture are all evenly distributed and the entire mixture has the same properties. For example, air, tap water and soft drinks are all homogeneous mixtures, because wherever you take a sample from, the properties of the samples will be the same. Solutions are homogeneous.

Heterogeneous mixtures are mixtures that can be separated into their parts, and those parts

retain their original properties. The mixture is not blended together evenly and is not the same consistency throughout, so if you were to take a sample from different parts of the mixture, you would find all of your samples have different properties. Examples include fruit salad, pizza, choc chip cookies, **smog** and salad dressing. Suspensions, colloids and emulsions are generally considered to be heterogeneous; although, to the naked eye, they do have some of the same qualities of homogeneous mixtures as well.

smog
a mixture of smoke, gases and chemicals, especially in cities

Try this 4.4

Observing mixtures

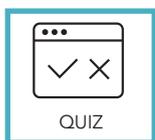
Observe a selection of the following mixtures, first with only your eyes, then with a magnifying glass and then with a microscope. Record your observations and classify the mixtures as heterogeneous or homogeneous. Remember, your opinion may change as you move through the three levels of observation, and that is not unusual for scientists. As a scientist investigates and delves deeper into something, their opinions and theories can change.

Mixtures you could look at: orange juice with pulp, tomato sauce, chicken noodle soup, mustard, homogenised milk, salsa, relish, jam, toothpaste, soda water, chocolate chip cookie, shampoo, dish detergent.

Quick check 4.3

- 1 Define the term 'heterogeneous'.
- 2 Recall the characteristics that allow you to identify if a mixture is heterogeneous.
- 3 Define the term 'homogeneous'.
- 4 Recall the characteristics that allow you to identify if a mixture is homogeneous.
- 5 Classify the following substances as either a homogeneous mixture, heterogeneous mixture or a pure substance.
Substances: pure water, cola, iron nails, green paint, chunky salsa, silver ring, chocolate chip cookies, concrete, orange juice with pulp, table salt.
- 6 Research online to find out about your local recycling process and then describe the properties of the different components of the recycling that allow the parts to be separated.

Section 4.1 questions



Remembering

- 1 **Identify** which of the following would not be described as a colloid:
smoke, foam, salt water, hair gel.

Understanding

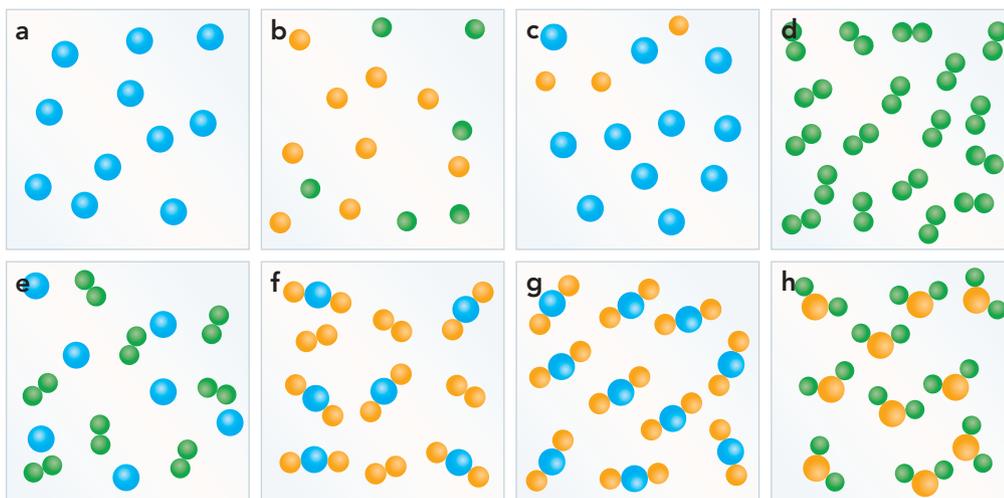
- 2 **Summarise** the differences between pure substances and mixtures and provide two examples of each.
- 3 **Outline** the differences between heterogeneous mixtures and homogeneous mixtures and provide two examples of each.

Applying

- 4 Is 100% pure carrot juice a pure substance? **Explain**, using the definitions you have learned.
- 5 You are looking at a beaker with a substance in it. **Describe** how can you tell if it is a solution, suspension, colloid or emulsion. Show your knowledge of the characteristics of the four types of mixture in your answer.

Analysing

- 6 **Categorise** the following particle diagrams using the following words: pure substance; heterogeneous; homogeneous.



Evaluating

- 7 **Justify** that all solutions are mixtures, but not all mixtures are solutions.

4.2 Solutes, solvents and solutions

Learning goals

- 1 To be able to define an aqueous solution including the terms solute and solvent.
- 2 To be able to compare a dilute, concentrated and saturated solution.



To fully understand the properties of both homogeneous and heterogeneous mixtures, and consequently how you can separate the components of a mixture, you need to understand more about what makes a solution a homogeneous mixture.

Solutions

A solution is a type of mixture that is formed when the particles of one substance separate and spread out evenly into another substance, i.e. dissolve. Recall that the solute is the name given to the substance that dissolves, and the solvent is the name given to the substance it dissolves into. A solution is therefore the name given to a mixture of a solute dissolved in a solvent.

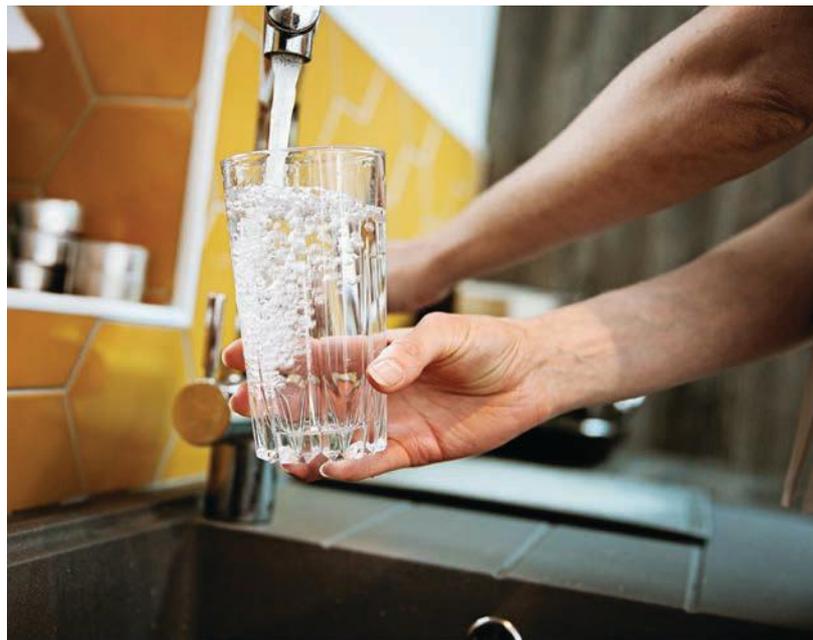


Figure 4.8 Tap water is a solution as various trace elements from the groundwater plus chlorine and fluorine added by water treatment are distributed evenly throughout pure water.

Try this 4.5

Particle theory

Put a sugar cube in a glass of water. Describe what is happening using the terminology you have been learning about. What happens in terms of particles? Where are the particles? What are the particles doing?

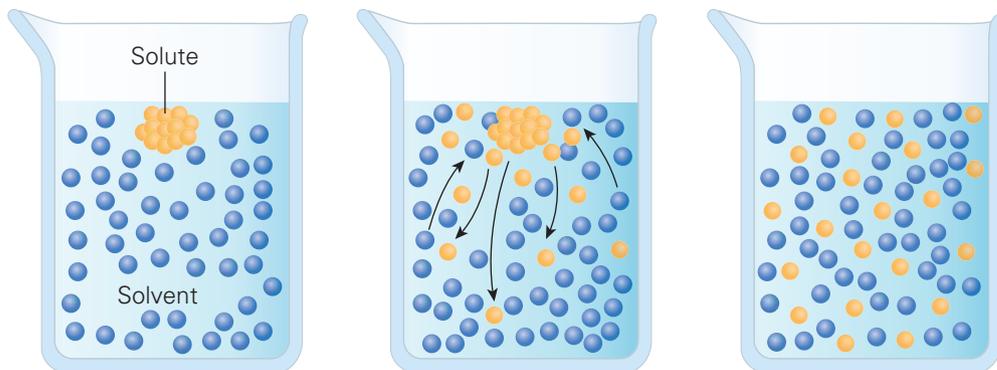


Figure 4.9 Particle diagram of a solid solute dissolving into a liquid solvent to form a solution

aqueous solution

solutions where the solvent is water

soluble

substances that can dissolve

insoluble

substances that cannot dissolve

dilute

a solution with only a small amount of the solute

concentrated

a solution with a large amount of the solute

Examples of solutions

An everyday example of a solution is the oxygen dissolved in the water of a fish tank, where the oxygen is the solute and the water is the solvent.

Other examples: the cordial (solute) dissolved in a glass of water (solvent) and the carbon dioxide (solute) dissolved in a fizzy drink water

(solvent). You will notice that many of

the solutions mentioned so far are made of solutes dissolved in the solvent water. Water is sometimes called the 'universal solvent' due to its versatility to dissolve a wide variety of different solutes. Solutions using water as a solvent are called **aqueous solutions**.

Not everything is able to dissolve to form a solution. Substances that can dissolve are



Figure 4.10 Oxygen is a solute that is dissolved in the solvent water to form the solution that organisms like fish and plants live in.

called **soluble** and those that are unable to dissolve are called **insoluble**. Substances that are insoluble have very strong forces of attraction between their particles. The solvent cannot break apart those particles and thus the substance remains undissolved.

Solution concentrations

A solution that has very little of a substance (solute) added to the solvent is said to be **dilute**. It is also described as a solution with a low concentration. For example, a friend asks you to make a weak glass of cordial. You would need to add only a little of the cordial (solute) and a lot of water (solvent) to make a weak or dilute solution.

A solution that has a lot of a substance (solute) added to the solvent is called **concentrated**. It is also described as a solution with a high concentration. How would you make your friend's cordial drink in this case?



Figure 4.11 The more dilute solutions are on the left, while the more concentrated solutions are on the right.

Quick check 4.4

- 1 Identify the correct word from the list to copy and complete the sentences below:
aqueous solution, dissolves, soluble, solute, solution, solvent.
When sugar is mixed with water it _____, and this shows that sugar is _____ in water. When it dissolves, it forms a _____. The sugar is called the _____.
This type of solution, where water is the _____, is called an _____.
- 2 Identify the solute and solvent in the following solutions:
sea water, vinegar, tap water, antifreeze, lemonade.
- 3 Define these terms: solution, solvent, solute, aqueous solution.

Try this 4.6**Investigating solubility**

Investigate the solubility of household substances in water, at home or in class.

- 1 Collect seven containers of the same size. (Alternatively, use test tubes in a rack from your science laboratory.)
- 2 Add a teaspoon of one of seven common household substances to each container and label the container. Typical substances are sugar, salt, baking soda, flour, coffee, sand and jelly crystals.
- 3 Add a couple of tablespoons of cold water from the tap and mix the substances together using a spoon or by carefully swirling or jiggling the test tube.
- 4 Record your observations of each substance as soluble, partly soluble or insoluble.
- 5 Why is it that some substances dissolve in the water but others do not? Can you ever put too much solute in a solvent so it stops dissolving? Try adding more and more solute to one of the containers to find out.

Explore! 4.1

Water Corporation manages Western Australia's water assets on behalf of the community. They:

- process and supply water for drinking water from groundwater and sea water
- recycle wastewater
- protect the waterways
- maintain drainage systems.

Research and find out what is added to our drinking water to make sure it is safe to drink. What is the role of each added substance?

Saturation

Did you try adding more and more solute to one of your containers in the Try this 4.6 activity? When you do this, you will notice that the solution reaches a point where no more solute can dissolve. The solution is now called a **saturated** solution. This is like having a towel saturated with water after you drop it in the pool – the towel just cannot take in any more water. A saturated solution is so concentrated that no more solute will dissolve into the solvent.

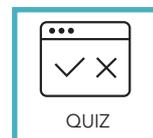
saturated
a solution with the maximum amount of solute dissolved

Section 4.2 questions**Remembering**

- 1 **Define** the following terms: saturated solution, aqueous solution, dilute solution, concentrated solution.

Understanding

- 2 Each of the following statements is incorrect. Rewrite each statement, and **select** the appropriate word(s) to make each statement correct.
 - a Soluble is when a substance cannot be dissolved in a solvent.
 - b The solvent dissolves to form a solution.
 - c A mixture is when different substances are chemically combined.
 - d A saturated solution is a solution in which the minimum amount of solute has been dissolved at a given temperature.
 - e In a solution, it is the solute that is unable to dissolve into the solvent.
 - f Concentrated solutions have a lot of solvent compared to the amount of solute.
 - g A suspension is a mixture in which a solute is dissolved in a solvent to form a transparent liquid.



Applying

- 3 **Explain** why it is possible to see solid salt crystals in water but not possible to see the dissolved salt particles.
- 4 **Identify** the solvent, solute and solution in the following mixtures:
 - a fizzy water
 - b vinegar
 - c syrup.
- 5 You were given a diluted mug of cordial and a concentrated mug of cordial and asked to work out which was which without looking in the mug. **Describe** how could you do this and the results that you would expect.

Analysing

- 6 **Compare** solutions and mixtures. You may like to use a Venn diagram.

Evaluating

- 7 **Justify** whether all solutions are mixtures or all mixtures are solutions. Give some reasons for your choice.
- 8 Look at this diagram of a test tube containing a liquid substance and a soluble solid substance. **Create** labelled diagrams to illustrate the following key terms. You may be able to include several terms on one diagram.



dilute solution	concentrated solution
dissolve	aqueous solution
insoluble	soluble
solution	saturated solution

4.3 Separating heterogeneous mixtures

**Learning goals**

- 1 To be able to describe how magnetism can be used to separate a mixture.
- 2 To distinguish between separation of mixtures using techniques such as decantation, flocculation, flotation and filtration.
- 3 To recognise the use of centrifugation in the separation of mixtures.

You may recall, from earlier in this chapter, that heterogeneous mixtures like fruit salad can be easily separated into their parts, and those parts retain their original properties. So, what are the techniques that are used to separate out the different components?

The easiest way is by hand-sorting, that is, using your fingers to get your favourite lollies out of a lolly bowl, or pulling the strawberries out of the fruit salad. But there are other ways of sorting materials!

Magnetic separation

Magnetic separation is another technique that is easy to use. Imagine you are building a skateboard in woodwork class and you drop some screws on the sawdust-covered floor. Magnets attract iron containing substances like screws, and so you would be able to pull the screws out from under the sawdust as wood does not contain iron. This is how steel cans are separated from the rest of your recycling at the Materials Recovery Facility.



Figure 4.12 Magnets can be used to separate magnetic substances from non-magnetic substances.

Decantation

If you have dropped a piece of fruit in your drink at a birthday party, the fruit will sink to the bottom of your glass. The process of **decantation** can help you separate your drink from the piece of fruit. Decantation is a technique where you carefully pour the liquid off the top of a solid–liquid mixture or a liquid–liquid mixture, to separate the two components. You may have done this when pouring water off the top of your vegetables once they have been boiled for dinner.

Flocculation

A **flocculant** is a chemical that helps with decanting. It causes suspended particles to clump together so that they sink (forming sediment) and can be separated from the liquid they were suspended in by decantation. For example, you collect muddy water from a river and let the sediment settle to the bottom but the water is still cloudy. A flocculant would help clear the water by causing the particles to clump and sink. It is also used to clarify water in swimming pools.

Flotation

Flotation is another separation technique but, in this case, the components of a mixture are separated based on their density or capacity to float. For example, oil floats on water so this allows for the clean-up of ocean oil spills. Firstly, booms (floating barriers) are placed around the oil to help contain it. Skimmers (boats with vacuum machines, sponges, cork or oil absorbent ropes) then soak up the spilled oil from the surface within the booms. It can then be stored and disposed of.

decantation
the process of separating by using gravity

flocculant
a substance that causes particles to clump together

flotation
separating a mixture based on the capacity to float



VIDEO
Explain how spills in the ocean are cleaned up



Figure 4.13 Booms and skimmers helping to clean up an oil spill

Filtration

Filtration is a technique used to separate the components of a mixture based on their size and solubility, by passing them through a filter. You may have heard of filter baskets in pools that catch the leaves, or filters used in

your vacuum cleaner so that the air pumped out is cleaned, or perhaps the filters used in cafes when making coffees. The holes in the filter will be different sizes depending on what is being filtered. For example, a filter basket in a pool has holes that you can

see, as leaves are not microscopic; however, the holes in a coffee filter are much smaller as the coffee granules are smaller.

Sieving is another type of filtration and is perhaps a lot more familiar to you – watching your fish and chips being pulled out of hot oil using a wire basket, sifting flour when baking a cake or straining your spaghetti by pouring it through a colander.

filtration

separating a mixture by passing through a filter

filtrate

the substance that passes through the filter

residue

the substance that is left in the filter



Figure 4.14 Cafes use filters when making coffee.

Quick check 4.5

- 1 Recall what you should use to separate a mixture of sand and iron.
- 2 Explain what might prevent a magnet being useful to separate the components of a mixture.
- 3 Identify a situation when hand-picking would be the most appropriate way to separate a mixture.
- 4 Explain the separation technique of decantation.
- 5 Explain the relationship between density and the separation technique of flotation.



Figure 4.15 Flocculants can be used to help clean pool water.

Did you know? 4.2

Combustion engines in cars may have a very fine particulate filter. These can trap extremely small carbon particles such as soot and stop them from polluting the atmosphere.

Filtrate and residue

When you talk about the process of filtration, you use words like **filtrate** and **residue**. The filtrate is the name of the substance that passes through the filter. For example, the clean air coming out of an air conditioner. The residue is the name of the substance left behind in the filter after the process of filtration. For example, the dust in the air that enters the air conditioner from outside.

Did you know? 4.3

Toothless whales have filters

The humpback whale, and other toothless whales, possess a unique feeding adaptation called baleen. The baleen is a wide plate in the whale's mouth, made up of hundreds of long, fringed blades made of the same substance as our hair and nails. The blades filter small animals such as krill, plankton and small fish out of the sea water.



Figure 4.16 The mouth of a humpback whale contains baleen which allows them to filter the ocean water for krill.

Try this 4.7

Drawing a filter

Draw a cartoon strip, make an animation using PowerPoint or make a stop-motion short film demonstrating the movement of different-sized particles through a filter with fixed-sized holes.

Practical 4.1: Investigation

Separating heterogeneous mixtures**Aim**

To compare the effectiveness of *different* separation techniques for cleaning contaminated water.

Prior understanding

Separation of heterogeneous mixtures relies on each different substance having a unique set of physical or chemical properties. Each difference in property (e.g. one substance is magnetic and the others are not) is used to simultaneously remove one substance from a mixture while the other substances are left behind.

Real-life example: an excellent application of this can be seen by researching the winner of the 2019 Google Science Fair, who was a school student who discovered a way to remove microplastics from sea water safely using a ferrofluid (fluid that is attracted to magnets).

Materials

- alum (potassium aluminium sulfate) or equivalent
- contaminated creek water (simulated) – water from a fish tank (water left over from cleaning the filter is ideal), sand, clay, mud
- 3 glass beakers
- metal spoon
- 2 glass cylinders

Be careful

Do not test water by consuming it.

continued...

...continued

- stirring rod or spoon
- funnel
- filter paper
- retort stand and clamp
- *optional: microscope, with dropper, slide and coverslip to observe water*

Method

Use each of the following methods separately to identify which substances are removed by the process *and* the physical or chemical property that was used to isolate one substance from another.

- 1 Draw the table shown in the results section in your science book.
- 2 Test each of the following methods and record the results in the table for comparison.

Decantation

- 3 Measure 100 mL of water into a cylinder.
- 4 Stir the water until it appears cloudy.
- 5 Leave the mixture undisturbed for 5–10 minutes so that solid substances can settle on the bottom.
- 6 Very carefully, pour the liquid off the top of the solid substances into a beaker so that they remain in the cylinder.
- 7 Record observations in the table.

Flocculation

- 8 Measure 100 mL of water into a cylinder.
- 9 Transfer into a beaker.
- 10 Stir the water until it appears cloudy.
- 11 Measure 3 mL of alum solution and stir the mixture for 2 minutes.
- 12 Leave the mixture undisturbed for 15 minutes.
- 13 Record observations in the table.

Filtration

- 14 Fold your filter paper as shown in Figure 4.17.
- 15 Set up your equipment as shown in Figure 4.18 on the next page.
- 16 Measure 100 mL of water into a cylinder.
- 17 Stir the water until it appears cloudy.
- 18 Pour the mixture through the funnel and let it filter through the paper.
- 19 Record observations in the table.

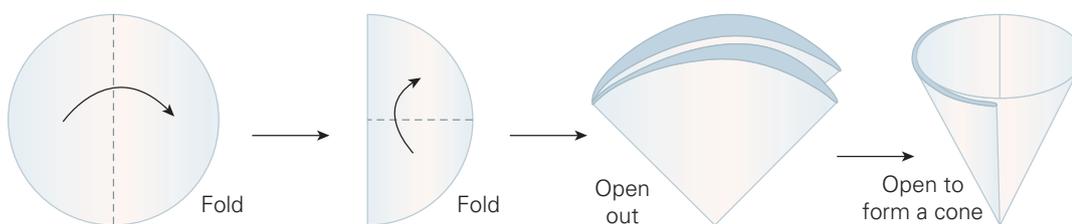


Figure 4.17 How to fold your filter paper

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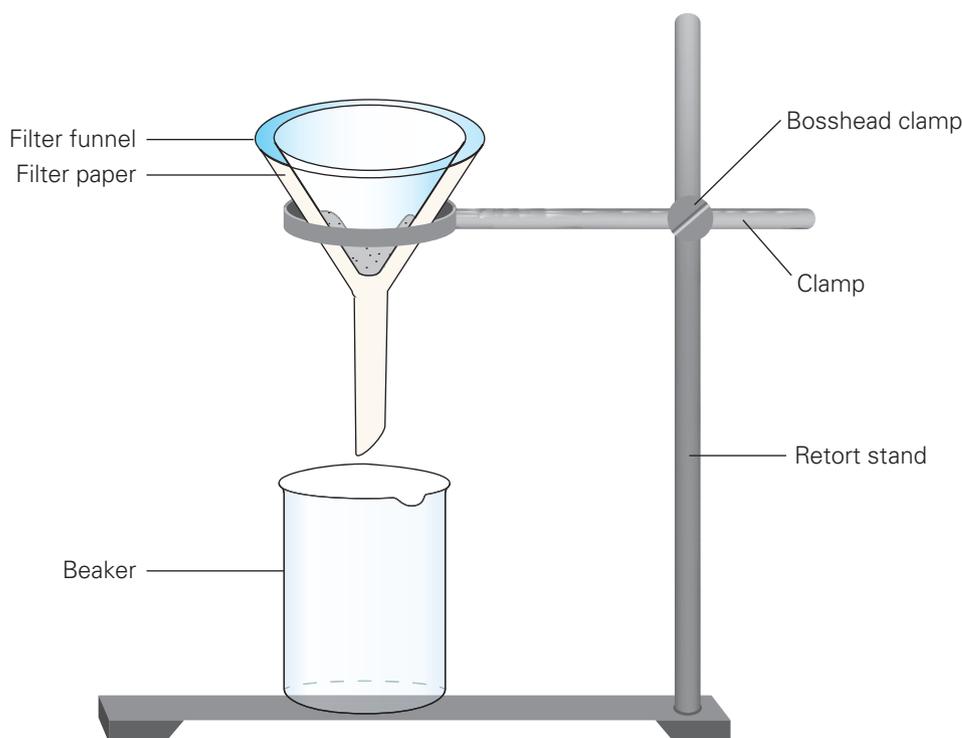


Figure 4.18 Practical set-up

Results

Independent variable: Separation technique	Dependent variable: Water quality		
	Describe the initial condition of the water	Describe the solid residue and collected water	Issues that may have affected the results e.g. speed, incomplete removal of substance
Decantation			
Flocculation			
Filtration			

Discussion

- 1 Critique the effectiveness of each method by considering the number of contaminants removed and any issues that were found when testing it.
- 2 Describe how you could use these three methods in combination to remove contaminants from water.
- 3 Compare the results with other class groups. Determine how much variation was found in the results.
- 4 Identify the method which was the most reliable at separating out a contaminant based on the response in the previous question.
- 5 Discuss whether these three methods effectively clean the water so that it could be consumed by humans.
- 6 *Optional: place a drop of the contaminated water under a microscope and observe. Review the answer to Question 3 above.*
- 7 Propose any changes that could be made to the method to improve the quality of the data in future experiments.

Did you know? 4.4

Our kidneys have filters

After your body has processed the nutrients you consume, waste products are formed. One of the main jobs of the kidneys is to filter this waste out of the blood. Your blood supply circulates through the kidneys about 12 times every hour. Each day, your kidneys process around 200 litres of blood. Each of your kidneys has more than a million mini-filters called nephrons.



Figure 4.19 The haemodialysis machine filters blood by trying to mimic what your kidneys do.

Quick check 4.6

Charcoal and salt are accidentally mixed together. The mixture is placed in water and stirred before being passed through filter paper.

- 1 What will remain in the filter paper?
- 2 What will pass through the filter paper?
- 3 Determine which is the filtrate.
- 4 Determine which is the residue.
- 5 Where is the residue found?
- 6 Identify the missing word: 'A filter funnel can separate two substances in a mixture when those two substances have different _____.'



Science as a human endeavour 4.1

Desalination Plants in Western Australia

Western Australia has two large desalination plants: the Perth Seawater Desalination Plant in Kwinana, and the Southern Seawater Desalination Plant in Binningup. Together, these plants provide almost half of Perth's water supply – a source of water that is unaffected in times of drought or flooding. In a desalination plant, water is filtered over the several steps of purification. After sea water has been drawn in through an underground pipe, the water is first filtered to remove any sand and other solid substances. The second filtration technique, called reverse osmosis, then starts. This is where the filtered sea water is forced through an ultra-fine membrane that contains extremely small pores, which only lets water particles through. The salt particles are too large to pass through and so are returned to the sea as a concentrate, and fresh water continues on in the process to be treated and then distributed.

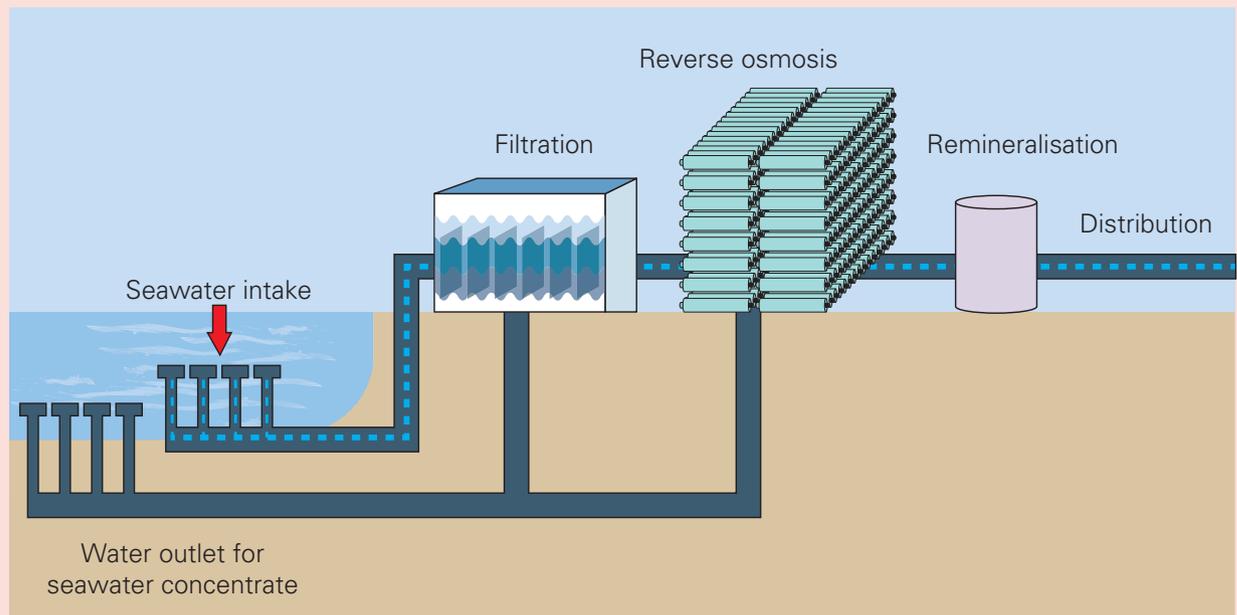


Figure 4.20 Desalination process

Explore! 4.2

Aboriginal and Torres Strait Islander peoples have been separating heterogeneous mixtures for centuries. Separation techniques were essential to purify food and water sources. Research how each of the following methods might have been used by Aboriginal and Torres Strait Islander peoples to prepare a meal:

- 1 hand-picking
- 2 sieving
- 3 winnowing
- 4 yandying.

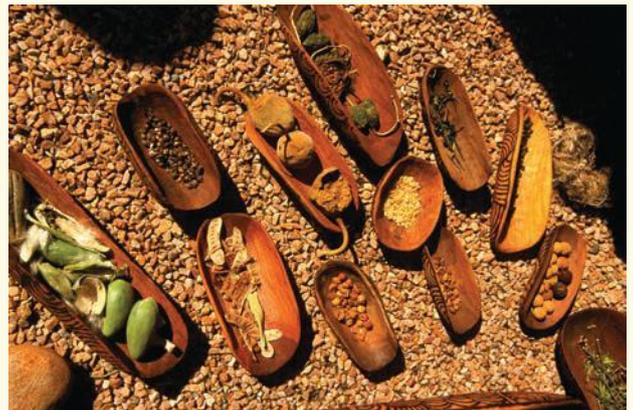


Figure 4.21 A variety of bush tucker items carried in several yandi (Noongar word for a carrying vessel)

Centrifugation

centrifuge

a device that uses speed to separate substances based on mass

A **centrifuge** is a device that can separate substances based on their mass (how heavy they are) by spinning them very fast. High-speed centrifuges can spin up to 20 000 times a minute! It is like your washing machine spin cycle or a salad spinner, where the water and the items inside are separated.



VIDEO
Centrifuging

Did you know? 4.5

Blood has different components

Blood fractionation is the process of separating the blood from your body into its components, using centrifugation. When you spin blood, the heaviest components (red blood cells) move to the bottom of the tube and the lightest components (plasma) move to the top. White blood cells and platelets are often found in the middle. What does that suggest about their mass?

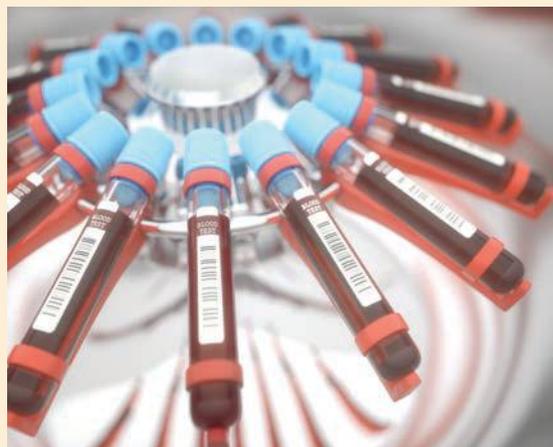


Figure 4.22 Whole blood being centrifuged to separate the components

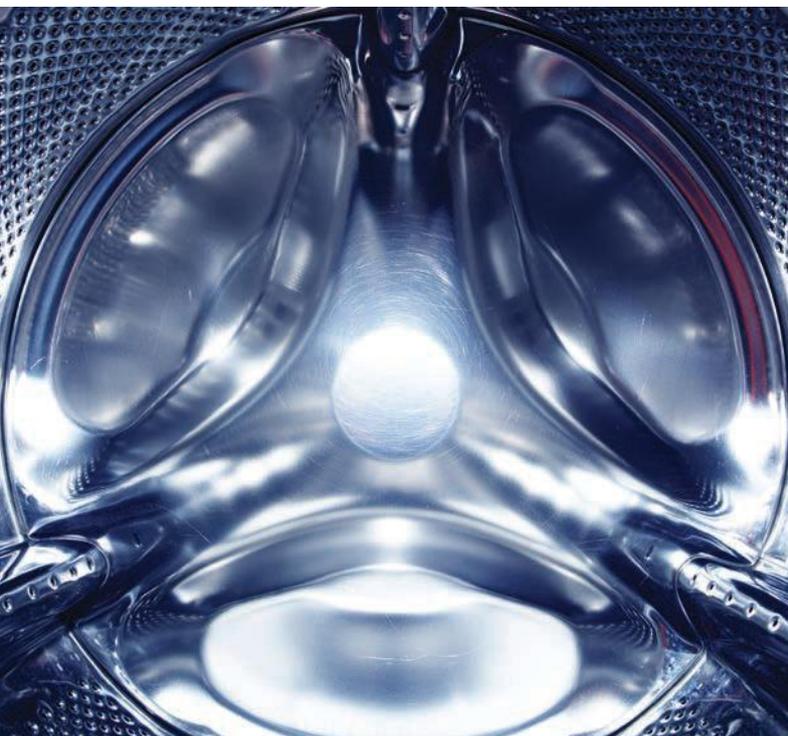


Figure 4.23 Both the inside of your washing machine and a salad spinner are designed to spin so fast that the water moves outwards through the holes, while the clothes or salad remain in the centre.

Section 4.3 questions

Remembering

- 1 **Identify** which of the following cannot be separated using a centrifuge: components of blood; water from lettuce leaves; cream from milk; salt from sea water.

Understanding

- 2 **Describe** how centrifugation separates the substances in a mixture.
3 **Explain** why filtration does not always separate a mixture.

Applying

- 4 **Explain** why dissolved sugar cannot be filtered from water. Use the terms you have learned earlier in this chapter in your response.
5 **Describe** the separation technique of hand-picking used by Aboriginal and Torres Strait Islander peoples to sort various food items. Comment on whether this technique could be used to separate a bin full of recycling material.

Analysing

- 6 Gas masks are becoming more and more sophisticated to combat the development of dangerous nerve gases. Nerve gases interfere with the nervous system. This means you may lose your ability to move your muscles, including those muscles that help you breathe. **Propose** why a paper-filter mask will not work with nerve gases.
7 **Explain** why filtering water does not mean that the water is necessarily pure.

Evaluating

- 8 a All of the filters in Figure 4.25 are used in the home. For each, **consider** its role and state the:
• components of the mixture
• residue
• filtrate.
b Each of the filters has a different mixture to separate. **Explain** how this affects the different-sized holes of each of the filters, and the different-shaped holes of each of the filters.
c **Order** the filters from largest holes to smallest holes.

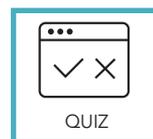


Figure 4.24 A modern-day gas mask

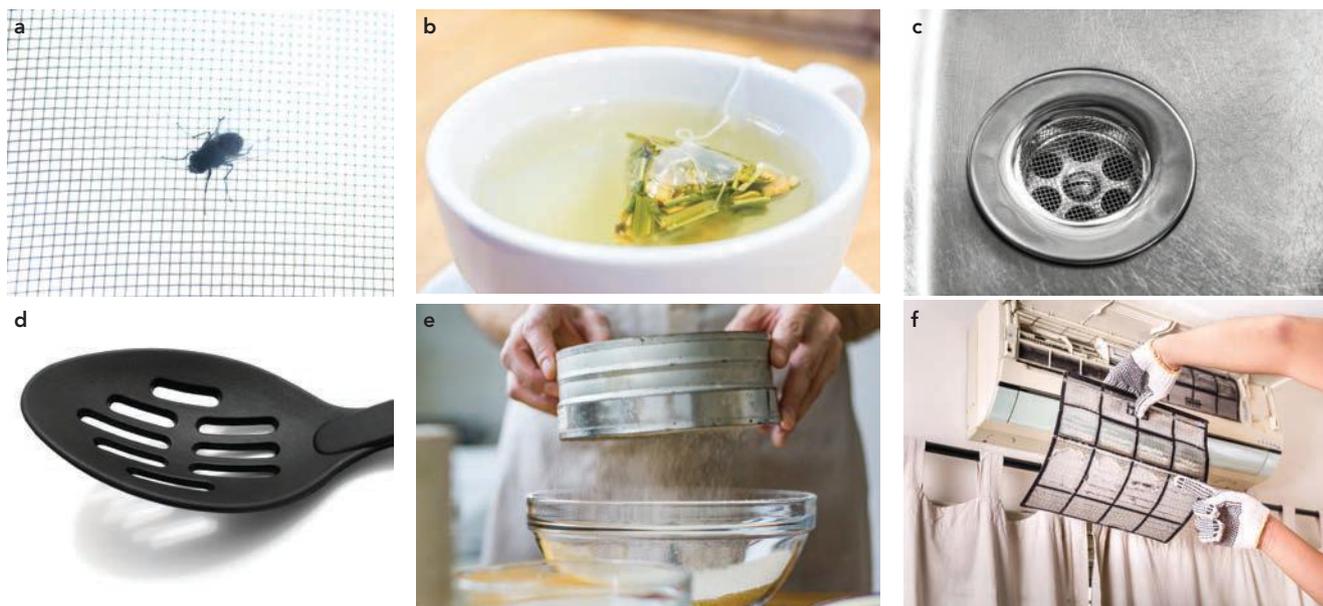


Figure 4.25 Filters

4.4 Separating homogeneous mixtures



chromatography

a technique to separate substances based on movement at different rates due to solubility

Learning goals

- 1 To be able to recall the use of chromatography for industrial applications.
- 2 To distinguish between evaporation and crystallisation as techniques to separate a dissolved solid from a solvent.
- 3 To be able to identify distillation as a method to separate a mixture of soluble liquids.

There are a variety of separation techniques that can be used to separate homogeneous mixtures. Think back: what does 'homogeneous' mean?

Chromatography

Chromatography is a technique used to separate the substances in a mixture based on their solubility, which is their ability to dissolve in a solvent (and also their attraction to a solid material, for example paper). Look at Figure 4.26.

This is the common set-up for carrying out paper chromatography, in this example, to separate the colours that make up the ink in felt-tip marker pens. The mixture (components of ink) is made to move by a solvent (often water or methylated spirits),

through another substance that stays still (filter paper) until the components separate. The more soluble the components of the ink are in the solvent, the more quickly they will move up the filter paper in the solvent.

The 'mobile phase' is the name given to the solvent moving with the soluble parts of the mixture in it. The substance that stays still is called the 'stationary phase' (filter paper).

Chromatography is used a lot in industry, although it is probably not something you commonly hear about. These are some examples:

- In forensics, chromatography allows you to analyse and separate the components of ink in pens to catch the forger or the writer of a ransom note.



Figure 4.26 Paper chromatography: the separation of the components of ink. Note that the green ink is made up of yellow (less soluble) and blue (more soluble) components.

- In toxicology, gas chromatography is used to separate the components of a poison so that it can be identified and neutralised.
- In pharmacology, chromatography allows for the testing of the purity of medicines and drugs.
- In fashion, chromatography helps break down the different components of the dyes in clothing.
- In athletics and other sports, gas chromatography is used to check if the sports person has been using any prohibited substances.

Practical 4.2

Separating the pigments in water-soluble colour marker pens

Aim

To separate the pigments from water-soluble marker pen ink using chromatography.

Materials

- water
- large beaker
- long strips of filter paper
- icy-pole sticks
- paperclips
- ruler
- water-soluble colour marker pens

Method

- 1 Use a pencil to draw a line across each filter paper strip 1.5 cm from the bottom. Label the icy-pole sticks A, B and C – one position for each of three strips of filter paper.
- 2 Add enough water to the beaker so that the pencil lines will sit above the water line.
- 3 Using the water-soluble colour marker pen, draw a small dot on the filter paper in the middle of your pencil line.

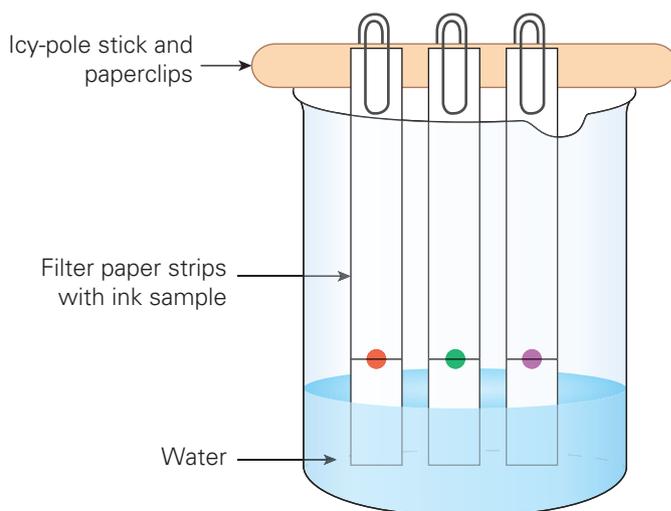


Figure 4.27 Experimental set-up

- 4 Fold the paper strips over the icy-pole stick, as shown, and clip them on using the paperclips.
- 5 Repeat the first four steps this time using different coloured marker pens.

continued...

...continued

- 6 Lower the three samples into the water in the beaker, making sure the ink spot is above the water and the end of the paper stays in the water.
- 7 Leave the strips for about 10 to 20 minutes after placing them into the water.
- 8 Remove the paper strips (called chromatograms) from the beaker when the water has reached approximately 2 cm from the top of the paper and leave them to dry somewhere safe.

Results

Stick your dried chromatograms into your science book (or take a photo and upload it to your practical report file).

Discussion

- 1 The chromatogram formed is unique for each type of pigment. Discuss what you found out about the different pigments in the ink of the different coloured pens.
- 2 Identify possible sources of error when using this separation technique.
- 3 Discuss how you could minimise the impact of these sources of error in the future.

Conclusion

Copy and complete this statement in your science book. From this activity we can claim that pen ink _____. This is supported through observations that _____. Therefore it can be concluded that _____.

Evaporation and crystallisation

Evaporation is a change in state from a liquid to a gas, but it can also be used as a separation technique. Evaporation can be used to separate a dissolved substance (solute) from its solvent in a solution, by heating the mixture up so that the

evaporation
when liquid changes to a
gaseous state

liquid part turns into gas. For example, the water in salt water will evaporate when heated, leaving behind salt crystals – the water and the salt are separated by evaporation. Can you think of some examples where evaporation has been used in your home to separate substances? For example, washed clothes that are drying in the sun on the clothes line.

Try this 4.8

Invisible ink

Use lemon juice as invisible ink to write a message on paper. After it is dry, deliver it to a friend. Under the supervision of an adult, they can 'cook' the juice gently with an iron, near the flame of a candle or with a heat lamp to read your message.

Did you know? 4.6

Painting uses evaporation as a separation technique

Paints, you may recall, are a type of mixture called a colloid. Wet paint is a mixture of colour pigments suspended in a binding medium (allows the paint to stick to surfaces and remain solid once it dries) and a solvent. Sometimes, there are also additional additives to make the paint dry quicker or allow it to be used on sailing boats or on railings prone to rust or to resist being broken down by sunlight. When the solvent dries and evaporates, only the colour pigment is left behind, suspended in the binding medium. It is the evaporation of the solvents that creates the distinctive smell of paint drying.

Crystallisation

Often when you use the process of evaporation to separate a mixture, crystals form after the solvent has evaporated. This is called **crystallisation** and occurs because as the solvent forms a gas or evaporates, the solution left behind becomes more and more concentrated. Eventually the solution is so concentrated that it becomes saturated; that is, not all of the solute can remain in solution. Consequently, some of the solute will start to come out of the solution in the form of crystals. The crystals grow as the solvent continues to evaporate. The amazing thing about crystals is that they come in amazing shapes and sizes depending on the solute and how quickly evaporation occurs.

Have you seen salt crystals forming on your skin as you dry off after a swim in the ocean? Very slow evaporation of the solvent, like



Figure 4.28 Crystals of salt can be formed and harvested by slow evaporation of water from a salt crystallisation pond.

the water in a crystallisation pond, can form even bigger crystals of salt.

crystallisation
solidification of a substance into a highly structured form

Quick check 4.7

- Select the correct term from the list to copy and complete the sentences: filter, pigments, solvent, water.
Chromatography is a technique that can separate different components of a mixture, such as different _____ in ink or in a leaf. Samples of different mixtures are put on a piece of _____ paper, and the paper is put into a solvent. If the mixture dissolves in water, then _____ can be used for the solvent. If the mixture does not dissolve in water, then a different _____ such as methylated spirits, must be used.
- Organise the following statements by numbering them to indicate the order in which they occur in the process of paper chromatography.
 - _____ Place your sample in the centre of the pencil line.
 - _____ Place a small volume of water into a beaker (about 1 cm deep).
 - _____ Make sure the sample dot does not go below the surface of the liquid in your beaker.
 - _____ Leave for 20 minutes until the solvent reaches the top of the filter paper.
 - _____ Draw a line using a pencil across a filter strip 1 cm from the bottom.
 - _____ Fold the paper strips over the icy-pole stick, clip them, and lower them into the water in the beaker.
- Define the key terms 'evaporation' and 'crystallisation'.
- Develop a method that would allow you to separate salt and ground pepper (which can float) when they are all mixed up together. Include the concepts of 'evaporation' and 'crystallisation' in your explanation.

Practical 4.3

Using evaporation to separate mixtures

Aim

To analyse the mass of salt contained in a concentrated salt solution.

Prior understanding

Homogeneous mixtures contain particles too small to be seen with the naked eye. Solutions are mixtures where one substance is dissolved into another. Separation of substances in a solution relies on each substance having a unique set of physical or chemical properties. One unique property of substances is their boiling point. When a mixture is heated, each substance will evaporate at different temperatures, leaving the other substances behind.

Materials

- concentrated salt water
- measuring cylinder
- 250 mL beaker
- Bunsen burner
- tripod
- matches
- heatproof mat
- gauze
- safety goggles
- scales

Method

- 1 Copy the results table into your science book.
- 2 Weigh the mass of the beaker using the scales. Record in the table.
- 3 Measure 100 mL of concentrated salt water into the beaker.
- 4 Set up the tripod and gauze over the Bunsen burner.
- 5 Place the beaker on the gauze.
- 6 Light the Bunsen burner as described in Practical 1.3 in Chapter 1.
- 7 Allow the mixture to boil until there is 25 mL of water left in the beaker.
- 8 Turn off the gas.
- 9 Leave the beaker on the tripod to cool.
- 10 When cool, pack up the equipment and leave beaker in a warm place to allow the remainder of the liquid to evaporate for a few days.

Be careful

- Observe general fire safety.
- Wear safety equipment.

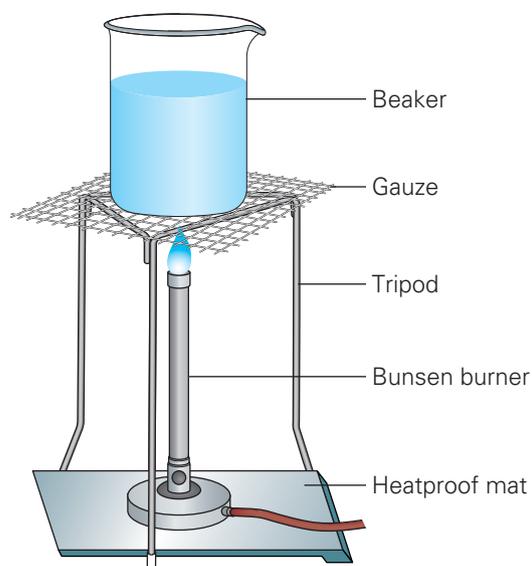


Figure 4.29 Experimental set-up

continued...

...continued

Next lesson

- 11 Weigh the beaker and record the mass.
- 12 Calculate the change in mass.

Results

Mass (grams)	Group result	Class mean
Empty beaker		
Beaker + salt		
Salt in beaker (= mass of salt in beaker)		

Peer review

- 1 Swap experimental diagrams with another group and give each other feedback on how clearly the diagram communicates how to set up the separation method. Your feedback should discuss the following:
 - how well the diagram follows the rules for scientific drawing
 - any other suggestions to improve the quality of communication.
- 2 After receiving feedback, make alterations to the diagram to address the identified issues and write up a final copy to present to the class.

Discussion

- 1 Compare your result with the actual mass of salt that was dissolved in the water (your teacher has this information).
- 2 Compare your result with other groups. How much variation was observed between the final results for the mass of the salt?
- 3 Calculate a class mean for the mass of salt that was dissolved in 100 mL of water.
- 4 Determine if a reliable conclusion could have been drawn about the mass of salt per 100 mL based on the mean class results.

Most natural water sources contain a variety of dissolved salts.

- 5 Discuss how this would affect the validity of the conclusion drawn about the mass of salt that was dissolved into the water to make the test solution.
- 6 Propose changes to the method to improve the quality of the data in future experiments.





VIDEO
Distillation

Distillation

You may have thought about the process of evaporation and how when you separate salt from salty water, all the water is lost into the atmosphere as water vapour. But what if you could catch it so that you could use it?

This is where **distillation** comes in. It is a technique that uses evaporation (heating) and condensation (cooling) to separate the components of a liquid mixture according to their boiling

temperatures. All components of the mixture are retained. The solute remains in the flask, while the solvent evaporates and is caught in the beaker at the end as it condenses to form the **distillate**.

distillation
a technique to separate substances in a liquid using evaporation (boiling) and condensation

distillate
the condensed liquid product from distillation



Figure 4.30 Distillation equipment used for the food and beverage industry

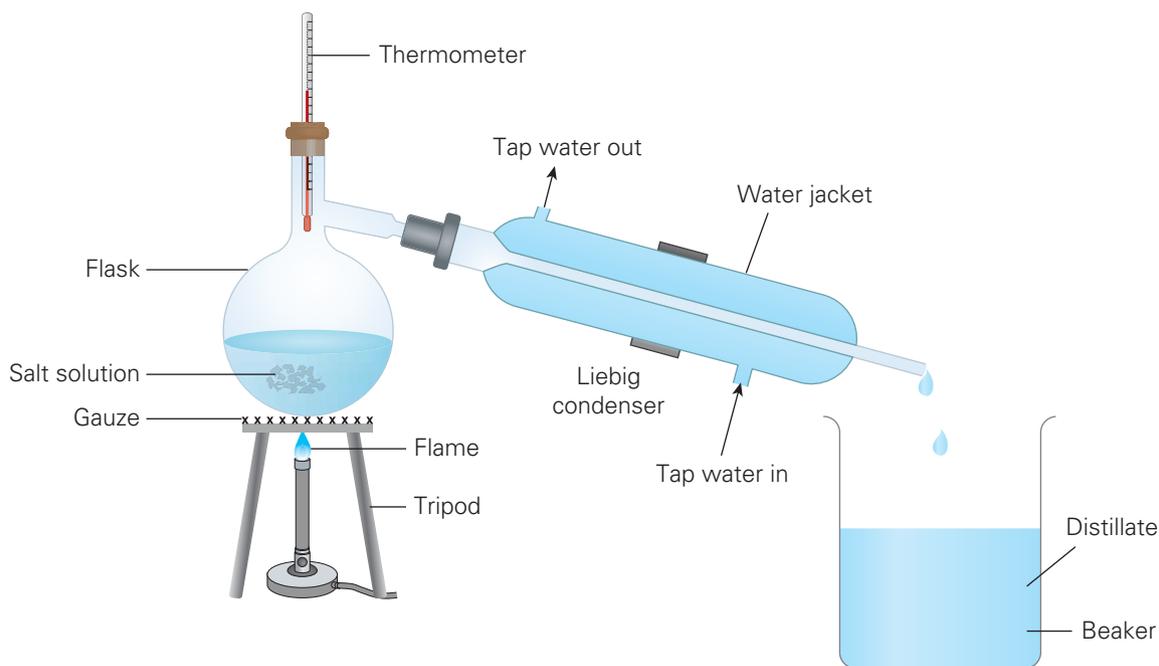
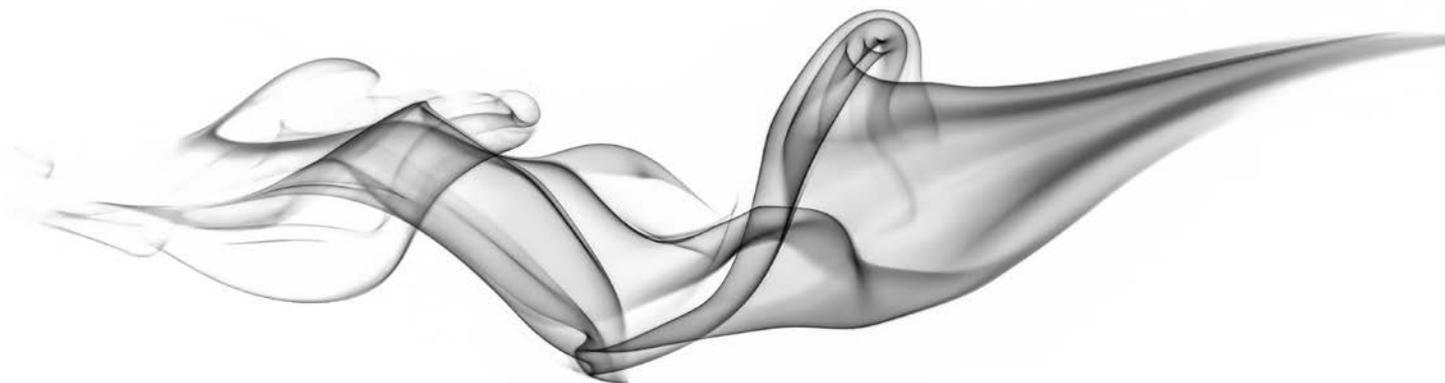


Figure 4.31 A Liebig condenser is used for the process of simple distillation.



Practical 4.4: Teacher demonstration

Distillation

Aim

To observe the process of distillation.

Materials

- water
- table salt
- 2 × 250 mL beakers
- Bunsen burner
- distillation apparatus
- spatula
- tripod
- safety goggles

Method

- 1 Set up the equipment for distillation as shown in Figure 4.31.
- 2 Wear safety goggles.
- 3 Put 100 mL of water into one of the beakers. (The other one will collect the distilled water.)
- 4 Use the spatula to add salt and stir.
- 5 Continue adding salt until the solution is very concentrated but not saturated. Pour the concentrated salt solution into the round-bottomed flask of the distillation apparatus.
- 6 Turn on the water that circulates in the condenser.
- 7 Heat the salt solution.

Results

Describe your observations of this process. How did the original solution look? What substance was left behind in the round-bottomed flask?

Discussion

- 1 Why was it necessary to heat the salty water solution?
- 2 Explain how the condenser works.
- 3 Which part is the distillate?
- 4 What were possible sources of error when using the different separation techniques?
- 5 How could you minimise the impact of these sources of error in the future?

Be careful

Apparatus can become extremely hot during the experiment.

Ensure water pressure is slowly increased so as not to introduce internal stress to the condenser.



Science as a human endeavour 4.2

Purifying mixtures without using heat

Scientists and engineers are trying to find ways of purifying mixtures without using heat. If they could achieve this, it would lower energy use across the world and consequently lower the amount of dangerous emissions and pollution. Distillation and other separation techniques using heat account for 10% to 15% of the world's energy consumption. Alternatives such as the separation techniques covered in this chapter are very expensive to do on such a large scale.

Currently, crude oil is removed from the ground, and its components are separated by fractional distillation. When crude oil is heated, petrol is one of the first gases that forms as it has a low boiling point compared to other liquids in the mixture. Engineers in industry are looking to develop other ways to separate the components of crude oil when there are many groups of particles in the mixture.

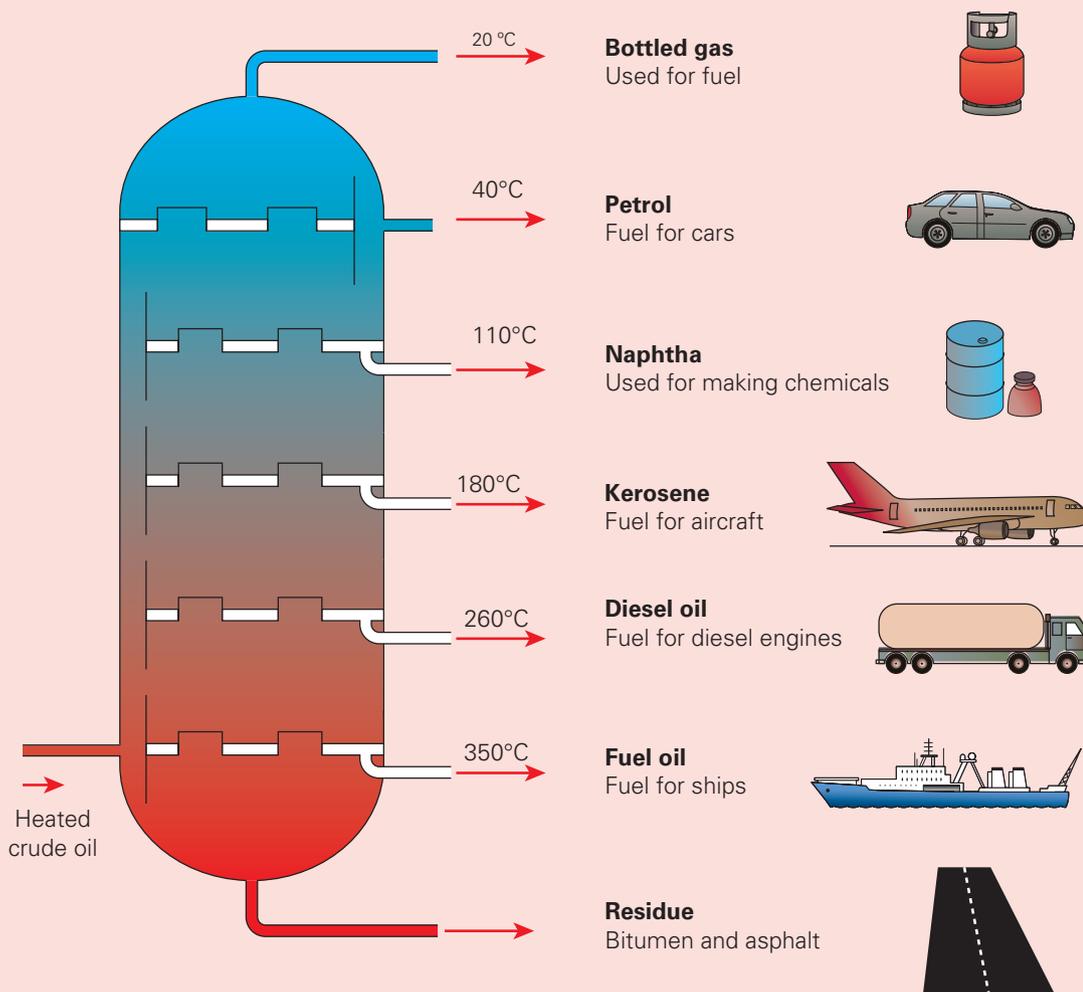


Figure 4.32 Fractional distillation of crude oil

Explore! 4.3

The formation of essential oils and perfume relies on the separation technique of distillation.

- 1 Investigate the role of distillation in the creation of essential oils and perfume.
- 2 Compare the distillation process used to make essential oils and perfume to the one used in your classroom.
- 3 Summarise how and why three other industries use distillation.



Figure 4.33 To bottle peppermint essential oil, distillation of the peppermint plant must first occur.

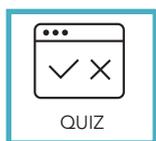
Think about your future

Whichever career you may be interested in, separation techniques will be a part of your world! It seems unbelievable, but think about the careers and industries you have come across in Chapter 4.

Toxicology	Doctors/medical	Pharmaceuticals	Forensics
Fashion industry	Geologists	Water treatment	Engineers
Pathologists	Refineries	Farmers	Chefs
Archaeologists	Mining	Beverage industry	Sports industry
Recycling	Desalination plants	Crude oil processing	Environmental work
Dairy industry	Dentistry	Perfume industry	Botany



Section 4.4 questions



Remembering

- 1 Label the parts (A–G) of the Liebig condenser and other equipment indicated in Figure 4.34.

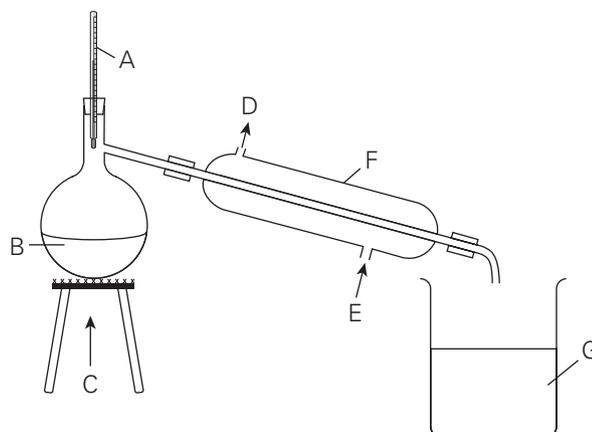


Figure 4.34 Liebig condenser and other equipment

Understanding

- 2 Define the terms 'distillation' and 'evaporation'.
 3 Describe the similarities and differences between distillation and evaporation.

Applying

- 4 Explain what happens to particles during the process of evaporation and the process of condensation. Draw pictures of the particles to help in your explanation.

Analysing

- 5 Compare the separation techniques of evaporation and crystallisation.

Evaluating

- 6 a Label the diagram in Figure 4.35 (A–C).
 b Explain what is meant by 'mobile phase' and 'stationary phase'.
 c List the colours in order from least to most soluble in the solvent.
 d Describe why the bottom line should be drawn in pencil and not in pen.
- 7 Substances X, Y, Z, W and sugar were mixed in water. The properties of each substance are listed below.

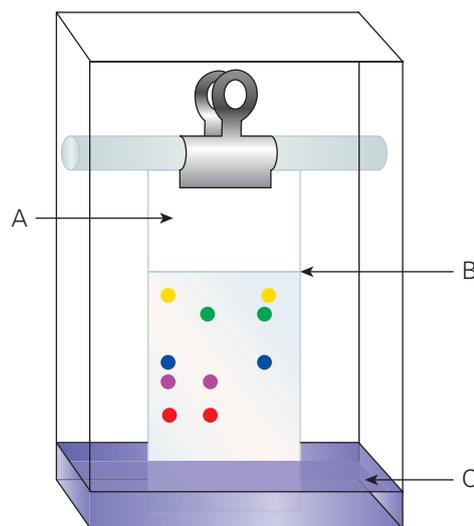


Figure 4.35 Chromatograph

Substance	Solubility in water	State at room temperature	Boiling temperature (°C)
Sugar	Soluble	Solid	> 110
X	Soluble	Liquid	86
Y	Soluble	Liquid	68
Z	Insoluble	Solid	> 800
W	Insoluble	Solid	86

Determine the steps for how you would separate the mixtures.

Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked questions	Check
4.1 I can identify and describe the differences between pure substances and mixtures.	9	
4.1 I can contrast homogeneous and heterogeneous mixtures.	2	
4.2 I can identify solvents, solutes and solutions.	1	
4.3 I am able to describe a range of physical separation techniques.	28	
4.3 I am able to describe a range of separation techniques used by Aboriginal and Torres Strait Islander peoples.	25	
4.4 I am able to describe a range of physical separation techniques to separate components of homogeneous mixtures.	26	

Review questions

Remembering

1 **Define** the following key words:

- a Solvent
- b Solute
- c Solution.

2 **Recall** a real world example of a homogeneous mixture and a heterogeneous mixture.

3 **Recall** the name of the piece of paper at the end of a chromatography experiment.

4 **Select** words from this list to complete the following paragraph.

boiling temperatures condensed distillate evaporated liquids

Distillation is a method used to separate _____ according to their _____. The liquid is _____ at a certain temperature, the vapour collected and then _____ to form a liquid again. The liquid collected during this process is called the _____. The residue is the mixture that remains in the original container.

5 **Select** words from the list to complete the following paragraph (some words may be used more than once):

filter filtrate funnel large residue small

The apparatus used to separate the sand from the salt solution consists of _____ paper inserted in a glass _____. The mixture of the salt solution and sand is poured into the _____. The _____ paper acts as a sieve separating the particles by size. _____ particles flow through the tiny holes of the filter paper and go into the beaker. These particles are called the _____. The _____ particles become trapped in the filter paper and are called the _____.



Understanding

- 6 **Identify** industries that use the following separation techniques:
- | | |
|----------------|------------------|
| a Distillation | c Centrifugation |
| b Filtration | d Evaporation |
- 7 **Identify** which method of separation (1–5) you would use to perform the separations (A–E):
- | | |
|------------------|--|
| 1 Evaporation | A Separating based on magnetic properties |
| 2 Filtration | B Separating based on heating liquid |
| 3 Chromatography | C Separating based on evaporation and condensation |
| 4 Distillation | D Separating based on size |
| 5 Magnetism | E Separation based on solubility |
- 8 a You decide to make toffee by dissolving sugar in water. **State** which would be faster: using big sugar cubes or using regular sugar crystals.
- b **Recall** what else you can do to make the sugar dissolve faster.
- 9 **Identify** which of the following substances is a mixture: smog; distilled water; oxygen gas; pure gold.

Applying

- 10 **Determine** whether the following separation techniques are of a solid, liquid or a gas, and describe the property that this separation is based on. Give an example from home. You may choose to do so in table format as shown.

Method of separation	Description of how it works	Example from home
Decanting		
Flocculation		
Evaporation		
Filtration		
Crystallisation		

- 11 Provide an example of a mixture you would separate using evaporation. **Explain** why no other method would work better.
- 12 **Describe** the correct order of the steps needed to obtain salt from a mixture of salt and pepper.
- 13 **Distinguish** between:
- | |
|-------------------------------|
| a a colloid and a suspension |
| b a suspension and a solution |
- 14 **Describe** how the following mixtures could be separated into their components:
- | |
|--|
| a How could you get the copper sulfate from copper sulfate solution? |
| b How could you get the water from clothes? |
| c How could you get the peas out of a mixture of peas and water? |
| d How could you get the oil out of a mixture of water and oil? |
| e How could you get sand from a mixture of sand and iron filings? |
| f How could you get the red dye from the blue dye? |
- 15 a An emulsion is a type of mixture that is formed when a colloid of two or more liquids spread evenly through one another. Provide an example of an emulsion and **explain** how it is different from a suspension.
- b Mayonnaise and salad dressing often contain similar substances. A bottle of salad dressing is usually shaken before it is added to a salad. **Provide** an inference for this.

16 **Organise** the colloid name (A–E) to the states of matter that make up the colloid (1–5).

Colloid	State
A Hair gel	1 A gas in a liquid
B Mist	2 A liquid in a solid
C Smoke	3 A liquid in a gas
D Foam	4 A solid in a gas
E Emulsion	5 A liquid in a liquid

17 Lottie was testing the solubility of some different household substances. Some details of what she found out are shown below.

Substance	Quantity (in grams) that dissolved in a 100 mL glass of water
Baking powder	15
Salt	45
Sugar	223
Flour	1

a **Determine** which substance Lottie found the most soluble.

b **Identify** which substance was the least soluble.

18 Lottie then looked at two glasses of salt solution she had on the bench at home. She thought one was a saturated solution and one was not but could not remember which was which. She put a crystal of salt in each glass and then left it overnight. What she saw in the morning is shown in Figure 4.36.

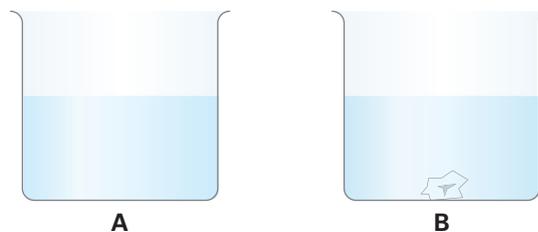


Figure 4.36 The crystal in glass A has disappeared, while the crystal in glass B has grown.

a **Determine** which glass contained the saturated solution.

b **Justify** your response to Part a.

19 Some liquid antibiotics suggest that you shake the bottle before you use them. **Explain** why this may be required, using terms you have learned in this chapter.

20 **Describe** the state of the substances being separated and their properties, for each separation technique. You may choose to do so in a table as shown.

Separation technique	Separation of solid/liquid/gas?	Property separation is based on
Distillation		
Magnetism		
Filtration		
Centrifuge		
Chromatography		

- 21 a **Draw** and label a diagram of a heterogeneous mixture showing how the particles are distributed.
 b **Draw** and label a diagram of a homogeneous mixture showing how the particles are distributed.

Analysing

- 22 **Explain** why soluble nutrients can be absorbed by the roots of plants through microscopic holes, but insoluble nutrients cannot.
- 23 **Explore** how you could separate:
 a a liquid from a liquid
 b a solid from a liquid
 c a solid from a solid.
- 24 You have been doing a graphic design course and have created an awesome poster. However, you have forgotten which ink pen you used to create the main heading. Figure 4.37 shows the results of a chromatography experiment you carried out to identify the ink. Five inks were compared: A, B, C, D and E.

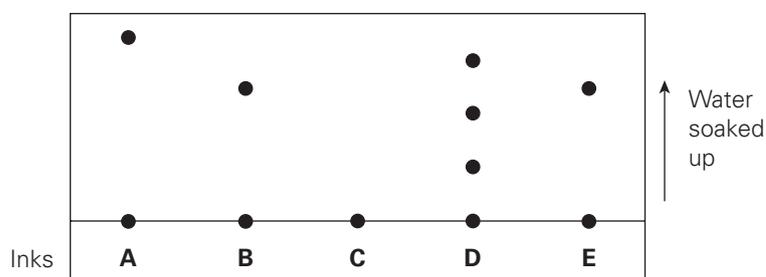


Figure 4.37 Chromatogram of your results

- a You know your ink is just one colour. **Identify** which ink sample is a mixture of different colours.
- b **Determine** which two inks are the same.
- c Given your ink is not soluble in water, **identify** which ink sample is yours.
- 25 Sieving is a useful separation technique for varying sized solid particles. **Describe** how sieving could be used in a recycling centre as well as how Aboriginal and Torres Strait Islander peoples use sieving to purify food sources.

Evaluating

- 26 A mixture of pure water and ethanol were accidentally mixed with an unknown substance X. X is highly soluble in water and proved very difficult to separate. **Describe** how the mixture can be separated to give pure water, ethanol and substance X. Below are the boiling points of the three liquids.

Substance dissolved in the mixture	Boiling temperature (°C)
Substance X	120
Ethanol	78
Water	100

- 27 **Propose** the separation processes you would use to separate a mixture of pebbles, sand, salt and water. You may do so in a flow chart. Clearly show what was separated at each step.
- 28 **Design** a contraption that could separate polystyrene balls from sand and gravel suspended in muddy water. Include an annotated diagram and a glossary of the separation techniques used.

Data questions

Under the Government of Western Australia, the Waste Authority recovers multiple types of waste categorised in seven types of material. The relative proportion of each is reported in Figure 4.38.

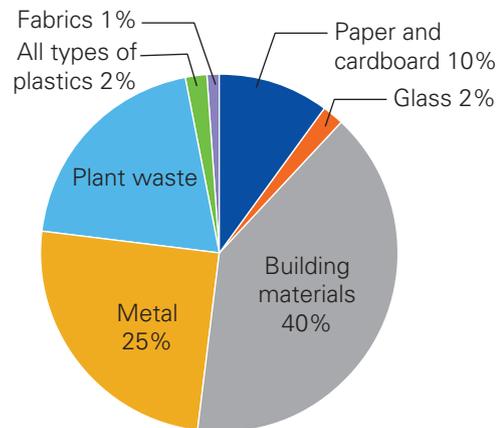


Figure 4.38 Proportion of each material type recovered in WA in 2017–18

The mass of glass materials recovered in Western Australia from 2004–18 is shown in Figure 4.39.

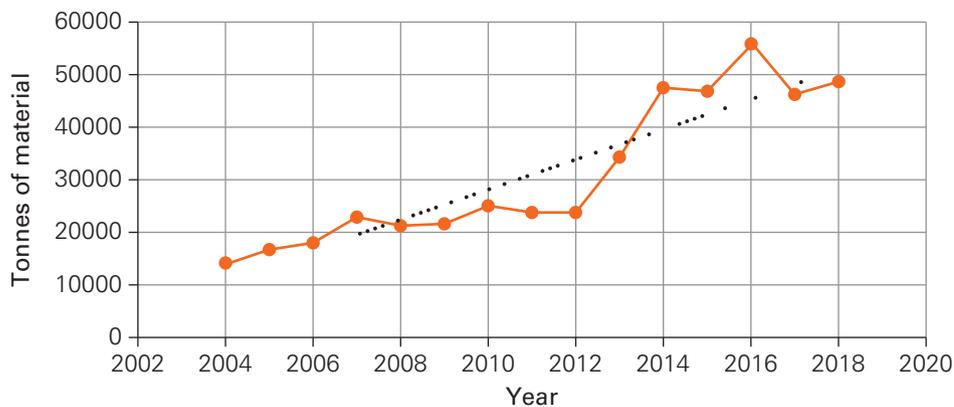


Figure 4.39 Approximate mass of glass collected (orange) for recycling in Western Australia from 2004–2018. Trendline (black)

Questions 1–4 refer to Figure 4.38.

- 1 At a recycling plant in Western Australia, a mixture containing each of the materials listed in Figure 4.38 is sorted using separation techniques, such as hand picking and magnetic separation. **Identify** whether the mixture of recovered materials is a homogeneous or heterogeneous mixture.
- 2 **Determine** which type of material accounts for the smallest mass.
- 3 **Calculate** the percentage of mass, which is made up of plant waste.
- 4 **Sequence** the material type in order of the decreasing relative mass.

Questions 5–9 refer to Figure 4.39.

- 5 **Identify the trend** in the mass of glass recovered over the past 15 years.
- 6 **Distinguish** between the information provided by the orange line and the black dotted line in Figure 4.39.
- 7 **Predict** how the trend in mass of glass recovered will progress over the next ten years.
- 8 **Justify** why the trend would progress in the way you have predicted in Question 7.
- 9 **Extrapolate** the trendline in Figure 4.39 to the year 2020. What mass of glass can be estimated to be collected to recycle in 2020?

STEM activity: Cleaning up an oil spill

Background information

The Great Barrier Reef is a Natural Wonder of the World. It is home to thousands of different types of fish, soft and hard coral, sharks, rays, turtles and marine mammals. This vulnerable ecosystem located off the Queensland coastline is threatened by many external factors, one being oil spills.

In 2010 a cargo ship struck the reef, which not only caused large damage to the reef, but also caused approximately 3 to 4 tonnes of oil to be released into the ocean. This oil slicked on the surface, and although chemical dispersants were used to break up the oil, oil tar balls were found washed up on islands nearby. Booms and skimmers could not be used as a physical collection method as the weather had caused large waves, making physical collection impossible.

Oil is a low-density substance, which means it floats on water and never mixes into it. Although this is a convenient property, oil also has the property of clinging to anything that is not water, and this is what makes it tricky to clean up – it clings to plants, animals and land, and impacts on marine ecosystems. Oil spills therefore need to be cleaned up very quickly and effectively to lessen the impact. Clean-up strategies used by environmental engineers include first using booms (inflatable barriers to contain the spill), skimming (scooping the oil off the surface using a vacuum), absorbing



Figure 4.40 A dolphin swims next to an oil spill.

(soaking up the oil using sponges and absorbent rope), and dispersing the oil (breaking it into smaller drops). Some of these methods are more effective than others.

Design brief: Determine the most effective way to clean an oil spill from the Great Barrier Reef.

Activity instructions

In this task you will play the role of environmental engineer and work together in your group to determine the most effective way of cleaning oil from the Great Barrier Reef. You will carry out a simulation of an oil spill and how it can be cleaned up. You will collect data about the oil removal and consider the effectiveness and cost of each method. You will present your findings in either a report or a presentation for the local government, which includes the perspective of the oil company.



Figure 4.41 Booms and skimmers helping to contain and clean up the oil spill.

Research and feasibility

- 1 Complete the table by listing all the possible ways of cleaning up an oil spill and what materials you have access to that could do the job. For each material, consider whether they are a skimmer, absorber or dispersant. Then record how expensive you think each might be.

Material	Effect on oil spill	Skimmer, absorber or dispersant (and cost)
Detergent		
Cotton balls		
Plastic spoon		
Small sponge		
Paper towel		

- 2 Consider how you will record your data on effectiveness of oil removal and cost.
- 3 Predict which material will be most effective at removing oil.

Design

- 4 Design a method in your group for the following three different techniques of oil spill clean-up:
 - a using a skimmer
 - b using an absorber
 - c using a dispersant.

Note: You may want to pour your oil from a beaker into the tray and then as you collect the oil, place it back into the beaker to help you measure before and after amounts to compare how effective the removal was. You should try to collect all the oil before it reaches the coastline.

Create

- 5 Using your set-up reef, place the ship in an agreed location (group consensus), and pour your oil mixture onto the water slowly. Try to completely remove the oil mixture using the skimmer technique. Spill the oil back into the water, then repeat for the absorber, and then the dispersant. Record your results in the table you designed in Step 2.

Evaluate and modify

- 6 Analyse your results. Begin by drawing a graph showing the effectiveness of each clean-up method (from the environmental engineer's point of view and that of the oil company), and another showing the cost of each clean-up method (from the environmental engineer's point of view and that of the oil company).

- 7 Discuss with your colleagues the effectiveness of each method of cleaning up an oil spill. Did your findings support your hypothesis or not? Were there any sources of error in your experiment? How could you work to prevent these errors from occurring in the future?
- 8 Consider skimming as a clean-up technique. Hypothesise on what impact the ocean waves might have on the effectiveness of this technique. Is it cost effective when you need to have boats with specialised equipment for the task?
- 9 Consider an absorber as a clean-up technique. Reflect on how you would dispose of absorbers that have soaked up the oil after the clean-up. Have you considered that the oil removed from the ocean must be stored elsewhere? Hypothesise on how effective absorbers would be to remove oil in the ocean.
- 10 Consider dispersants as a clean-up technique. Explain what the dispersant does to the oil on water. Is it appropriate to be putting more chemicals in the water? Discuss with your group three possible impacts of the dispersants on the marine ecosystem.
- 11 Compare the measured volume of crude oil spilt into your ocean with the volume of crude oil you successfully remove from the ocean? Did one technique prove to be more effective? Explain the possible causes of any differences between the two volumes.
- 12 You now have enough information to write your report. Prepare a report for local government that summarises your simulation findings. Include:
 - a the different methods, their effectiveness and their costs
 - b both points of view: the environmental engineer and the oil company
 - c which method/s you think should be utilised by environmental engineers in the future when cleaning up an oil spill in a local waterway.

Chapter 5

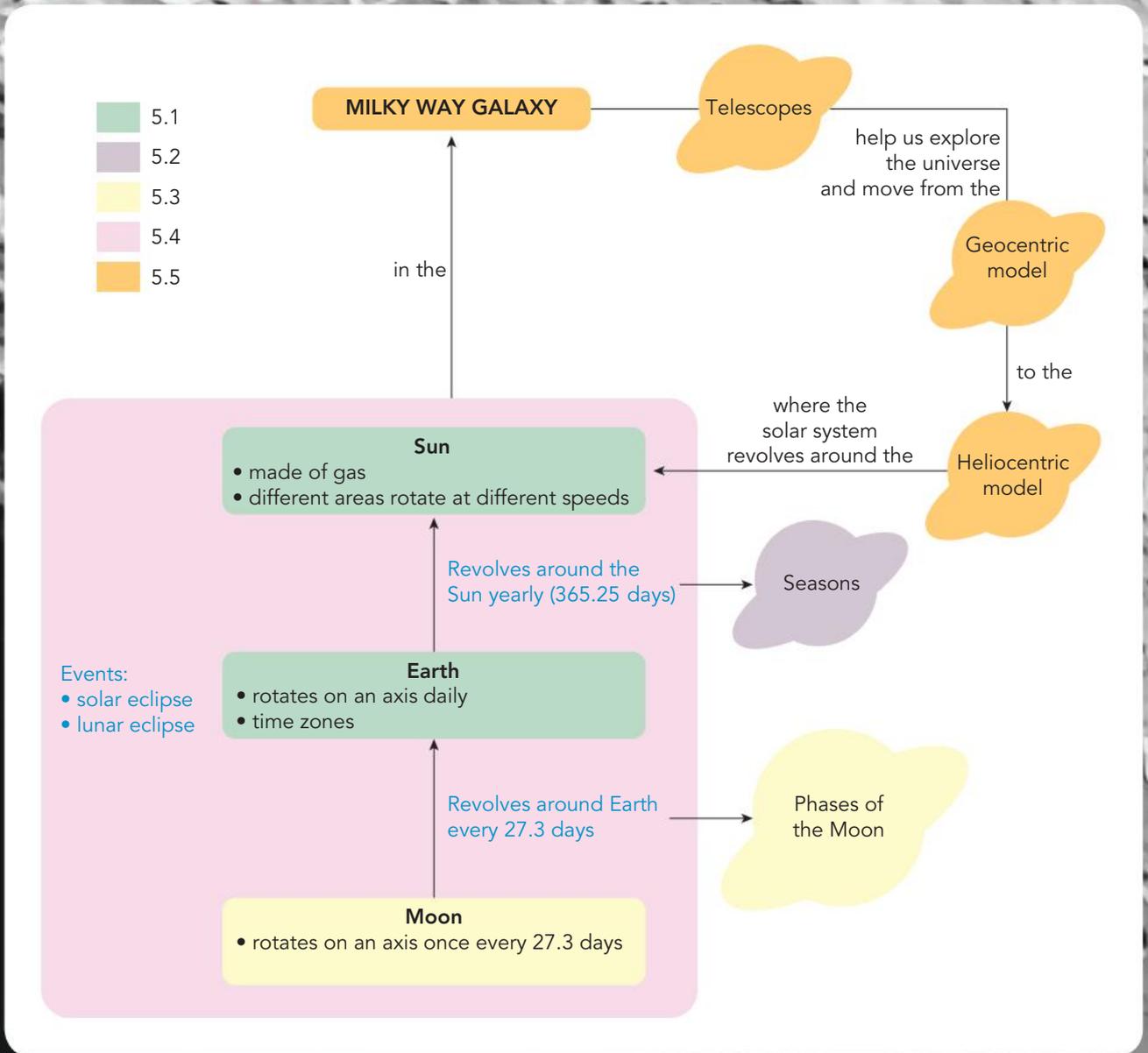
Planet Earth



Chapter introduction

In this chapter, you will find out more about the world you live in and investigate the motion of Earth, the Moon and the Sun through space. You will learn why a day is 24 hours long and why different countries have different time zones. You will also learn why there are seven days in a week and 365.25 days in a year, and why there are seasons, phases of the Moon, and solar and lunar eclipses. You will investigate how technology has been used to improve the observations made of the night sky and how these observations have given us a clearer picture of the structure of our solar system, our galaxy and the large-scale structure of our universe.

Chapter map



5.1 Our rotating Earth



Learning goals

- 1 To be able to describe the effect of Earth's rotation on temperature and time zones.
- 2 To be able to state the rotation times for the Earth, Moon and Sun.

The daily cycle

Have you ever thought about how much of your life is regulated by a daily routine? Much of this is determined by Earth, the Moon and the Sun.

Try this 5.1

The daily cycle

In small groups, think about and describe your observations of the Sun, Earth, Moon and stars during a typical day. For example, the day begins officially at midnight when the date changes. The new day starts in darkness. Most people are asleep as the dawn approaches. When the morning sun appears over the horizon, it is time for us to wake up. Birds announce the dawn, animals that hunt at night look for somewhere to hide and animals that are busy during the day get up to look for food. Now, keep going with the list, but remember to focus on the changes in the Sun, Earth and the Moon. List any other changes you have seen as the day or night progresses. Remember, you are only looking at what changes over a period of 24 hours, so do not include weather events because they do not repeat every day.



Figure 5.1 Perth City at sunrise. Temperatures usually rise during the day as the Sun provides heat to the environment.

Did you know? 5.1

Some flowers have a daily cycle. Daisies close their petals at night and open them again during the day. Arctic poppies and sunflowers turn their heads to follow the Sun as it moves across the sky.



Figure 5.2 Daisies have their petals open during the day (left) and close them as the light fades (right).

Try this 5.2

Finding out why

For this activity, you will need a round yellow balloon or ball, another smaller balloon or ball, and a marker pen.

In small groups, choose a question from the list below and come up with an explanation to share with the rest of the class.

- Why does it get warmer during the day and colder at night?
- Why does the Sun appear to move across the sky?
- Why do stars appear to move across the sky at night?
- Why is there maximum risk of sunburn between 10 a.m. and 2 p.m.?
- Why does the length of your shadow change during the day?

To help with your explanation, use the larger yellow balloon/ball to represent the Sun, the smaller balloon/ball to represent Earth. Draw a map of Australia on the smaller balloon/ball with a small dot to represent your location.

Our rotating Earth

Earth is a giant ball in space that is spinning anticlockwise (when viewed from the North Pole), one rotation per day. Sunlight shines on one side, while the other side is in darkness. The side of Earth facing towards the Sun experiences day and the side facing away experiences night. **Dawn** and **dusk** lie on the boundary between light and dark when the Sun is on the **horizon**. The Sun does not actually move across the sky. It appears to do so because Earth is rotating. If you are facing north, then Earth rotates from the west to east, which is why the Sun appears from the east and sets in the west.

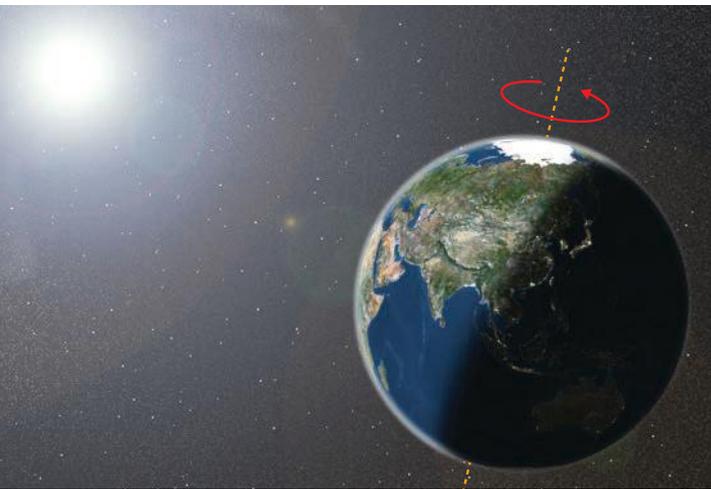


Figure 5.3 It is night-time in Australia as Earth turns on its axis with the Sun in the distance. This picture shows how day and night are caused by Earth's rotation.

Did you know? 5.2

Venus rotates in the opposite direction to Earth, so on Venus the Sun rises in the west and sets in the east.

Did you know? 5.3

Because Earth is rotating anticlockwise, the whole state of Western Australia is moving to the east at around 400 metres per second, which is faster than the speed of sound. You do not feel like you are moving because everything around you is moving as well. In addition to the motion caused by its rotation, Earth is also moving anticlockwise around the Sun at a speed of around 28 kilometres per second. If an aircraft could fly at that speed, it would get to New York City from Perth in about 10 minutes!

Temperature and shadow changes

The temperature changes on Earth during the day are due to the position of the Sun in the sky. If you track one location on our spherical Earth, it is turning towards the Sun in the morning and away from the Sun in the afternoon. Noon, or midday, is when the Sun is at the highest point in the sky. This means the temperature at that location increases in the morning as the Sun rises in the sky and continues to increase throughout the day as the Sun provides heat. At night, there is no heat from the Sun in that location, and the temperature falls until the next day when the cycle repeats again.

dawn
the time of day when the Sun rises over the horizon or night turns into day

dusk
the time of day when the Sun drops below the horizon or day turns into night

horizon
the point where the sky appears to meet the land or the sea

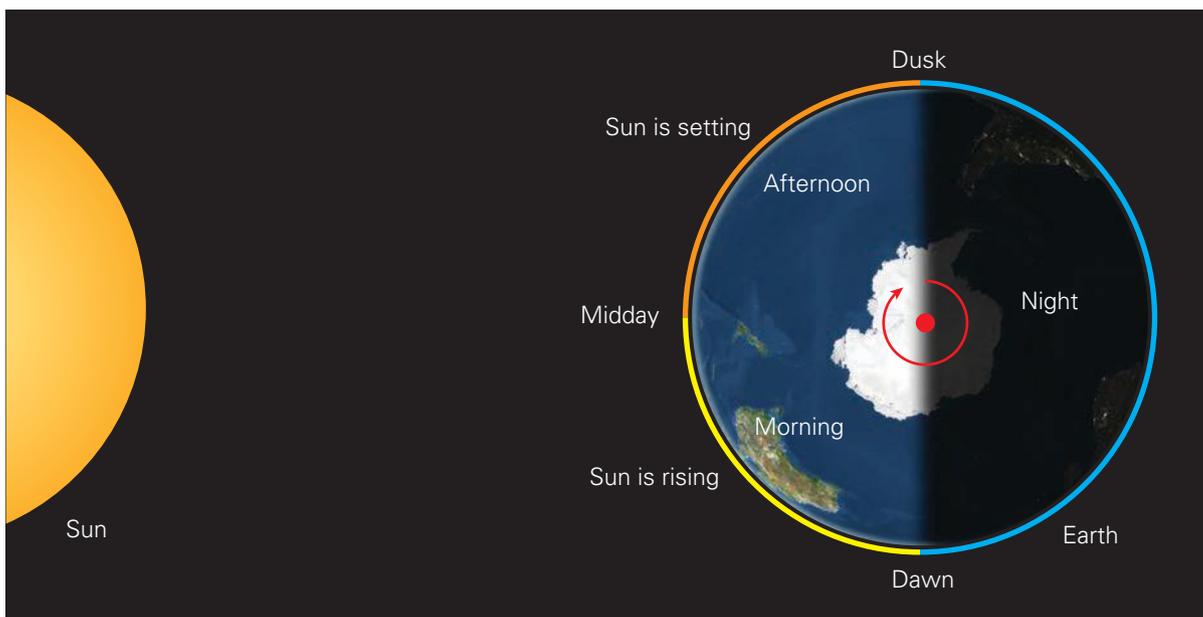


Figure 5.4 The view of Earth from above the South Pole. Earth is rotating clockwise from this pole. Different parts of the world experience morning (yellow), afternoon (orange) and night (blue). This image shows morning in Australia.

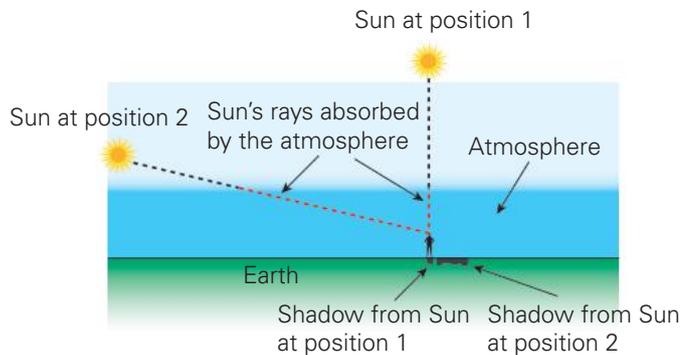


Figure 5.5 The Sun's rays pass through less atmosphere when it is close to being overhead due to their angle. For this reason, the midday sunlight is more intense and more likely to cause sunburn. The length of your shadow also changes.

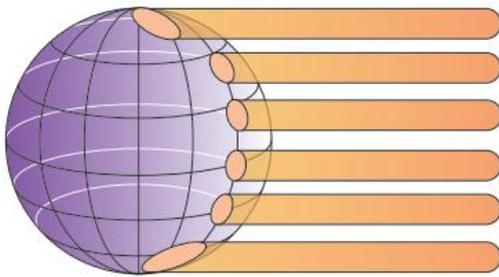


Figure 5.6 The angle of the Sun's rays also produce the different temperatures found around Earth. Equatorial regions are hotter than polar regions because they receive perpendicular rays (at a 90° angle).

Try this 5.3

Simulating the movement of the Sun

In a group, use a yellow balloon and a camera for this simulation. A simulation is a model of an event, or a way to see what happens without it actually happening.

- 1 Choose someone to be Earth and hold a camera.
- 2 Choose a second person to be the Sun by holding the balloon.
- 3 The person with the camera stands in front of the Sun and rotates slowly on the spot while recording a video.

What did you see? Did it appear as though the Sun is moving past the camera? What was the cause of the movement?

Did you know? 5.4

Antipodes

The place on the exact opposite side of the world to a region is called its antipode. The antipode of Perth can be found in Saint George's Island in Bermuda. If the Sun is setting in Perth, it is rising at its antipode. If it is winter in Perth, it is summer at the antipode.

continued...

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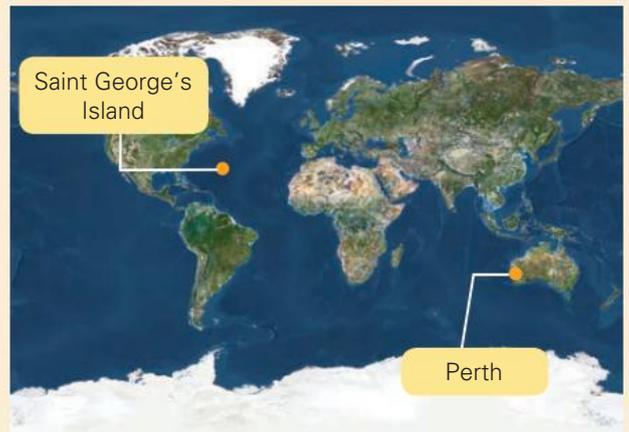


Figure 5.7 The antipode of Perth is in Saint George's Island, Bermuda.

Why do the stars move across the sky at night?

Like the Sun, the stars do not travel across the sky in a single night. Their movement is an illusion caused by Earth's rotation. To direct someone around the night sky, it makes no sense to say that a star is 5 cm to the right of another. So, we measure angles (out of 360 degrees) instead. But what if you don't have a protractor? No matter! You have an inbuilt one. Hold your hand out at arm's length and close one eye. Make a fist so you can see the back of your hand. Stick your index and little finger up and look at the night sky, this makes approximately 15 degrees in the night sky. If you then stretch out your thumb and little finger, this is approximately 20 degrees. One finger is one degree.

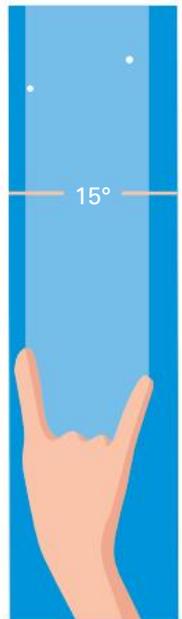


Figure 5.8 You can measure the distance stars travel by using your hand.

Did you know? 5.5

The changing night sky

The night sky appears differently over time. The current North Star is Polaris, but in about 13 000 years it will be Vega. This is owing to a rotation of the Earth's axis (precesses) caused by the gravitational pull of the Sun and the Moon. The period of precession takes about 26 000 years.



Figure 5.9 A star trail photograph illustrates the apparent motion of stars in the night sky due to Earth's rotation.

Quick check 5.1

- 1 Define the following terms in your own words: rotation, dawn, dusk.
- 2 Explain why the Sun and stars appear to move across the sky.
- 3 Explain why it is cooler at night and warmer during the day.
- 4 Explain the effect of the Sun on shadows when it is directly overhead, as opposed to at a low angle in the sky.



VIDEO
Describe the movement of the stars

Time zones

It takes about 24 hours for Earth to complete one rotation, which is 360 degrees. This means Earth is rotating at a rate of about 15 degrees per hour. For this reason, Earth is divided vertically into 24 **time zones**, each of which is about 15 degrees or one hour apart. At certain times of the year, there may be up to 38 time zones because of time differences due to daylight saving of half or one hour. It does get complicated! Time zones are measured from Greenwich in the UK, with the time in Greenwich called Greenwich Mean Time (GMT). As a time standard, it is now referred to as Coordinated Universal Time (UTC).

time zone
Earth is divided into 24 time zones, each about 15 degrees of longitude and each one representing a time difference of 1 hour

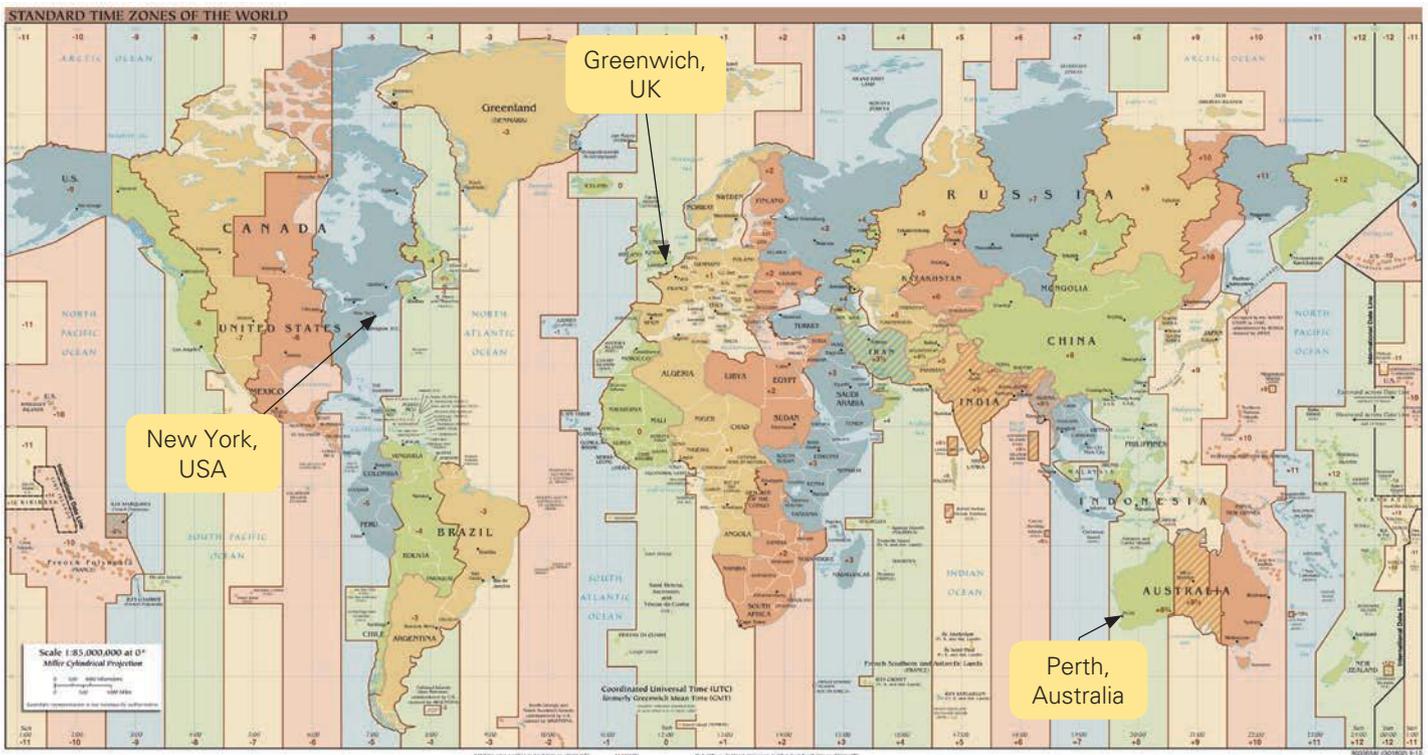


Figure 5.10 The time zones of the world. The state of Western Australia is 8 hours ahead of GMT because it is about 120 degrees east of Greenwich, whereas New York is 5 hours behind GMT because it is about 75 degrees west of Greenwich.

Some states and countries adopt daylight saving, which involves moving clocks forward at the beginning of summer. There are two good reasons for daylight saving. Firstly, it delays the dawn in summer by an hour, so people who are sleeping get an extra hour of sleep before being woken by the rising Sun. Secondly, daylight saving saves energy since the Sun sets an hour later so households do not use as much electricity for lighting at night. In Australia, daylight saving is used in South Australia, New South Wales, Australian Capital Territory, Victoria and Tasmania. Western Australia trialled daylight saving in 2006 for three years, but residents voted against the continuation of daylight saving time thereafter.

Did you know? 5.6

Mars has blue sunrises and sunsets!

The Martian atmosphere is too thin to scatter blue light, but it is full of dust particles that scatter red light. This means that during the day, the red light is scattered to observers on the surface instead of blue light and the sky looks red! On the other hand, at dawn and dusk the sunrises and sunsets are blue!



Figure 5.12 A beautiful blue sunset on Mars, taken by the NASA Mars Curiosity rover

Explore! 5.1

Indirect effects of Earth's rotation

Some amazing things in our world are linked to Earth's daily cycle but are not directly a consequence of Earth's rotation. Using the internet, research to find out more about these indirect effects. For example, why does the wind usually seem to blow from the sea during the day?



Figure 5.11 Why is the sky red at sunset?

Clouds are illuminated by the Sun at sunset. The blue light from the Sun has travelled through the atmosphere and has been scattered, leaving only red light to illuminate the clouds. Red light does not scatter as much because it has a longer wavelength than blue light.

Quick check 5.2

- 1 State by how many degrees Earth rotates in one hour.
- 2 State how many time zones there are.
- 3 Describe how the time zones are determined.
- 4 Describe the advantages of daylight saving time.

Does the Sun rotate like Earth?

The Sun also rotates but at a very different speed to Earth. Unlike Earth and the Moon, the Sun is not solid – it is a hot gas – so different parts of the Sun rotate at different speeds. The equator of the Sun rotates about once every 25 days, while the poles (top and bottom) rotate at a much slower rate, about once every 38 days. Even though 25 days sounds like a long time, the Sun is so big that the surface at the equator is still travelling at around 2 kilometres per second!

sunspot
feature on the Sun's surface
that moves very slowly across
the surface

There are dark spots on the surface of the Sun called **sunspots**. These can be seen

with special equipment and are seen to rotate with the surface of the Sun, which provides evidence that the Sun rotates. You must **never** look at the Sun to see sunspots – you will not see them anyway and it is dangerous to look at the Sun, even with sunglasses.

Be careful

Never use binoculars or telescopes to look anywhere near the Sun.

Quick check 5.3

- 1 State how long one rotation of the Sun takes.
- 2 Explain how it is known that the Sun rotates.

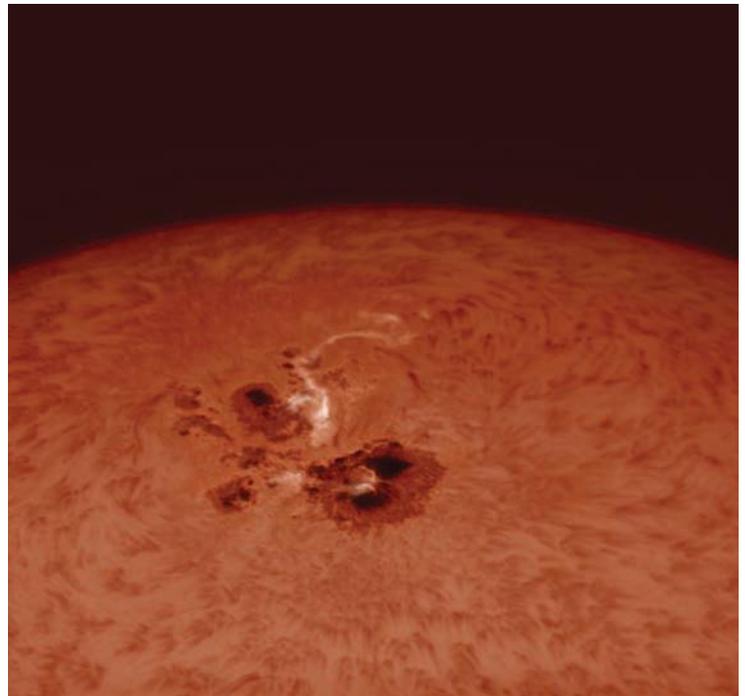


Figure 5.13 Sunspots, such as the one shown, stay visible for about 11 years.



VIDEO
Describe the Sun's surface and contrast it to Earth's



QUIZ

Section 5.1 questions

Remembering

- 1 **Recall** how long it takes Earth to complete one full rotation.
- 2 **State** what time of day the Sun reaches its highest point in the sky.
- 3 **State** what the abbreviation GMT means.
- 4 **Describe** how sunsets on Mars are different from those on Earth.

Understanding

- 5 **Explain** how Earth experiences day and night.
- 6 **Describe** why the Sun, Moon and stars rise in the east and set in the west.
- 7 **Explain** how your shadow changes length over a day.

Applying

- 8 Find out what the current time is in Perth and Melbourne. **Explain** your findings.
- 9 **Explain** at what time of the day is it most important to wear sunscreen and seek shade in Western Australia.

Analysing

- 10 **Predict** what would happen if Earth did not have different time zones.
- 11 **Propose** the benefits of introducing daylight saving time.

Evaluating

- 12 'If Earth stopped rotating, one side of Earth would be in total darkness all the time.' **Decide** whether you think this statement is true. Give your opinion on how life would be different if Earth did not rotate and justify your answers.

5.2 Earth's yearly cycle



Learning goals

- 1 To be able to recognise that gravity keeps planets in orbit around the Sun.
- 2 To be able to describe the cause of seasons in different regions on Earth.

elliptical
oval shaped

orbit
the curved path of a celestial object or spacecraft round a star, planet or moon

revolution
one complete orbit

leap year
a year that happens every four years and has an extra day on 29 February

mass
the amount of substance in an object that never changes, even in space

gravitational field
the region around an object where another object can experience its gravity or pull

Southern Hemisphere
the half of Earth south of the equator

Northern Hemisphere
the half of Earth north of the equator

equator
an imaginary line drawn around the middle of Earth equidistant between the North and South poles

Apart from rotating on its axis, which results in the day-night cycle that repeats every 24 hours, Earth also orbits around the Sun following an **elliptical** path. It takes 365.25 days for Earth to travel around the Sun; the path is called an **orbit**. One complete orbit around the Sun is called a **revolution**. The calendar is made simple by using 365 days and adding an extra day once every 4 years, on the 29th of February. We call that year a **leap year**.

Why does Earth orbit the Sun?

The Sun has a large **mass** and attracts the Earth which has a smaller mass. The **gravitational field** of the Sun

causes the Earth to orbit the Sun. The Sun is 333 000 times heavier than Earth and so the gravitational field of the Sun causes Earth to orbit the Sun.

Seasons

You may have observed that over the course of a year, each day is slightly different. In the **Southern Hemisphere**, where Australia is located, the day length decreases from January to June and increases from July to December. The shortest day occurs around 21 June. The longest day occurs around 21 December. The opposite happens in the **Northern Hemisphere** where the longest day is in June and the shortest day is in December. Interestingly, for places on the **equator**, the day length is always 12 hours every day of the year.

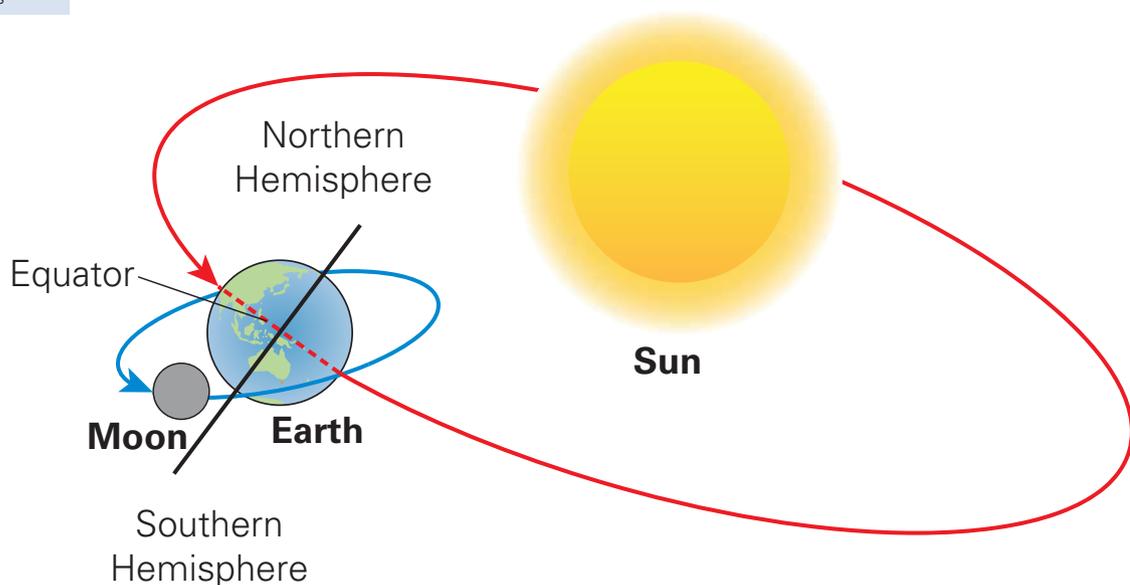


Figure 5.14 The Moon orbits around Earth, and Earth orbits around the Sun. Standing at the North Pole, the rotation appears anticlockwise.

Aboriginal and Torres Strait Islander seasons

Aboriginal and Torres Strait Islander peoples have different ways of mapping the seasons, depending on where they live. In the south-west of Western Australia, the Noongar people's calendar shows six *bonar* (seasons). *Birak* is a dry and hot season and falls between December and January. *Bunuru* is the hottest time in Western Australia's south west and falls between February and March. *Djeren* is when the temperature starts to decrease and falls between April and May. *Makuru* is the cold and wet season and falls between June and July. *Djilba* is when the temperature starts to rise and fall between August and September. *Kambarang* is the start of the dry seasons and falls between October and November. Other Aboriginal groups in Western Australia consider different numbers of seasons depending on the subtle changes in climate across Western Australia.

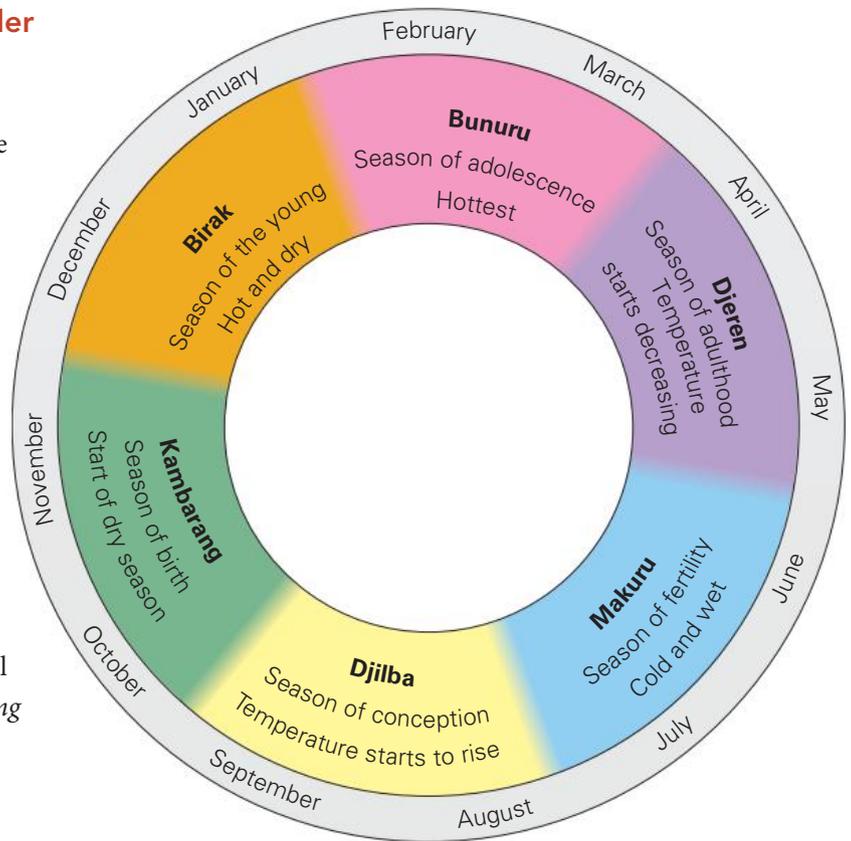


Figure 5.15 Noongar seasonal calendar



Figure 5.16 Serpentine Falls in Whadjuk, Noongar boodja (Country)



Why do seasons occur?

Believe it or not, Earth's tilt can explain all of these observations! The axis of rotation of Earth passes through the North and South Poles. It is set at an angle of 23.5° from the vertical and the angle does not change as Earth goes around the Sun.

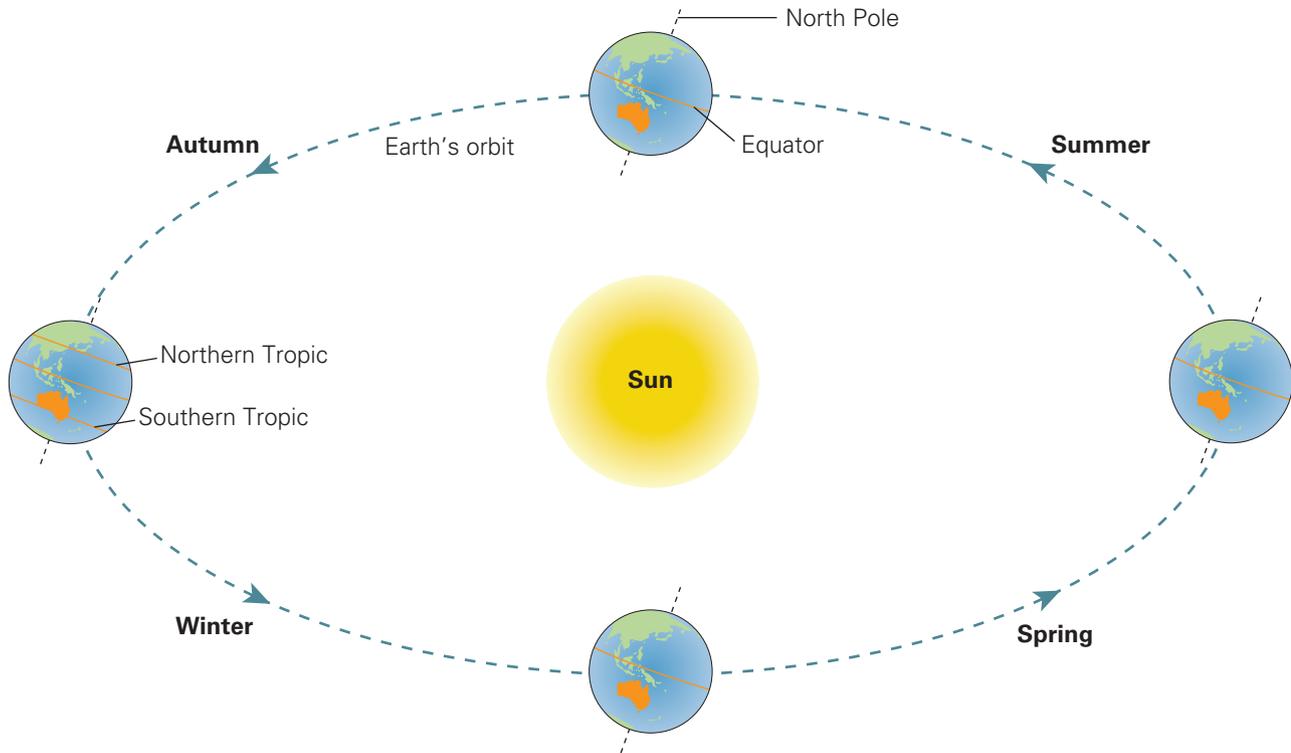


Figure 5.17 Seasonal arrangements of the Earth and the Sun. The tilt of the Earth causes the different seasons during the year. Australia is shown in orange.

Did you know? 5.7

The length of a year

In the 10th century, Al-Battani, an astronomer who lived in what is now known as Syria, discovered that the length of a year was 365 days, 5 hours, 46 minutes and 24 seconds. In 1073, this was refined by the Persian astronomer poet Khayyám. He found that 1 029 983 days made 2820 years, producing a year length of 365.2422 days. We now know the average year length is 365.242189 days, which is less than one second different from Khayyám's 11th century calculation!

Figure 5.18 Summer at Jurien Bay, Western Australia



Figure 5.19 Autumn at Balingup, Western Australia



What changes during the year from season to season?

What things do you observe throughout the year that can be explained by the seasons changing? Discuss with your group and see how many of the following you came up with.

- The number of hours of daylight changes. During the year, the time the Sun rises and sets changes. In spring, the days get longer and in autumn the days get shorter.
- The places on the horizon where the Sun rises and sets moves. The Sun always rises

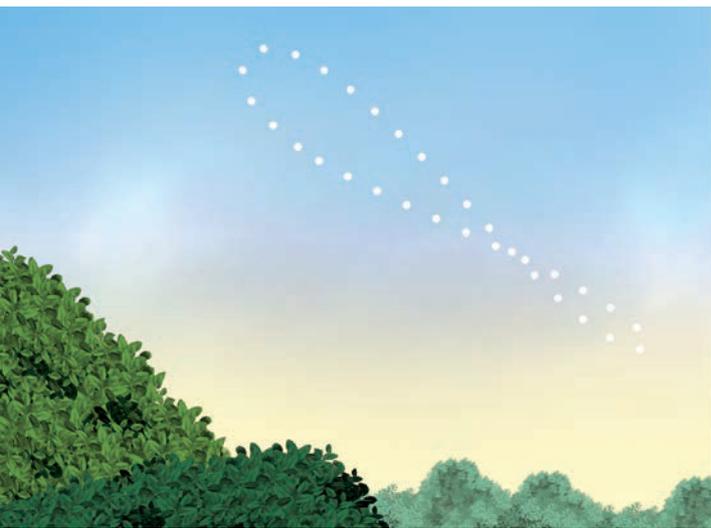


Figure 5.20 This illustrates the position of the Sun at the same time each week for a whole year.

- in the east and sets in the west, but the position varies, moving south in spring and north in autumn.
- The average daily temperature is colder in winter and hotter in summer. The difference between average summer and winter temperatures increases as you move away from the equator.
- The height of the Sun in the sky at midday increases in summer and decreases in winter.
- Some animals and plants change their behaviour and appearance at different times of the year. In winter, deciduous trees lose their leaves, some animals hibernate and others migrate. In the warmer months, birds nest and lay eggs, and plants produce flowers and then fruit though there are winter-flowering plants as well.
- Seasonal changes also affect people. For example, farmers are heavily reliant on seasons for their livelihood. They can only sow and harvest at certain times of the year.

Quick check 5.4

- 1 Define the terms 'orbit', 'revolution' and 'elliptical' in your own words.
- 2 State how long it takes for the Earth to orbit the Sun.
- 3 Describe things that change during the year due to the seasons.

Figure 5.21 While it does not typically snow in Western Australia, light snowfall has been reported in some areas such as Bluff Knoll, during winter.



Figure 5.22 Wildflowers blooming in spring in Cape Naturaliste, Western Australia



Practical 5.1: Investigation

Modelling the seasons

Aim

To investigate how the angle of Earth to the Sun affects the temperature of the area where the light hits.

Prior understanding

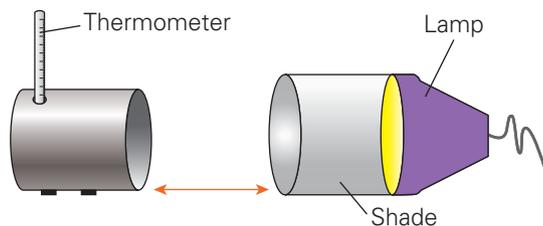
Light is energy from the Sun. Light rays can cause an area to heat up when they hit the surface of the area and are absorbed. When the Sun's rays hit Earth's surface close to the Equator, the energy is more direct (as it is closer to a 90° angle), so the area becomes warmer.

Materials

- 1 opened aluminium can with a small hole drilled in the side for the thermometer
- 1 thermometer
- putty adhesive
- lamp (a lamp used to heat reptile cages would be ideal)
- cylinder/rectangular shape to cover the lamp and direct light forward
- 1 m ruler or tape measure
- whiteboard with 1 cm graph paper or grid attached

Method

- 1 Attach a shade to the light to direct the light forward as much as possible.
- 2 Attach the thermometer through the hole in the can, making sure it is not touching the bottom. Secure in place with some of the putty adhesive.
- 3 Set up the equipment as shown. Keep the can upright, securing the bottom to the table with the adhesive putty.



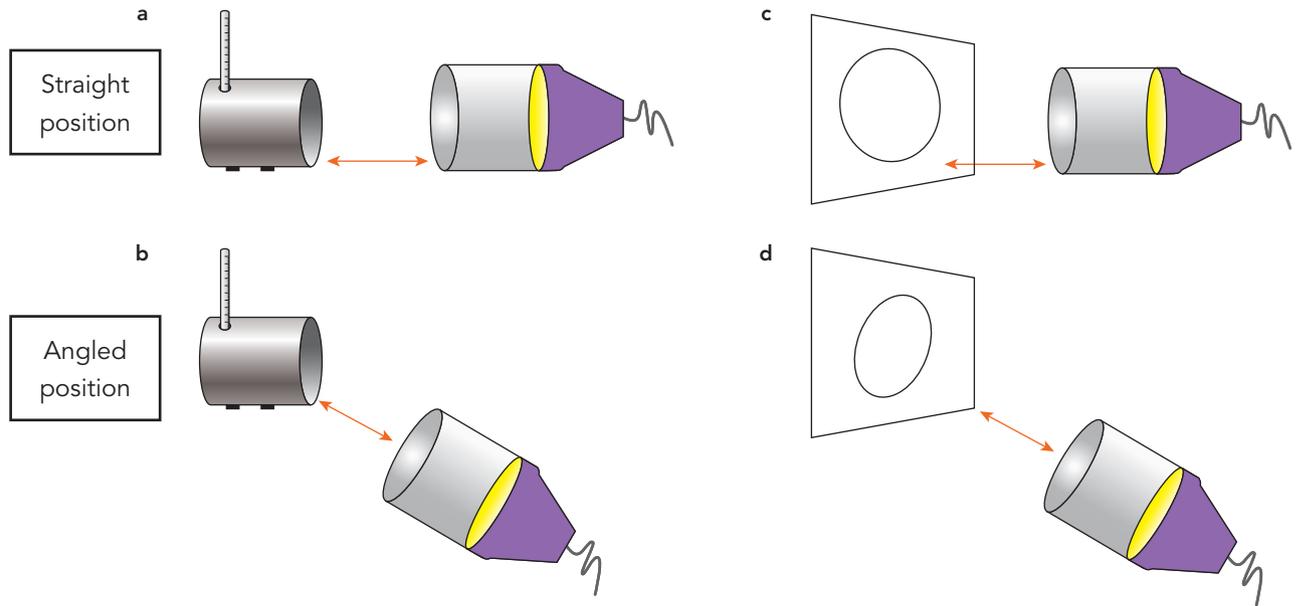
- 4 Copy the results table into your science book.
- 5 Measure the *direct, or straight position*
 - a Measure the temperature inside the can and record.
 - b Turn on the light for 15 minutes.
 - c Measure the temperature inside the can and record.
- 6 Repeat steps **5a–5c** for two more trials.
- 7 Place the whiteboard in front of the lamp and measure the diameter of the beam hitting the board, as shown in Figure **c** on the next page. Record the result.
- 8 Rotate the light until it is 30° to the tin as shown in Figure **b**.
- 9 Repeat steps **5–7** to measure the *angled position*.

Be careful

Take care when handling light sources after extended use. They may be hot.
Take care when handling the opened can as it may have sharp edges.

continued...

...continued



Results

Independent variable: Angle to the light		Dependent variables					
		Temperature (°C)			Light		
		Initial	Final	Change	Diameter of the beam (cm)	Radius of the beam (cm)	Area of the beam (cm ²)
Straight position	Trial 1						
	Trial 2						
	Trial 3						
	Mean						
Angled position	Trial 1						
	Trial 2						
	Trial 3						
	Mean						

- 1 Add up your three initial temperatures for the straight position, then divide by three. This is your mean.
- 2 Repeat for the final temperatures and the change in temperature.
- 3 Repeat for the angled position data.
- 4 Divide your diameter data into two to calculate the radius.
- 5 Use this radius data to calculate the area, by using $A = \pi r^2$ ($3.14 \times \text{radius}^2$).

Discussion

- 1 Describe the differences between the change in temperature when the lamp is in the straight position and when it is in the angled position.
- 2 Compare the area of the beam when it is in the straight position to when it is in the angled position.
- 3 Identify which group simulated the way the Sun hits the South Pole. Explain your reasoning.
- 4 Discuss how much variation was observed between the trials for each group.
- 5 Identify any other factors (control variables) that may have changed and affected the results.
- 6 Identify any changes that could be made to the method to improve the quality of the data in future experiments.
- 7 Discuss how the investigation could be extended in future experiments.

Conclusion

Develop a conclusion about the relationship between the area of the light beam and the temperature change.

Explore! 5.2

How do animals adapt to the seasons?



Figure 5.23 Short-beaked echidnas hibernate.

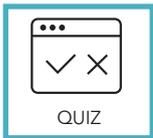


Figure 5.24 The common greenshank is one of many shore birds that migrate to and from the Broome region every year.

The cycles of animal and plant life follow the seasons.

Research bird migration and animal hibernation. Select one species from each category and summarise what you find out, including a picture and why it hibernates or migrates.

Section 5.2 questions



Remembering

- 1 **State** how long a complete cycle of all four seasons takes.
- 2 **Describe** how plants and animals act differently in summer than in winter.

Understanding

- 3 **State** the reason for the seasons on Earth.
- 4 **Explain** the progression of the seasons. You may draw a diagram to help. Remember to label each position with the corresponding season.

Applying

- 5 It is winter in Australia. **Infer** the month.
- 6 It is winter in Canada. **Infer** the month.
- 7 It is spring in New Zealand. **Infer** the month.

Analysing

- 8 **Deduce** how the seasons are different in the most northern part of Western Australia. Think about the geographical location in comparison to Perth.
- 9 **Describe** what the effect would be if the angle of tilt of Earth's axis of rotation was increased by 5°.
- 10 The table shows hours of daylight in Perth on 30 April 2020.

Date	Sunrise	Sunset	Hours of daylight
30 April	6:47 a.m.	5:39 p.m.	10 h 52 min.

State whether you expect the number of daylight hours to be more or less than 10 hours 52 minutes on 1 May 2020.

Evaluating

- 11 The Sun only lights up a tunnel containing a statue of Rameses twice a year. **Propose** how the Egyptian sculptors might have seen in the dark to carve a statue of Rameses if the Sun only lights up the tunnel twice a year.
- 12 The summer solstice is when the Sun reaches its highest point in the sky, and the winter solstice is when the Sun reaches the lowest point in the sky. These are marked by the longest and shortest days respectively. **Propose** in which months these occur in the Southern Hemisphere. Justify your answer.

5.3 Movement of the Moon

Learning goal

- 1 To be able to describe how the phases of the Moon are caused.

Recall that Earth orbits around the Sun because the Sun has greater mass. Earth's mass is 81 times the mass of the Moon and so, for the same reason, the Moon revolves around Earth (at about one kilometre per second).

The phases of the Moon

Although the Moon looks bright, it does not give out any light of its own. All the light that comes to us from the Moon is reflected from the Sun. Only the half of the Moon that faces the Sun is bright, the other half is in shadow. The area of the bright side that you can see from Earth depends on the phase of the Moon. Figure 5.25 shows the names of the phases of the Moon.

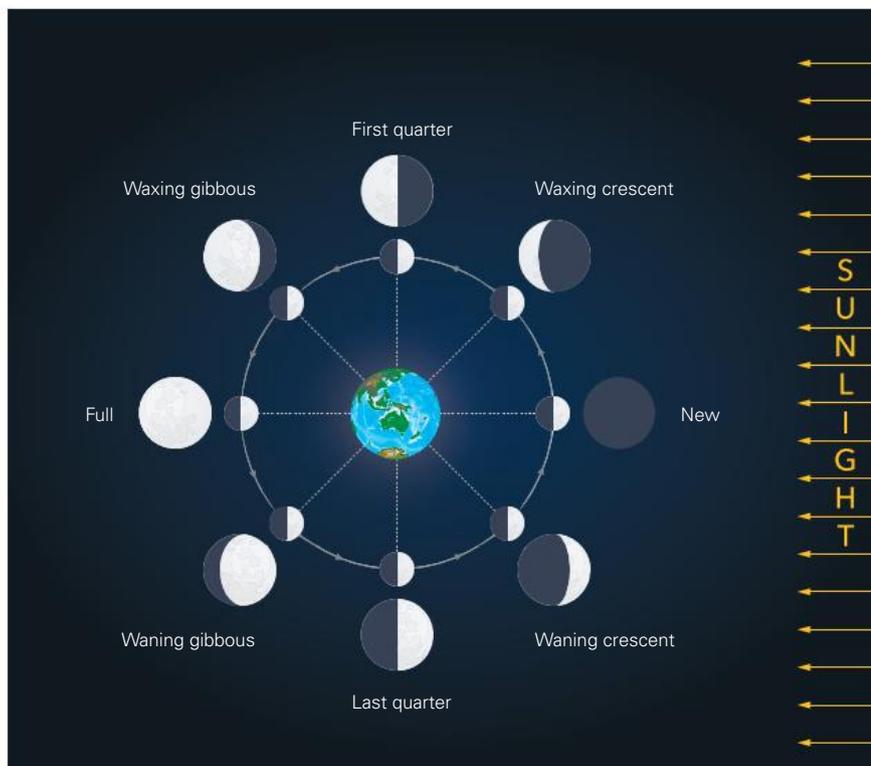


Figure 5.25 The phases of the Moon in the Southern Hemisphere

waxing

the period of about two weeks where the illuminated part of the Moon is increasing from a new moon to a full moon

waning

the period of about two weeks where the illuminated part of the Moon is decreasing from a full moon to a new moon

synchronous rotation

occurs when the rotation of an orbiting body is the same length of time as its revolution around a larger body

Note that between a new moon and a full moon, the Moon is **waxing**.

Between the full moon and a new moon, the Moon is **waning**.

Have you ever wondered how the Moon keeps the same face towards Earth? Observe the Moon over a period of two weeks. You will see that even though the phase changes,

the craters and coloured areas on the Moon stay the same.

The reason the Moon always presents the same face to Earth is that the time taken for it to rotate once is the same as the time it takes to orbit Earth. The Moon takes about 27.3 days to orbit Earth – the same time it takes to rotate just once. This is known as **synchronous rotation**.

Quick check 5.5

- 1 Explain how you can see the Moon if it does not give off any light of its own.
- 2 Explain why the Moon's surface always looks the same from Earth.

Explore! 5.3

Neap tides

The gravitational pull of the Moon and the Sun on the Earth affects the oceans, causing a continuous change between daily low and high tides. When new moons and full moons occur, the gravitational force of the Sun and the Moon act together and create spring tides which are higher and lower than usual. Neap tides, on the other hand, occur when there is the smallest difference between high tide and low tide. Aboriginal and Torres Strait Islander peoples have traditional stories regarding how the Moon is associated with tides. Research how knowledge of neap tides helps Torres Strait Islanders.

Science as a human endeavour 5.1

The days are getting longer!

The Moon is moving through space at a speed of one kilometre every second! It used to move much faster and was much closer to Earth. Over millions of years, it has slowly moved away and now moves more slowly around Earth. Scientists study rocks that are millions of years old to understand what planet Earth was like a long time ago. They have found that when the Moon was a lot closer to Earth, the days on Earth were only 18 hours long! The further away the Moon is, the slower Earth rotates. The Earth's speed of rotation is constantly being recalculated for use in systems such as the Global Positioning System (GPS).

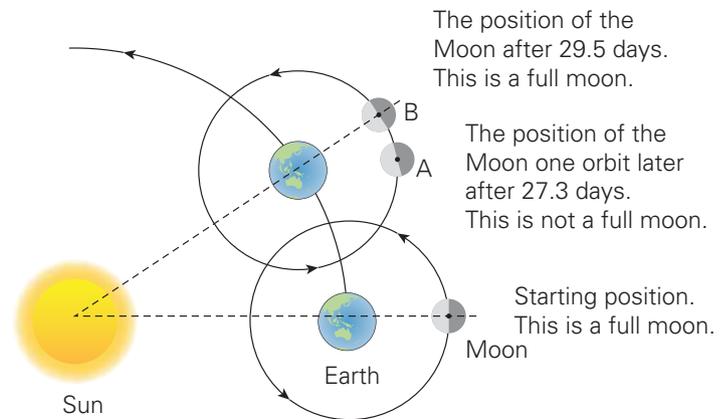


Figure 5.26 The Moon used to be closer to Earth. It is moving away from us at a rate of 3.8 cm per year.

Moon orbit versus moon phase

One thing you might notice is that the time the Moon rises and sets is an hour later every day. You might also notice that each day the Moon's phase changes slightly. It takes 29.5 days (hence a month is about 30 days) to complete a cycle of phases from new moon to full moon and back to new moon. Recall that it takes 27.3 days for the Moon to rotate and orbit once around Earth. Why are they different?

If Earth was not orbiting the Sun, both times would be the same. This means the reason must be related to Earth's movement. A full moon occurs when Earth, the Sun and the Moon form a straight line. After the Moon has completed an orbit 27.3 days later, Earth has moved and the Moon is no longer in line with Earth and the Sun.



It takes the Moon 2.2 days to move from A to B. The Moon has completed one orbit at A, the next full moon is at B.

Figure 5.27 The time between full moons and the orbital period of the Moon is different by 2.2 days.

To form the next full moon and to line up with Earth and the Sun again, the Moon has to keep moving for another 2.2 days.

Explore! 5.4

How many times have astronauts landed on the Moon?

The lunar map on the right shows the face of the Moon with the NASA Apollo and Surveyor, and Soviet Luna Moon landings labelled. The first Moon landing was Luna 9 in 1966 and the first crewed landing was Apollo 11 in 1969. Like most maps and pictures of the Moon, the North Pole is at the top.

Investigate the other times astronauts have landed on the Moon. Draw up a timeline to summarise all the landings you find out about. Include details of the date, landing location, country of origin and names of the spacecraft.

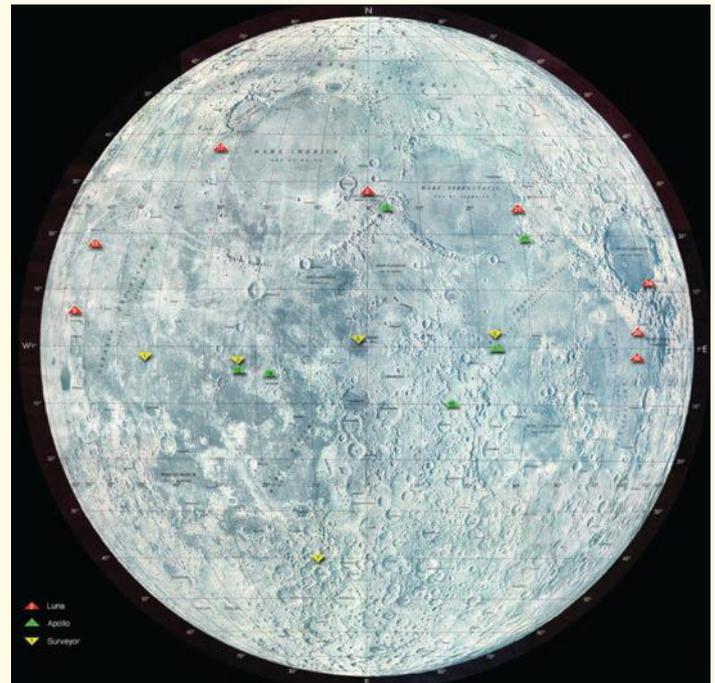


Figure 5.28 Soviet (red triangles) and USA (green and yellow triangles) lunar landing sites

Science as a human endeavour 5.2

What does the far side of the Moon look like?

Because the Moon always turns the same face towards Earth, the **far side** was not seen until spacecraft started to visit the Moon. The first images were seen in 1959 when the Soviet probe Luna 3 sent back pictures to Earth. Over the past 60 years, NASA has sent out many probes to explore the solar system and have obtained clearer images of the far side of the Moon.

far side

the face of the Moon that is always turned away from Earth; also called the dark side

Figure 5.29 Image of the far side of the Moon taken in 1959. Detailed maps have now been made of the far side but until now, no crewed mission has landed on its surface.

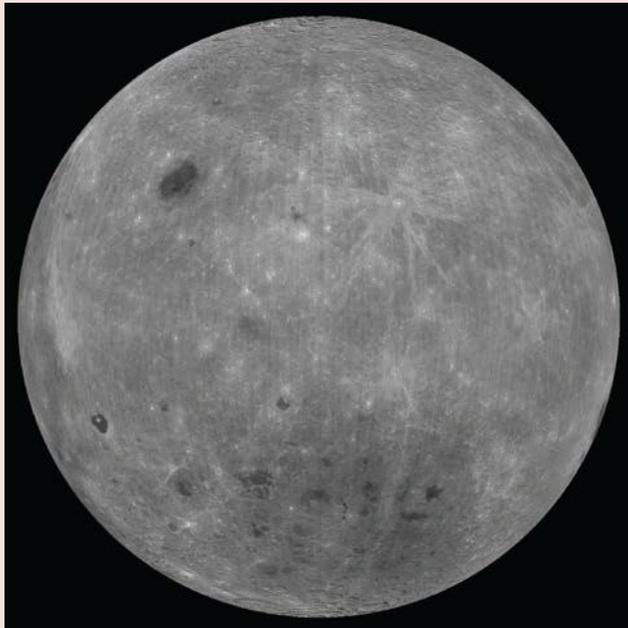
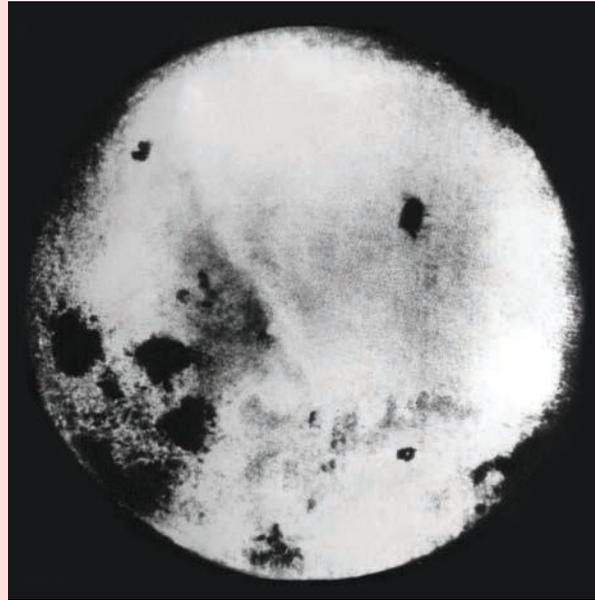


Figure 5.30 (a) The far side of the Moon and (b) the near side (Northern Hemisphere view). The dark patches visible on the Moon's surface are called seas. They are not made of water but were once liquid in the form of molten rock or lava that flowed out into low-lying areas on the Moon's surface.

Quick check 5.6

- 1 Define the terms 'waxing' and 'waning'.
- 2 Explain how you can tell the Moon is moving through the sky.
- 3 State how long it takes to complete a full cycle of the Moon's phases.
- 4 How do scientists know what the far side of the Moon looks like?

Try this 5.4

Modelling the phases of the Moon

Using an electric lamp, an 8 cm polystyrene ball and a pencil, follow the instructions to model the phases of the moon. Draw diagrams of your observations at each point in the cycle.

- 1 Stick the pencil into the foam ball so that the pencil can act as a handle. Place the lamp in the centre of a darkened room.
- 2 Extend your arm so you are holding the foam ball in front of you. The ball should be between your eyes and the lamp. The foam ball is modelling the Moon, the lamp is the Sun and your head is Earth. Note that the polystyrene ball does not generate light of its own, it reflects light from the lamp.
- 3 The Moon starts off in a 'new moon' position, as you can only see the unlit side.
- 4 Sweep your right arm in a clockwise direction to model the waxing moon phases. Move your head to the side to observe these phases. Record what you see in a results table.
- 5 Once the Moon is behind your head, it will be in the 'full moon' phase unless your head (Earth) is blocking the light and creating a lunar eclipse.
- 6 Switch the ball to your left hand and continue moving it clockwise back to the start to simulate waning phases of the Moon.

Describe where the ball was in relation to your head when it was at the following phases: new moon, full moon, waxing gibbous, waning gibbous, waxing crescent, waning crescent, first quarter, last quarter. Propose how you could improve this simulation.

Be careful

Take care when handling light sources after extended use – they may be hot.

Section 5.3 questions

Remembering

- 1 **State** how fast the Moon is moving.
- 2 **State** how long the Moon takes to orbit Earth.
- 3 **Describe** the surface of the Moon.
- 4 **List** the phases of the Moon.

Understanding

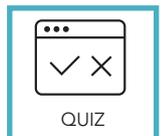
- 5 **Explain** why the time taken for the Moon to orbit Earth is different to the time between full moons.
- 6 **Explain** why a half-lit moon is called a quarter moon.

Applying

- 7 **Compare** the speed of the Moon today to the speed it travelled millions of years ago.
- 8 **Explain** with the aid of a diagram why the Moon takes 27.3 days to orbit Earth and yet there are 29.5 days from one full moon to the next.
- 9 **Determine** the approximate number of weeks there are from first quarter phase to last quarter phase of the Moon.

Analysing

- 10 Use the chart in Figure 5.31 on page 200 showing the phases of the Moon for a particular year to answer the questions.



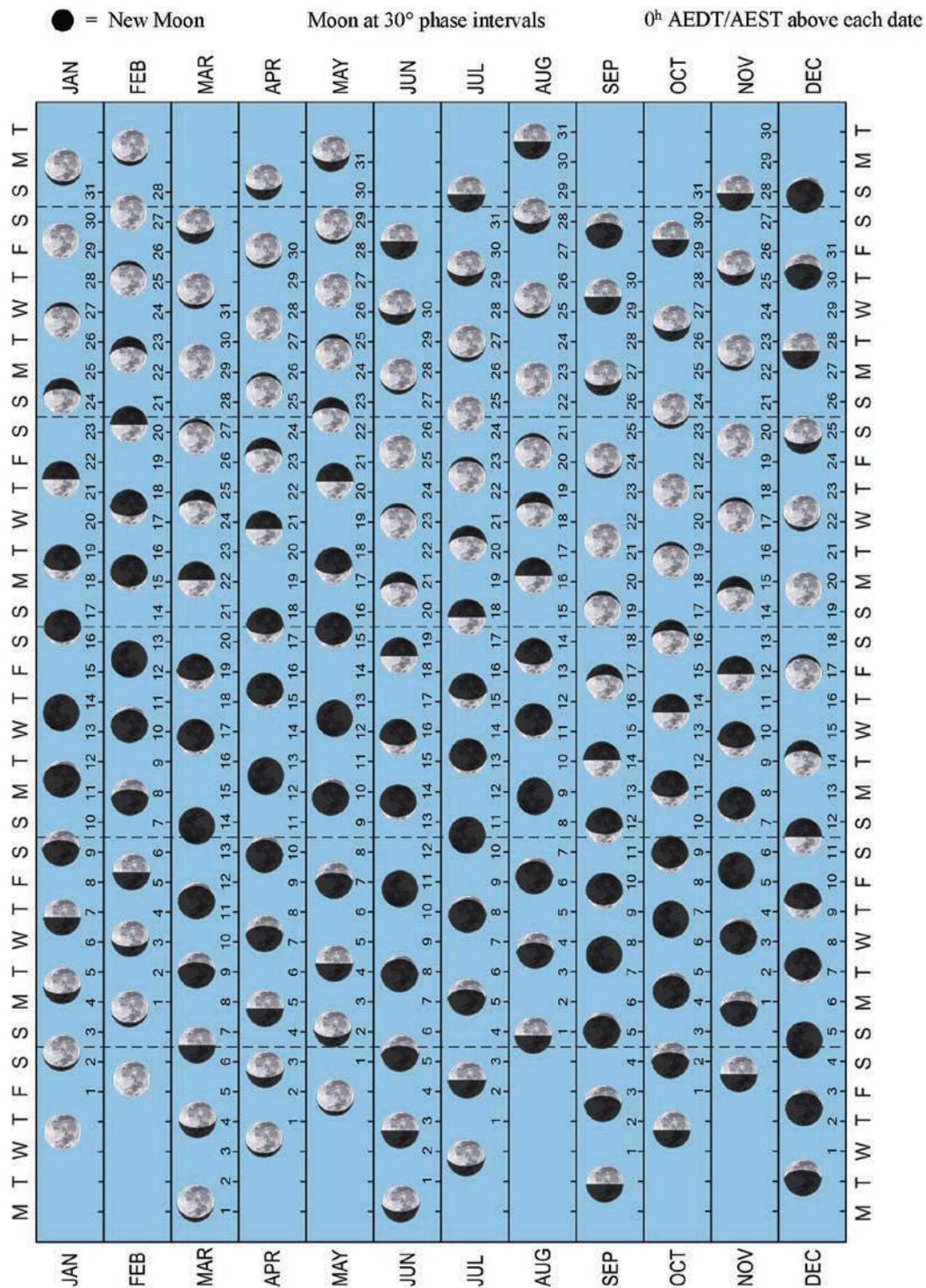


Figure 5.31 This chart from the Astronomical Society of Victoria shows the dates for each of the Moon phases in the year 2021.

- Describe** the phase of the Moon on July 13.
 - Describe** the phase of the Moon on February 12.
 - The saying 'Once in a blue moon' is used when discussing anything that happens rarely. A blue moon occurs if there are two full moons in a month. **Analyse** Figure 5.31 to see if there were any blue moons in that year.
- 11 Explain** how it is possible for the Sun's equator to rotate at a different rate to the Sun's polar regions.

Evaluating

- 12 Predict** how the Moon would look if it did have an atmosphere and experienced weather.

5.4 Eclipses

Learning goal

- 1 To be able to describe the cause of a solar and a lunar eclipse.

The motions of Earth around the Sun and the Moon around Earth are complex and require mathematics to describe them precisely. However, they are predictable. By looking for patterns in observations made over many years, ancient astronomers could anticipate with reasonable accuracy some of the events you are going to learn about, such as:

- **solar eclipses**, where the Moon blocks the light from the Sun and casts a shadow on a small part of Earth
- **lunar eclipses**, which occur when Earth's shadow blocks the light travelling to the Moon.

Solar eclipses

What happens when the Moon blocks the Sun?

Once a month, in its orbit around Earth, there is a chance that the Moon may come exactly between Earth and the Sun. If this

happens and the Sun, Moon and Earth all line up, astronomers call it a **syzygy** and the result is a solar eclipse. Because the Moon is considerably smaller than Earth, a solar eclipse is only visible from a small region on Earth's surface.

Total versus partial eclipse

During a solar eclipse, the Moon blocks the light from the Sun on a small part of Earth's surface. A **total eclipse** is visible from the dark coloured central part of the shadow called the **umbra**. A **partial eclipse** occurs when the light from the Sun is partially blocked, and the eclipse is visible from the area that is lightly shaded on Earth called the **penumbra**. Both the umbra and penumbra are so small that even if there is a solar eclipse most people will not see it.



WORKSHEET



VIDEO
Eclipses

solar eclipse

an event when the Sun partly or completely disappears from view, while the Moon moves between it and Earth

lunar eclipse

a full Moon becomes dark as it enters Earth's shadow

syzygy

the occurrence in astronomy of three or more objects moving into a straight line

total eclipse

an event when the Sun is completely blocked by the Moon

umbra

the region in a shadow where the light is completely blocked

partial eclipse

an event when the Sun is partially blocked by the Moon

penumbra

the region in a shadow where the light is partially blocked

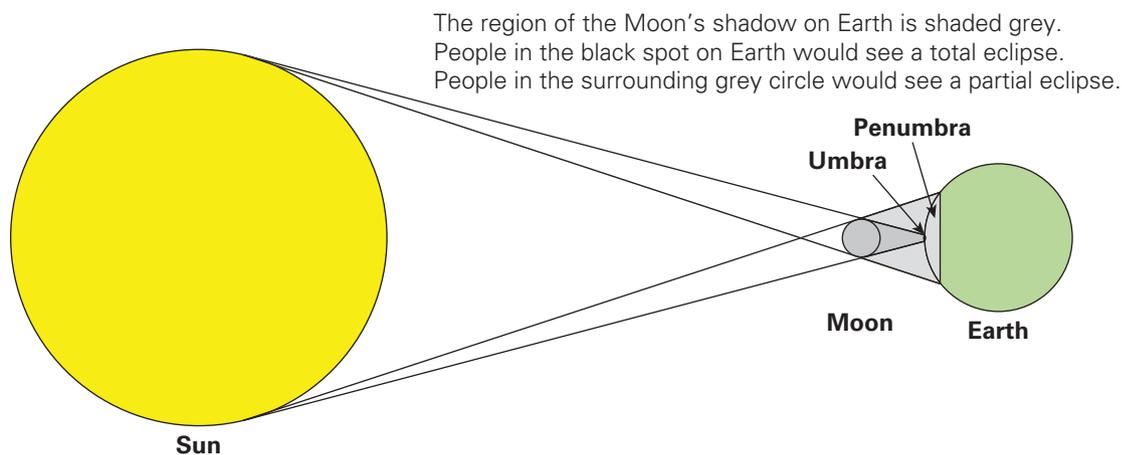


Figure 5.32 A solar eclipse occurs when the Moon comes between Earth and the Sun. This diagram is not to scale and the size of the shadow areas is greatly exaggerated.

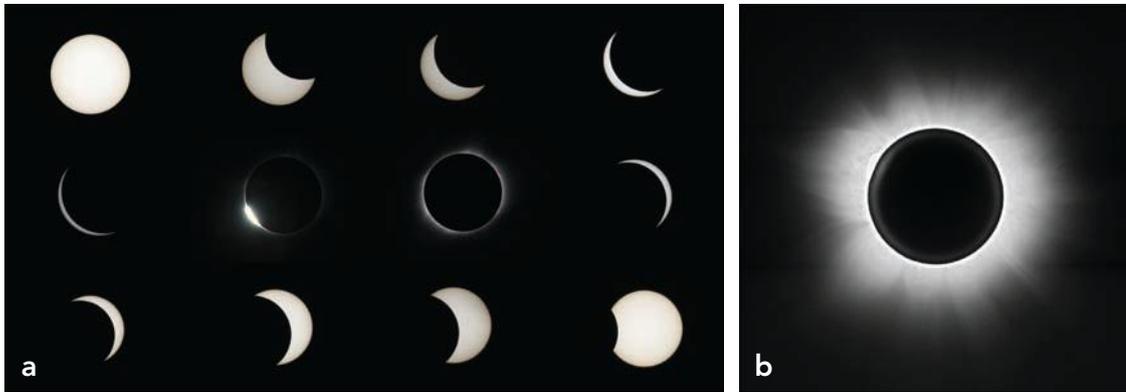


Figure 5.33 This series of images shows (a) the stages of a total solar eclipse, and (b) totality.



Figure 5.34 A solar eclipse photographed from the International Space Station. The Moon's shadow covers only a small fraction of Earth's surface.

Try this 5.5

How far is it to the Sun?

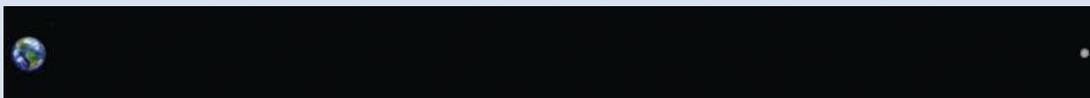


Figure 5.35 Earth and the Moon are drawn here to scale. The Sun is 400 times further away than the Moon.

Measure the distance from Earth to the Moon in Figure 5.35. Multiply the distance by 400 to work out how far away the Sun would be if it were also included in the picture. The distance between the Earth and the Sun is known as 1 Astronomical Unit (1 AU). Using this unit prevents having to write huge numbers when we are measuring in kilometres.

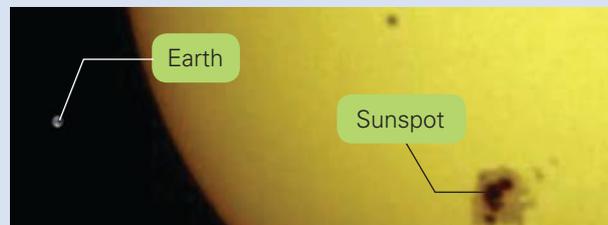


Figure 5.36 It might be tempting to think that the Sun is of a similar size to Earth because its light can be blocked by the Moon, but the Sun is much larger than Earth. In this image, Earth is placed next to a portion of the Sun to show their relative sizes.

What is an annular eclipse?

The Sun is about 400 times bigger than the Moon but is also 400 times further away, so from Earth the Moon and Sun appear to be about the same size. This means that the Moon is just big enough to hide the Sun when it passes in front. However, the orbits of Earth and the Moon are not perfect circles and the Moon's apparent size can vary by up to 12% in its orbit around Earth. If the

solar eclipse occurs when the Moon is closest to Earth, (**perigee**), the result is a total eclipse. If the Moon is at its furthest point, (**apogee**), the result is an **annular eclipse**.

The mathematical word for the shape you get when you cut a small circle from the centre of a larger circle is an annulus, so this type of eclipse is called an annular eclipse.

perigee
the point in the Moon's orbit when the Moon is closest to Earth

apogee
the point in the Moon's orbit when it is furthest from Earth

annular eclipse
an event when the Moon blocks the Sun but the Moon is further away and the outer edge of the Sun is still visible

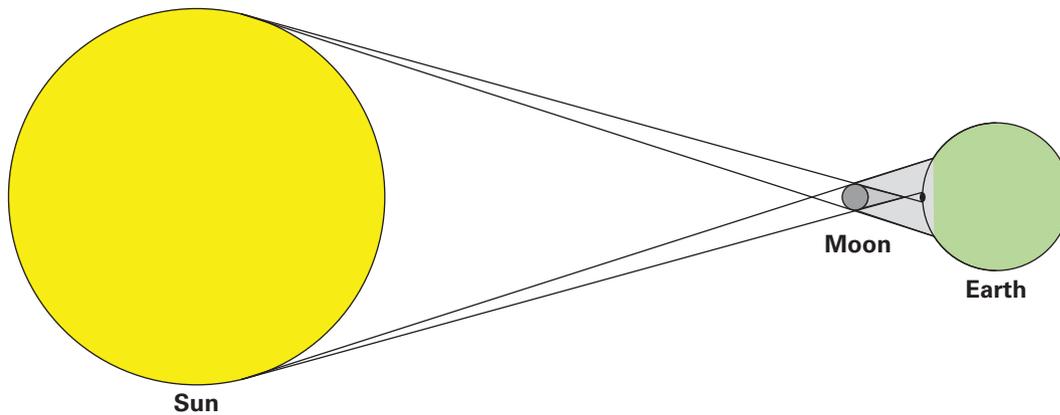


Figure 5.37 If the Moon is not at its closest to Earth at the time of the eclipse, the result is an annular eclipse. The dark area is where an annular eclipse can be seen; the lightly shaded region on Earth's surface experiences a partial solar eclipse (not to scale).



Figure 5.38 An annular solar eclipse seen through a cloud

Explore! 5.5

Aboriginal and Torres Strait Islander stories of the Sun and Moon

For some Aboriginal and Torres Strait Islander peoples, the Sun is female and the Moon is male. Many traditional stories involve one chasing the other across the sky, meeting whenever there was an eclipse.

Research the story that the Yolngu people of northern Australia tell of *Ngalindi* (the Moon).

Quick check 5.7

- 1 Define the term 'syzygy'.
- 2 Explain why a solar eclipse is visible from only a small part of Earth.
- 3 Explore the difference between a blue moon and a super moon.

Lunar eclipses

What happens when the Moon moves into Earth's shadow?

A lunar eclipse occurs when the Moon moves into Earth's shadow.

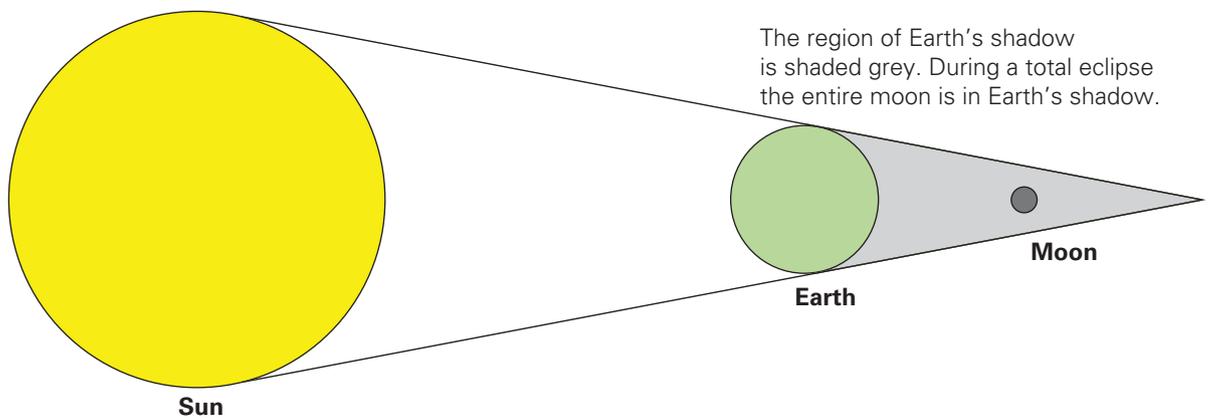


Figure 5.39 Earth is much bigger than the Moon, so Earth's shadow is big enough to cover the whole of the Moon.



Figure 5.40 A total lunar eclipse in progress. The round edge of Earth's shadow is visible.

When the Moon is completely in Earth's shadow during a total lunar eclipse, it is called a **blood moon**. The red colour is due to red light being refracted (bent) by the atmosphere around

Earth. Hence only red light reaches Earth during the total eclipse.

blood moon

a name given to the Moon during an eclipse while it is completely in Earth's shadow



Figure 5.41 A blood moon during a total eclipse is due to the red light being refracted by Earth's atmosphere.

Comparison of solar and lunar eclipses

Although the Sun and Moon are involved in both kinds of eclipse, solar and lunar eclipses are very different. A solar eclipse is a rare event and results in the sky turning dark during the day, whereas a total lunar eclipse happens at night and results in the full moon moving into Earth's shadow.

	Total solar eclipse	Total lunar eclipse
Duration	A few minutes	A few hours
Who can see it	A small area only	Everyone on Earth who can see the Moon
Occurrence	Once every 18 months	1–2 per year
Safety	Special equipment required to view	Safe, anyone can watch, no special equipment required
Cause	Moon's shadow on Earth	Earth's shadow on Moon
Moon phase	New moon	Full moon

Table 5.1 Differences between solar and lunar eclipses

Try this 5.6

Modelling solar and lunar eclipses

Use the materials listed to model a solar and lunar eclipse.

- high wattage lamp
- globe
- tennis or golf ball
- string

Record your observations of the shadows created in this model. Explain how you modelled a solar eclipse in this activity. Explain how you modelled the lunar eclipse. Predict what would happen if you change the size of the ball. Discuss how this model could be improved.

Be careful

Take care when handling light sources after extended use – they may be hot.

Section 5.4 questions

Remembering

- 1 **Recall** the phase of the Moon when a lunar eclipse occurs.
- 2 **Recall** the phase of the Moon when a solar eclipse occurs.

Understanding

- 3 **Describe** why eclipses are so rare.
- 4 **Explain** why a person is likely to see many more lunar eclipses in their lifetime than solar eclipses, even though both events occur with similar frequency.
- 5 **Explain** why the Sun and Moon appear the same size in the sky.

Applying

- 6 **Describe** how our experiences on Earth would be different if the Moon was larger.

Analysing

- 7 **Compare** a partial and a total solar eclipse.

Evaluating

- 8 **Outline** the factors that need to be considered when viewing a solar eclipse versus a lunar eclipse.



5.5 Exploring the universe



Learning goal

- 1 To be able to describe how models of the solar system have changed over time.

The solar system

Earth is one of eight planets that orbit the Sun. All the planets except Mercury and Venus have moons. Jupiter, which is the biggest planet, has more than 70 moons. The solar system is the name given to the Sun and all its orbiting planets, including Earth, as well as dwarf planets such as Pluto.



Figure 5.42 The solar system includes Earth. All the planets except Uranus and Neptune can be seen without a telescope.

telescope

an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

The invention of the **telescope** gave us much more information about the solar system. With the introduction of the telescope, scientists discovered that Jupiter had moons and Saturn had rings. Scientists were able to look further into the solar system and the planets Uranus (1781) and Neptune (1846) were discovered.

Explore! 5.6

Pluto, discovered in 1930, used to be considered a planet. Investigate why Pluto was reclassified as a dwarf planet in 2006. State the criteria that disqualified Pluto from being a planet.



Figure 5.43 Dwarf planet Pluto



Figure 5.44 Jupiter and three of its moons: Ganymede, Europa and Callisto

Science as a human endeavour 5.3

Geocentric versus heliocentric models of the solar system

Aristarchus of Samos who lived from around 310 BC to 230 BC developed the first known **heliocentric model** of the solar system; that is, all planets, including Earth, rotated around the Sun. His theory was rejected by many philosophers and astronomers at the time because they did not think such a thing could be physically possible.

The most popular theory held by many astronomers in ancient times assumed that the Sun, planets, even the whole universe revolved around Earth. This model is called the **geocentric model** and was published in a book *The Mathematical Collection* by Ptolemy (Figure 5.45), an astronomer, geographer and mathematician who lived in 90–168 AD. All astronomers at that time used this model and it continued to be the preferred explanation of how the solar system works for more than a thousand years.

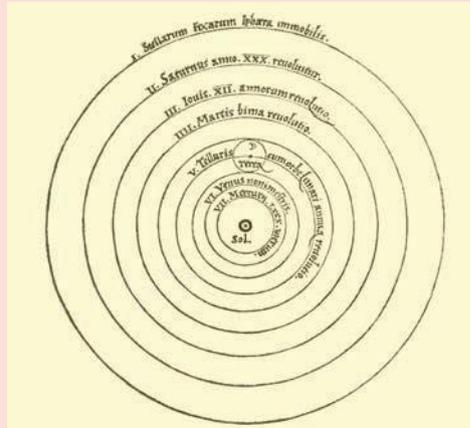


Figure 5.46 The diagram of Copernicus' heliocentric system, in Latin, as it appears in his book *De Revolutionibus orbium coelestium, On the revolutions of the heavenly bodies*, in 1543. 'Sol' is the Sun and 'Terra' is Earth.

heliocentric model
a model with the Sun as the centre of the solar system

geocentric model
a model where Earth was the centre of the universe

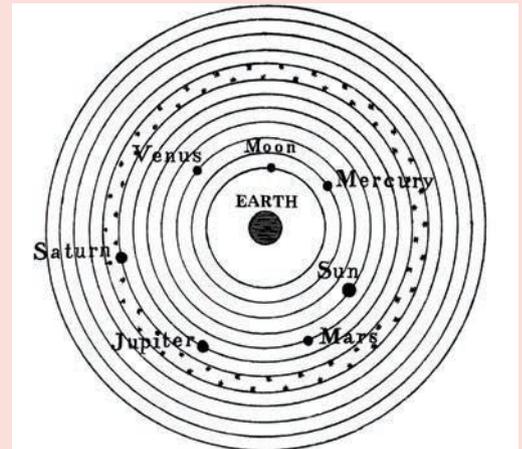


Figure 5.45 Historical artwork of the Earth-centred (geocentric) Ptolemaic cosmological model

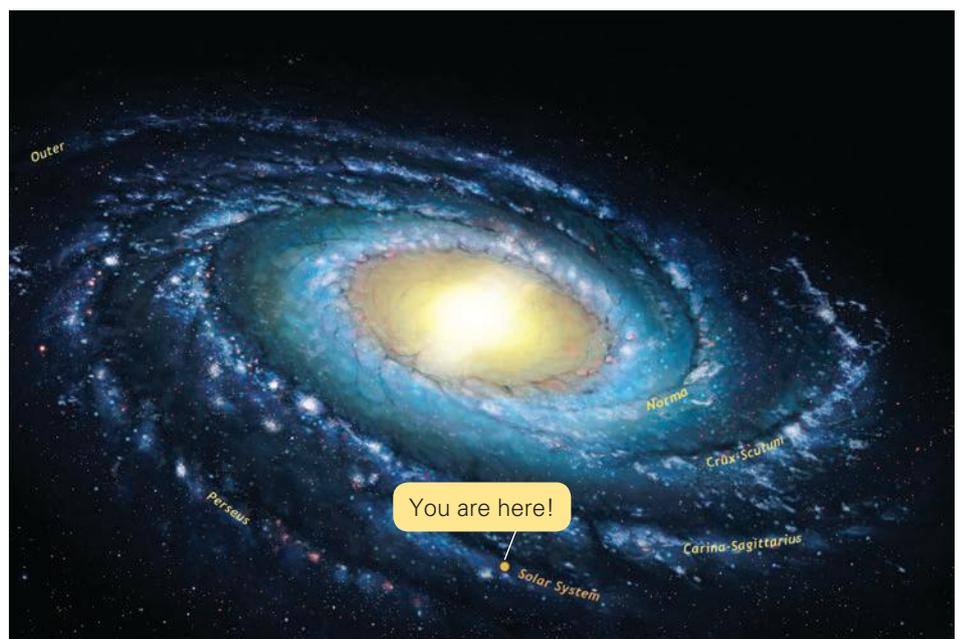
It was not until the year 1543, approximately 1400 years after Ptolemy (and 1800 years after Aristarchus!), that Nicolaus Copernicus published his heliocentric model, borrowing from the work of Aristarchus. The model stated that, in fact, it is Earth that revolves around the Sun (Figure 5.46).

In 1610, Galileo Galilei, an Italian astronomer, first looked at the heavens with a telescope and made observations confirming that the geocentric model was incorrect. About 150 years after Copernicus published his work, Isaac Newton (a physicist and mathematician) finally produced convincing proof that supported the heliocentric model.

Our galaxy

Outside the solar system is where the most exciting discoveries were made. The band of light that can be seen on dark moonless nights was found to be made up of countless individual stars and it was realised that our Sun is just one star in a galaxy of billions of stars called the Milky Way.

Figure 5.47 The Milky Way Galaxy showing the position of our solar system



Try this 5.7

Making a refracting telescope

Materials

- 2 cardboard tubes
- convex lens with 30 cm focal length
- convex lens with 5 cm focal length
- piece of card paper
- poster adhesive or glue
- elastic bands

Method

- 1 Use poster adhesive or glue to fix the lenses to each of the cardboard tubes, as in Figure 5.48.
- 2 Wrap the piece of card around the tube with the lenses facing outwards. Secure with elastic bands.
- 3 Look at an object in the distance with your eye closer to the smaller lens. Focus the telescope by lengthening or shortening the tube. The length of the tube should be about 35 cm for viewing distant objects.

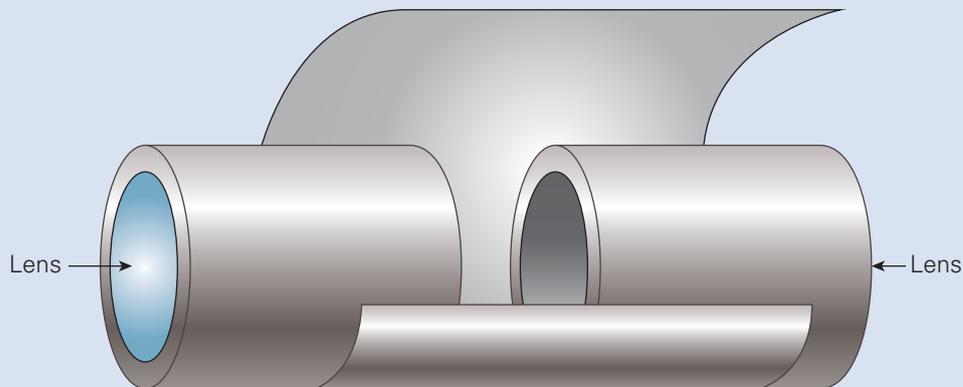


Figure 5.48 Make your own telescope

Describe how well your telescope worked. Explore how simple telescopes like this have helped scientists throughout history.

Improvements on the telescope

The telescope has had a huge influence on our understanding of the universe and our place within it. There have been several technological advances in telescope design over the centuries. The first big advancement in telescope design was an invention by Newton who discovered a way to make powerful telescopes by replacing the refracting lenses with reflecting mirrors. Over time, bigger telescopes were made that could see more detail. Observatories were built to house these giant telescopes on top of mountains to minimise the distorting effect of the atmosphere.

While it is easy to measure the brightness of a star, more information can be obtained by attaching a spectrometer to a telescope.

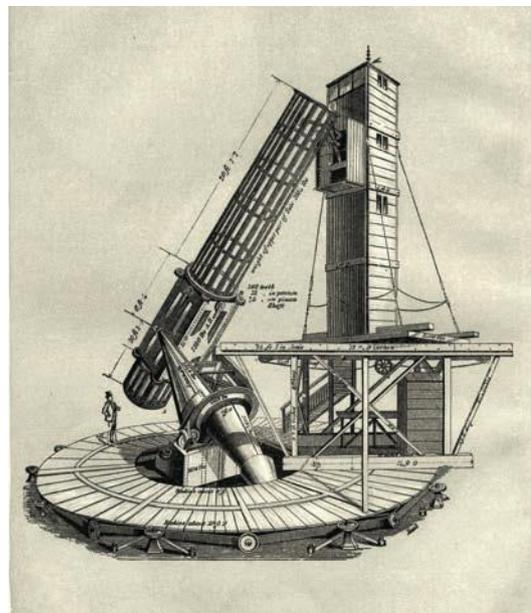


Figure 5.49 A sketch of a Newtonian telescope, 1870, a type of reflecting telescope that used two mirrors

This allows astronomers to analyse the colours in the light from a star. The colour of a star indicates its temperature and by looking at the temperature and sizes of many stars, astronomers realised that stars do not stay the same but evolve over time. Using this information, astronomers estimate that our Sun is about 4.6 billion years old and is expected to continue shining for a further 4.6 billion years.

Galaxies outside our own?

Edwin Hubble was an American astronomer who made a significant contribution to astronomy in the 1920s. Not only was he the first to realise that our galaxy, the Milky Way, was just one of billions of galaxies in the universe but he also discovered that the galaxies were all moving apart from one another. Using this fact, he estimated that the universe formed 12–13 billion years ago in an event now called the Big Bang and that it has been expanding ever since.

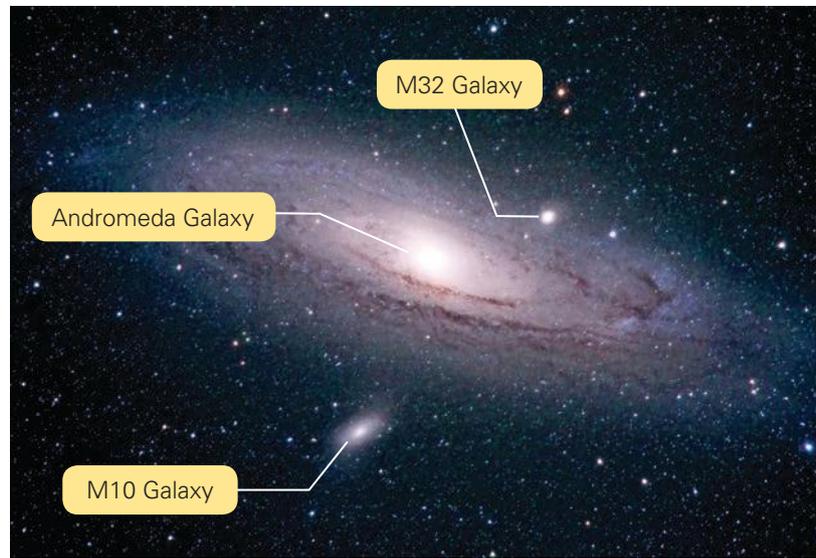


Figure 5.50 The Andromeda Galaxy. This nearby galaxy is similar in structure to the Milky Way. Two other galaxies (M10 and M32) are also visible.

Science as a human endeavour 5.4

The Hubble Space Telescope

Hubble's contribution was recognised when a telescope launched into space was named after him. The Hubble Space Telescope takes images that are free from any distortion from the atmosphere and, by using long exposure times, the images it takes are often both stunning and beautiful.

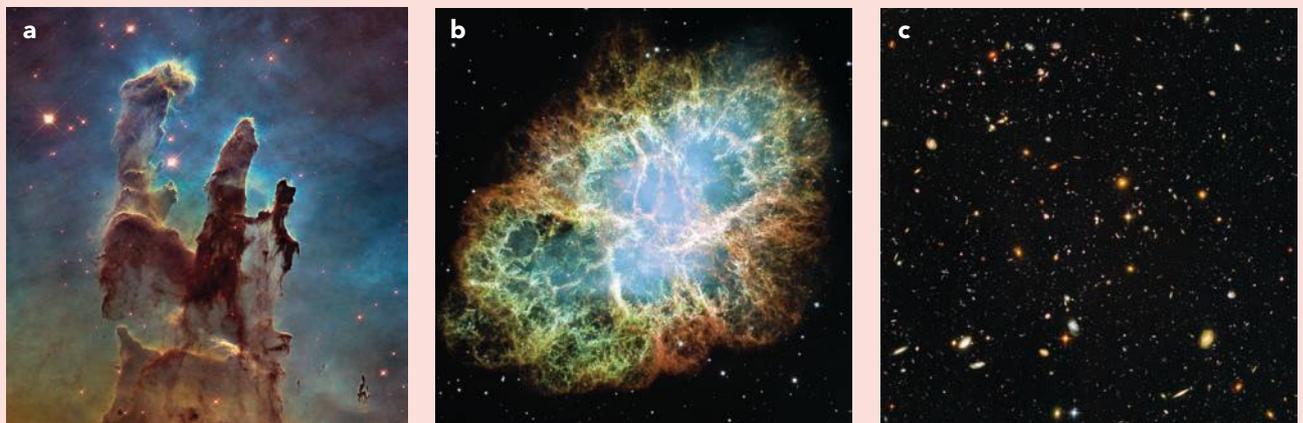


Figure 5.51 Images taken by the Hubble Space Telescope: (a) The Pillars of Creation, a star-forming region in our galaxy, (b) The Crab Nebula, the remains of a star that exploded in 1054 AD, (c) Hubble Space Telescope shows that even the darkest patch of sky is found to be full of galaxies.

Science as a human endeavour 5.5

The LUVOIR

While the Hubble Space Telescope provided a huge leap forward in making more of the universe visible, it has just about reached the end of its useful life. A new concept for a telescope named LUVOIR, (Large UltraViolet, Optical, and InfraRed Surveyor) can do much more than Hubble. It will be 15 metres in diameter and be able to collect 40 times the amount of light that Hubble could. Making use of the newest technology for telescopes today, it will provide much clearer pictures of the universe. It will be able to take pictures in the visible light spectrum (light that you can see) and also the ultraviolet and infrared spectrum (light that our human eyes cannot see).

It is hoped that LUVOIR will be able to analyse the atmospheres of planets orbiting other stars for signs of life. The proposed launch date for the telescope is 2039.

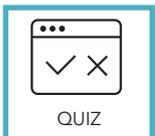


Figure 5.52 Artist's impression of the LUVOIR telescope

What are the challenges for the future in astronomy?

Scientists now have a very good understanding of the structure and history of the universe owing to the many observations made since the invention of space probes such as the Voyager 2, a probe launched from Earth in 1977 and that left our solar system in 2018. However, there are still aspects of the universe for which science has no explanation, such as the nature of dark matter and the existence of dark energy.

Section 5.5 questions



Remembering

- 1 **List** some things that make up a solar system.
- 2 **Recall** the galaxy in which Earth is found.

Understanding

- 3 **Explain** how telescopes can see in more detail.
- 4 **Explain** why telescopes are built on top of mountains.
- 5 **Describe** the sorts of discoveries that can be made with telescopes.

Applying

- 6 **Explain** what the colour of a star can tell an astronomer.
- 7 **Describe** how a reflecting telescope might differ from a refracting telescope.

Analysing

- 8 **Explain** why it is important to have telescopes that can gather data on light other than visible light.
- 9 **Compare** the geocentric and heliocentric models.

Evaluating

- 10 **Evaluate** how telescopes have changed our understanding of the universe, including how our understanding of the universe might be different if the telescope had not been invented.

Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked question	Check
5.1 I can state the rotation times for the Earth, Moon and Sun.	1	
5.2 I can recall that gravity keeps planets in orbit around the Sun.	3	
5.2, 5.3 I can compare the orbit times for the Earth and Moon.	7	
5.2 I can describe the cause of seasons, including why different regions of the Earth experience different seasonal conditions and how these seasonal changes affect people.	9	
5.2 I am able to describe some differences between the seasonal calendars used by Aboriginal and Torres Strait Islander peoples and the typical four-season calendar used in Australia.	4	
5.3 I can describe how the phases of the moon are caused.	2	
5.4 I can describe the cause of a lunar eclipse and solar eclipse.	10	
5.5 I can describe how models of the solar system have changed over time.	16	

Review questions

Remembering

- 1 **Recall** the approximate number of times that Earth spins in one month.
- 2 **Recall** the approximate number of complete phase cycles of the Moon in one year.
- 3 Earth orbits the Sun. **State** the physical property that pulls the Earth towards the Sun.
- 4 **List** the six seasons used by the Noongar peoples of the south west of Western Australia.
- 5 The antipode of a point is that point projected through Earth to the opposite side. **Determine** the antipode of the North Pole.

Understanding

- 6 **Explain** why an eclipse can never occur during a quarter moon.
- 7 **Compare** the time taken for Earth to orbit the Sun with how long it takes the Moon to orbit the Earth.
- 8 **Provide** two reasons why the average winter temperature is higher in Port Hedland than in Bunbury.

Applying

- 9 **Explain** if places near the Equator experience seasons.
- 10 **Explain** whether there could be a solar eclipse and a lunar eclipse in the same month.
- 11 The Moon is slowly moving away from Earth. **Show** why total solar eclipses will become less likely in the future. You may sketch a labelled diagram to help.



Analysing

- 12 Seasons have been observed on Mars, the Martian polar ice caps have been seen to grow and shrink with the changing temperature in a similar way to Earth's polar ice caps. What can you **infer** about the angle of tilt of the axis of rotation of Mars?

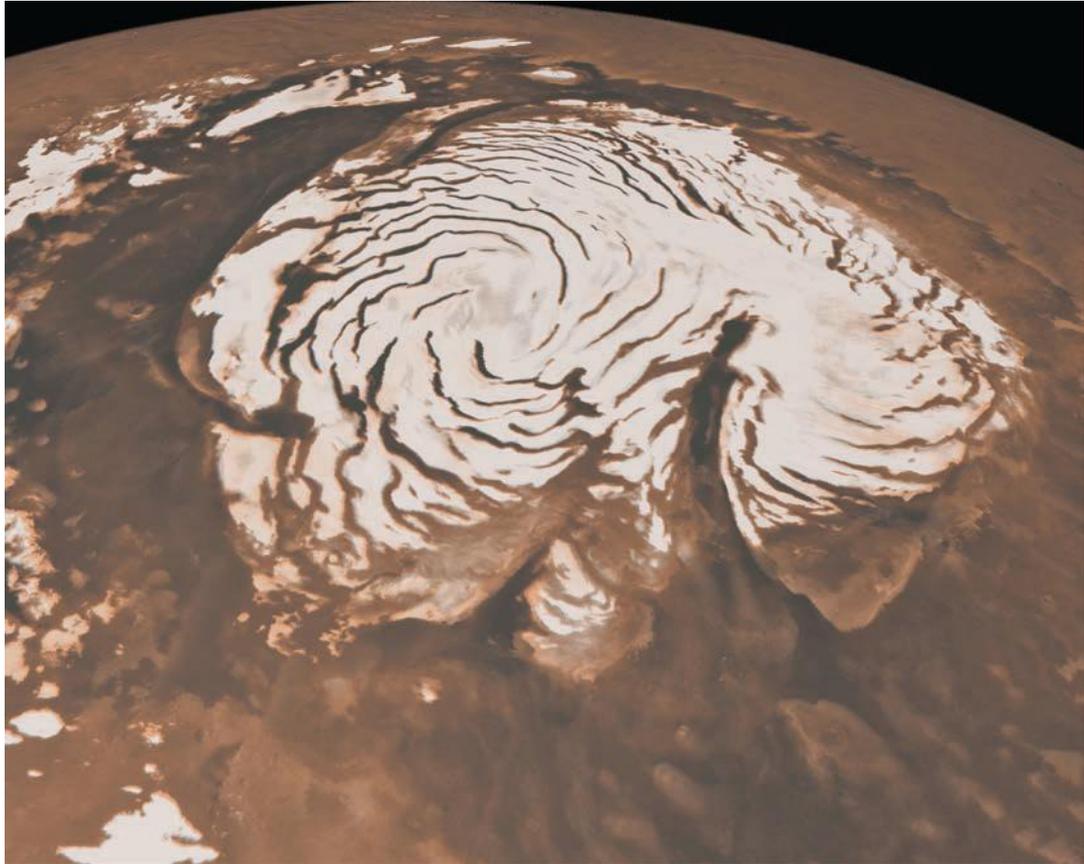


Figure 5.53 A polar ice cap on Mars

- 13 **Describe** the climate of Earth if it did not have a tilt.

Evaluating

- 14 **Describe** what the night sky would look like on Saturn, which has 62 moons.
- 15 Research how telescopes have progressed through the years and **summarise** how the technology has changed.
- 16 **Create** a list of things discovered about the universe throughout history and speculate what might be found in the future with developing technology.

Data questions

Just like Earth's moon, the Moon, there are moons that orbit the planet Jupiter. In fact, Jupiter has 79 known moons! These vary in size and distance from the planet. The eight innermost moons and the periods of their orbits are shown in Figure 5.54.

- Identify** which of the moons in Figure 5.54 orbits furthest in distance from Jupiter.
- Use the data to **determine** which moon takes approximately 1.8 days to complete a full orbit of Jupiter.
- Adrastea has an orbit time of 0.3 days, whereas Amalthea has an orbit time of 0.5 days. **Calculate** the difference in the number of hours it takes these moons to orbit Jupiter.
- Galileo Galilei first discovered the four largest of Jupiter's moons in the 17th century, when he saw them through a telescope. They are those with an average orbit distance between 0.3 to 2 million km from Jupiter. **Categorise** the moons in Figure 5.54 as 'Galilean' or 'inner orbiting' (for those that orbit at distances other than 2 to 20 million km).

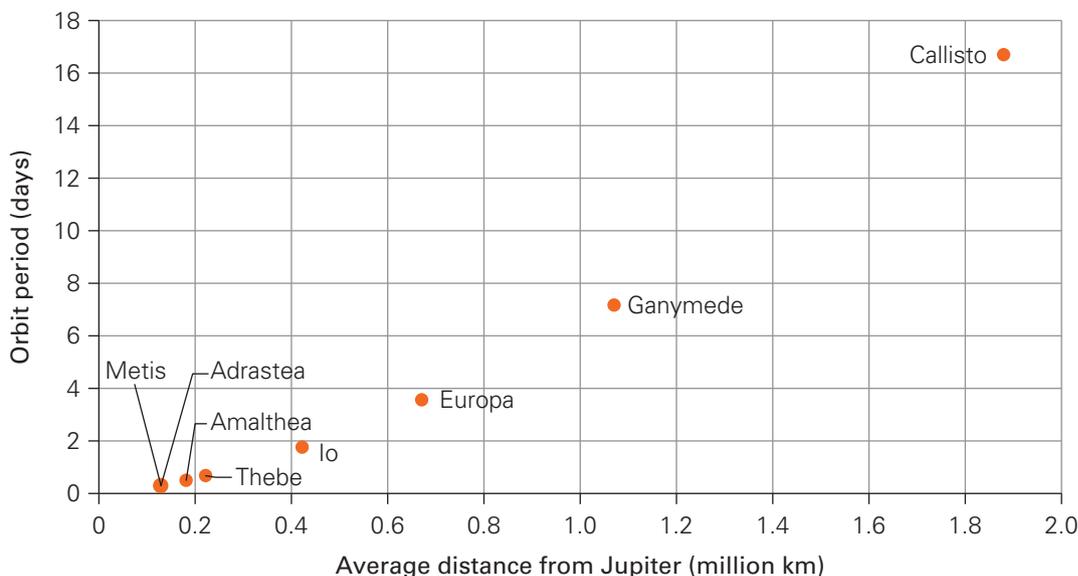


Figure 5.54 Orbital period of Jupiter's inner and Galilean moons

- Distinguish** the Galilean moons from the inner orbiting moons by referring to their possible size.
- Identify** the trend in the average distance of a moon from Jupiter and the time it takes for the moon to complete a full orbit of Jupiter.
- Jupiter's ninth moon is called Thermisto, and its average distance from Jupiter is approximately 7.3 million km. A student has estimated, based on the trend in Figure 5.54, that the orbital period for Thermisto would be approximately 20 days. Use the data to **deduce** whether this would be an accurate estimate.
- Earth's moon, the Moon, has an average distance from Earth of approximately 0.4 million km and has an orbit period of 27.32 days. **Compare** this data point to those provided in Figure 5.54 for the moons of Jupiter. Does Earth's moon orbit period fit the trend identified in Question 6?
- Justify** your response to Question 8 with an appropriate scientific explanation.

STEM activity: Simulating the orbit of planets in the inner solar system

Background information

Have you ever wondered why Earth or other planets do not go flying off into outer space? Or how large bodies (planets!) have followed the Sun across the emptiness of space for billions of years? This is the best explanation scientists have come up with so far: *gravitational forces*. You will learn more about gravity in Chapter 8.

Gravitational forces operate in a very interesting way. It turns out that the larger an object, the more gravitational pull it has. So, in the case of our solar system, our Sun (as the most massive object within this system) possesses a powerful gravitational attraction on all the other objects in the solar system. In other words, all objects within the solar system are under the gravitational attraction of the Sun.

Now, you might remember that here on Earth, the gravitational force pulls objects towards the centre of the planet. In other words, things (including you and me) are always falling to the ground. Here is a question for your curious mind: why aren't Earth and the other planets falling into the Sun?

It turns out that they are indeed falling, as the Sun's gravity pulls them towards it. However, they were born in a vast rotating cloud of dust and have a huge amount of momentum directed in a straight line into deep space. The Sun's pull balances the momentum meaning they move in a curved path around the Sun, always falling towards it, but never reaching it. The closer a planet is to the Sun, the faster it needs to travel to prevent gravity pulling it into the Sun.

Design brief: Create a simulation of the solar system planets orbiting the Sun.

Activity instructions

In this task, you will investigate how Kepler's Laws of Orbital Motion explain why different planets orbit our Sun at different speeds. In a nutshell, Kepler's Laws of Orbital Motion is straightforward, summarised as:

A planet's orbital speed changes, depending on how far it is from the Sun. The closer a planet is to the Sun, the stronger the Sun's gravitational pull on it, and the faster the planet moves.

We can observe the effects of Kepler's laws within our own solar system right now. Table 5.2 shows the relationship between distance and orbit of the planets Mercury, Venus, Earth and Mars.

Planet	Distance from the Sun (km)	Orbital period (days)
Mercury	55 000 000	88
Venus	105 000 000	225
Earth	150 000 000	365
Mars	228 000 000	687

Table 5.2 Distance and orbital period data for planets located in the inner solar system

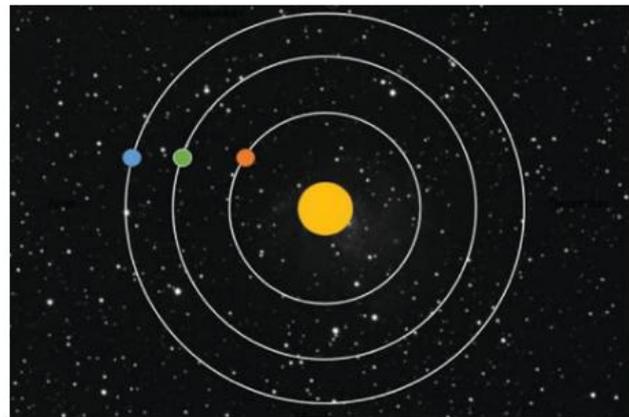


Figure 5.55 Model of the solar system

Your task is to use Microsoft PowerPoint to create your very own simulation of the solar system (like the one shown in Figure 5.55), and to gain a visual understanding of how Kepler's Laws of Orbital Motion apply to planets orbiting the Sun.

Suggested materials

- laptop
- Microsoft PowerPoint
- paper and pencil to perform simple calculations

Research and feasibility

- 1 Research our solar system, the names of the planets, their orbiting speed and distance from the Sun.

Design

- 2 Design a labelled model of the solar system. Include planet names, their orbital speeds and each planet's distance from the Sun.

Create

- 3 Use Microsoft PowerPoint to create your model.
- 4 Microsoft PowerPoint has given all planets within the inner solar system the same orbital period (2 seconds). However, you know that planets closer to the Sun (e.g. Mercury) have shorter orbital periods compared to planets located further away (e.g. Saturn). Therefore, you should make changes to your simulation to make it behave as closely as possible to the real solar system.
- 5 Assuming that, on your model, Mercury orbits your Sun in 2 seconds (orbital period = 88 days), *estimate* the number of seconds required for Venus (orbital period = 225 days) and Earth (orbital period = 365 days). After you finish your

estimation, you can change the values (seconds) to make your simulation more realistic.

Evaluate and modify

- 6 Discuss with your group the challenges you have encountered throughout this project. List the strategies or actions that allowed you to overcome it.
- 7 Reflection is an integral and vital aspect of any project in the real world. In your honest opinion, *list* what you would like to have included, removed or modified from this challenge as well as ways to improve the way we visualise our solar system.

Extension

Planets in our solar system orbit the Sun like clockwork. For example, Mercury will always orbit the Sun in around 88 days, while Earth takes around 365 days to complete one orbit; this is due to the distance between the Sun and the planets (that is, the closer they are to the Sun, the shorter the time it takes them to complete one round of their orbit).

Now, imagine the following scenario: scientists just released news that the mass of our Sun has shrunk by half, while the distance between the Sun and the planets remained the same. The scientific community would be worried about this development since the Sun is at the centre of our solar system. Predict, using your own words and by reading the definition of Kepler's laws, whether the orbital period of planets would change at all in this new hypothetical scenario.

Now consider creating a model of the Sun-Earth-Moon system using Microsoft PowerPoint. Could you use your new skills to simulate a solar or lunar eclipse?

Chapter 6

Earth: Resources and management

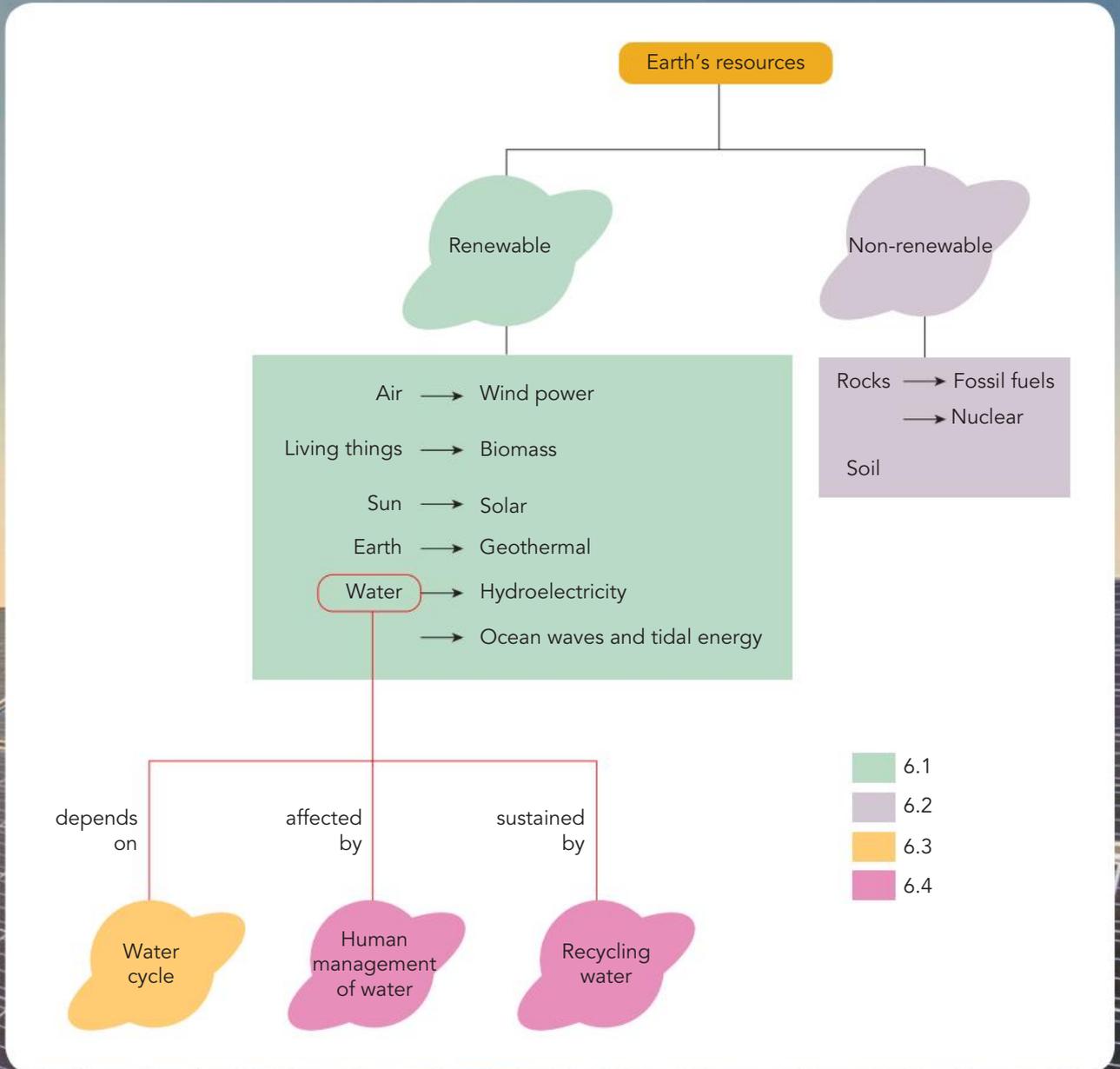


Chapter introduction

This chapter will help you understand the amazing resources that our Earth provides. Renewable and non-renewable resources will be investigated as well as how long they will last.

You will look at water in more detail as it is a very important example of a resource that cycles through the environment but is largely affected by the things we humans do to change our world.

Chapter map



6.1 Renewable resources



Learning goals

- 1 To be able to define renewable and non-renewable resources.
- 2 To be able to list some examples of renewable sources of energy.

Introduction to Earth's resources

Every year, you start school by bringing certain **resources** to your classes – for example,

textbooks, laptop, sports gear and stationery – things that will support your learning. So, when the word 'resources' is used, it means something that is useful. Now consider the major resources of Earth. They are water, air, living things, rocks (containing **minerals** and **fossil fuels**), soil, heat from the earth and **energy** from the Sun. How are these things useful to us?

Some of Earth's resources are **renewable**. This means that the resource is replenished by natural

processes within a human lifetime. There are variations in our planet's ability to replenish resources and the speed of their replenishment. Therefore, a close eye must be kept on how much and how quickly all resources are used. For example, wood is used for building, for heating and for cooking. Trees can be replaced by planting and can reach maturity within 30 to 40 years, and so are called renewable. A non-renewable resource is a resource that cannot be replaced or takes a very long time to be replaced, much longer than a human lifetime. For example, some of the minerals buried deep in the earth have taken millions of years to form and so are called **non-renewable**. Renewable and some non-renewable resources need close monitoring.

- resource**
something that is useful
- mineral**
substance formed naturally in the ground
- fossil fuel**
fuels, such as gas, coal and oil, that were formed underground from plant and animal remains millions of years ago
- energy**
the capacity to do work
- renewable**
replenished by natural processes within a human lifetime
- non-renewable**
existing in limited quantities that cannot be replaced after they have all been used



Figure 6.1 Guess the types of energy sources in the image. Are they renewable or non-renewable? You can discuss this with your classmates.

Left to right, top to bottom: coal (non-renewable), hydroelectricity from water (renewable), nuclear (non-renewable), wind (renewable), oil (non-renewable), solar or sun (renewable).

Quick check 6.1

- 1 Name six major natural resources on Earth.
- 2 Define the terms 'renewable' and 'non-renewable'.
- 3 For each of the following, decide if the resource is renewable or non-renewable, and identify which of the major resources it fits into.

coal	wind energy	rice
solar energy	water	sand
timber	nuclear energy	oil
natural gas	minerals	

Renewable resources

Australia is lucky to have access to so many of Earth's renewable resources. Water, air, living things and energy from the Sun are all renewable resources. This means that these resources can also provide ongoing supplies of energy, for example, to power homes. Renewable forms of energy are **geothermal energy** (heat from Earth), fuel from **biomass** (living things), **solar energy** (energy from the Sun), and energy from the movement of water or air: **hydroelectricity** (energy from ocean waves and tides) and wind energy. These forms of energy are termed 'cleaner' than non-renewable forms, as they usually do not produce as much **greenhouse gas**.

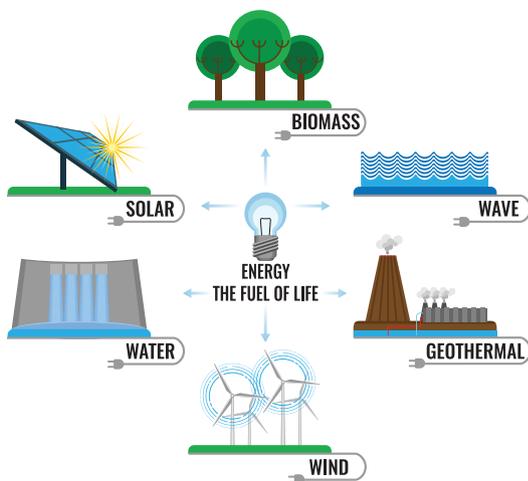


Figure 6.2 There are many different types of renewable energy sources.

Water

Water is a renewable resource as it cycles through the environment many times within a human lifetime. Fresh water is an extremely important resource that living things (other than marine life) need for their survival. However, only about 3% of all water on Earth is fresh water, and only one third of this is available for land-based plants, animals, manufacturing, agriculture and the ecosystems in which we all live. The rest of the fresh water (2% of all water) has a massively important role in regulating the temperature of our planet and is locked away in ice caps and glaciers.

You probably know that Australia is one of the driest continents on Earth. Therefore, we often experience water restrictions because it is essential that our fresh water is conserved and, of course, contamination of our water supplies is minimised. So, how do we get fresh water? Where does it keep coming from? The answer is the **water cycle** and you will learn about this a little later in this chapter.



geothermal energy
energy from the heat inside Earth

biomass
plant and animal material suitable for using as fuel

solar energy
the energy from the Sun used to produce electric power or to heat water

hydroelectricity
electricity produced by the force of fast-moving water

greenhouse gas
gases that trap heat in the atmosphere

groundwater
water that collects beneath Earth's surface

water cycle
the way that water is taken up from the sea, rivers, lakes and soil, and then comes back down as rain, snow or hail

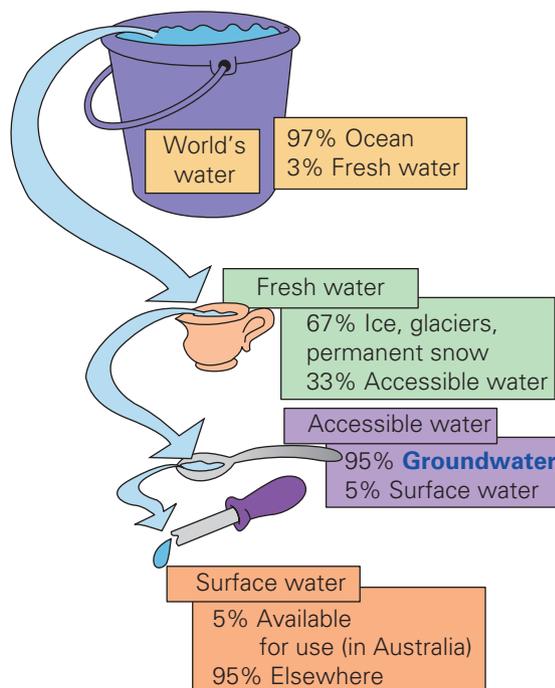


Figure 6.3 Only about 1% (33% of 3%) of the world's water is accessible fresh water.

Did you know? 6.1

In 2018, Hobart made the list!

There are only 42 major cities in the world that are 100% powered by renewable energy. About another 59 cities are at least 70% renewable-powered, including Hobart, the only Australian city to make the list! Most of the cities on the list were generating renewable electricity with hydroelectricity, followed by wind, solar, biomass and geothermal.

Energy from water: Hydroelectricity

Hydro (water) electricity is a clean source of energy, producing no greenhouse gases (apart from those used in construction of dams and power stations). First, rivers are dammed to capture huge amounts of water. The dams hold water at a height, increasing the pressure of the water due to the pull of gravity. The water trapped in the dam is then allowed to run through pipes at great speed (and force) to a power station lower down. This is where the water turns turbines that drive the generators to produce hydroelectricity.

ocean energy
energy harnessed from the movement of the ocean such as waves and tides

barrage
a dam to generate electricity from tidal power

Unlike other renewable sources, the water can be stored, which means electricity can be produced whenever it is needed. However, producing electricity in this way is limited to areas with large river systems and land big enough for building dams.

Energy from water: Ocean waves and tidal energy

There is so much coastline around Australia, it makes sense to try to harness the energy provided by the marine environment. There are several different sources of **ocean energy**, including:

- **wave energy** – energy from waves (swells) converted into electricity
- **tidal energy** – movement of tides converted into electricity. Tides on Earth are caused by the gravitational pull of the Moon and the Sun. You will learn more about gravity in Chapter 7. One method of converting this energy is through tidal **barrages** – water enters a basin next to the barrage and builds up. It is then released through gates (called sluice gates) to flow through turbines and this is what generates electricity.



Figure 6.4 Cross-section of a hydroelectric dam



Figure 6.5 Wellington Dam Hydro Power Station near Collie, Western Australia

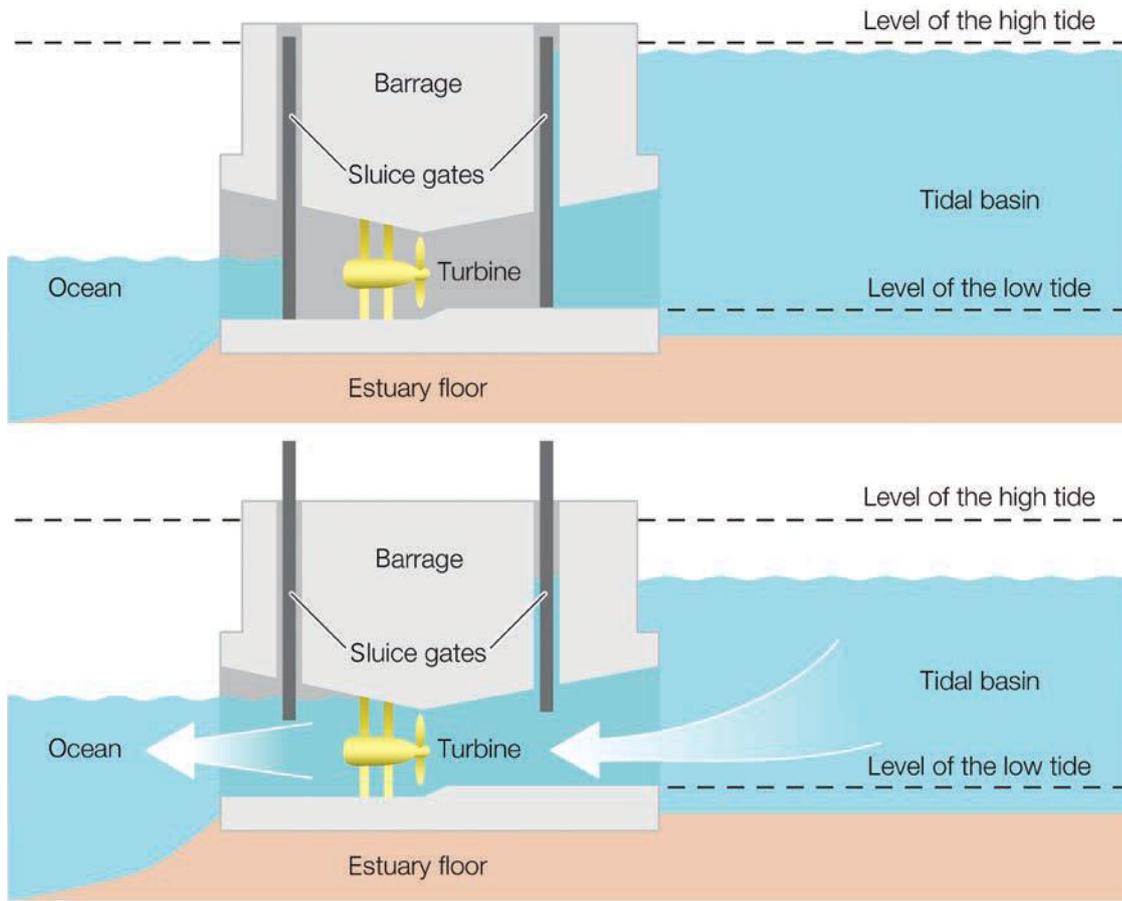


Figure 6.6 A tidal barrage, a kind of dam built across an estuary or coastal inlet to generate electricity by tidal power

Science as a human endeavour 6.1

Generating power from the ocean

In 1975, the CETO (Cylindrical Energy Transfer Oscillating) wave-energy system was conceived, designed and built by an Australian inventor, Alan Burns. His system was (and currently remains) the first wave-power converter to sit on the seabed. The submerged buoys move up and down as the ocean waves pass by and drive pumps to pressurise sea water. It requires only a small pipe to carry high-pressure sea water ashore to drive a turbine and generator to produce electricity with no dangerous emissions. For the past few years, the CETO 5 has been operating the world's first multi-machine wave-energy installation off the coast of Western Australia. In 2016, development of the CETO 6 (more efficient and powerful than the CETO 5) began. The project to install a CETO 6 unit off the coast of Albany, Western Australia, was completed at the end of 2019.



Figure 6.7 The CETO 5 harnessing ocean energy off the coast of Western Australia

Heat from the Earth

Energy from the Earth: Geothermal

Geothermal energy is naturally occurring heat from deep within the Earth. The deeper you go below the surface, the hotter it gets and so you can find geothermal energy in granite rocks

(often called 'hot rocks') or trapped in water (hydrothermal sources), 3 to 5 kilometres below the surface! The most common source of geothermal energy around the world is hot springs associated with volcanic activity.

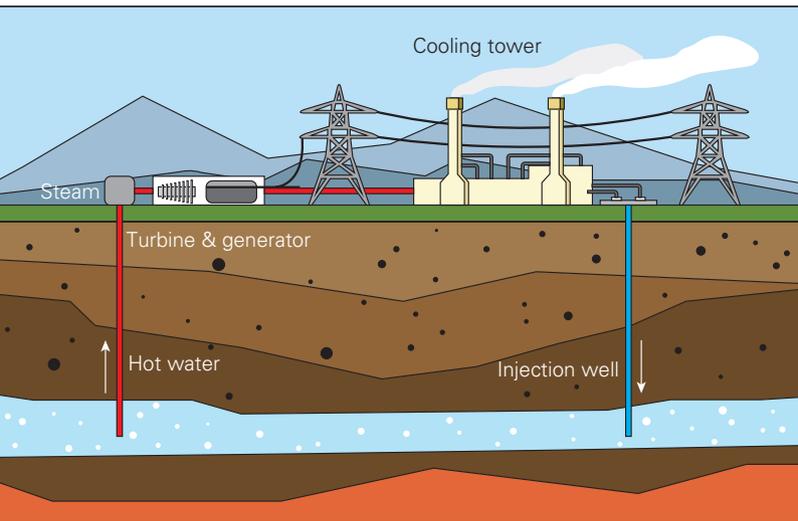


Figure 6.8 In geothermal power stations, heat from the Earth's crust is used to heat water, which turns to steam, and this is then used to turn a turbine. The water is cooled and returned to the heat source.



Figure 6.9 Geothermal power station

Quick check 6.2

- 1 Recall why water is so important as a resource for all living things.
- 2 Explain why water is considered to be renewable.
- 3 Draw a flow chart to illustrate the steps involved in making electricity from the flow of water.
- 4 The following are incorrect statements about geothermal energy. Rewrite each statement so that it is correct.
 - a This form of energy is made by using the heat from the Sun.
 - b This form of energy uses the energy made when burning plant and animal matter for heating our homes.
 - c Hot mineral springs have never been used for bathing, cooking and heating.
- 5 Read the following statements and decide whether each is true or false.
 - a Ocean wave energy uses waves to make electricity.
 - b Ocean wave energy depends on the gravitational pull of the Moon and the Sun, and Earth's rotation.

Air

The air is mostly made up of particles of nitrogen (78%) and oxygen (21%) with small amounts of other gases, including carbon dioxide. You may already know that animals (and also plants) need oxygen to produce energy, and carbon dioxide is used by plants in the special process of making sugars (called photosynthesis). Nitrogen is also needed for survival as it is an important component in proteins – living things need proteins to function and grow.

Energy from air: Wind

Winds are caused by the uneven heating of Earth and the atmosphere by the Sun. This means that as long as there is a Sun, there will be wind. Like old-fashioned windmills, today's wind turbines harness the free energy of the wind to produce electrical energy. The wind pushes against the blades on top of the tower, making them spin. The blades are attached to a rotor and the rotor spins a generator to produce electricity.

Large-scale wind farms are an amazing sight to see, and when connected to the electricity grid, can supplement the electricity supply of large towns and cities without producing any greenhouse gases.



Figure 6.10 The Albany Wind Farm on the south coast of Western Australia. What do you think may be the downside of wind farms?

Living things

Living things are considered a renewable resource because they can reproduce, meaning they are continually being replaced. For example, timber is considered a renewable resource as a tree chopped down can be renewed by another in about 25 years.

Energy from living things: Biomass

Biomass is the name given to any material derived from plant and animal matter, as well as their waste. Plants convert the Sun's energy into a stored form that can be used later, and if animals eat the plants they essentially consume the stored energy. There are several other ways in which the energy can be used:

- The breakdown of manure and food scraps produces methane gas that releases energy when burned.
- Burning biomass, such as wood, releases energy that can be used for heating and cooking.
- The processing of biomass produces biofuels such as biodiesel, biogas and alcohol, which can be used instead of traditional fossil fuels.



Figure 6.11 Wood pellets (left) and dry dung (right) are both examples of biomass – fuel developed from organic materials.

Practical 6.1: Investigation

Which plant produces more biomass?

Aim

To determine which type of plant produces the most biomass in a set period of time.

Research question

Which type of plant produces the most biomass in 16 days?

Materials

Day 1

- 15 wheat or rye seeds
- 15 corn seeds
- 15 oat seeds
- potting mix
- 9 milk containers or small seedling pots (3 per independent variable group)
- well-lit area to place seedlings or a natural light source to set up inside
- *recommended: camera*

Day 16

- 9 (new) milk containers or small seedling pots
- bucket or sink with water
- paper towel

Day 20

- electronic scales
- 9 identical takeaway containers (or similar)

Planning

- 1 You need to provide some background information to the investigation. Complete some research and write a brief paragraph to explain the key concepts of biomass and factors that affect plant growth. Ensure you reference appropriately.
- 2 Identify the independent variable in this investigation.
- 3 Identify the dependent variable in this investigation.
- 4 Identify the controlled variables in this investigation.
- 5 Create a risk assessment for this investigation.

Method

Day 1

- 1 Prepare three containers to plant seeds. Label each container to identify the independent variable group number, description (the type of plant you will plant in it), date and student name.
- 2 Place moist soil in each container.
- 3 Carefully count out fifteen seeds of one species of plant. Spread five seeds evenly across the soil in each of the three containers.
- 4 Then plant them at the depth specified on the seed packet.
- 5 Repeat steps 1–4 with fifteen seeds of the two other species of plant, each in their own three containers (bringing the total number of containers used to nine).
- 6 Spray the soil to moisten the soil thoroughly, at least to the depth of the seeds.
- 7 Place all nine containers under similar conditions in an undisturbed area to grow. Set it up so that all containers receive similar temperature and air flow and even amounts of light.

Be careful

Wear a dust mask and gloves when using potting mix.

Group number:

Description:

Date:

Student/s name:

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- 8 Continue to spray the soil daily to keep it moist.
- 9 Monitor each group for 14–16 days. Taking photographs of each container including the label is recommended.
- 10 If any part of the set-up is changed, then note the reason for this.

Day 16

- 11 Label three new takeaway containers for drying each species of plant (nine in total).
- 12 Remove the plants from the first container and carefully wash the roots in a bucket of water to remove any soil.
- 13 Dry the plants with a paper towel.
- 14 Repeat steps 2–6 with the other containers.
- 15 Place the takeaway containers in the sun to dry out the plants.

Day 20

- 16 Copy the results table for collecting the raw data.
- 17 Identify and label the different types of variables in the table.
- 18 Weigh an empty takeaway container to subtract from each mass of dried plants + container.
- 19 Weigh each of the nine takeaway containers of dried plants.
- 20 Record the mass in the table minus the mass of the takeaway container.
- 21 Calculate the mean measurement for each *independent variable* group.
- 22 Calculate the range for each independent variable group on the table.
- 23 What type of graph would be best to represent the mean of each of the three groups to compare them? Make that type of graph and discuss your observations.

Results

Independent variable _____	Dependent variable _____			
	Trial 1	Trial 2	Trial 3	Mean
Group 1 _____				
Group 2 _____				
Group 3 _____				

Discussion

- 1 Decide which plant had the greatest biomass production.
- 2 Describe how much variation was observed between the measurements within each group.
- 3 Describe how much the set-up or method was adjusted once the experiment was started.
- 4 Explain if the controlled variables were managed properly to ensure they did not change and affect the measurements.
- 5 Discuss any other changes that could be made to the method to improve the quality of the data in future experiments.
- 6 Evaluate the method and write out an improved version based on the answers to Question 4.



Figure 6.12 Which plant produces more biomass?

Conclusion

Answer the research question, using evidence to support your statement.

Quick check 6.3

- 1 Recall what makes air a resource.
- 2 Explore some advantages and disadvantages of wind farms.
- 3 Explain why biomass is considered renewable.
- 4 Identify five examples of biomass that could be found at a garbage dump.

The Sun

The Sun is one of more than a billion stars in the Milky Way. Its energy is considered renewable as it has enough nuclear fuel to keep shining for another 4.6 billion years! This is certainly good news as plants need sunlight to make sugars by photosynthesis, which we (and other organisms) then need to eat to sustain our bodies. Our planet also needs the Sun's energy to keep warm.

Energy from the Sun: Solar

You are probably very familiar with **photovoltaic** or solar cells, as there are so many solar-powered toys, calculators and outdoor lights on the market.

photovoltaic
able to produce electricity
from light

These all use solar cells to convert the Sun's energy into electricity. Solar cells are made up of silicon, the same substance that makes up sand, and have no mechanical parts to wear out. There are currently five operational solar farms in Australia, with another five under construction. There are not many large photovoltaic power plants around due to their expense, and the limitation that they cannot produce electricity at night! Until recently, solar power stations were more expensive than other types, but the cost has been falling. From 2020, there are multiple large scale solar farms under construction in Western Australia – the largest in Waroona.

Energy from the Sun: Heat (solar thermal)

Solar thermal panels on rooftops are becoming more common for heating



Figure 6.13 The Sun's energy shines down on us and is essential for life on Earth.



Figure 6.14 These photovoltaic solar panels convert the Sun's energy directly into electricity.

domestic water and swimming pools. These circulate water in flat panels or tubes where it is warmed by absorbing *radiant* heat (also known as *infrared* 'light'). The warmed water is then fed into the pool or stored in insulated tanks in or on the roof.

Quick check 6.4

- 1 Explain why we call the Sun's energy a resource.
- 2 Decide if solar power is a reliable source of energy.
- 3 Outline how using solar energy impacts on the environment.

Practical 6.2: Investigation**Which solar collector is the best?****Aim**

To investigate how different colours affect the absorption of heat on a solar shower.

Prior understanding

Solar thermal collectors absorb radiant heat from the Sun and transfer or store it for use. In Australia, the use of solar collectors is increasing, now that better methods of storage are being developed.

One simple solar collector that has been used by campers for a long time is the solar shower. This is a plastic bag with a shower hose attached. The bag is filled in the morning and left in the sun to heat the water during the day. The hot water can be used to shower at night. The design of the solar shower needs to allow the bag to efficiently absorb the radiant heat with as little waste as possible and retain the heat once absorbed.

Materials

- 4 balloons of different colours, e.g. black, green, red and white, to act as solar collectors
- 4 straws
- 4 ice cream containers
- aluminium foil
- approximately 1.5 L of sand, soil, or other packing material
- sticky tape
- a thermometer or data logging temperature sensor
- paper and pen or computer for the table entry

Planning

- 1 Identify the independent variable in this investigation.
- 2 Identify the dependent variable in this investigation.
- 3 Identify the controlled variables in this investigation.

Method

Follow these steps to make a solar collector.

- 1 Copy out and label the results table to record your data.
- 2 Line each ice cream container with aluminium foil. Place it so that the shiny side is visible.
- 3 Fill the bottom of each container with packing material and make an indent in the middle to support the balloon.
- 4 Fill each balloon with about 200 mL of water. All four balloons must contain the same amount of water.
- 5 Place the balloons onto the sand in the ice cream container.
- 6 Secure the opening of each balloon by taping the opening tightly around a straw, with the straw facing upwards.
- 7 Slide the thermometer into each full water balloon and record the *initial temperature*.
- 8 Place the solar collectors on the ground in sunlight for the same amount of time for each collector. Leave them for 15–20 minutes.
- 9 Record the *final temperature* inside the collector when the time is up.
- 10 Calculate the change in temperature.

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Results

Independent variable	Dependent variable		
	Initial	Final	Change
Group 1			
Group 2			
Group 3			
Group 4			

Discussion

- 1 Describe any trends or patterns in your results.
- 2 Organise the colours of the balloons from most effective to least effective in terms of absorbing radiant heat. Use data to justify your answer.
- 3 Critique your management of the controlled variables. Were they managed properly to ensure they did not change and affect the measurements?
- 4 Now that you know the best colour of solar collector, develop a new method that will allow you to investigate how the effectiveness of this colour can be improved further. Perhaps resting the balloon on a reflective surface, or changing the size or shape of the balloon, could increase the effectiveness.

Explore! 6.1**Engineering as a career**

Engineering is a career that helps make people's lives easier and safer. Engineers are applied mathematicians and scientists, inventors, designers and builders. Depending on their area of engineering, they can construct tools, create vehicles, run simulations, manufacture chemical compounds and more.

- 1 Investigate and then summarise the role of a renewable energy engineer.
- 2 Make a list of some of the different skills a renewable energy engineer would have.



Figure 6.15 Some of the many roles of renewable energy engineers

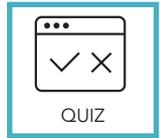
Section 6.1 questions

Remembering

- Read each statement and **identify** which renewable energy source is being described.
 - Water turns turbines in order to generate this type of renewable energy.
 - This energy source captures the energy from the movement of air.
 - By drilling deep wells and pumping the heated underground water or steam to the surface, this energy can heat homes.
 - This type of energy depends on the gravitational pull of the Moon and the Sun.
 - This energy source includes wood, straw and manure.
 - This energy source involves building a dam to raise the level of water in a reservoir.
 - This type of energy comes from Earth's core.
 - This energy source involves using buoys connected to pumps to pressurise sea water, which is then used to spin turbines.



Figure 6.16 Solar panels on the roof of a Western Australian University



Understanding

- Identify** the missing information in the table regarding different renewable energy sources.

Type of energy	How it works
	Water is collected behind a dam. When released, the fast-flowing water is used to turn a turbine and generator, thus generating electricity.
Solar	
Wind	
	Energy that comes from heat deep within Earth's core. It is often used in countries where there is high volcanic activity.

Applying

- Explain** what prevents hydroelectricity from being used everywhere in Australia.
- Deduce** why solar energy is sometimes called 'green' energy.
- State** the main disadvantage of using solar energy.

Analysing

- Summarise** the advantages and disadvantages of a hydroelectric power station. You may do so in table format.
- Turbines usually spin in one direction, but the turbines used to capture tidal energy move in two directions. **Explain** why this would need to be the case.



Figure 6.17 Gordon Dam in Tasmania

Evaluating

- Discuss** reasons why some people think forests can be classified as a renewable resource and others consider them to be a non-renewable resource.

6.2 Non-renewable resources



Learning goal

- 1 To be able to list some examples of non-renewable sources of energy.

Remember that non-renewable resources cannot be replaced easily and not within a human lifetime. Of Earth's resources, rocks, minerals and soil are all non-renewable resources. These resources also provide non-renewable energy sources like fossil fuels and **nuclear energy**.

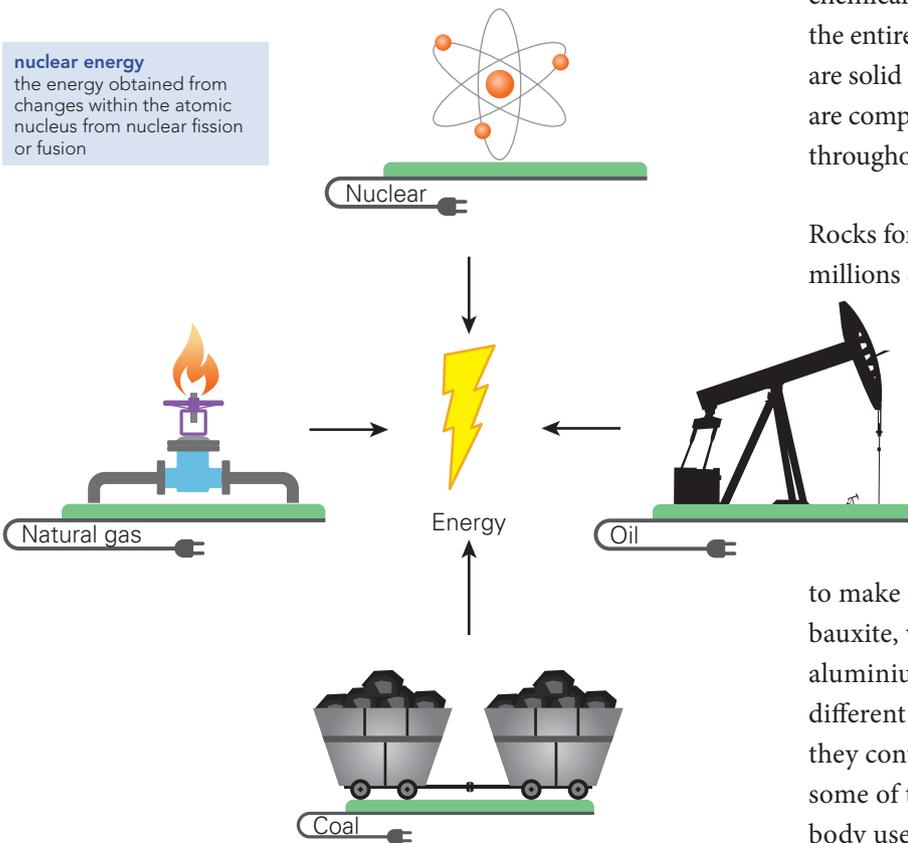
Rocks and minerals

Rocks and minerals are all around us – we have them in our homes, in our gardens, at our schools and in our cities. Minerals are the building blocks of rocks and each has a specific chemical structure that is the same throughout the entire mineral. Rocks, on the other hand, are solid materials found in Earth's crust and are composed of different minerals that vary throughout the structure of the rock.

Rocks form over many thousands or even millions of years. Once they have been mined and used, they are considered a non-renewable resource as they are not replaced quickly.

The minerals contained in rocks are needed by living things.

There are lots of minerals used to make our lives easier, like the mineral bauxite, which is the main source of aluminium. The human body also needs different types of minerals for the elements they contain. The following table summarises some of the mineral elements your body uses.



nuclear energy
the energy obtained from changes within the atomic nucleus from nuclear fission or fusion

Figure 6.18 There are many different types of non-renewable energy sources.

Mineral element	Calcium	Zinc	Potassium	Iron
Use in the body	Helps make your bones strong	Supports your immune system in fighting illness and infection	Keeps your nervous system and muscles working properly	Carries oxygen around your body in your blood
Mineral source				

Table 6.1 Some of the different mineral elements that our bodies need

Energy from rocks and minerals: Fossil fuels

Rock layers also contain resources that are not minerals, such as coal, oil and natural gas (though these are counted as part of mineral and mining industries). These are collectively known as fossil fuels and are a major source of energy. Unfortunately, they are non-renewable because the process of forming fossil fuels takes millions of years, and we are using them faster than they can be renewed.

Why do you think fossil fuels are called fossil fuels? The energy in fossil fuels originally came from the Sun. Plants use the Sun's energy to make sugars (by photosynthesis), and this energy in plants passes to the animals that eat them. Once the living things have died, the effects of pressure and temperature due to burial can change the plant and animal remains into fossil fuels. While fossil fuels are not mineralised *fossils* of prehistoric living things, they are resources that have been formed over millions of years from the burial of ancient dead organisms. To be specific, coal is formed from dead plant material, while oil and gas are formed from dead marine life. The burning of the fossil fuels releases the energy for humans to use. Unfortunately, it also releases greenhouse gases into the atmosphere.



Figure 6.19 Coal

In the case of coal, once it is removed from the ground, it is transported to a coal-fired power plant. Here the coal is crushed and burnt in a furnace. The energy released is used to heat water into hot steam used to turn turbines. The turbines drive generators, which produce electricity. The steam is then condensed and recycled.



Figure 6.20 A coal-fired power station. The short wide towers you can see are cooling or condensing towers; they are involved in recycling steam and they release water vapour. The tall narrow chimneys release carbon dioxide and ash as they are connected to the furnace.

As with all energy sources, whether renewable or non-renewable, there are advantages and disadvantages to the use of coal. Advantages that people see with the use of coal are that it is abundant, it releases a lot of energy compared to its cost and provides a steady amount of heat. The disadvantages are that it is dirty, pollutes the air, and the mines destroy the landscape.

The other fossil fuels, oil and gas, are also important raw materials for manufacturing products. Every day, we use many things that are made from oil or gas. Look at Figure 6.21 and think about all the things you may have used today that rely on oil or gas.



Figure 6.21 We use oil and gas every day in many ways. Can you list all the different items you use regularly that are made from oil or gas?

Quick check 6.5

- 1 Define the terms 'rocks' and 'minerals'.
- 2 Explain why rocks and minerals are considered to be non-renewable.
- 3 Name the three resources that collectively are called fossil fuels.
- 4 Summarise the steps involved in turning coal into electricity.

Practical 6.3: Teacher demonstration

Foul smelling gas

Aim

To model the production of natural gas from organic material.

Materials

- 1 tablespoon of fresh or tinned fish
- 1 cup of chopped green leaves (for example, lettuce or spinach)
- 1.5 L of pond water or water that has been sitting under pot plants
- sand and soil
- 2 L clear plastic bottle
- 1 large balloon
- gaffer/duct tape
- funnel
- stirring rod

Method

- 1 Use a funnel to pour about 2 cm of sand into the bottom of the plastic bottle.
- 2 Then alternate layers of fish, green leaves and sand, ending with sand on the top about three-quarters of the way up the bottle.
- 3 Place the stirring rod in the top of the bottle touching the sand and gently pour the pond water down it so as not to disturb the sand 'sandwich'.
- 4 Pre-stretch a balloon by blowing it up several times, then fit the uninflated balloon over the top of the neck of the bottle and tape it down so there are no gaps.
- 5 Label the bottle with a safety warning, as the bottle should not be opened under any circumstances during this activity.
- 6 Put the bottle beside a sunny window so that it will warm up. Watch the changes over several days, up to a week.
- 7 Write a prediction: what do you think you will observe in the bottle and what will you observe in the balloon?

Results

Record your observations of the changes in the bottle, and the changes in the balloon.

Discussion

- 1 Explain the changes observed. If a gas was produced that inflated the balloon, research what gas it could be.
- 2 If a gas was produced, propose how the results of this experiment can be used to suggest alternative uses of garbage dumps. Identify somewhere in the world where this is already happening.
- 3 Considering the time you let this experiment run, explain why the content of the bottle did not create oil or fossil fuels.
- 4 Describe how you could improve this activity to better model the production of natural gas from organic material.

Be careful

Dispose of all materials in a well-ventilated area.



Figure 6.22 Experimental set-up

Energy from rocks and minerals: Nuclear

Nuclear power stations use energy released from some radioactive metals, like uranium, to boil water. This produces steam that drives turbines to produce electricity.

The origin of the energy released in a nuclear power station is the energy from the centre of the particles we learned about in Chapter 4. There are two types of nuclear energy: fusion and fission. These are summarised in Table 6.2.

Nuclear energy is not renewable, but it is potentially unlimited. Its main advantage is that it does not produce as much greenhouse gas as burning fossil fuels, but its disadvantages are serious. Nuclear power stations are very expensive to build, and there are safety concerns about radioactivity, toxic waste, security and the risk of explosions.

Method of release	Description	Example
Nuclear fusion	Where particles are fused together to form new particles. This fusion causes a large amount of energy to be released.	The Sun
Nuclear fission	Where particles split to form new particles, which release a large amount of energy as a result.	Nuclear power plants heat water and produce steam, which is used to run turbines and generators that generate electricity.

Table 6.2 Summary of the two methods of releasing nuclear energy: nuclear fusion and nuclear fission

Explore! 6.2

Going nuclear

Australia has more than one third of the world's known uranium resources. New uranium mines are being constructed in Western Australia and South Australia, but all the uranium is exported to other countries.

- 1 Research the environmental impact of both the extraction of the uranium and disposal of nuclear waste.
- 2 Explain the arguments for and against building a nuclear power station in Australia.

Quick check 6.6

- 1 Describe the two different methods of releasing nuclear energy.
- 2 State the advantages and disadvantages of nuclear energy.

Figure 6.23 A nuclear power station. Nuclear fission takes place in the dome on the right to produce steam, while the steam turbines and generators are in the large rectangular building on the left.



Soil

Soil is made primarily from rocks. Rocks are worn back and broken down by the action of natural elements such as wind and rain (**weathering**). Soil also contains air, water, and often material from decaying plants and animals as well as living things (such as worms, bacteria and fungi). This forms small particles – clay, silt, sand or gravel – that are carried away from the source rock in a process called **erosion**. The particles mix with air, water, living things (such as worms, bacteria and fungi) and their waste and dead, decaying parts to form soil. Soil production occurs over very long periods, sometimes only a centimetre of depth forms every thousand or so years.

weathering

the process by which rocks are broken down through natural means

erosion

the process by which broken rock particles are carried away by the action of wind and water

Did you know? 6.2

Aboriginal and Torres Strait Islander peoples' land management

For more than 50 000 years, Aboriginal and Torres Strait Islander communities cared for Australia using land and water management strategies.

When Europeans arrived, they brought farming practices from their homelands, which were very different environments to Australia. This led to problems like erosion and salinity. Nowadays, some people want to return to the practices of the Aboriginal and Torres Strait Islander peoples to repair the damage to the land. One example is the use of traditional fire management, which you have read about in Chapter 3.



Figure 6.24 Selecting what areas to burn, when and how often, is part of Aboriginal and Torres Strait Islander peoples' knowledge of the land.

Quick check 6.7

- 1 Recall what soil is made up of.
- 2 Explain why soil is considered to be a non-renewable resource.
- 3 Describe the process of weathering.
- 4 Contrast the processes of erosion and weathering.

Figure 6.25 Here you can see the evidence of erosion – the formation of London Bridge along the Great Ocean Road in Victoria.



Try this 6.1

As a class, discuss and come up with some strategies that you can use as an individual, family and community to reduce your use of Earth's resources.

How can re-using help to reduce? Give examples.



Figure 6.26 A slogan used to help us remember ways to reduce the impact of our way of life on Earth's resources

Section 6.2 questions**Remembering**

- 1 Rewrite the following terms and definitions, **selecting** the correct definitions from the second column.

Term	Definition
Mineral	Made from eroded rock, living things and their wastes and remains.
Soil	Solid materials found in Earth's crust
Rock	A building block of which there are many types forming Earth, each with its own specific chemical structure

- 2 **Name** a non-renewable energy source that is not a fossil fuel.
- 3 For each resource, **identify** whether it is renewable or non-renewable:
- water
 - oil
 - gum trees
 - sheep
 - natural gas.

Understanding

- 4 If oil and gas resources run out, **identify** three of our uses for oil and gas that will be affected.

Applying

- 5 **Explain** why coal, oil and gas are fossil fuels.
- 6 **Explain** why coal, oil and gas are considered non-renewable.
- 7 **Describe** how a hydroelectric power station is similar to a coal-fired one.

Analysing

- 8 **Distinguish** between a nuclear power station and a coal-fired power station and the way they work.
- 9 **Explore** why nuclear power stations are considered as alternatives to coal-fired power stations in attempts to reduce greenhouse gases.

Evaluating

- 10 **Justify** why there is a shift in farming practices to return to the ways of the Aboriginal and Torres Strait Islander peoples in terms of land management.



6.3 The water cycle



WORKSHEET

Learning goal

- 1 To be able to create a labelled diagram of the water cycle.

Good management of water is essential to the future of life on the planet. The water cycle is a way of showing how this resource moves through the environment. Before you look at it in more detail, it is important to note that water has three states – solid (ice), liquid (water) and gas (water vapour/steam).

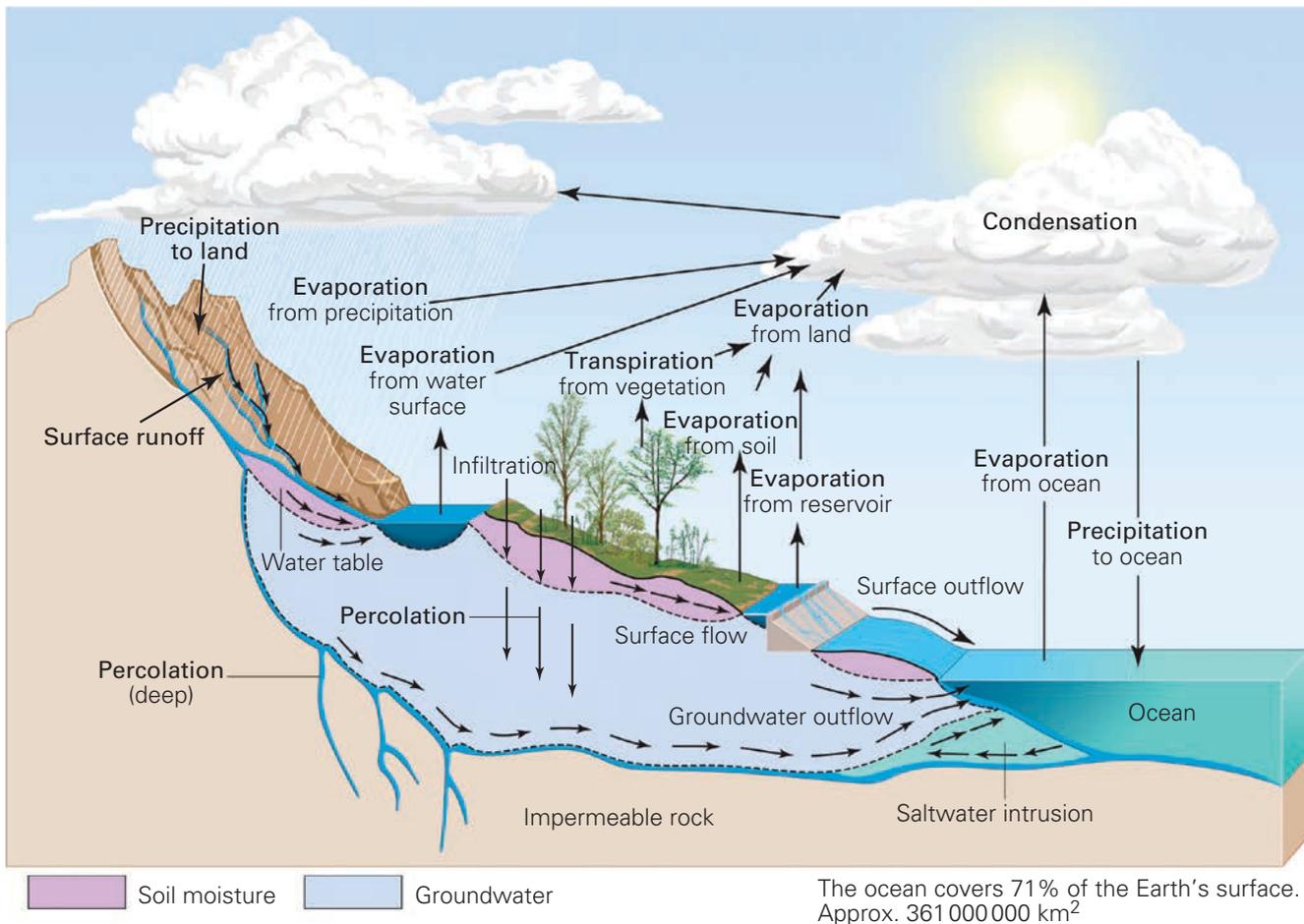


Figure 6.27 A representation of the water cycle demonstrating the processes involved



VIDEO
The water
cycle

The water cycle

Uptake from roots

Plants take up soil water through their roots, absorbing water and nutrients to grow. Some trees have roots that grow deep underground. Some send roots down to more than

10 metres to find water! Such trees can extract huge amounts of water, and in this way, trees can affect the rate at which water moves from the soil to the atmosphere.

Transpiration

Transpiration is the process by which plants draw water up through their stems and trunks to their leaves. It is driven by **evaporation** into the atmosphere through tiny pores in the leaves called stomata. It is an essential process by which nutrients and water absorbed by

the roots reach the stems and leaves. When there is not enough water coming in through the roots to balance water loss from the leaves – for instance, due to the soil drying out – these stomata may close to reduce water loss.

transpiration
the movement of water upwards through a plant to its leaves, from where the water evaporates

evaporation
when liquid changes to a gaseous state

Practical 6.4

Transpiration

Aim

Investigate the movement of water through a plant.

Materials

- oil
- 2 cuttings from the same plant (each about the same size and with the same number of leaves)
- water
- 2 test tubes
- petroleum jelly (Vaseline or similar)
- test-tube rack
- permanent marker

Method

- 1 Set up the test tubes in the rack.
- 2 Smear petroleum jelly over both sides of all the leaves on one of the cuttings.
- 3 Place the cutting with petroleum jelly in one test tube.
- 4 Place the other cutting in the other test tube.
- 5 Add water to fill two-thirds of each test tube.
- 6 Add a layer of oil on top of the water in both test tubes to prevent evaporation.
- 7 Mark the water line with the marker.
- 8 Place the test-tube rack in a sunny spot.
- 9 Monitor the test tubes (about once a day) until your teacher tells you to stop. Each time you check the test tubes, mark the side of the test tube, write the date, and measure how far the water level has fallen in each test tube.

Results

- 1 Design a results table for this experiment. Record your results.
- 2 Graph your results. Put both sets of data on one set of axes.

Discussion

- 1 Describe any trends, patterns or relationships in your results.
- 2 Explain why petroleum jelly was smeared on the leaves of one plant.
- 3 Explain why there were two test tubes in the experiment.
- 4 Identify any sources of error in this experiment and how they could be minimised in future experiments.

Conclusion

What can you conclude about the action of water in plants, from this activity? Explain the evidence of the action you describe.

Quick check 6.8

- 1 Name the three states of water.
- 2 Explain how water taken up into the roots of plants is linked to transpiration.
- 3 Describe what changes in state occur during transpiration.

Evaporation

Changing from the liquid state to the gas state, as in the evaporation of water, requires heat. Heat from the Sun therefore increases evaporation of liquid water from the sea, lakes and wet land surfaces, turning it into water vapour. Hot air rises and so the water vapour gets carried upward.

Did you know? 6.3**Reducing evaporation**

Some Aboriginal and Torres Strait Islander peoples dig wells to reach groundwater. Before moving to another area, the well is filled with clean sand. This not only means that animals and birds cannot bathe in or foul the water, but it also reduces water loss by evaporation. It only takes 90 cm of sand to reduce evaporation to almost zero!



Figure 6.28 Aboriginal and Torres Strait Islander peoples have lived on the land for so long that they understand how to work with the environment to ensure their survival.

Did you know? 6.4

Rain shadows

The Great Dividing Range (GDR) is located along the coastline of Queensland and New South Wales. It affects the overall climate on the East Coast because air cools as it travels over the ranges, creating rain. In the GDR, winds blowing across the ranges from the ocean fall as rain on the eastern side of the divide, meaning the western side is far drier. This is known as the rain shadow effect.



Figure 6.29 The Great Dividing Range

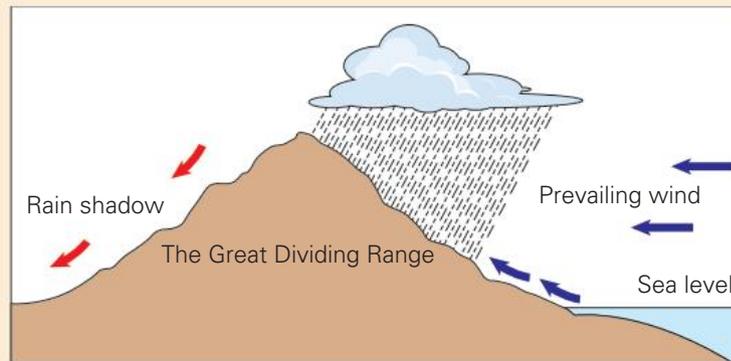


Figure 6.30 This diagram illustrates a rain shadow and its effects.

Condensation

Water vapour (water that has evaporated) rises up into the atmosphere, and as it gets higher, the temperature becomes lower. When the temperature drops below a certain point, which we call the dew-point temperature, **condensation** causes water vapour to turn into liquid water droplets. This is how clouds are formed. A cloud always has parts that are evaporating and condensing at the same time, causing certain areas to shrink or grow.

condensation
when heat is lost causing a gas to become a liquid

Did you know? 6.5

Planes drawing in the sky

Have you seen planes drawing in the sky? Aeroplane exhaust contains water vapour, and when up high in the atmosphere, the air is so cold that the water vapour in the exhaust 'condenses out', resulting in those white streams seen behind the plane. These white streams are called contrails.



Figure 6.31 Contrails of a plane

Try this 6.2: Teacher demonstration**Making clouds**

There are other ways to create 'clouds' in a bottle. Here is one way to do it.

Materials

- a little methylated spirits or ethanol
- hot water
- a 2 L clear plastic cool-drink bottle with lid
- a match

Instructions

- 1 Swirl a little methylated spirits or ethanol inside the bottle and empty it out.
- 2 Pour about a glass of hot water into the bottle and screw on the lid.
- 3 Give it a good shake.
- 4 Squeeze and release the bottle.
- 5 Unscrew the lid, light the match, blow it out and drop the smoking match into the bottle.
- 6 Rapidly screw the lid tightly onto the bottle and squeeze.
- 7 If you squeeze again, what happens?

Question

Explain your observations using the following terms: pressure, smoke, condense, water vapour, water drops, cloud.

Quick check 6.9

- 1 Link the processes 'evaporation' and 'condensation' to the formation of clouds. State whether they are heating or cooling processes.
- 2 State if the water in clouds is fresh water or salt water. Why?

precipitation

water that falls from the clouds towards the ground as rain or snow

infiltration

to move slowly into a substance

percolation

the process of a liquid moving slowly through a substance that has very small holes in it

Precipitation

Precipitation is condensed water vapour that falls as rain, snow or hail.

The tiniest droplets that condense in clouds are too small for gravity to have an effect. As they grow larger, they may fall too slowly or be held up by rising air – condensation actually warms the air around them. When the

weight of the water droplets is too great to be held up by rising air, they fall.

Infiltration and percolation

Infiltration is the movement of water into the soil after precipitation has occurred.

Percolation is the movement of water within the soil and underlying layers. This is affected by the characteristics of the soil, like grain size, geological features, gravity and how fast infiltration is happening in the surrounding soil.

Remember, for something to be a cycle, it must complete a loop, so the water that was evaporated from the sea, condensed as rain and fell on the land must percolate through



Figure 6.32 As of early 2020, 2019 was the hottest and driest year on record for Australia.



Figure 6.33 Uluru in the rain. Erosion by water smooths its surface and enlarges cracks into gullies.

the land to rejoin the sea. Moving water and the sediment it carries changes the surface of our planet. Erosion also contributes by changing the shape of mountains and taking sediments into the sea.

But what happens if the rate of precipitation exceeds the rate of infiltration, or the precipitation lands on rock, not soil, so infiltration cannot occur? If rain falls on an **impermeable** surface (a surface that water cannot move through, such as granite, clay or concrete) the water may evaporate directly

back into the atmosphere, run into rivers or may be directed to a dam or reservoir. This is called surface **runoff**.

To replenish our underground reservoirs, water must be able to seep through soils and rocks that are **permeable**. Sand is an example of a permeable surface as it will allow water through, while clay will not allow water through and so is called impermeable. Soils and rocks with high permeability allow water to penetrate not only through to plant roots, but all the way down to join the underground layer of water-bearing permeable rock (called **pervious** rock).

impermeable

not allowing liquid or gas to go through

runoff

water that flows away from high areas to low areas

permeable

allows liquids or gases to go through it

pervious

a substance that allows water to pass through via cracks or defects in the rock

Quick check 6.10

- 1 Define these terms: precipitation, infiltration, percolation, surface runoff.
- 2 Identify the stage of the water cycle that follows the process of condensation in the atmosphere.
- 3 State the term that is used to describe the movement of water into Earth's surface.
- 4 Explain the permeability of rock.

Practical 6.5

Modelling the water cycle

Aim

To investigate a model of the water cycle.

Materials

- 250 mL beaker
- water
- ice cubes
- Bunsen burner
- heatproof mat
- tripod
- gauze mat
- large watchglass
- matches
- safety glasses

Be careful

Be careful when using a Bunsen burner. Be careful of hot equipment and hot water. Wear your safety glasses.

continued...

...continued

Risk assessment

Safety is important when carrying out experiments. Look at the illustration and consider what you already know about safety in the laboratory. List the safety precautions you need to follow when using a Bunsen burner.

Method

- 1 Half fill the beaker with water.
- 2 Use the Bunsen burner to heat the water to boiling.



- 3 Stop heating and carefully cover the beaker with the watchglass. It needs to act as a lid on the beaker. Observe what happens to the bottom of the watchglass. Record your observations.
- 4 Remove the watchglass and heat the water again until it boils.
- 5 Stop heating and turn the burner and gas supply off.
- 6 Quickly cover the beaker with the watchglass and place ice cubes on its top.
- 7 Observe what happens to the space between the water and the watchglass.

Results

Record your observations at each stage.

Discussion

- 1 In detail, describe what happened to the bottom of the watchglass the first time you covered the boiling water with it. What was the change of state?
- 2 In detail, describe what happened to the space between the water and the watchglass the second time the beaker was covered, but with ice cubes on its top. What change of state has taken place this time?
- 3 Explain how clouds are formed in nature. Describe in detail how the experiment represents the formation of clouds.
- 4 Explain which components of the water cycle are represented in this model. Explain each component and which part of the experiment represents them.
- 5 Describe how the model could be improved to better model the water cycle.

Natural factors affecting the water cycle

In this section, you have worked through the natural processes involved in the water cycle. You may have noticed that you have also been learning about how factors in the environment affect these processes. Table 6.3 summarises the natural factors affecting the water cycle.

Factor in the environment	What process is affected?	Description of how it affects the water cycle
Temperature	Evaporation Transpiration	The higher the temperature (e.g. from hot sun), the more evaporation occurs from oceans, rivers and the soil. The higher the temperature, the faster transpiration occurs. Plants can manage this water loss by closing the stomata (tiny openings) in their leaves so the water cannot escape.
Humidity	Evaporation Transpiration	When the air is humid (contains lots of water vapour), evaporation and transpiration slow down. It is as though the air is already too full of water, so it cannot take on any more.
Wind	Evaporation Transpiration	When there is wind or moving air, evaporation increases as the air carries away the water vapour, allowing for more to evaporate.
Surface permeability	Runoff Infiltration	When the precipitation lands on a permeable surface, there is a high amount of infiltration and very little runoff.
Vegetation	Transpiration	The more vegetation there is, the more transpiration that occurs. The type of vegetation and amount of groundwater also plays a part. Plants in rainforests have access to lots of water, so can carry out transpiration as much as they like, while desert plants must minimise their water loss from their leaves, and so have a low rate of transpiration.

Table 6.3 Summary of the natural factors that affect the water cycle

Drought

When there is not enough precipitation for a long period of time, the result may be a **drought**, especially if there are unusually high temperatures.

drought
a prolonged period of unusually low rainfall that leads to a shortage of water

Explore! 6.3

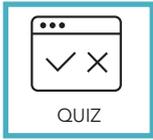
Drought-proof strategies

Over the years, there have been many suggestions regarding 'drought-proofing' Australia with different management strategies. Research some of the ideas below, and summarise the potential advantages and disadvantages.

Management strategy	Advantage	Disadvantage
Desalination plants		
Irrigation system through pipes		
Replant with native species		
Cap bores		
Store/tap northern river floodwaters		
Minimise land clearing		
Move away from European farming practices		
Install rainwater storage tanks at every house		
Install greywater systems		
Increase the price of water		



Section 6.3 questions



Remembering

- 1 **List** the everyday terms for the states of water.
- 2 **Name** the change of state that is involved in water changing from gas to liquid.
- 3 **Describe** how rain is formed.

Understanding

- 4 **Deduce** whether the following statements are true or false and then justify your answer.
 - a The water cycle has no start and no end.
 - b Clouds are made of water in gas form.
 - c When clouds become full of water droplets, they fall as rain, snow or hail.

Applying

- 5 Study Figure 6.34 and **determine** what process each number represents. Name each of the processes and include a definition.

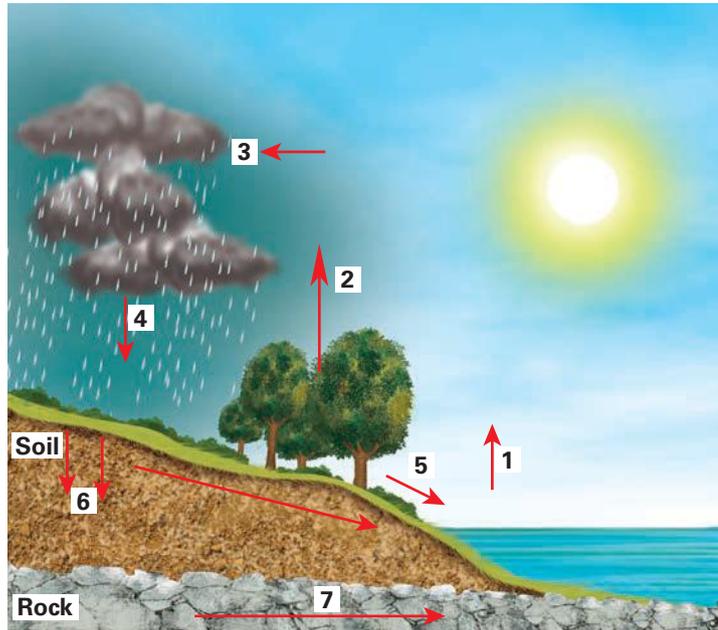


Figure 6.34 The water cycle

Analysing

- 6 For each of these processes, **identify** the state of the water at the start and at the end. If there was a change in state, identify where it took place.
 - evaporation
 - transpiration
 - condensation
 - precipitation
 - runoff
 - infiltration
 - percolation
- 7 Gardeners with pot plants or gardens that are sandy are likely to have experienced water-repellent soils if the soil has been dry for long periods of time. Thankfully, wetting agents can be used. **Identify** which process in the water cycle the soil wetting agents help with.
- 8 **Discuss** the natural factors in the environment that can affect the process of transpiration.

Evaluating

- 9 'If we are not careful, one day Earth will run out of water.' **Decide** if this statement is true or false. Using the terms you have learned in this section, give reasons to support your opinion.
- 10 **Predict** what would happen to Earth if the process of precipitation was not part of the water cycle.

6.4 Human management of water

Learning goal

- 1 To be able to describe how human management of water can impact the water cycle.



The natural water cycle is free of any objects made by humans, and natural environments are mostly composed of permeable surfaces like soil. Remember, these permeable surfaces encourage the water to sink in by infiltration, resulting in higher levels of groundwater. However, humans have changed the landscape and developed ways to store water, move water and treat water.

The urban water cycle

The way we humans have urbanised our world has affected the natural water cycle, and consequently, it often gets referred to as the **urban water cycle**. As our population grows, the management of this urban water cycle becomes increasingly important.

Water catchments to tap

Western Australia has many **catchments** directing water into dams for storage, such as the Mundaring Weir shown in Figure 6.36. These dams make up our water supply system (that is, the clean water that we can use in our homes). The Mundaring Weir supplies water



Figure 6.35 An illustration of the Western Australian town of Coolgardie in the 1800s. Imagine how the town has changed since then. Can you explain how these changes would have affected the water cycle?

by the *golden pipeline* to towns in the Western Australian Goldfields region such as Coolgardie.

Is this a natural process? No, humans have interfered with the water cycle so that we can store water for when we need it, tap into bores for use on agricultural land, and use pumps and pipes to transport the water to our homes and gardens.

urban water cycle
a water cycle that includes the consequences of increased development

catchment
a natural drainage basin that catches and directs water flow into a single lake or outlet to the sea

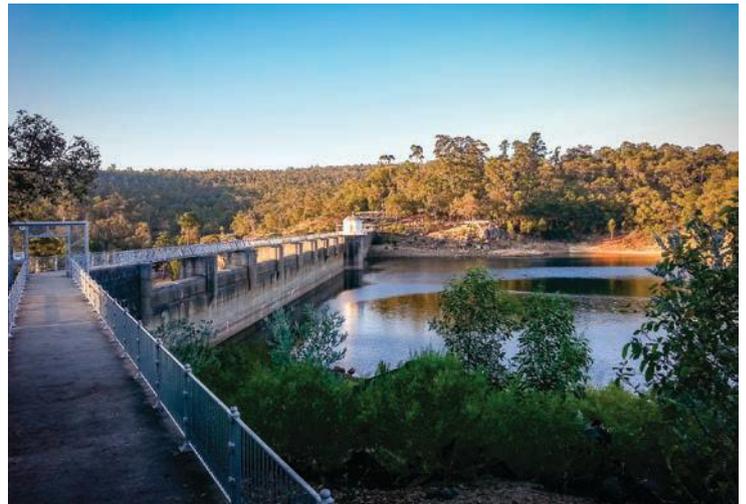


Figure 6.36 A view of the Mundaring Weir wall built in 1903 in Mundaring, Western Australia (top), and the adjacent Lake C.Y. O'Connor (bottom)

Practical 6.6

Gravity and water pumps

Aim

To build a working pump.

Materials

- 2 plastic cups
- 2 basins for holding water
- soap dispenser pump
- plastic tub that both cups can sit in
- a straw
- measuring cylinder
- sticky tape
- 1.5 m of clear vinyl tubing (6 mm or 1/4 inch inner diameter)
- 0.5 m of PVC pipe

Method

Part A

- 1 Place the two cups in the plastic tub. Fill one cup with 100 mL tap water.
- 2 Now try to pour water from one cup into the other through the straw. Record your observations and measure how much water is lost into the plastic tub.
- 3 How could you transfer the water through the straw more efficiently? Try some ideas and again record your observations and how much water is lost to the plastic tub.
- 4 Next, you will try the soap dispenser pump. First write down how you think the results will change if we use a pump like the soap dispenser pump.
- 5 Repeat the experiment and this time use the pump to transfer water from one cup to the other. Record your results.

Part B

- 6 Archimedes was a Greek inventor who lived in the 3rd century BC. His water pump invention is still used today! Find out about the Archimedes water pump called a screw. You can see a sketch of this pump in Figure 6.37.
- 7 Collect your materials and carefully wrap the tubing around the pipe leaving a couple of centimetres hanging from each end of the pipe.
- 8 Place one basin on top of a short stool. Leave the other on your bench and fill with water.
- 9 Place the wrapped pipe into the lower basin and lean the pipe so that the tube at the top will empty into the top basin.
- 10 Gently turn the pipe, watching the water move up the tubing and exit into the empty basin on the bench. This is like moving water up a hill.
- 11 Play around with how tightly the tube is wrapped around the pipe and the incline, to see if you can determine the fastest way of moving water up the hill.

Results

- 1 Record your observations from the different steps of the experiment including how much water is lost to the plastic tub that the cups are sitting in each time you try something new.
- 2 Record your findings on the fastest way to move water up an incline.

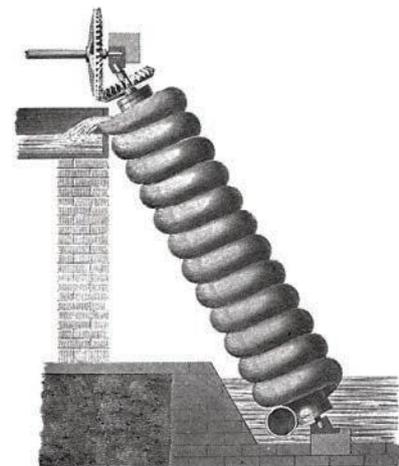


Figure 6.37 A nineteenth century engraving of Archimedes' pump, called a screw, used to lift water

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Discussion

- 1 Summarise your findings from Part **A** by comparing the results of the different techniques you tried.
- 2 Summarise your findings from Part **B** by describing the conditions that were needed for the most efficient transport of water up the incline.
- 3 Recall where we use pumps in our everyday lives.
- 4 Water is pumped to the top of water towers by many kinds of pumps. Water tanks are elevated because height affects the pressure. Predict whether it would take more pressure to pump water to a house that is at the top of a hill or to one at the bottom of the same hill. Fully explain your answer.

Sewage – toilets to treatment plants

The water that leaves our homes is typically classified as wastewater and enters into a sewer system. Sewer systems travel under the urban environment, transporting our wastewater to wastewater treatment plants. These treatment plants remove toxic substances, so the sewage can be safely pumped out to sea and back into the natural water cycle. It may be also recycled and used, among other things, for irrigation on farms, parks and golf courses.

Stormwater – drains to our bays

In urban areas, the natural water cycle cannot function normally because buildings, concrete

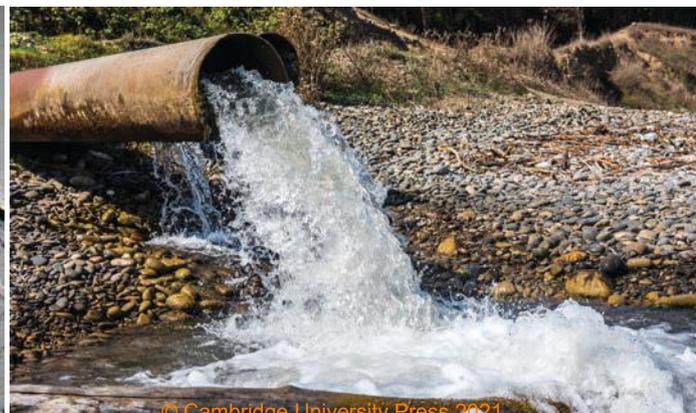
and other sealed surfaces prevent water from soaking into the ground. As a result, natural water flows are altered and stormwater is created. When stormwater collects on impermeable surfaces, it is called stormwater runoff and is guided along parking lots, curbs and streets to gutters and then into the stormwater system. This is different from the sewer system. Eventually, the stormwater reaches nearby rivers and creeks, then travels out into our bays, where it re-enters the natural water cycle.

It is important to keep in mind there are problems with stormwater, which are summarised in Table 6.4.

Problem	Consequence
Picks up rubbish/toxic substances	<ul style="list-style-type: none"> • Pollutants are carried directly into our waterways, bays and oceans
High volumes with heavy rainfall	<ul style="list-style-type: none"> • More pollution • Stream banks will erode more quickly • Habitat of aquatic animals may be damaged • Breeding cycles of those aquatic animals may be disrupted
Low soil moisture	<ul style="list-style-type: none"> • Trees develop shallow root systems • Trees become unstable

Table 6.4 Summary of the issues with stormwater

Figure 6.38 Stormwater drains and pipes return water to rivers and the oceans but not always in the condition it should be in.



Explore! 6.4**The Great Artesian Basin**

The Great Artesian Basin is one of the largest and deepest artesian basins in the world. Underlying more than 22% of the country, it stretches for 1700 000 km² over four states. Artesian water is pressurised water that is trapped underground. This water can be tapped by a bore, allowing it to flow naturally to the surface. The basin provides freshwater to much of inland Australia, and the area is home to an amazingly rich variety of birds, fish, insects, plants and marsupials. Because of its great importance, the federal government has set up a special authority to manage it.

- 1 Use your preferred search engine to research and read about the Great Artesian Basin Coordinating Committee (GABCC). Why was it important for such a committee to be set up?
- 2 What is the cause of the long term decline in water pressure across the basin? How is this being managed?

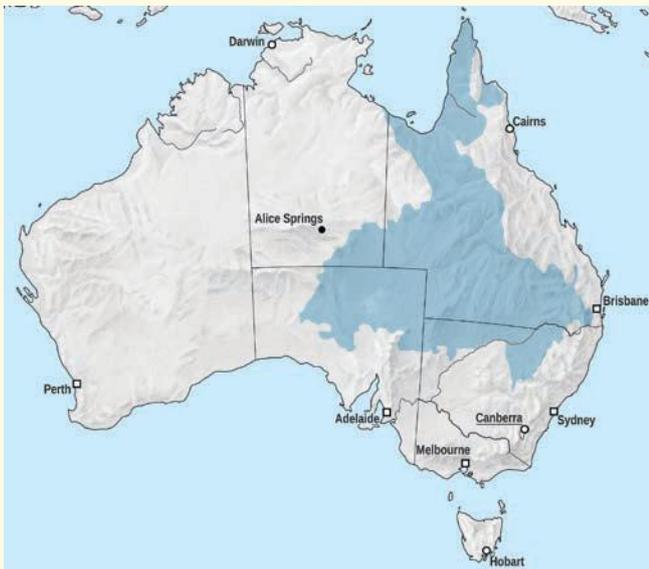


Figure 6.39 The Great Artesian Basin lies under the arid and semi-arid land of Queensland, New South Wales, South Australia and the Northern Territory.

Recycling water

Two types of wastewater are created in your home: **greywater** and **blackwater**.

greywater
water that has already been used for washing, which can be stored and used again for other uses such as toilets

blackwater
wastewater from toilets

Greywater

Greywater is wastewater from non-toilet plumbing in your house, such as showers, basins and taps. The exact contents of greywater depends on the household producing it. So, if you keep your chemical use to a minimum by using environmentally friendly, biodegradable soaps and detergents whenever possible, you could recycle the water by using it to water your plants. Greywater can also be treated and then reused indoors for things like toilet flushing and clothes washing, both significant water consumers.



Figure 6.40 The use of greywater has become popular.

Quick check 6.11

Compare what happens in the case of the natural water cycle and what happens in our urban water cycle for the following processes. You may need to do some research online.

evaporation

precipitation

infiltration

condensation

transpiration

runoff

percolation

How do we recycle greywater?

If you want to recycle your greywater at home, you will need to use some sort of treatment process. This may be biological, chemical, mechanical or a combination of these. Some of the key steps are outlined below and may be quite familiar if you have completed Chapter 4 Mixtures:

- Coarse filtration – removes large particles, including hair, and prevents clogging
- Fine filtration and biological treatment – microbes in a sand filter breakdown plant/ animal matter in the water
- Disinfection – UV or ozone disinfection

Blackwater

Blackwater is water that has been mixed with waste from the toilet. In addition, water

from kitchens and dishwashers is excluded from greywater (and called blackwater) because of the potential for contamination by germs and grease. This waste does not break down and decompose in water fast enough for use in domestic watering systems. It requires biological or chemical treatment and disinfection before re-use.

Water treatment

In the state of Victoria, Werribee has one of Melbourne's two water treatment plants. It is a historic plant that treats half of Melbourne's sewage, and also is an internationally recognised bird habitat! Can you believe it produces 40 billion litres of recycled water a year and is totally energy self-sufficient? It uses sewage gas to create all the electricity it needs!

Quick check 6.12

- 1 Explain the difference between greywater and blackwater.
- 2 If you want to recycle your greywater, list the places where it comes from and what you could do to improve its quality before recycling.
- 3 Explore the advantages and disadvantages of re-using your household greywater.



Figure 6.41 The lagoons of the Western Treatment Plant in Werribee, Victoria

Explore! 6.5

The Waugal and water perspectives

Aboriginal and Torres Strait Islander peoples view bodies of water as special places. The Waugal (rainbow serpent) is recognised by the Noongar people as the creator and maintainer of fresh water sources. As it moved across the land and rested, its body created bodies of water, including the Gngangara Mound. The Gngangara Mound is Perth's largest source of fresh water.

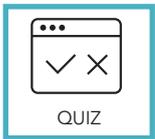
Aboriginal and Torres Strait Islander peoples also created tools to help carry water. Conduct research to find out about the following in relation to Aboriginal and Torres Strait Islander peoples and discuss your findings as a class. Remember to note down the details of the regions you research, as there are many different communities throughout Australia.

- Finding water
- Water management
- Technology for carrying water
- Use of water throughout time



Figure 6.42 The Waugal, as depicted on a Bibbulmun track marker

Section 6.4 questions

**Remembering**

- 1 **Recall** the process of recycling greywater.
- 2 **Identify** two ways our water in nature can be kept unpolluted.

Understanding

- 3 **Explain** why water tanks that supply water are built high up in towers.
- 4 **Describe** how blackwater is different to greywater.

Applying

- 5 **Illustrate** the urban water cycle using a simple diagram.
- 6 **Identify** one method you could use at home to recycle water and explain why it is important that water is recycled in nature.
- 7 You want to recycle your greywater and use it to water your vegetable garden. **Describe** what you should do to ensure your greywater is safe to use on plants.

Analysing

- 8 **Classify** the wastewater created in the following situations as either blackwater or greywater.
 - a Ahmed is having a shower.
 - b Babak is brushing his teeth at the bathroom sink.
 - c Carla is using the toilet in the restroom.
 - d David is washing his dishes in the dishwasher.
 - e Etsuko is doing her laundry using a washing machine.
 - f Fabien is using the urinal in the restroom.
- 9 **Explain** whether evaporation and transpiration rates would be higher on average in Broome or in Albany.

Evaluating

- 10 **Discuss**, based on what you have learned in the last two sections of this chapter, why water should be considered an important renewable resource and how we are threatening its quality as a resource.
- 11 **Justify** your decision to use or not use recycled water.

Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked question	Check
6.1 I can state the definitions of 'renewable' and 'non-renewable'.	1	
6.1 I can list examples of renewable sources of energy.	16	
6.2 I can list examples of non-renewable sources of energy.	16	
6.3 I can describe the water cycle, including the changes in the states of water and the factors that affect each part of the cycle.	15	
6.3 I can describe how human management of water can impact the water cycle.	24	

Review questions

Remembering

- 1 **Identify** the missing Earth resources and what their uses are in the following table.

Resource	Uses
Water	
	Living things to breathe, burning things, wind for drying clothes, powering windmills
Living things	
Rocks	
	Growing food
Energy from the Sun	

- 2 **Define** the terms 'urban water cycle' and 'stormwater'.
 3 **Provide** two examples of fuels made from biomass.

Understanding

- 4 **Identify** where greywater and blackwater come from.
 5 **Compare** a hydroelectric power station and a nuclear power station.
 6 **Describe** why minerals are non-renewable.
 7 **Outline** the advantages of recycling greywater at home.

Applying

- 8 **Summarise** how ocean energy is used to create electricity.
 9 We are often encouraged to recycle, reduce and re-use rather than buy new items. **Explain** why this is the case.
 10 **Identify** two reasons why soil is such a precious resource.
 11 **Identify** the reasons why it is so important for us to reduce our dependence on fossil fuels.
 12 **Identify** two advantages of using nuclear energy as an energy source.



- 13 **Summarise** the purpose of transpiration for trees.
- 14 **Explain** why hydroelectricity would not be possible if it was not for solar energy.
- 15 **Describe** the process of transpiration as it relates to the water cycle.

Analysing

- 16 **Classify** each of the resources as renewable or non-renewable, identifying the timescale for renewal. You may do so in a table, as shown.

Resource	Renewable or non-renewable	Timescale for renewal
Geothermal		
Coal		
Wind		
Tides		
Natural gas		
Biofuel		

- 17 The Sun, wind, waves, tides, hydro and geothermal are all renewable sources of energy. While there are many advantages to using these sources, **discuss** some limitations of renewable energy.
- 18 **Compare** hydroelectricity with a giant battery as a source of electricity.
- 19 Most of the methods of generating electricity involve using turbines. **Discuss** some examples of how turbines are used in different situations to produce electricity, stating what other device needs to be connected to them.
- 20 **Compare** pervious rock and impermeable surfaces with respect to their interaction with water.
- 21 **Compare** natural water flow to stormwater flow with respect to the impact on the environment.

Evaluating

- 22 In 2017, Australian researchers developed printable solar technology. They made an electronic ink product from non-toxic materials, and when this ink was printed onto plastic sheets, they had flexible solar panels. **Predict** some of the uses of this new solar panel in the future.
- 23 Imagine that you have just got out of the pool and your towel is all wet. **List** three environmental conditions, which will dry the towel the fastest i.e. cause the most rapid evaporation of water.
- 24 **Discuss** whether humans have altered the water cycle. Give reasons for your decision.



Data questions

With the current strong government policies to reduce pollution, Western Australia could produce up to 37% of its electricity from renewable energy sources by 2030. The state's main renewable energy sources can be categorised as solar, hydro, wind, and biomass. The approximate amount of electricity produced by each sector from 2009–2018 is represented in Figure 6.43.

- 1 **Identify** which of the renewable energy sources contributed the largest percentage of renewable energy in Western Australia in 2018.
- 2 **Determine** the amount of electricity produced in Western Australia from biomass in 2015.
- 3 **Recognise** whether solar electricity or hydroelectricity generation has increased more over the period of 2009–18.
- 4 **Contrast** the growth of wind energy to that of solar over the ten-year period.
- 5 **Identify** the trend in the total use of renewable energy in Western Australia over time.
- 6 **Identify** a limitation to attempting to accurately predict the energy that will come from renewable sources in the future.
- 7 **Predict** whether Western Australia will achieve a goal of generating 15 000 GWh of electricity from renewable energy in 2030.
- 8 Using the data presented, **justify** which renewable energy source is likely to make up the lowest percentage of Western Australia's electricity generation in the year 2030.

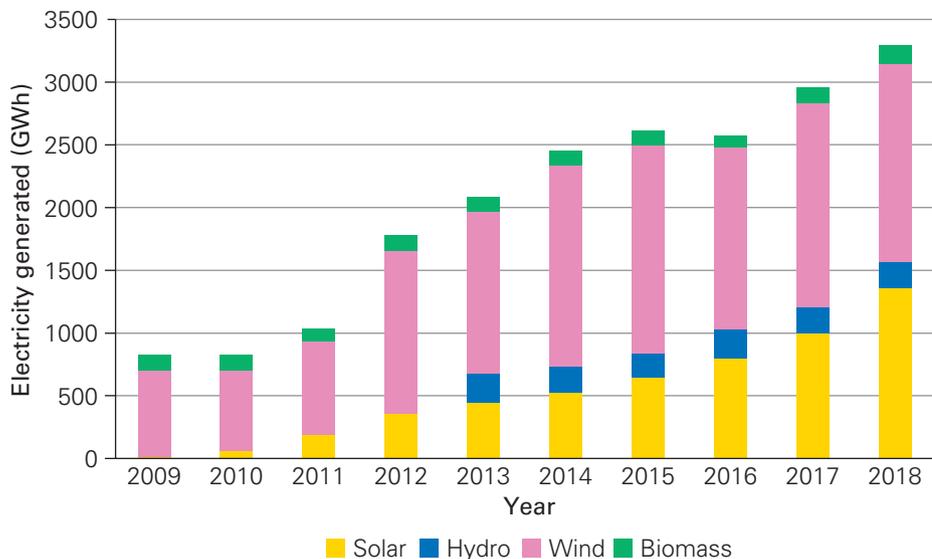


Figure 6.43 Approximate amount of electrical energy produced from renewable energy sources in Western Australia from 2009–2018

STEM activity: Diseases in water

Background information

Waterborne diseases (diseases that spread through water) are caused by a variety of microorganisms that can lead to devastating illnesses. Outbreaks of waterborne diseases often occur after severe weather events like droughts, floods and tsunamis. Because climate change increases the severity and frequency of some of these major weather events, communities – especially in the developing world – could be faced with more widespread outbreaks of diseases. The drinking of polluted water, poor sanitation and overcrowding in temporary settlements are all contributing factors to the spread of the disease.

Many types of engineers (for example, civil, material, mechanical, environmental and chemical engineers) have roles in improving our existing water treatment systems and designing new ones to meet the ever-changing nature of our world. This will become more important as the need to build more greywater and blackwater recycling plants grows. The purification of water is not a straightforward and easy process, with so many different possible pollutants and diseases. Therefore, full water treatment generally includes multiple steps to cover as many bases as possible. These steps include sedimentation (a process in which small pieces of a solid material fall to the bottom of a liquid and form a layer), filtration and disinfection.



Figure 6.44 Outbreaks of waterborne diseases often occur after severe weather events.



Figure 6.45 Bacteria can reproduce very quickly and so require immediate removal from water sources to prevent their spread.

Design brief: Build a water filtration device using commonly available materials.

Activity instructions

In this activity, you will be challenged to design and build a water filtration device using commonly available materials. To meet this challenge, you will take on the role as an engineer from the 'Super Dooper Clean Water Company' and work through the engineering design model, which includes designing, building, testing and evaluating the performance of the filtration device. You will then use this information to work towards an improved water filtration design.

You will need to begin by looking at:

- different types of common materials that can be used to filter polluted water
- the constraints that need considering before you design and build your prototype
- how you will determine if your design was successful.

Suggested materials

- 'polluted' muddy water (supplied by your teacher)
- 2 L plastic bottles with the bottoms cut off
- scissors
- paper towel
- squares of textiles, such as fine nylon or calico
- elastic bands
- spoons for stirring
- filtering materials like coffee filters, filter paper, soil/sand/pebbles, activated charcoal, cotton wool balls etc.
- measuring cups
- beakers or jars to work in

Research and feasibility

- 1 Research and identify different common materials that can be used to filter polluted water.
- 2 List the constraints you will need to consider before you design and build your prototype for

the polluted water you will need to filter (size of the particles in the polluted water, sterilisation of microorganisms, testing the cleanliness of the water etc.).

Design

- 3 List and describe the important design features required to filter polluted water.
- 4 Design your prototype filtration system, including labels for all key components.

Create

- 5 Construct your prototype filtration system.
- 6 Use your filtration system to filter the polluted water your teacher has given you.
- 7 Measure the volume of polluted water poured into your filtration system and the volume of cleaned water produced. What was the change? Calculate it as a percentage of the original volume.

Evaluate and modify

- 8 Explain the possible causes of any differences between the volume of water before and after filtration.
- 9 Evaluate the effectiveness of your prototype filtration system. Did your filter work as you expected it to? Did the different materials remove what you thought they would? Explain why or why not.
- 10 Consider the quality of your water. Do you think the filtered water is clean enough to drink? Or clean enough to put into a river? Explain why or why not.
- 11 Reflect upon your design. What improvements would you make to your prototype filtration system? List some ideas for ways you might get the 'polluted' water even cleaner. Are there other materials you would like to use that could improve your design?
- 12 Draw your new and improved design.
- 13 What design constraints or limitations might be different for engineers developing real water filtration systems?

Chapter 7

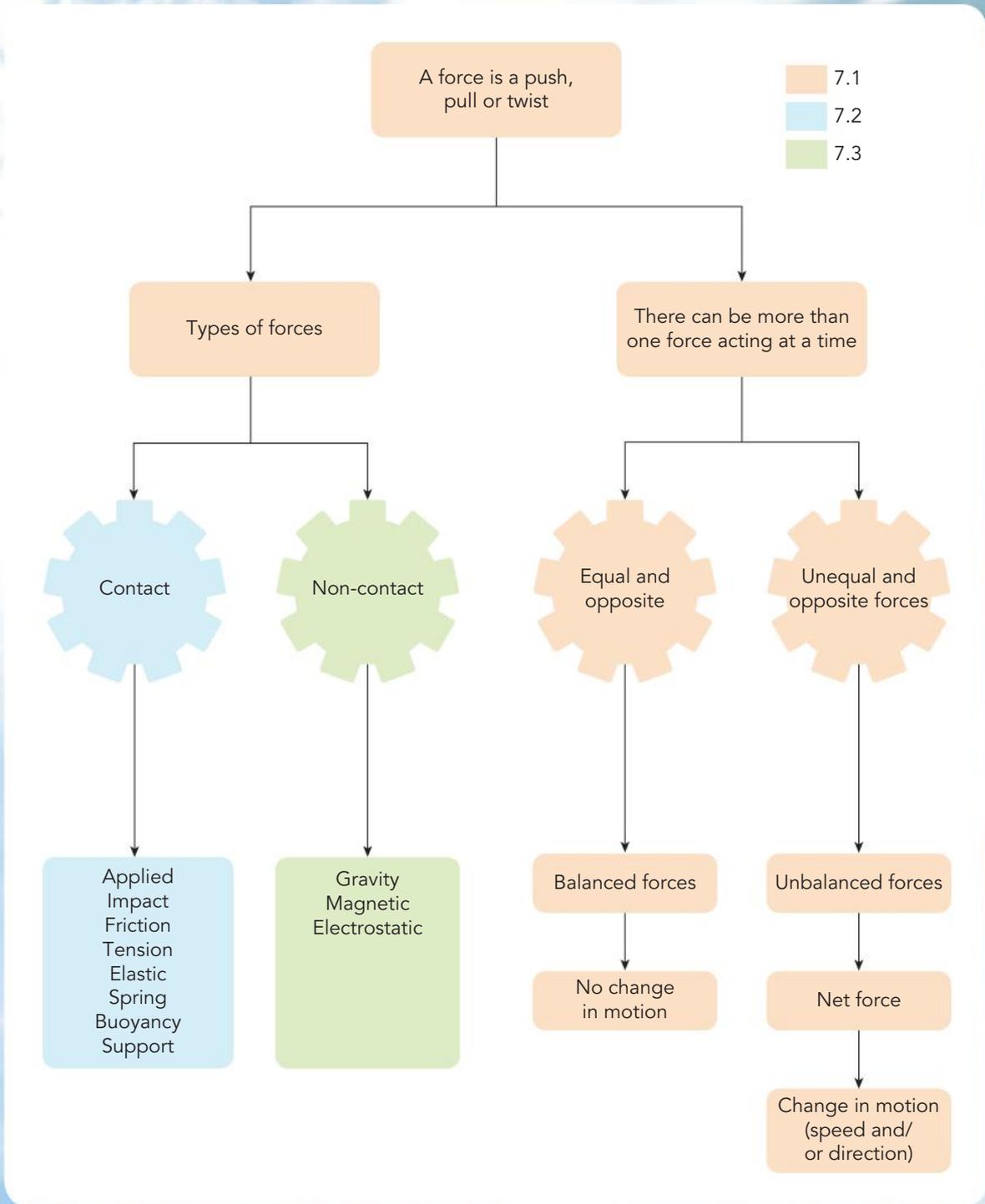
Forces



Chapter introduction

When you travel to school, you might use a train, car, bus, bicycle or even walk, all of which use forces. At school, you open doors, use a pen to write, open your lunch box, carry your bag and play sport, all of which involve forces. Even if you are just sitting still, the chair you are using provides a force to support your weight to stop you falling down. In this chapter, you will learn how to identify, measure and classify forces. You will also see how two or more forces may be combined to make a stronger force or to cancel each other out completely. In the final part of the chapter, you will learn about gravity and how its effects can be felt on Earth and in space.

Chapter map



7.1 Applying forces on objects



Learning goals

- 1 To be able to recall the term 'force' and how forces are measured.
- 2 To be able to describe the impact of balanced and unbalanced forces on an object.
- 3 To be able to draw a force diagram to indicate forces acting on an object.

force

a push, pull or twist in a specific direction

push

to exert a force away from something

pull

to exert a force towards something

muscle

tissue in the human body capable of exerting a force

A **force** is being applied whenever something is given a **push** or a **pull**, or is rotated or twisted. Forces are part of our everyday life. They are found in sport, music, transport, at home and in the work place. For example, when you push your pen across the paper to write, pull on

your socks, strum guitar strings or kick a football ... those are all forces! In your own body, your **muscles** apply forces when you move. In nature, the forces from the flap of a bird's wings allows it to soar in the air, the sweep of a whale's tail moves it through the water, and the push in a grasshopper's legs lets it jump.

Try this 7.1

The following picture demonstrates forces in action. Make a list of all the pushing and pulling forces you can see in the following image, and if you can, describe what it is in each case that is doing the pushing or pulling.

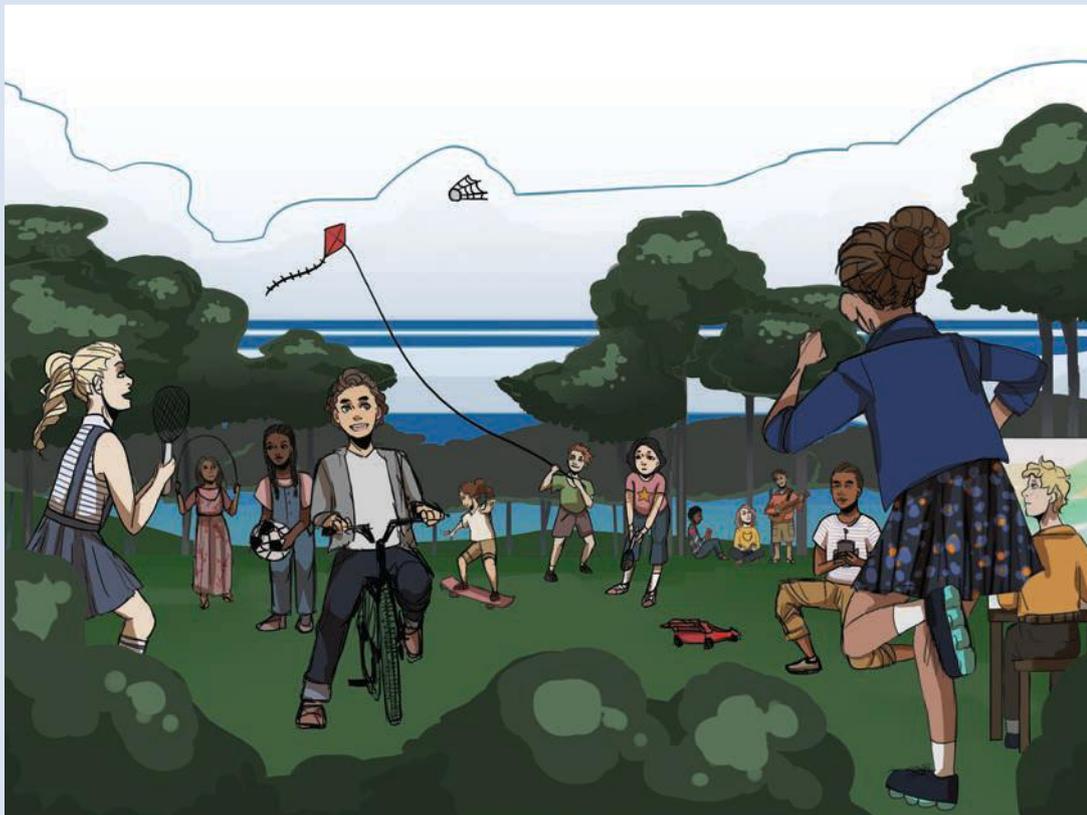


Figure 7.1 Having fun in the park means many forces are in action.

Table 7.1 gives a summary of some of the forces and associated terms.

Contact or non-contact	Type of force	Description	Example
Contact forces	Pushing	One object moves or tries to move another that it is touching, away from it.	Pushing a trolley.
	Pulling	One object moves or tries to move an object which it is attached to, towards it.	Pulling on a lead to move an animal.
	Impact	The force of one object hitting another.	Action of a bat on a ball.
	Friction	The force between two things rubbing together that makes them slow down relative to each other.	Brake pads rubbing on the wheel of a bike.
Non-contact forces (acting at a distance)	Gravity	The apparent force of attraction when one thing moves near something that has mass.	The force that keeps you on the ground.
	Magnetic	The attraction or repulsion of electrically-charged particles that are moving.	A magnet picking up bits of iron.
	Electrostatic	The attraction or repulsion of objects that have an electric charge.	Attraction of pieces of paper to a rubbed balloon.

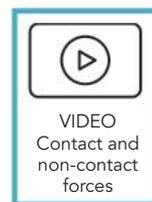


Table 7.1 Summary of forces

How are forces measured?

Forces are measured using a unit called the **newton** (N). One newton is approximately the force you need to keep a 102 g apple from falling.

Springs are usually used to measure forces because a spring will stretch when a pulling force acts on it and will be squashed or compressed when a pushing force acts on it. In your classroom, you may use something called a spring balance, which can measure a pulling force. At home, you may use kitchen or bathroom scales to measure the force of a push. The bigger the force you are measuring, the stronger the spring will need to be.

You may wonder why you are using scales and spring balances to measure forces, when in homes and stores they measure **weight**. In daily life we use the terms **mass** and weight interchangeably; however, they are not the same thing in science. An object's mass is related to the amount of material that it contains, measured in grams or kilograms, and it is the same everywhere in the universe. Its weight, on the other hand, depends on its mass *and* the strength of gravity at its location.

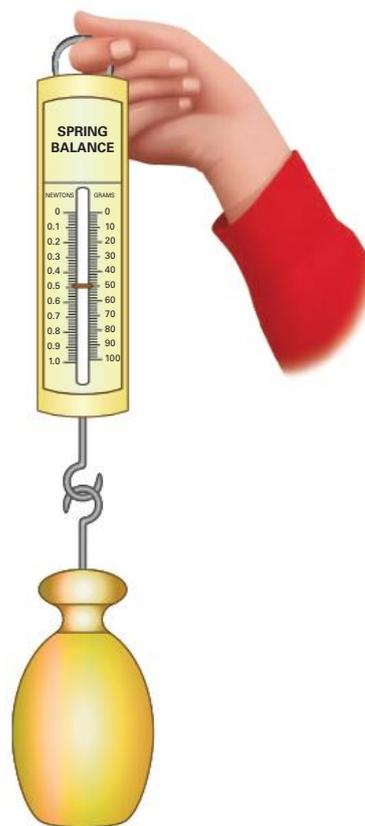


Figure 7.2 A spring balance can be used to measure a pulling force such as the weight of an object hanging from it.

newton
the unit of force; one newton is roughly equal to the force you need to keep a 102 g apple from falling

weight
the force of gravity on an object; it is measured in newtons and changes in space

mass
the amount of substance in an object that never changes, even in space

The weight of an object is the force with which gravity pulls it towards the centre of the Earth, whether it is falling or pressing down on the surface that it is resting on. So, scales and balances really measure a force – weight – even though they may be labelled in units of mass such as kilogram or grams.

On the surface of the Earth, an object with a mass of 1 kilogram has a weight of about 9.8 newtons (N). Your kitchen or bathroom scales can provide an approximation of a force in newtons if you use a conversion of $1 \text{ kg} = 9.8 \text{ N}$.

Practical 7.1

Using a spring balance

Aim

To select the most appropriate spring balance.

Materials

- a range of spring balances (e.g. 1 N, 5 N, 10 N, 50 N)

Method

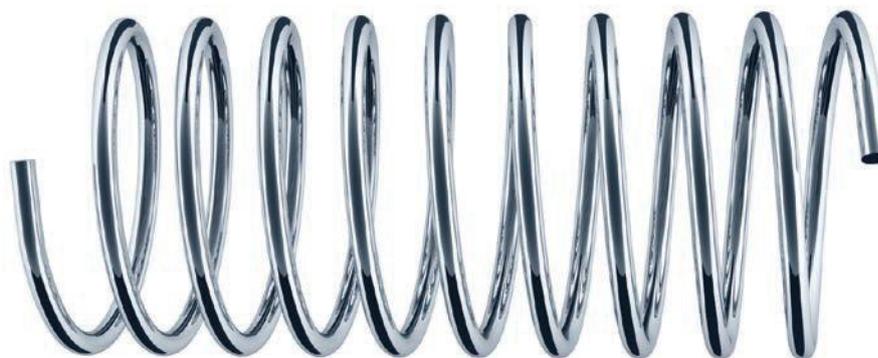
- 1 Copy the results table into your science book.
- 2 Determine the force needed to complete the actions in the table.

Results

Item	Force required (N)
Hold your pencil case	
Drag this textbook across the table	
Remove a piece of sticky tape from your desk	
Open the lab door	
Drag your stool across the floor	
Hold your school bag	

Discussion

- 1 State whether the forces applied to the items are push or pull forces.
- 2 Name the forces involved when hanging and dragging an item.
- 3 Sequence the items in order from most to least force required to drag them.
- 4 Explain why the same spring balance could not be used for all of the actions.



Science as a human endeavour 7.1

A new device to measure the force of a bird's wings while flying

In 2015, research was reported about a new device that is going to help scientists understand the forces that birds generate while flying. You know that a bird flaps its wings to fly, but determining how a bird generates lift has been a problem for scientists. The device is called an aerodynamic force platform, and it works like the force platforms that have allowed bioengineers to study the forces that humans exert to walk or run. Essentially, it is a box the size and shape of a large birdcage, with supersensitive force sensors attached to the bottom of the box. As the bird flies, each beat of its wings pushes against the air, which in turn pushes against the bottom of the box. These forces are recorded to produce a precise measurement for each stroke of the bird's wings.



Figure 7.3 Identifying how a bird generates lift has been an issue for scientists.

How do you draw forces?

When you want to indicate the forces acting on an object, you draw a force diagram. This diagram uses arrows to show both the direction and size of the force. For example, look at the image of a hanging plant held by a hook in Figure 7.4. The plant is being pulled down due to **gravity**,

and the length of the arrow on the diagram represents the size of this force. What stops the plant from falling is a force called **tension**, which comes from the chain. The size of the tension force must be the same as that of gravity, and work in the opposite direction, to hold the plant in place. In other words, the forces of gravity and tension are equal and opposite, so they are balanced. On the diagram, the arrow for the tension force is drawn with the same size as the arrow for gravity, but pointing up.

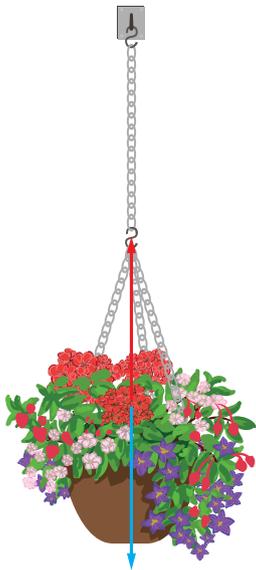


Figure 7.4 The tension in the chain pulling up (red) balances the pull down (blue) of the plant due to gravity.

In Figure 7.5, there are three plants and you can draw a force of gravity arrow for each one, with length proportional (corresponding) to their weight. The size of the tension force to

hold the three plants up must equal the total of all their gravity forces. So on the diagram, the tension arrow is drawn as long as the three gravity arrows added together.

gravity

a non-contact force describing the pull of any object with mass

tension

the force in a wire, cable or string when being stretched



Figure 7.5 The tension in the chain pulling up (red) is equal to the sum of the pull down (blue) of the three plant baskets due to gravity.

Interactions of forces

Forces can either work together or against each other. Imagine a group of people trying to push a car that will not start. One person pushing cannot move it, but when they all push together in the same direction the car starts to move. The push force from everyone in the group combines into one big force that is now larger than the gravity and friction forces holding the car in place. On a diagram, the push forces of each person are added up and could be shown by one force arrow with a length equal to the individual force arrows added up.

On the other hand, in a tug of war or rugby scrum, the two teams apply forces in opposite directions (Figure 7.6). If the forces are equal in size, there will be no change in the movement (in this case, because there is no movement then there will continue to be no movement). Equal and opposite forces are said to be **balanced**.

balanced forces
forces of the same size but which act in opposite directions

unbalanced forces
a combination of one or more forces that has an overall effect, and which changes an object's motion

Sometimes forces are **unbalanced**, meaning that one is bigger than another.

For example, if you have a tug-of-war with all the people having the same strength, and one side has more people, then that side will pull with a greater force, so the forces are said to be unbalanced, and the stronger team will move the other team. Unbalanced forces cause a change in movement. This change in movement can be seen by something slowing down, speeding up, changing direction, changing shape or rotating.



Figure 7.6 In a rugby scrum, the forces of the two teams are working against each other.



Figure 7.7 Unbalanced forces exist when there are not equal sized forces pulling in opposite directions, this causes change in movement.

Quick check 7.1

- 1 Define the following key terms in your own words: force, newton, balanced, unbalanced.
- 2 Identify which of the following activities use a push force and which use a pull force:
 - a catching a fish on a fishing rod
 - b dragging your toboggan behind you in the snow
 - c cutting up salad vegetables for lunch
 - d writing in your exercise book
 - e typing on your computer
 - f lifting a heavy school bag
 - g hitting a hockey ball
 - h putting on your slippers at night.
- 3 Explain how a spring can be useful in measuring force.
- 4 Match each force to its approximate value.

Weight of an apple	700 N
Weight of a car	1 N
Weight of an adult	100 N
Weight of a dog	7000 N

- 5 A hiker in Figure 7.8 exerts an upward force on her bag when she carries it, while the downward force is gravity.
 - a Decide if these forces are acting together or working against each other.
 - b Communicate this by drawing and labelling arrows on the picture.



Figure 7.8 A hiker carrying a backpack.





VIDEO
How do you know a force is acting on an object?

What are the results of applying a force?

You may have noticed that a force can be applied to change the motion of an object, but this is not always the result. There are five main things that forces can do and it depends on whether the forces are balanced or unbalanced:

twist
to turn something

rotate
to turn or spin on an axis

- 1 A force can balance another force so there is no change in its motion. (The important word here is 'change'.
- 2 A force can change an object's speed to make it go faster or slower, including starting from rest when its speed was zero.
- 3 A force can make an object change its direction of motion.
- 4 A force can make an object **twist** or **rotate**.
- 5 A force can change an object's shape by moulding, bending, stretching or breaking it.

Balanced forces can be acting on a moving object as long as its speed and direction are not changing.)

Try this 7.2

Observing forces

Use the materials listed to perform the tasks listed in the table below.

- rubber band
- lump of modelling clay
- tennis ball
- bar magnet
- paperclip
- inflated balloon
- plastic counter

Draw the table in your book and record your observations.

Task	Observations	
	Change in motion or shape	Force that caused the change
Stretch a rubber band.		
Squash a lump of modelling clay.		
Drop a tennis ball and catch it when it bounces.		
Bring a bar magnet close to a paperclip.		
Use your hands to compress an inflated balloon (be careful not to pop it).		
Rub an inflated balloon against your head and then hold it near your hair.		
Use your fingers to flick a plastic counter across a table.		

1 A force can balance another force.

You saw earlier that two forces that are equal in size and are applied in opposite directions balance each other out and so have no overall effect on the movement of an object. When forces are balanced, a stationary object remains stationary, and a moving object keeps moving at the same speed and in the same direction. There are plenty of examples of this in your classroom and at home; let's have a look at just a few.

What forces act on a book when it is resting on a surface such as a shelf? The weight of a book is balanced by the shelf pushing up on it. This force is equal and opposite to the weight, so they are balanced. If the pull of the book down due to gravity was bigger than the push up of the shelf, the book would fall through the shelf. What would happen if the shelf pushed up more than the book is pulled down?

As you continue on through the years studying Science, you will learn more about the force of surfaces and objects opposing the weight of masses resting on them, which for now we'll call the 'support force'. You will learn it is an example of 'reaction force', also called 'normal force'.

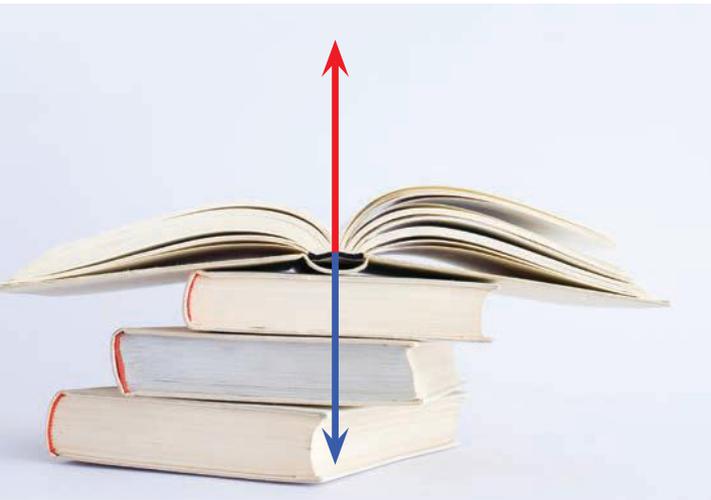


Figure 7.9 The weight of the book (blue) is pulling down towards Earth due to gravity. This is balanced by the normal force of the other books pushing back at it (red).

An object floating in water, like the ball in Figure 7.10, has an upwards **buoyancy force** that balances the pull of gravity on the ball down (its weight). Consider what would happen if the pull of gravity was larger than the buoyancy force.



Figure 7.10 The weight of the ball (blue) is balanced by the buoyancy force of the water (red).

Try this 7.3

These rocks at Stonehenge in England have been exerting forces on each other for around 5000 years. Begin by identifying where the forces are acting. Then explain whether they are balanced or unbalanced. What is the evidence that allowed you to come to this conclusion?



Figure 7.11 Stonehenge is one of the wonders of the world.

Just because a force is balanced, does not mean there is no movement going on. For example, if a car is travelling at a constant speed in a straight line on a flat road, there are four forces that act on it as it moves. The force of the road against the wheels pushes the car forward, while **air resistance** and a force called **friction** slow it. The weight of the car pulls it down and the road surface pushes it back up. The car will continue to travel at a constant speed, neither speeding up or slowing down. This is because when the forces are combined, they cancel each other out. The overall force on an object is called the **net force**. In this case, the forces are balanced and the car has no net force and will travel at a constant speed. If the car was to speed up, slow down, stop or change direction, this would require a non-zero net force.

buoyancy force

the force experienced by an object that is partially or fully submerged in a fluid, e.g. water or air

air resistance

the frictional force of the air

friction

a contact force opposing motion due to the interaction between two surfaces

net force

the sum of all forces acting on an object

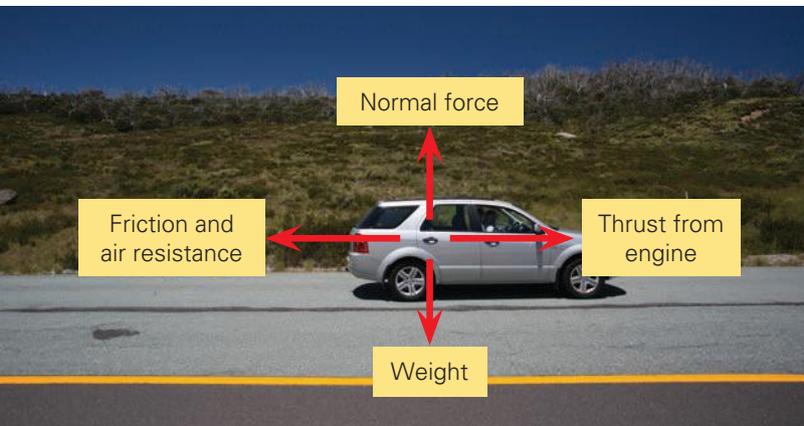


Figure 7.12 The forces on the car are balanced and the car travels at a constant speed.

The same could be true of a yacht gliding through the water in a race. The continuous force of the wind on its sail pushes the yacht forward, while the **drag** force of the water cancels it out, and so the yacht continues to travel at a constant speed.

drag
the frictional force of a liquid or gas



Figure 7.13 The force of the wind on the sail of a yacht helps it move steadily through the water.

Quick check 7.2

- 1 A painting is hanging on a wall from a nail. Decide if the forces on it are balanced or unbalanced.
- 2 A drone is hovering in the sky. Its weight is pulling it down and the force of its rotors is pulling it upwards. Decide if these two forces are balanced.
- 3 A swimmer is racing from one end of the pool to the other at a constant speed. Explain what must be true of the forces on the swimmer.
- 4 Draw a sailing boat, like the one in Figure 7.13, which is changing its speed and going faster as the wind blows harder. Add force arrows to your drawing for the force of the wind pushing it along, the drag of the water, the weight of the boat and the buoyancy force.



2 A force can change an object's speed.

Sports are great activities to look for unbalanced forces. Can you think of some examples in sports of when something has sped up due to a force? A golf club hitting a golf ball is a very sudden and quick change in the speed of the ball, and for this reason is classed as an **impact force**. Many ball sports involve impact forces, because the ball is hit by a tennis racquet, hockey stick or cricket



Figure 7.14 The force of the golf club changes the speed of the golf ball from zero to extremely fast in a matter of milliseconds.

bat. Can you think of other examples of where a force makes something speed up?

Objects changing speed can get slower as well. Brakes on a bicycle and car apply forces to reduce the speed in this way. You may have noticed if you stop pedalling your bicycle on a flat road, even if the wind is minimal, you will slow down and eventually stop.

This is because friction has been working in the opposite direction of your travel the entire time. When you stop applying force via pedalling, friction is now the larger force and will slow you until you stop.

impact force

a contact force, which sometimes only lasts for a short time; often impact forces change an object's speed

turning force

a force that makes an object start or stop rotating

3 A force can make an object rotate or change its direction.

As well as changing the speed of an object, unbalanced forces can also make objects rotate, change direction or spin. Think of all the vehicles that use force to turn their wheels and you will realise that rotating forces are very common. **Turning forces** are not just found in transport, but also bathroom taps, door handles and even doors themselves turn when a force is applied to open them.



Figure 7.15 In the bathroom, the force of your hand results in the top of the tap rotating.



Figure 7.16 In the workshop, screwdrivers and drills require a force to make them turn.



Figure 7.17 In the kitchen, a food mixer uses turning forces.

What about changing the direction of an object using force? In Figure 7.18 on the following page, you can see how a wall will exert an impact force that will change the direction of a ball that is thrown at it. There are lots of sports where you can see a force change the direction of an object like a ball.

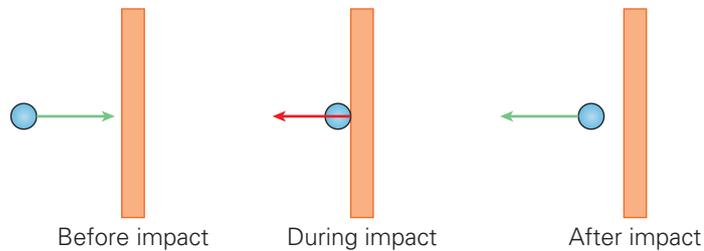


Figure 7.18 When a ball directly hits a wall, the direction of the rebound will be in the opposite direction to how it was thrown. The green arrows indicate the direction of the ball, and the red arrow represents the force of the wall on the ball.

Quick check 7.3

- 1 Name some sports where a force can change the speed of an object or a person.
- 2 Name some sports where a force can change the direction of an object or a person.
- 3 Name some sports where a force can change the rotation (spin) of an object or a person.
- 4 Explain if it is possible for an object to speed up or change direction without a net force.
- 5 Decide if two forces that speed up, slow down, or change the direction of an object are called balanced or unbalanced. Explain your answer.

4 A force can change an object's shape by moulding, bending, stretching or breaking it.

When bread is made by hand, a baker uses forces to mix the ingredients and to mould the dough into a new shape. Potters use forces to mould clay spinning on a wheel to create bowls. In these examples, the material is soft and is easily moulded into a new shape. Plasticine and

mouldable
soft enough to be shaped

brittle
a material that is likely to break or snap when subject to a big enough force

Play-Doh are examples of materials that children enjoy moulding. A material that can be moulded easily is called **mouldable**.

However, not all substances can change their shape easily when subjected to a force. Substances that tend to break instead of bending are called **brittle**. Two examples are glass and pottery, which break into pieces if they are subjected to a large enough force.



Figure 7.19 Dough is moulded by forces into a new shape.



Figure 7.20 Potters use a wheel to spin the clay as they shape it to form a bowl.

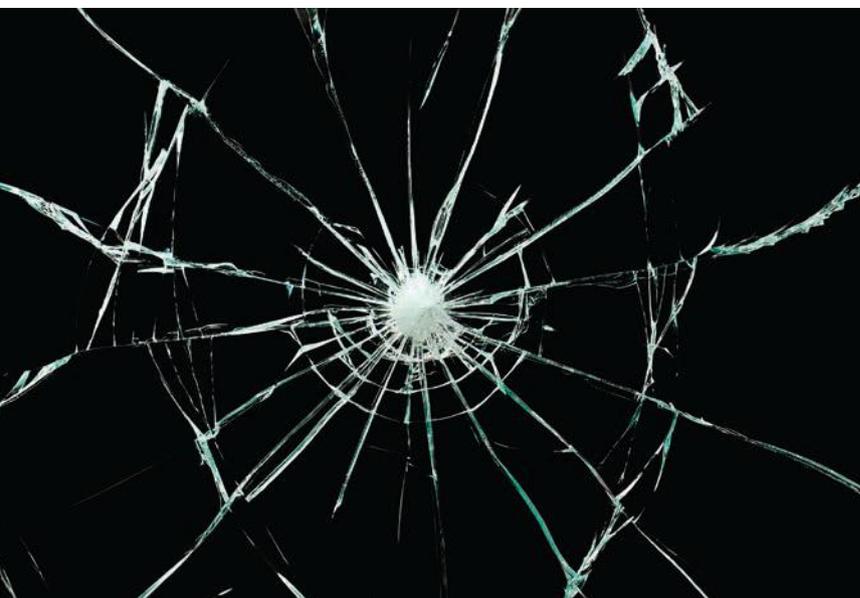


Figure 7.21 Glass can shatter if a large impact is applied.

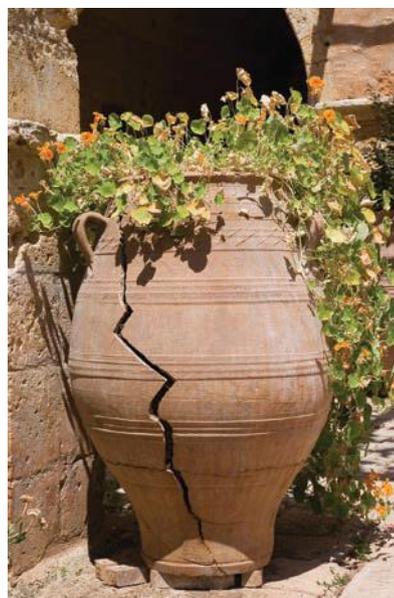


Figure 7.22 Once the clay has been fired in a kiln, pottery becomes very brittle.



Elastic materials include metal springs, rubber bands and elastic. These materials stretch or bend when a force is applied and then return to their original shape when the force is removed. Elastic materials can also exert a force of their own, called an elastic force, when their shape is changed.

elastic
elastic materials bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

Figure 7.23 The spring on this park ride will allow the turtle to move around while staying upright.

Practical 7.2: Investigation

Investigating forces

Aim

To measure some everyday forces.

Materials

- a range of spring balances (e.g. 1 N, 5 N, 10 N, 50 N)
- a selection of masses (e.g. 10 g, 20 g, 50 g, 100 g, 1 kg, 2 kg)

Planning

- 1 Identify the independent variable.
- 2 Identify the dependent variable.
- 3 Develop a hypothesis by predicting how a change in the mass will affect the dependent variable.
- 4 Identify the controlled variables and describe how these will be managed.

continued...

...continued

Method

- 1 Copy the results table into your science book.
- 2 Record the masses you have selected in the first column.
- 3 Hook each mass onto an appropriately scaled spring balance and measure the force required to hang (suspend) it against gravity. Record the measurement in your results table.
- 4 Place each mass on a bench, attach a spring balance near the base, and record the force required to get it moving.
- 5 Then drag the mass steadily at constant speed (drag each mass at roughly the same speed) along the laboratory bench. Record the force reading when it is moving at a steady rate. Write it in your results table.

Results

Mass (g)	Force required to suspend the mass (N)	Force required to get the mass moving (N)	Force required to drag mass at constant speed (N)

- 1 Plot a graph showing the relationship between mass and the force required to suspend it. Draw a single straight line so that it best fits through the average line of all the data points.
- 2 Plot another graph showing the relationship between mass and the force required to drag the mass at a constant speed. Again, draw a line of best fit for the data points you have.

Discussion

- 1 Identify the relationship between the mass and the force required to suspend it.
- 2 Identify the trend in your second graph.
- 3 Identify any **anomalous** results in your second graph.
- 4 Extrapolate your second graph to find out how much force would be required to drag a 4 kg mass at the same constant speed you used previously.
- 5 If you had any anomalous results, explain how these may have been caused.

anomalous
an outlying result that does not fit in with the pattern of the other results

Conclusion

- 1 Propose a valid conclusion that can be drawn from these results.
- 2 Justify this conclusion using data from your results.
- 3 State whether your hypothesis is supported or not.

Quick check 7.4

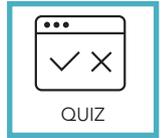
Match each word to its correct description.

- | | |
|-------------|--|
| 1 Brittle | A Can be stretched but always returns to its original shape when the force is removed. |
| 2 Elastic | B Can be made into a new shape. |
| 3 Mouldable | C Breaks into pieces when a force is applied. |

Section 7.1 questions

Remembering

- 1 **State** the name given to two forces that cancel one another's effect.
- 2 **Name** one body component that can exert a force.
- 3 **Identify** four examples of impact forces.
- 4 **List** the different things that forces can do to an object.
- 5 **List** the features of balanced and unbalanced forces. Include an example where possible.



Understanding

- 6 **Identify** an everyday example of each of the different results that forces can cause.

Result of the force	Everyday example
No change in motion	
Speeding up of object	
Slowing down of object	
Rotating of object	
Changing direction of object	
Changing shape of object	

- 7 If a boat is travelling at a constant speed in a straight line on the water, what can you **infer** about the drag and the force of the engine?
- 8 **Provide** an example from everyday life for each of the following types of force:
 - a A force that changes the motion of an object
 - b A force that changes the shape of something
 - c A force that stretches or bends something.
- 9 **Provide** two examples of materials that are:
 - a able to be moulded
 - b brittle
 - c elastic.
- 10 **Explain** whether water can exert a force.
- 11 **Explain** how a spring balance can be used to measure force.

Applying

- 12 You push a door, and find it is locked and will not open. Apply your knowledge of forces to **decide** if you still exerted a force even though the door did not move.
- 13 If you hold a carton of milk at arm's length in front of you, **determine** if a force is still exerted on the milk carton if it is not moving.
- 14 You are sitting on the couch at home after a big day swimming at the beach. Sketch yourself on the couch and draw arrows to represent the forces acting on you. **Describe** if the forces are balanced.
- 15 In Figure 7.24, the weight (force of gravity) of the gymnast is balanced by the tension in the ropes. **Sketch** the gymnast and include arrows to represent the forces acting on him.

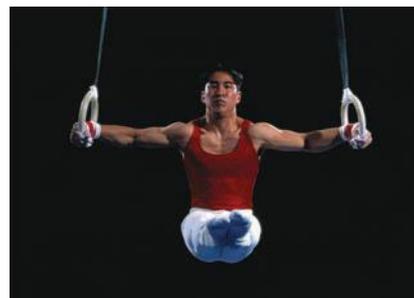


Figure 7.24 A gymnast

Analysing

- 16 Analyse Figure 7.25 and **describe** the forces on the cyclist. Assume they are moving at constant speed in a straight line.
- 17 Force is measured in newtons. **Describe** the mass of 30 N.

Evaluating

- 18 Three cycling triplets are identical in every way, including their size, mass, and clothing, and they have identical bikes. They start a sprint race side by side at the same time, and after 10 seconds, Albert has gone 200 m, Ben has gone 160 m and Charlie has gone 120 m. **Discuss** these results. Was the average force each exerted on the pedals the same during the 10 seconds, or different? Who exerted the highest force, and who exerted the lowest? Was it a fair comparison? Explain your reasoning.



Figure 7.25 A cyclist on a bike path in Perth

7.2 Types of forces: Contact

**Learning goal**

- 1 To be able to list some contact forces.



You have learned that forces can have a number of different effects. Using the definition that a force is a push, pull, twist or rotation, you will now learn that there are many types of forces and you will learn how to classify the forces you encounter at school and at home.

Contact forces are pushes, pulls and rotations which require the objects to be in contact

with each other. A contact force that is part of everyday life is friction. You will look at this and some of the other contact forces caused by ropes, chains, levers, pulleys, motors and human muscles.

Friction forces

Friction is a force that is part of everyday life. Friction is a contact force and occurs

Try this 7.4**Push and pull**

In groups, take a few moments to think of different pushes or pulls (i.e. forces) you have experienced in the last few days. (Leave aside twists and rotations for the time being as they tend to be trickier.) You may like to choose one from a sport, and one from playing a musical instrument, from home or at school, or even on public transport – are there any forces involved? When all the groups have finished, create a list for your class and, if you can, try to give the forces names and to classify them into groups. How did you go? There are lots of possible forces that you could have included in your list, so keep your list handy and now you will start looking at some of the categories of forces that exist in our world.

whenever surfaces rub together, or when a liquid or gas flows over a surface. It happens when one object tries to move over another object it is in contact with, like trying to move an armchair across the floor. Friction always acts in the opposite direction of relative motion, and so it either slows down or halts moving objects.

Imagine life without friction. Walking would be difficult because your shoes would have no grip on the floor. Normally you push your foot backwards against the ground

and the ground pushes back on you (note: the friction is pushing you forward here), but if there were no friction, it would feel like everything was covered in a thin film of slippery soap. This type of friction is called traction. Without friction, car brakes would not work and without the grip of the tyres on the road, cars would not be able to move in any direction: backwards, forwards, nor around corners. On the positive side, playground slides would be really fast and a roundabout, once started, would carry on spinning forever.

Practical 7.3

Surfaces and friction

Aim

To observe the effect of various surface types on the frictional force on a moving object.

Materials

- large block of wood with hook attached
- spring balances (10 N, 20 N and 100 N)
- a variety of different surfaces (e.g. vinyl floor, carpet, concrete, polished concrete, sandpaper, grass or bitumen in a safe area).

Method

- 1 Copy the results table into your science book. Ensure the independent variable is in the left-hand column and the dependent variable trials and mean sit at the right of the table. Don't forget units in the headers.
- 2 Place the block of wood on the first surface and attach the appropriate spring balance. (Hint: Which spring balance would be the best for each surface? How would this be determined?)
- 3 Pull the block of wood at a constant speed across the surface and read the force on the spring balance. The force on the spring balance will be equal to the force of friction. Record this reading in your results table.
- 4 Repeat the measurement three more times and record in your table.
- 5 Repeat steps 1–4 on three other different surfaces.

Results

Surface	Friction force (N)			
	Trial 1	Trial 2	Trial 3	Mean

Discussion

- 1 Why was it necessary to measure the friction of each surface three times and find the mean?
- 2 List your surfaces in order of lowest to greatest friction force.
- 3 Explain why some surfaces create more friction than others.



VIDEO
Friction: an important force

Friction between surfaces

As you would have found by completing the practical activity, friction depends on the surfaces that are rubbing together. Rough surfaces tend to produce more friction than smooth ones. Friction also depends on the weight of an object. Think about that armchair you were trying to move earlier. If the chair is extremely heavy, there will be more friction opposing the push you are giving. Friction also depends on the speed at which an object is moving. It increases as the speed increases. This is why it is important to use the same constant speed in an experiment.

You have seen that friction can be a very useful force, but it can also have an unwanted consequence. When two surfaces rub against each other, the friction force can transfer energy which increases the temperature. On a cold day you may have rubbed your hands together to make them warm, or maybe you have rubbed sticks together at high speed to start a fire. However, higher temperature is not always welcome because it can represent wasted energy or be dangerous.

Minimising friction between surfaces

One way to reduce friction between two surfaces is to polish them or to use lubrication such as oil or graphite. This allows the surfaces to move over each other with less friction



Figure 7.26 Petrol engines need oil to lower the friction inside.



Figure 7.27 The wheel and axle allows objects to be moved over a surface with very little friction.

and thus generate less wasted energy. In Figure 7.26, clean oil is put into an engine to lower the friction between the moving parts. If there is no more oil, the extra frictional forces will destroy the engine because the metal expands as the temperature increases.

Another way friction can be reduced, especially when moving heavy loads from one place to another, is to use a wheel and axle. This is one of the earliest and most widely used inventions that has ever been made.

By using a wheel and axle, trains, cars, trucks and even aircraft taking off and landing can all move with little friction. Wheels are used all over the world. The only exception is on snow and ice, where surfaces have low friction and it is better to use skis or sledges on runners. Skis and runners do not sink into the snow and get stuck like a wheel would. Additionally, being long and thin, they tend to run straight where wheels would slide sideways.



Figure 7.28 Seaplanes use floats to land on water instead of wheels.

Wheels also do not work well if the ground is very rough, so trains need tracks, and cars work best on roads. Wheels do not work on water, so seaplanes designed to land on water use long thin hollow floats or pontoons shaped like closed canoes in place of wheels.

Try this 7.5

Use a spring balance to measure the force required to pull a wooden block across your bench. Next, lay out pencils or pens that are perfectly round and about the same thickness next to each other and measure the force required to pull the block on top of them. How does the force required differ? Can you explain your observations?

Friction in gases and liquids

In this section, you will learn about friction between solid surfaces and gases or liquids, which is also called drag. However, friction can also occur between liquids and gases, or even within liquids and gases. In the air, drag is also called air resistance. Friction in liquids and gases is very similar, and the two are often treated together as fluid friction.

As an arrow moves through the air, air resistance will act to slow it down, but because arrows are **streamlined**, the force slowing the arrow is small.

streamlined
designed to minimise air resistance or drag

Fish have a streamlined shape that helps them move through water easily. The same shapes are used by the designers of boats and submarines to reduce drag and to enable them to travel at high speed in water.



Figure 7.29 The friction force on an arrow as it flies through the air is small.

Figure 7.30 As trains have become more streamlined, their speed has increased.



In the air, birds have a streamlined shape to fly with as low an air resistance as possible. Air resistance is a major consideration for the designers of cars, trains and aircraft. Have a look at the two trains in the images in Figure 7.30 on page 275; their design has become more streamlined to allow them to go faster.

Quick check 7.5

- 1 Explain what friction is and how it works.
- 2 Describe two features of a car that are designed to minimise friction for better fuel economy.
- 3 Describe two features of a car that are designed to maximise friction for safety.
- 4 Define the key terms 'air resistance', 'drag' and 'streamlined'.
- 5 Explain why a shark's body is streamlined, whereas a koala's is not.



Figure 7.31 The streamlined shape of a kingfisher is useful to minimise drag during a dive.

Practical 7.4

Stretching springs

Aim

To observe the relationship between force and extension for a spring.

Materials

- spring
- retort stand, bosshead and clamp
- set of slotted weights
- ruler

Method

- 1 Using a retort stand, hang a spring on a bar and place an empty weight holder on the end of the spring.
- 2 Tape a ruler to the vertical bar of the retort stand. Use the scale of the ruler to record the initial position of the bottom of the weight holder.
- 3 Add masses to the weight holder. Each time a new mass is added, record the new position of the bottom of the weight holder. Be careful not to overstretch the spring.

Results

Mass (g)	Force (N)	Extension (m)

continued...

...continued

- 1 Calculate the force applied to the spring by dividing the mass in grams by 1000 and multiplying by 9.8.
- 2 Draw a graph of how force affects the extension of the spring.

Discussion

- 1 Identify the trend in your graph.
- 2 Identify any anomalous results in your graph.
- 3 Can you use your graph to make predictions about other masses?

Conclusion

From this activity we can claim that the extension of a spring depends on _____. This is supported through observing _____.

Elastic/spring forces

Forces in metal springs

Springs can be pulled, pushed or bent sideways. In each case they will exert a force in the opposite direction to the force applied: this is called a spring or elastic force.

Forces in elastic materials

Solid pieces of elastic or rubber can also be stretched, pulled sideways, and compressed. But a rubber band or strand of elastic cannot be compressed lengthwise, because of its shape.

Rubber and other elastic materials can be compressed when they are formed into a short, fat shape, and they are used in this way to absorb bumps and shocks in doorstops, in vehicles and machines.

Long pieces of wood, plastic or metal can also exert an elastic force when they are bent. They spring back to their original position when the force is removed, as long as the force is not large enough to break or deform them permanently. Tree branches are an example of this as they can bend in the wind. If they become rotten and unable to bend, they will break in a storm.

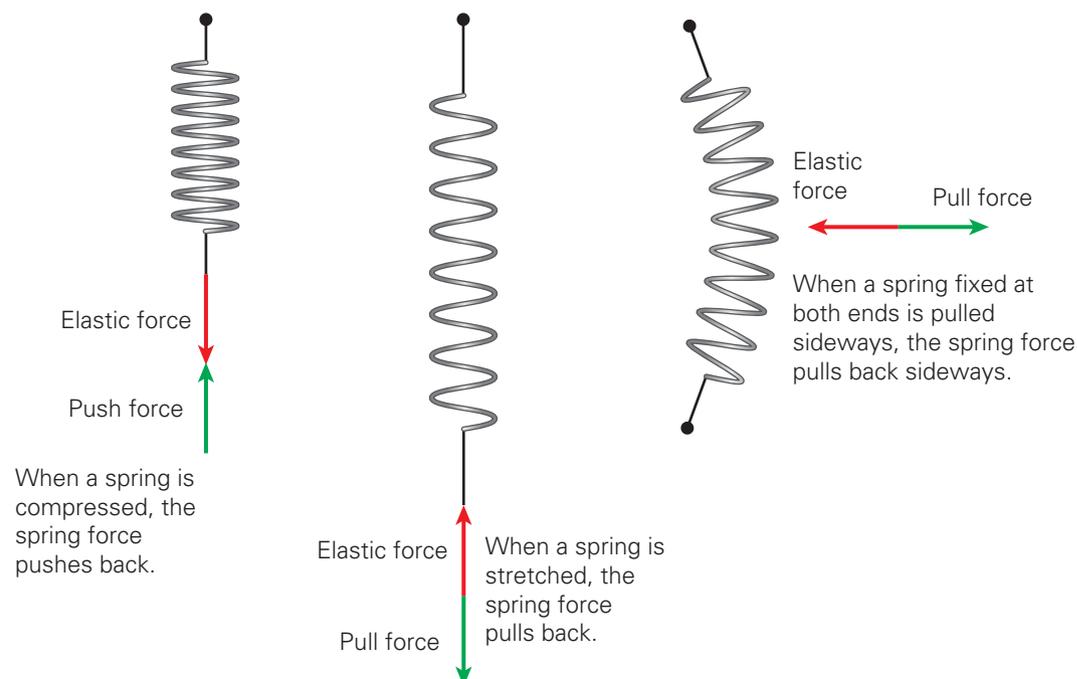


Figure 7.32 Three ways to apply a force to a spring

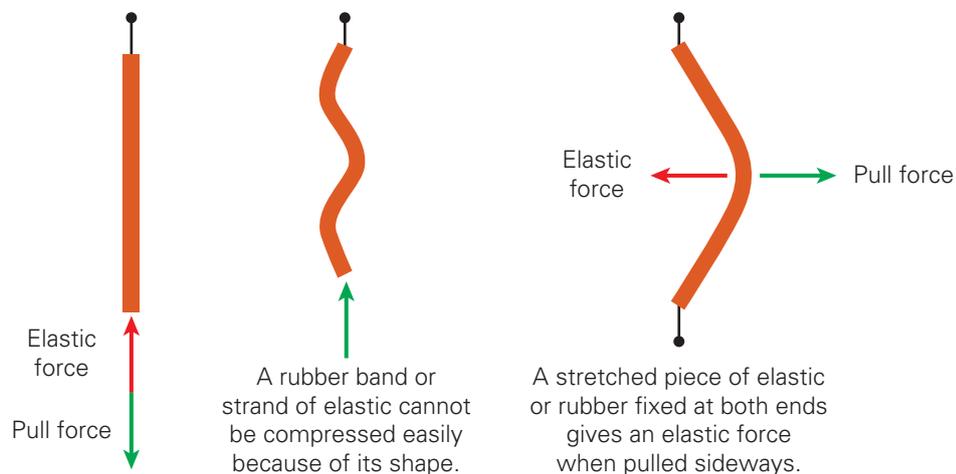


Figure 7.33 Two ways to apply a force to a rubber band



Figure 7.34 The diver makes use of the elastic forces in a springboard.

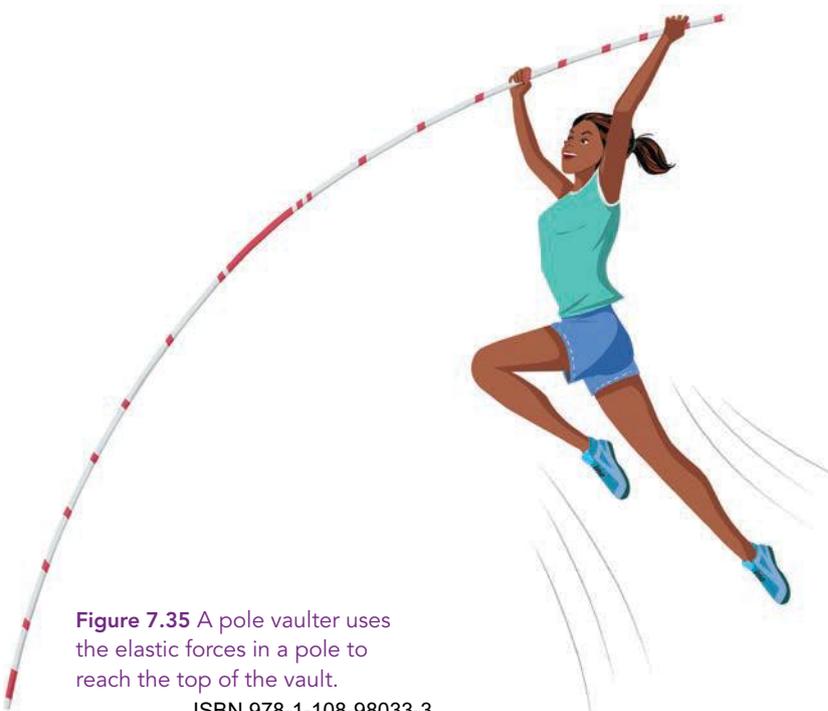


Figure 7.35 A pole vaulter uses the elastic forces in a pole to reach the top of the vault.

Elastic forces are used by divers on a springboard to gain extra height when they dive. The force exerted by a bow on an arrow is another example of an elastic force. Some of the force comes from the stretching of the string; however, most of the force comes from bending the wood or plastic of the bow.

Quick check 7.6

- 1 What is an elastic force?
- 2 Compare elastic forces on a spring and a rubber band.
- 3 Can you think of other sports or activities that have not been mentioned that use elastic or spring forces?

Buoyancy forces

The buoyancy force is the upward push that occurs when an object is partially or fully submerged in fluid such as water or air. If an object placed in water sinks, the buoyancy force acting upwards is smaller than the weight of the object. If it floats, the buoyancy force is equal to the object's weight.

There is also an upwards buoyancy force on an object in a gas, but it is much smaller, and can only be seen in an object that is very light compared to their size, such as a helium balloon. The air's upwards buoyancy force on a helium balloon can be greater than the balloon's weight (when it will rise) or equal to its weight (when it will float at a constant height).



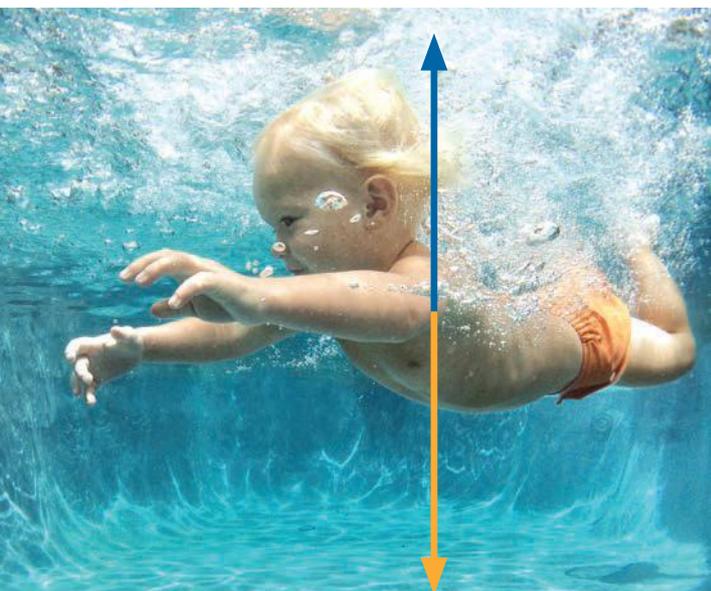
Figure 7.36 Buoyancy forces allow heavy container vessels to float.



Figure 7.37 In these glasses of lemonade, the lemon floats and bubbles of gas rise to the surface due to buoyancy forces.

You will have experienced a buoyancy force if you have been swimming: it is the force that makes you feel weightless in the water. Whether you are swimming on the surface or underwater as in Figure 7.38, the buoyancy force (blue) is approximately equal to the force of gravity (orange).

Figure 7.38 The buoyancy force on the baby is approximately equal to the baby's weight.



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Try this 7.6

Fill a bucket with water and collect a range of different balls such as a table tennis ball, golf ball, polystyrene foam ball, tennis ball, metal ball bearing and rubber ball.

Take each ball and submerge it in the water, releasing it at the bottom of the bucket.

Write down your observations when you let go of the ball. Did different balls act differently? What forces are acting in this situation? When are the forces balanced and unbalanced?

Did you know? 7.1

Buoyancy forces are everywhere!

Hot magma inside Earth is lighter than cooler magma, and buoyancy forces cause giant bubbles of hot magma to move towards the Earth's surface. These create volcanoes and earthquakes when they reach the crust. So, from tiny bubbles in a glass of lemonade to destructive volcanoes, you can find buoyancy forces everywhere.

Impact forces

The contact forces you exert or experience in daily life, such as moving an object or opening a door, are called **applied forces**. When objects collide, they typically exert or experience a force that lasts just a fraction of a second.

This is called an impact force, and it is a push that (usually) fast-moving objects or particles exert for the very short time that they are in contact with another object. These forces are increased if the moving objects are heavier or faster. Examples include ten-pin bowling skittles being hit by a bowling ball or a hammer hitting a nail. Can you name some other examples of impact forces?

applied force
force that is applied to an object by another object or person

Keep in mind that impact forces can be useful as well as dangerous. A pressure cleaner emits a jet of water at high speed, and when the water hits its target, its speed changes quickly, causing the water to exert a force that can be used to clean the surface.

In car accidents, impact forces can cause serious injuries, but these can be reduced by using seat belts, crumple zones and air bags. These safety measures spread the impact force over a larger area (thus decreasing the pressure at any point) and spread the change in speed over a longer time (thus decreasing the force).

Science as a human endeavour 7.2

Bike helmets

Australia has a proud record of leading the way when it comes to road safety. The origin of road safety legislation has its roots in evidence collected by doctors stating that road accident victims often had injuries that were preventable. The head is especially vulnerable to injury, and for this reason, both motorcyclists and cyclists are required to wear a helmet in Australia. The main function of the helmet is to protect the skull by stopping penetrating injuries, to spread the force over a larger area, and to make the change in speed of the head take a longer time as the head sinks into the foam thus reducing the force on the head. Similarly, occupants of cars wear a seatbelt to absorb the energy by spreading the impact forces over the chest and preventing the head from hitting the windscreen in an accident. The forces involved in the sudden changes of speed that can happen in a collision are very large. Injuries can be prevented if these forces are reduced by spreading the change in speed over a longer time and spreading the pressure of the force over a larger area, so the body is protected.

A major study presented in 2016 looked at the use of bike helmets around the world. Based on more than 64 000 cyclists, the study found helmets reduce the risks for a serious head injury by nearly 70%, face injury by 33% and fatal head injury by 65%. So, regardless of whether they are compulsory, wearing head protection is highly recommended!



Figure 7.39 Luke Bell of Australia wearing a helmet that protects his head and is also designed to minimise air friction.

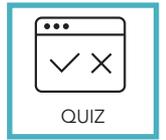
Quick check 7.7

- 1 Name the two forces acting on you when you are lying on an inflatable mattress in a swimming pool.
- 2 Define the term 'impact force' and provide three examples.
- 3 Explain why Australians are required to wear seat belts in cars and bike helmets when riding, in the context of impact forces.

Section 7.2 questions

Remembering

- 1 **State** the names of five main types of contact force.
- 2 **State** which contact force can be easily used to warm up a small object or surface.
- 3 **Recall** the common name for friction on an object moving through a liquid or gas.



Understanding

- 4 An impact force is a force that acts for a short time. **Provide** three examples of impact forces from sport.
- 5 The wheels of a car and some bikes are attached with springs. **Explain** using forces how the springs help give a smooth ride even on a bumpy road.

Applying

- 6 Look at the two cars in Figure 7.40 and **describe** which one is designed to go faster.



Figure 7.40 Which car will go faster?

Analysing

- 7 The foot in Figure 7.41 belongs to a swan. Use your knowledge of forces to **analyse** the structure of the foot and how it is adapted to be used in water.



Figure 7.41 The foot of a swan

Evaluating

- 8 **Propose** whether a glass or a plastic bottle is a better choice to carry water in a backpack.
- 9 Earthquakes are dangerous, and buildings in earthquake-prone places must be specially designed to withstand the shock of an earthquake. There are three types of building materials that could be used in an earthquake zone. Use your knowledge of forces to **propose** how you would use or modify each material to cope with earthquakes. Give your reasons and examples.
 - Brittle
 - Elastic
 - Bendable

7.3 Types of forces: Non-contact



Learning goal

- 1 To be able to list and describe three non-contact forces.

Non-contact forces are forces that act at a distance, through all matter, and outer space. They do not require physical contact for the force to act.

There are three key non-contact forces you will investigate:

- gravity
- magnetic
- electrostatic.

Gravity

Gravity is the name that we give to a force that exists when something changes its motion when it is near a body which has mass. If each body has mass, then each will change the motion of the other. You experience gravity as the force that pulls you towards the centre of the Earth. There is a force of attraction

between you and Earth. The effects of gravity near Earth's surface are familiar but Earth's gravity also extends into space. It holds the Moon in orbit, and keeps communication and weather satellites in orbit. But can you believe that the force of attraction between you and Earth goes both ways? You also pull the Earth towards you, but because the Earth is so much bigger than you, the effect of your force on the Earth is not noticed. Gravity is also the force that maintains all the planets in our solar system in orbit around the Sun.

What forces are acting on a falling object such as a book? It is moving towards the ground and speeding up as it falls, so you know that an unbalanced force is acting on it. As you have noted previously, the force pulling the book to the ground is due to gravity and is called weight. However, there is also a force pushing the book up. This force is called 'air resistance', which you can feel on your hand when you wave it quickly. But this force is much smaller than the weight of the book, so the book falls faster and faster (unless the book falls more than a few hundred metres, in which case, the air resistance can be enough limit the speed the book can reach).

Although the force of Earth's gravity gets weaker in space, the weight of an object is almost the same everywhere on Earth's surface. Remember, force is measured in newtons, so weight, which is a force, is measured in newtons, not kilograms.

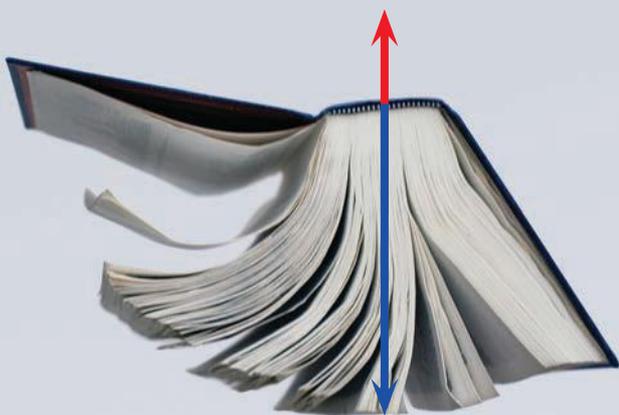


Figure 7.42 A book falls due to the force of gravity (blue arrow), which is opposed by the smaller force of air resistance (red arrow). The forces are unbalanced and there is a net force downwards.

Explore! 7.1

Fields

You may not be able to see gravity but it is always there. Earth's gravity creates a **field** (an example of a force field) around it.

- 1 Find out and summarise what it means to say that Earth's gravity creates a field around it.
- 2 Find a diagram of Earth's gravitational field and describe what happens to the strength of this field as you move closer to Earth. Describe the direction of the gravitational force as well.

Different gravitational pulls

At the beginning of Section 7.1, you learned that mass and weight are not the same, and on Earth's surface an object with a mass of 1 kilogram has a weight of about 9.8 N. Table 7.2 shows you how different locations in our universe have different pulls of gravity and so a mass of 1 kilogram has different weights in different places.

The Sun has the strongest gravity in the solar system, about 28 times the gravity on Earth.

Do not go for a holiday to the Sun!

Apart from being too hot, an average person would weigh about the equivalent of two cars on the Sun, and it would require a lot of effort just to move. Neutron stars are extremely dense objects which are left behind when some stars explode. They are so dense that 1 cm of human hair on a neutron star would weigh more than all the water in an Olympic size swimming pool on Earth. Black holes have such strong gravity that not even light can escape from them.

field

a region in space in which an object is affected by a force

Location	Mass (kg)	Weight (N) = mass × gravity
Surface of Earth	1.0	9.8
Surface of the Sun	1.0	275.0
Surface of the Moon	1.0	1.6
Surface of Mars	1.0	3.7
Deep space	1.0	0.0
Surface of a neutron star	1.0	200 000 000 000.0

Table 7.2 This table shows that a mass of 1 kg has a different weight at different locations in the universe because of the different strengths of gravity.

Try this 7.7

Jumping on planets: mass versus weight

Use a metre ruler and sticky tape to calculate how high you could jump on different planets.

- 1 Tape the ruler to a table leg or wall so that it is vertical.
- 2 Get a partner to kneel down so their eyes are level with the ruler.
- 3 Jump as high as you can while your partner records the height you achieved.
- 4 Repeat the jump two more times.
- 5 Swap roles so you are now recording the jump height of your partner. Repeat steps 2–4.
- 6 Copy the following table into your book and calculate the mean jump height.

continued...

...continued

Student name	Jump height (m)			Mean
	Jump 1	Jump 2	Jump 3	

- 7 Calculate how high you could jump on each planet, plus the Sun and Moon. Divide your mean height by the surface gravity (relative to Earth's) of each celestial body in the table below. For example, if you jumped a mean height of 0.65 m and wanted to calculate how high you could jump on Venus, you would divide 0.65 by 0.91. This would tell you that you could jump 0.71 m if you were standing on the surface of Venus.

Member of the solar system	Ratio of the surface gravity of each location to Earth's surface gravity	The height I could jump at each location (m)
The Sun	27.9	
Mercury	0.38	
Venus	0.91	
Mars	0.38	
Jupiter	2.36	
Saturn	0.92	
Uranus	0.89	
Neptune	1.12	
Pluto	0.06	
The Moon	0.16	

Quick check 7.8

- 1 Define these key terms: gravity, mass, weight.
- 2 Describe the relationship between the force of gravity, mass and weight.
- 3 You go to the butcher's shop to buy some sausages for a school fundraiser and the butcher says your sausages weigh 2.5 kg. Compare the meaning of the word 'weight' for the butcher in this situation versus what it actually means.
- 4 Use Table 7.2, which shows the pull of gravity at different locations, to decide where you would weigh the most, where you would weigh the least, and where you could jump the highest.

Air resistance

Do all objects of the same weight fall at the same rate? If they do, then identical pieces of paper, no matter how they are folded or not folded, should fall at the same rate. See whether this is the case or not in the following activity.

Practical 7.5

Surface area vs. air resistance

Aim

To determine how surface area and mass affect air resistance.

Materials

- one piece of A4 paper
- one piece of A4 card
- metre ruler
- stopwatch

Method

- 1 Copy the results table into your science book.
- 2 Take the A4 paper and measure its length and width to calculate its surface area. Record this in your table.
- 3 Drop the paper from a height of 1.5 m and record the time it takes to reach the ground. Repeat two more times.
- 4 Fold the paper in half and then repeat steps 1 and 2. Continue doing this until you have folded the paper 4 times.
- 5 Repeat using the piece of card.

Results

Number of folds	Surface area of paper (cm ²)	Time taken to drop paper (s)			
		Trial 1	Trial 2	Trial 3	Mean
0					
1					
2					
3					
4					

Number of folds	Surface area of card (cm ²)	Time taken to drop card (s)			
		Trial 1	Trial 2	Trial 3	Mean
0					
1					
2					
3					
4					

Plot both sets of results onto the same graph to compare them. Plot the surface area of each item against the mean time it takes to drop.

Discussion

Identify any trends, patterns or relationships in your results.

The experiment in Practical 7.5 demonstrates that the reason different objects hit the ground at different times is due to the interaction of the object with air: the air resistance of the object. When the flat piece of paper was used, the air resistance is much greater because it has to push more air out of the way. This is related to the area of the paper that pushes against the air. The side of the paper is a very

big area, so it falls much more slowly than the folded piece of paper where a smaller area pushes the air out of the way.

If these experiments were repeated without air (in a vacuum), then all the objects released from the same height at the same time, regardless of their mass, would hit the ground at the same time.

Did you know? 7.2

Galileo's experiment

Galileo Galilei was a scientist who did an interesting series of experiments on gravity. Up until Galileo's experiments, it was thought that lighter objects fall at a slower rate than heavy objects. This is our common experience: if a hammer and a feather are dropped together most people would predict that the hammer will hit the ground first because the force of gravity is greater on the hammer. Galileo had another explanation. He found that by dropping objects from towers and by rolling balls down ramps, all objects fall at the same rate, no matter how heavy they are. In other words, when two different stones are dropped, even if one has double the mass of the other, they should hit the ground at the same time. The rate at which an object falls on Earth is called the acceleration of Earth's gravity and is 9.8 m s^{-2} near the Earth's surface.

To explain why the feather hits the ground after the hammer, Galileo argued correctly that the reason was not due to gravity at all, but it was because of air resistance. The air resistance for the feather was much greater than for the hammer. Take away the air, Galileo argued, and the two will fall together. This surprising result has now been demonstrated many times, most famously by astronaut David Scott of Apollo 15 on the Moon, where there is no atmosphere.

Galileo had a ruler to measure distance, but clocks were not yet accurate enough to time the balls rolling down the ramp. So how did he measure time in his experiments?

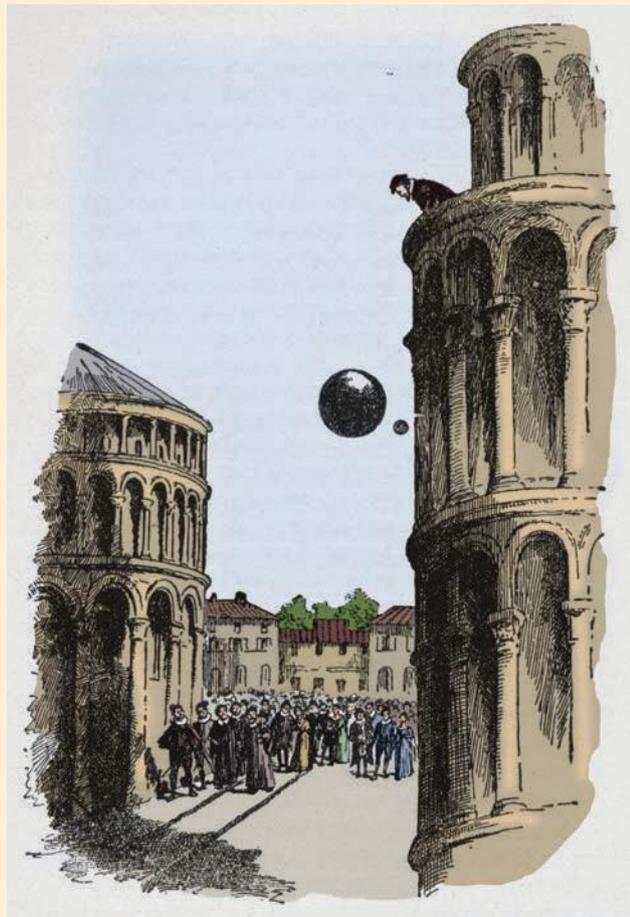


Figure 7.43 Galileo's experiment: dropping two stones of different mass out of a tower to see which one landed first.

He used his pulse.

Try this 7.8

Drop test

- 1 Find a 20 cent coin and cut out a piece of paper the same size and shape. Hold the paper in one hand and the coin in the other at eye level. Drop both the coin and the paper at the same time. What happened?
- 2 Now scrunch up the piece of paper and drop them both at the same time, again. What happened this time? What forces are acting on the coin and the piece of paper? Do these forces change in size between tests?

When air resistance is equal to the force of gravity, you will fall at a constant speed. The speed at which air resistance equals weight for a falling object is called the terminal velocity.

Parachutes are a practical application for air resistance. You can fall through the air safely if you have a parachute because the parachute increases your air resistance to the point where it overwhelms your weight, thus enabling you to slow down.

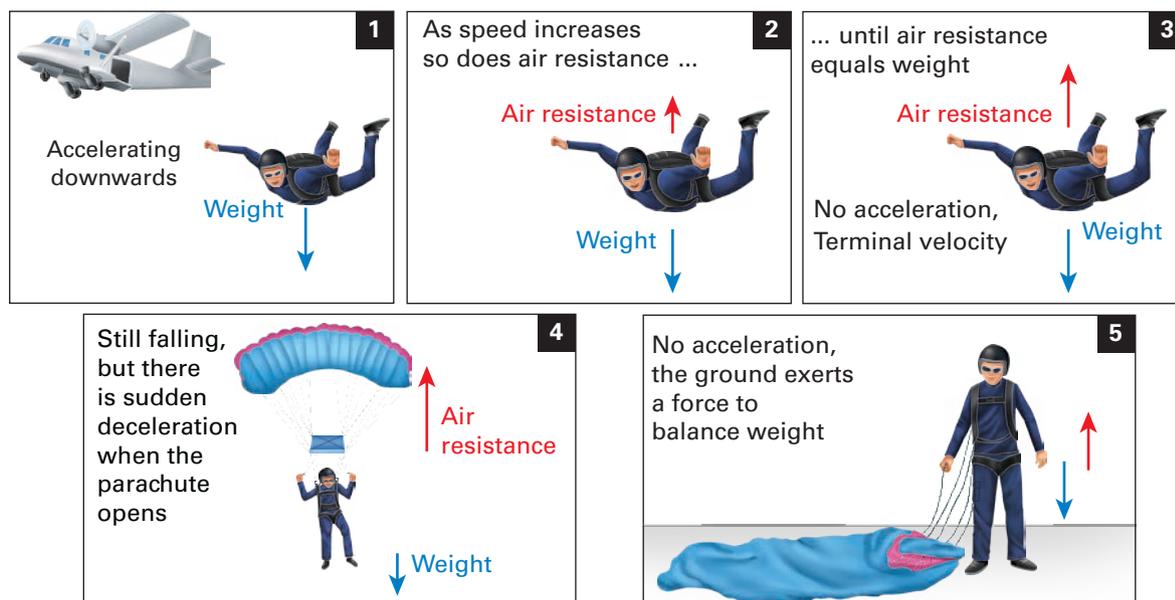


Figure 7.44 The way a parachutist falls depends on the size of the pull of gravity and the air resistance from the parachute.

Try this 7.9

Drop time of a parachute

Materials

- plastic freezer bags
- stopwatch
- scissors
- cotton or string
- modelling dough
- metre ruler

In small groups, use the materials provided to design and build a parachute. Then compare your group's design to other groups to explore the effect of one of the following variables on the drop time of a parachute:

- mass of the sky diver
- shape of the parachute
- surface area of the parachute
- length of the connecting string.

Quick check 7.9

- 1 Explain the meaning of the terms 'air resistance' and 'terminal velocity'.
- 2 Describe the relationship between the speed an object falls at, the pull of gravity and air resistance.
- 3 Look at Figure 7.45.
 - a Identify the forces acting on the capsule attached to the parachute.
 - b Describe how these forces change before and after the parachute is opened.



Figure 7.45 When astronauts return to Earth from space, the air resistance of their parachute provides an upwards force equal to the weight of the capsule they are safely enclosed within.

magnetic force
a non-contact force between a magnet and another magnet or magnetic metal

repel
to force back or apart

alloy
a substance composed of two or more metals

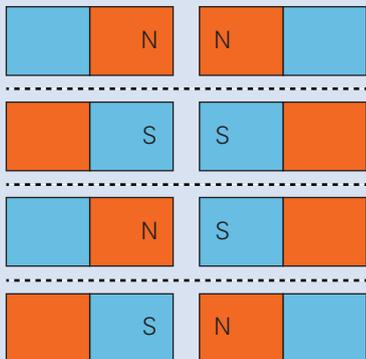
Magnetic forces

Magnetic force, like gravity, is a non-contact force. Remember, this means objects do not have to be touching to have an action. Magnetic forces are always strongest at the

ends of a magnet, which are called poles. There are two types of magnetic poles, north and south, and they always occur as a pair. Even if you break a magnet in half, it will still have a north and south pole at the ends of each of the pieces.

Try this 7.10

- 1 Which of the situations below display interactions between like poles?
- 2 Which situations display interactions between unlike poles?



If you used real magnets in Try this 7.10, you may have found that north and south poles attract each other, but two like poles **repel**.

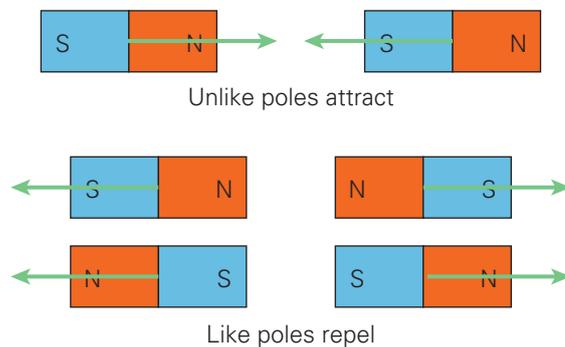


Figure 7.46 Forces between magnets

Some magnets always retain their ability to be magnetic and so they are called permanent magnets. An example would be a fridge magnet: they are always magnetic. On the other hand, metals like soft iron become magnets only when they are near a permanent magnet; they can become a temporary or induced magnet. Try hanging a paperclip from a magnet. While it is there, it will behave like a magnet and can be used to attract other paperclips.

In addition to each other, magnets also attract iron, cobalt, nickel and their **alloys**, such as steel (an alloy of iron).

Try this 7.11

Collect the following items: bar magnet, pencil, stainless steel utensils, pen, paper, plastic straw, coins, paperclips, iron nail, metal spoon, aluminium foil, copper wire.

- 1 Hold the magnet close to each of the items and record whether they are attracted to the magnet. What do the objects attracted to the magnet have in common?
- 2 Using the bar magnet, carefully pick up paperclips one at a time, forming a chain of paperclips. How are you able to do this?

The way that magnets exert their force is through **magnetic fields**, that is, the space around a magnet where the magnetic force acts. The magnetic field is a force field, like the gravitational field, although the two forces are different in most other respects. Look at

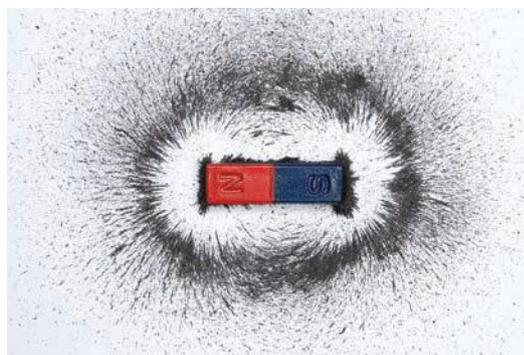


Figure 7.47 Magnetic fields around a magnet form a particular pattern.

Figure 7.47. You can see the iron filings are orienting themselves around the magnet's north and south poles in very particular ways. Some iron filings are also lined up on the magnet due to very strong magnetic attraction. Your job in the following activity is to investigate and explore what the shape of this magnetic field is and how it changes with different shapes of magnets.

magnetic field
the space around a magnet where the magnetic force acts

Practical 7.6**Magnetic field lines****Aim**

To visualise the shape of the magnetic field of different magnets.

Materials

- 2 bar magnets
- horseshoe magnet
- iron filings
- piece of A4 paper
- compass

Method

- 1 Place the bar magnet on a table and cover it with a piece of paper.
- 2 Sprinkle iron filings on the paper and look at the pattern formed.
- 3 Hold the compass at different points around the magnet. The direction that the compass points in indicates the direction of the magnetic field lines.
- 4 Repeat steps 1–3 with the horseshoe magnet.

Results

Draw a sketch of the pattern formed by the iron filings.

Discussion

- 1 Using your diagram, determine where the magnet's poles are.
- 2 Identify where the magnetic field appears to be the strongest.
- 3 Investigate different patterns formed with two or more magnets placed near each other.

Quick check 7.10

- 1 Explain why magnetism is considered a non-contact force.
- 2 Identify the missing words: Opposite poles _____ each other while poles that are the same _____ each other.
- 3 Explain the difference between a permanent and a temporary magnet.
- 4 Describe a magnetic field. Draw a picture of the field around a bar magnet and indicate the direction of the magnetic field lines.

Science as a human endeavour 7.3

A 3D printed magnet!

It used to be very difficult for scientists to produce a permanent magnet with a magnetic field of a specific pre-determined shape. In 2016, scientists at Vienna University were able to produce permanent magnets using a 3D printer. This new method can now produce magnets in complex forms. Scientists can customise the shape of the magnetic fields. Due to the cost effective and efficient nature of the process, scientists can now not just dream about the sorts of things they can do with magnets.

Earth is a giant magnet with magnetic poles near the geographic poles. What is called the North Magnetic Pole by geographers is called the south pole of the internal Earth magnet by scientists. A suspended magnet will turn until its north pole points geographically north, because of its attraction to the south pole of the Earth's magnet. This is a property of natural magnets or lodestones, and has been used by navigators for thousands of years.

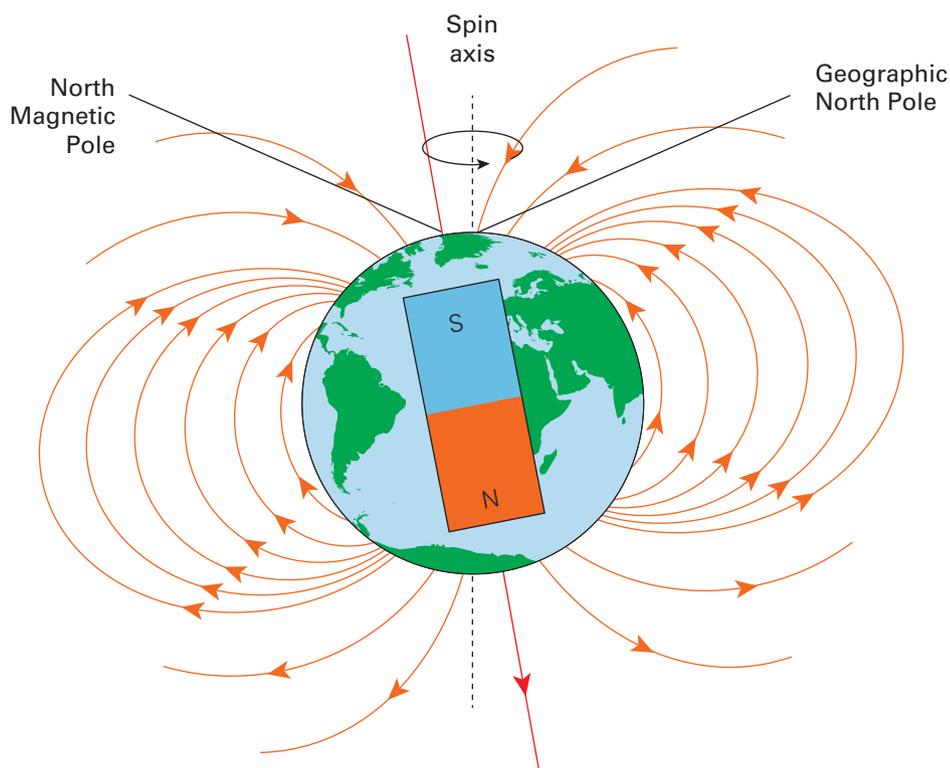


Figure 7.48 This diagram shows Earth's internal magnet. You can see that the south pole is equivalent to what geographers call the magnetic North Pole of Earth, which is close to the geographic North Pole. You know this because a compass always points north, and opposites attract, so the north of a compass is attracted to the south pole of Earth's magnetic field.

Try this 7.12

Making a compass

Use a steel nail, a strong magnet, a piece of cork (or polystyrene foam) and a bucket of water to make a compass. Follow these instructions.

- 1 Stroke the steel nail with the strong magnet in one direction. After each stroke, be sure to lift the magnet away from the nail before your next stroke. Repeat this process about 50 times.
- 2 Test your nail to see if it has become magnetised by holding it near some paperclips.
- 3 Place the cork or polystyrene in the bucket of water. Then place the nail on top. Identify which end of the nail is the north pole. How did you know this?

Check the accuracy of the homemade compass with an ordinary compass. Discuss the accuracy of the homemade compass. State one way in which the accuracy of the homemade compass could be improved.

Did you know? 7.3

Sea turtles use Earth's magnetic field to find home

Female sea turtles always return to the beach where they were born to lay their own eggs. Sometimes this means swimming thousands of kilometres, and the way they do this is by relying on Earth's magnetic field. Scientists are unsure how turtles detect the magnetic field, but it is possible that tiny magnetic particles in their brains help the turtles navigate.



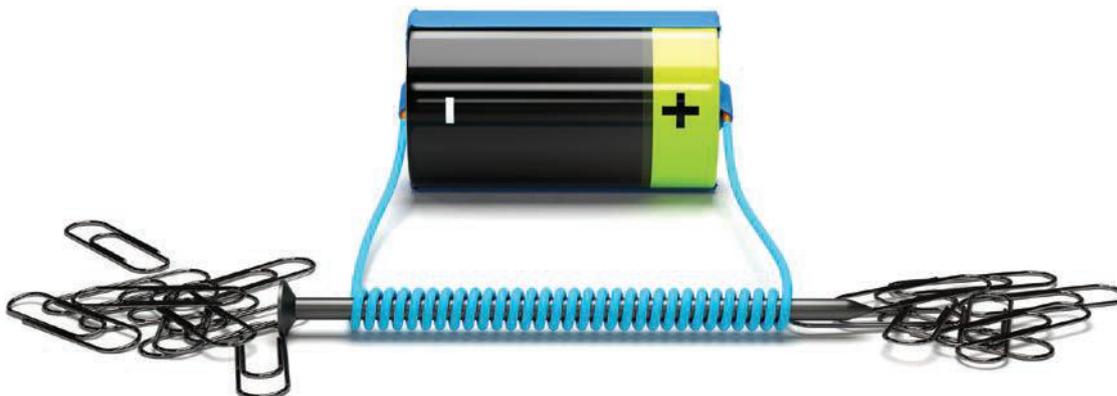
Figure 7.49 The sea turtle is guided along the coast by Earth's magnetic field.

Magnetism and electricity are closely related; wires carrying electricity create a magnetic field around them. Magnets called **electromagnets** are made by coiling a wire. When a battery is connected, the current flows along the wire, and a magnetic field is

created. When the current stops, the magnetic field ceases. The strength of the field can be increased by wrapping the coil around a piece of iron.

electromagnet
a magnet made by passing electricity through a coil of wire

Figure 7.50 An electromagnet can attract anything that a magnet can (in this case, paper clips).



Practical 7.7: Investigation

Making a simple electromagnet

Aim

To investigate how changing the number of coils on an electromagnetic will affect its strength.

Research question

How do the number of coils on an electromagnet affect its strength?

Materials

- 9 V battery or powerpack
- long nail
- compass
- 4 insulated copper wires (the longest one should be able to coil around the nail 40 times)
- 2 alligator clips
- switch
- paperclips

Be careful

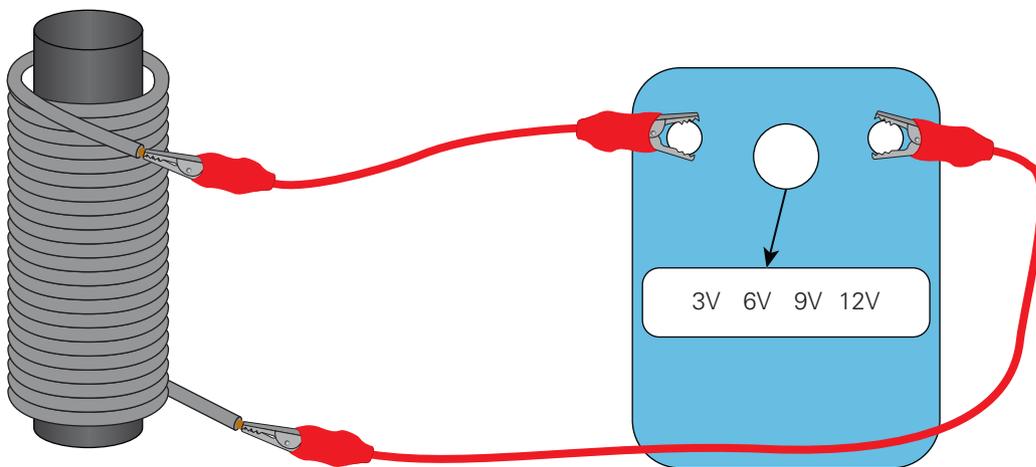
Make sure you only turn on your electromagnet for a short time. If left on, it will get hot.

Planning

- 1 You need to provide some background information to the investigation. Research electromagnets. Write a brief paragraph to explain how electromagnets work and the factors that can affect their strength.
- 2 Identify the independent variable in this investigation.
- 3 Identify the dependent variable in this investigation.
- 4 Identify the controlled variables in this investigation.
- 5 Create a risk assessment for this investigation.

Method

- 1 Draw the table shown in the results section into your science book.
- 2 Set the DC powerpack to 6 V and make sure the switch is OFF.
- 3 Carefully wrap the long wire around the nail 10 times, ensuring to only wind in one direction and avoiding any overlap of wires.
- 4 Connect the powerpack both ends of the long wire using the insulated wires with alligator clips.



- 5 Turn the powerpack ON.
- 6 Test your electromagnet by seeing how many paperclips it picks up. Record this number in the results table.
- 7 Retest the electromagnet two more times and record.
- 8 Repeat steps 2–6, increasing the number of coils each time, according to the results table.

continued...

...continued

Results

Independent variable: number of coils	Dependent variable: number of paper clips				
	Trial 1	Trial 2	Trial 3	Mean	Range
10					
20					
30					
40					

Use a spreadsheet application such as Excel or Google sheets to create a digital graph that displays the mean for each group. Label each axis appropriately and add an appropriate title.

Peer review

- 1 Swap graphs with a peer. Give each other feedback on how easily the graph can be used. Feedback should identify if the graph displays only the mean results, has appropriate labels, units and title, and any other features that could be improved to enhance how well the experimental results are communicated, such as scale or formatting.
- 2 After receiving feedback, make alterations to the graph to address the identified issues.

Discussion

- 1 Identify the trend in your graph.
- 2 Identify any anomalous results in your graph.
- 3 Extrapolate your graph to find out how many paperclips could be picked up if there was 80 coils.
- 4 If you had any anomalous results (ones that were much different than the others), explain how these may have been caused.
- 5 Describe how the investigation could be improved if you had the chance to do it again.

Conclusion

- 1 Propose a valid conclusion that can be drawn from these results.
- 2 Justify this conclusion using data from your results.

Explore! 7.2

Uses of magnets

You may not realise it, but electromagnets and permanent magnets are used everywhere and every day. Electric motors, door bells, computer hard drives, MRI machines, phone speakers and microphones, drills, hair dryers, bank cards and credit cards!

Research any two of these examples and write a short report on each. Include a picture and details of how an electromagnet or permanent magnet is involved in the function of the object.

Quick check 7.11

- 1 Discuss the reasons why we think that the Earth acts like a big magnet.
- 2 Explain how an electromagnet is different to a bar magnet.
- 3 Name some examples of electromagnets used every day.
- 4 Describe the advantages of an electromagnet over a permanent magnet.

Electrostatic forces

Try this 7.13

Take a piece of paper and rip it up into small pieces on your table. Rub a plastic pen against woollen material or a jumper. Bring the pen near the pieces of paper. What happens? Can you explain what you observe?

electrostatic force

a non-contact force between positive and negative charges; opposite charges attract, like charges repel

static electricity

a build-up of electric charge

The third non-contact force you need to know about is **electrostatic force**. This is that pesky force that can give you a small electric shock when you close a car door or drag your feet on carpet.

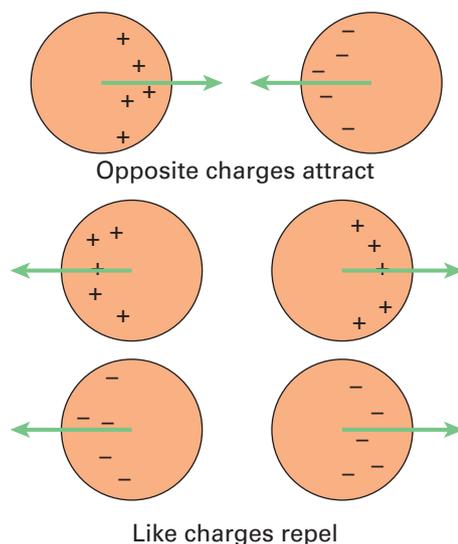


Figure 7.51 Forces between charges

It can be used to pick up pieces of paper with a balloon after rubbing it on your hair or clothes. On a much larger scale, electrostatic charges cause lightning to flash during a storm!

Like magnets, electrical charges attract and repel each other. There are two types of charge: positive (+) and negative (-). Opposite charges attract each other and like charges repel.

Like gravity and magnetism, objects with an electric charge also create a field around them. The electrostatic field is the region in which charged particles will feel the electrostatic force.

Look at Figure 7.52. The machine the girl is touching is called a Van de Graaff generator, and essentially it separates positive and negative charges. The negative charges go down to the ground; meanwhile, the positive charges in the metal dome stay in place. Because the girl is touching the dome, the negative charges from her hair flow to the dome, making her hair positively charged. Remember, like charges repel, so with all her hair turning positively charged, they all try to get away from each other!

So why do you get these small electric shocks after dragging your feet on the carpet? When electrical charges build up, like they do in the Van de Graaff generator, it is called **static electricity**. Usually this charge leaks away, but when it builds up a lot, the charge can jump to an object that conducts electricity like a metal door handle or stair railing. So dragging your feet on the carpet moves negative electric charges onto you; if they do not leak away they can jump to the door handle and this is the shock you feel.



Figure 7.52 Electrostatic forces can make your hair stand on end.

Quick check 7.12

- 1 Define the key terms 'electrostatic force' and 'static electricity'.
- 2 Identify the missing words:
Opposite charges _____
and like charges _____.
- 3 Explain how a Van de Graaff generator works.
- 4 Explain why you sometimes get a small electric shock even though you have not touched a supply of electricity.

Try this 7.14

Observing static electricity

Materials

- 2 balloons
- string
- a metre ruler
- woollen cloth

Instructions

- 1 Rub the inflated balloon with the woollen cloth and place it against a wall. Record your observations.
- 2 Suspend the balloon from the metre ruler using the string.
- 3 Suspend the second balloon so it is close to, but not touching, the first balloon.
- 4 Rub both balloons with the woollen cloth on the sides that are facing each other.
- 5 Record any observations of any movement in the balloons.

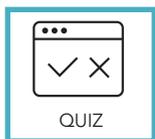
Questions

Discuss the following questions with your classmates.

- 1 What is the purpose of rubbing a balloon with a woollen cloth?
- 2 Did the balloon stick to the wall? Propose reasons as to why or why not.
- 3 Describe the movement of the two balloons when hung next to each other.
- 4 Does the movement indicate that the balloons had like or unlike charges? How do you know?



Section 7.3 questions

**Remembering**

- 1 **State** which forces are acting on a dropped book that falls to the floor.
- 2 **Name** the force which a magnet exerts.
- 3 **Recall** an object which uses electromagnets.
- 4 **Recall** three magnetic materials.
- 5 **Define** the term 'magnetic field' and illustrate with a picture.
- 6 **Name** the two types of electric charge.

Understanding

- 7 A falling object is pulled down by Earth. Earth is pulled up toward the object. **Explain** why the movement of Earth cannot be detected.
- 8 **State** whether the mass of an object changes as it moves around the universe.
- 9 **State** whether your weight would increase, decrease or stay the same if you travelled to the Moon.
- 10 **Determine** your weight in deep space.
- 11 **State** which ball will hit the ground first: a wooden ball, a plastic ball or a metal ball, if air resistance is ignored.
- 12 The north pole of a magnet points north if it is free to move. **Identify** which magnetic pole must be near the North Pole.
- 13 **State** the types of forces that have a force field.

Applying

- 14 **Calculate** the weight of a 5 kg cat on Earth ($g = 9.8 \text{ N kg}^{-1}$) and on Mars ($g = 3.7 \text{ N kg}^{-1}$).
- 15 **Describe** which would take longer to fall, a rock dropped from 1 metre on the Moon (gravity is about one-sixth of Earth's) or a rock dropped from 1 m on Mars (gravity is a little over one-third of Earth's). You can ignore air resistance on both planets.
- 16 **Identify** three situations where air resistance is useful and one situation where it is not useful.
- 17 **Summarise** how you can visualise the magnetic fields that surround a bar magnet.
- 18 Two balloons are hanging loosely near each other. One balloon is given a negative charge and the balloons start to move away from each other. **Explain** what is happening and what the charge on the other balloon must be.
- 19 **Compare** the similarities between charged objects and magnets.

Analysing

- 20 **Explain** whether a hammer and a feather will hit the ground together if dropped from the same height at the same time on the planet Mercury where there is no atmosphere.
- 21 Analyse how a compass works and **describe** why it is useful.
- 22 A parachute is made of large pieces of material. **Explain** what its purpose is and distinguish between how it makes an object speed up or slow down.

Evaluating

- 23 **Evaluate** the effects of living in a low gravity environment for a long time.

Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked questions	Check
7.1 I can recall what a force is and how forces are measured.	1	
7.1 I can describe the impact of balanced and unbalanced forces on an object.	9	
7.1 I can draw a force diagram to indicate the forces acting on an object.	11	
7.2, 7.3 I can describe the difference between contact and non-contact forces.	3	

Review questions

Remembering

- 1 **Define** the term 'force'.
- 2 **State** the units for mass and weight.
- 3 **List** three contact forces and three non-contact forces.
- 4 **Define** the term 'net force'.
- 5 **Recall** the word used to describe two forces that are equal in size and act in opposite directions.
- 6 **State** whether an object can change direction without a force.

Understanding

- 7 **State** whether an object at rest will start spinning without any additional forces.
- 8 **State** whether an object will always move when a force acts on it.
- 9 **Describe** what happens if the forces on an object are unbalanced.
- 10 There are many forces between the parts of the Matagarup bridge in Perth. **Explain** whether all the forces between the parts are balanced or unbalanced.



Figure 7.53 The Matagarup bridge over the Swan River in Perth.



- 11 **Draw** or describe the pair of equal and opposite forces on each of the Moroccan tree-climbing goats in the Figure 7.54.
- 12 Explain whether an object that is travelling horizontally in a straight line at a constant speed needs a force to keep moving.



Figure 7.54 Moroccan tree-climbing goats only climb argan trees.

Applying

- 13 Figure 7.55 shows a scientist inspecting seagrass. Around his waist he is wearing a heavy belt made of metal. Apply your knowledge of forces to **describe** the function of this belt.
- 14 Metal recycling takes place in most cities; aluminium, copper, iron and steel are common metals that are recycled. After collection, the first step is to flatten the metal and then cut it into small pieces. The second step is to separate the iron and steel from the aluminium and copper before finally melting the metals ready to be used again. **Describe** a method that could be used to carry out the second step.



Figure 7.55 Diver wearing a weight belt

Analysing

- 15 On snow and ice, wheels with tyres are often replaced by skis and tracks on vehicles. **Consider** the skis and the tyre in Figure 7.56 and how their shape and friction forces relate to their use.



Figure 7.56 Skis versus tyres

Evaluating

- 16 Use your answer to the question above and knowledge of forces to **explain** how a snowmobile works and **justify** why it is preferred for snow compared to a normal motorcycle.



Figure 7.57 Snowmobiles use skis and a track instead of wheels.

Data questions

Earth's Moon and the other planets in our solar system have different forces of gravity on their surface than Earth because they have different masses. The forces of gravity on the surface of each are shown with respect to that of Earth in the graph below.

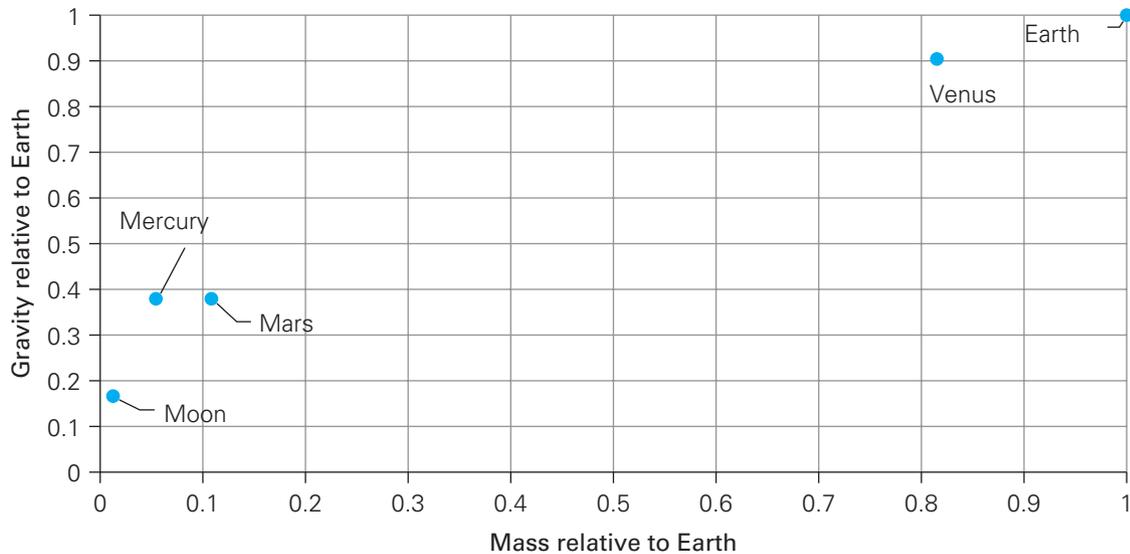


Figure 7.58 Gravity on the Moon and other planets relative to that of Earth given their relative masses

- 1 **Identify** which planet in the graph has the lowest mass.
- 2 **Determine** which planet has a force of gravity closest to that on Earth.
- 3 If the acceleration of Earth's gravity is 9.8 m s^{-2} , and Mars' gravity is 38% of that of Earth, **calculate** Mars' actual gravitational force.
- 4 **Identify** the general relationship between the mass of a planet and force of gravity.
- 5 Use the data presented in the graph to **contrast** the gravitational force of Earth and Mercury.
- 6 **Deduce** why the Moon orbits the Earth, instead of the Earth orbiting the Moon.
- 7 The mass of Jupiter is approximately 318 times that of Earth. **Predict** whether the gravitational force on Jupiter would be greater or less than that of Earth.
- 8 Among the planets shown, two of them are such that a person standing on their surface would weigh about the same. **Infer** which two planets they are.
- 9 Pluto has a relative force of gravity of 0.06 to that of Earth. Use the relationship identified in Question 4, to **justify** the statement that Pluto will have a mass less than that of Earth's Moon.

STEM activity: Designing and prototyping a ferry

Background information

Ferries are used worldwide to connect two or more points (e.g. Elizabeth Quay Ferry in Perth). They carry passengers, goods, and sometimes vehicles and machinery. Ferries are vital for transport in many developing countries, since highways are expensive to build and most waterways come free. Without ferries, whole populations in the Amazon Forest would not be able to communicate, get access to food and goods or even have contact with the modern world.

Ferries, like boats, ships and canoes, float in water as a result of buoyancy. Any object placed in water will either sink or float, and that outcome is related to the density of that object (the amount of mass in a certain volume). If an object is denser than water, it will usually sink, and if it is less dense, it will float. But how can a steel ship, capable of carrying thousands of passengers and cars, float in the ocean when a metal ring or coin would sink in your bathtub?

It is time to investigate how design can affect the buoyancy of a ferry!



Figure 7.59 Ferries are part of the public transport system in many places in the world.

Design brief: Design and construct a ferry boat.

Activity instructions

In teams (maximum of 3 people), you will design and construct a ferry capable of transporting a payload between two points (return trip). Your team has been assigned the task of designing and constructing a ferry for riverside communities to transport people and goods on the water.

As an engineer, you should investigate the science and technology of boats.

Suggested materials

- ruler and tape measure
- scissors
- cardboard
- bubble wrap
- plastic bags
- 5 × 100 g parcels of sugar/salt (payload)
- sticky tape (duct tape or gaffer tape would be good)

Research and feasibility

- 1 List the features that would make a useful boat.
- 2 Research the terms 'density' and 'buoyancy' and discuss in your group how these factors are important in boat design.

Design

- 3 List all the materials that you have available and that you plan to use for your ferry.
- 4 Design a ferry that is capable of transporting your payload (set mass) between two points and return.
- 5 Label and include measurements of your ferry.

Create

- 6 Build your ferry using the materials, checking as you progress that your ferry is capable of floating.

Evaluate and modify

- 7 Discuss the challenges you have encountered throughout this project with at least three of your peers. List the strategies or actions that allowed you to overcome it.
- 8 Create a list of improvements to your design that could be applied to this project to refine its performance.

Chapter 8

Simple machines



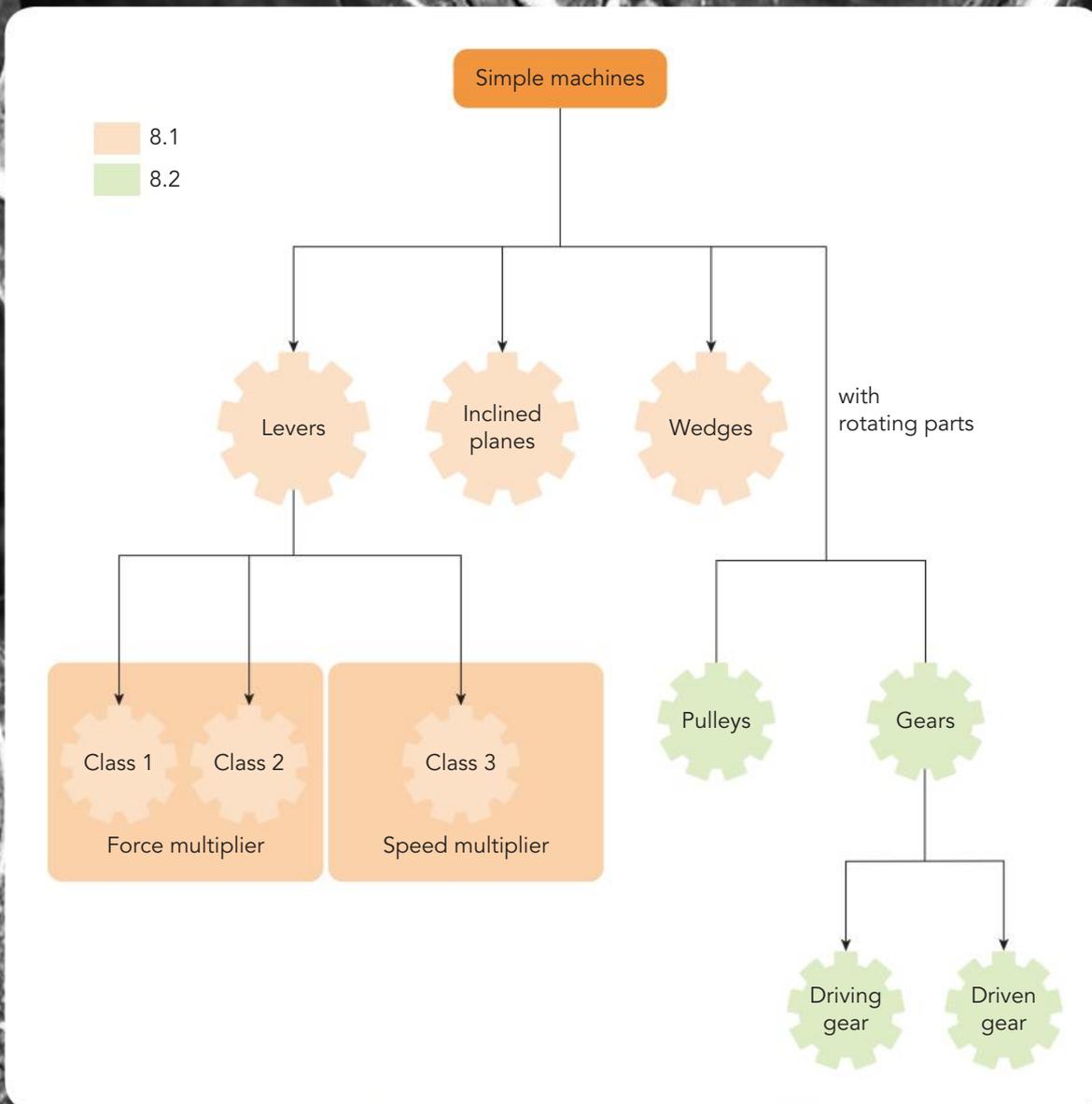
Chapter introduction

In the previous chapter, you learned about how forces affect the world around us. Forces are necessary to carry out practically everything we need to do in our day to day lives! In this chapter, you will learn about how you can use simple machines to make some of your tasks easier to perform.

You may not realise it, but we use simple machines every day, from door handles, taps and screwdrivers to the wheels of our car.

You can make machines that use forces to perform a function. You will learn how to identify three different types of levers and find out how pulleys and ramps work.

Chapter map



8.1 Investigating simple machines



Learning goals

- 1 To be able to recall some simple machines and how they work.
- 2 To be able to state the equation of mechanical advantage.
- 3 To be able to illustrate class 1, class 2 and class 3 levers.

simple machine

a basic mechanical device for applying a force and changing either its size or direction

lever

a rigid bar that moves around a fixed point so one end can be pushed or pulled to move the other end with a greater or smaller force

ramp

an inclined surface connecting a higher and a lower level

pulley

equipment consisting of a grooved wheel (or wheels) with a rope or chain attached to an object to be moved

effort

the input force to a simple machine

load

the object that is to be moved

load force

the output force of a simple machine

mechanical advantage

the ratio of the output force to the input force

In this section, you will learn about how **simple machines**, including **levers**, **ramps** and **pulleys**, can be used to perform tasks. The common factor between all these simple machines is that they all use forces to do something that would be difficult otherwise.

Simple machines generally work by increasing the amount of force applied to an object, but in a few cases they work by increasing the speed of movement. By doing this, it makes the job much easier for us to perform. The amount of force applied to the machine is called the **effort** and the object being moved is called the **load**. The **load force**, which the machine applies, is the amount of force required to move the load.

Mechanical advantage

Simple machines give us a **mechanical advantage**. The idea of most simple machines is that a small amount of effort can be used to

generate a large load force. The mechanical advantage of a simple machine can be measured by the following equation:

$$\text{mechanical advantage} = \frac{\text{load force (force applied by machine to object)}}{\text{effort (force applied by you to the machine)}}$$

Except in some special cases, the effort is less than the load, so this equation results in a mechanical advantage that is greater than one. The higher the mechanical advantage of a simple machine, the more our effort force is magnified, meaning the easier it is for us to move a load.

Levers

Levers are surprisingly common. You may have had to use a screwdriver to lift off the lid from a tin of paint or the end of a spoon to open a Milo tin, but did you know that golf clubs and brushes are also levers? What about wheelbarrows, scissors and nutcrackers? You guessed it, these are all levers as well.



VIDEO
Name and classify the simple machines you see



VIDEO
Lever classes

Worked example 8.1

You need to use a simple machine to move a load. The load force is 120 N and the mechanical advantage of the machine is 4. Calculate the effort required to move the load.

Working	Thinking
Rearranging the formula gives: $\text{effort} = \frac{\text{load force}}{\text{mechanical advantage}}$	To move the load force of 120 N using a simple machine with a mechanical advantage of four, you need to exert a force of 30 N.
Substituting the numbers into the formula gives: $\text{effort} = \frac{120 \text{ N}}{4} = 30 \text{ N}$	



Figure 8.1 A garlic press is an example of a lever.

Try this 8.1

Find a tin of Milo or hot chocolate with a metal lid and try to lift the lid off with your hands. Were you able to do it? Think about how much force you would have to apply to get the lid off.

Now grab a spoon or screwdriver and use it to remove the lid. Compare how much force is required when using a lever to lift the lid. Can you explain what is happening?

A lever consists of a rigid arm, which may be bent or straight, and made of wood, steel or similar material. Levers are used to exert a force on the load. Levers are classified into three types called **class 1**, **class 2** and **class 3**.

All levers have the following characteristics:

- Levers have a fixed point called the **fulcrum**.
- The lever pivots around the fulcrum.
- An effort force is applied to the lever.
- The effort force is transferred by the lever to exert a load force that moves or pushes the load.

Class 1 and class 2 levers are called **force multipliers** because they are able to magnify the effort force you put in. However, the trade-off is that the effort needs to be applied over a greater distance to move the load a small amount. Just like the bottle opener in Figure 8.4, levers can be used to move objects that would otherwise be very challenging to move with our bare hands.

Class 1 levers

In a class 1 lever, the fulcrum lies between the load force and the effort force. A class 1 lever can magnify the effort force to generate a larger load force, making it easier to move the load. To increase the mechanical advantage and make the job easier, the lever could be lengthened to increase the distance from the effort to the fulcrum. However, this comes at a cost. The distance you push down on the lever will be much greater than the distance your load moves.

Class 1 levers are illustrated in Figure 8.2. The blue and red arrows in the diagrams show the forces that are applied to the machine (the effort) and the load force applied to the load. Their length indicates the size of the force. In this chapter, the arrows do not show the weight of the load (which would be opposite to the load force), nor do they show speed or distance moved.

class 1 lever

a lever in which the fulcrum is between the load and effort

class 2 lever

a lever in which the fulcrum is at one end and the load is between the fulcrum and the effort

class 3 lever

a lever in which the fulcrum is at one end and the effort is between the fulcrum and the load

fulcrum

the point on a lever where a bar is supported; the lever turns about this point

force multiplier

something that increases the size of a force

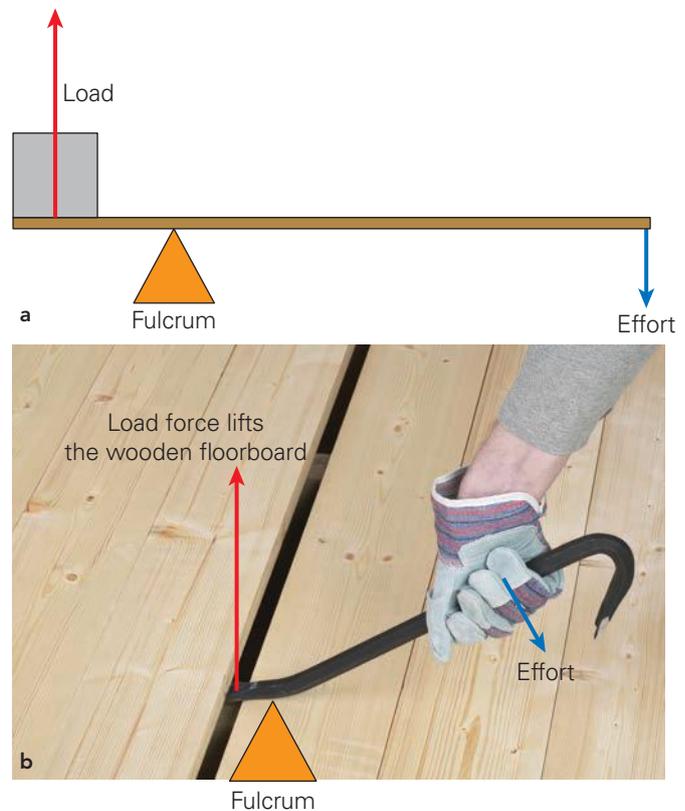


Figure 8.2 (a) A class 1 lever: the fulcrum is between the load and the effort. (b) A crowbar is a class 1 lever that can be used to lift a wooden floorboard. The effort force is shown in blue. In this case, the load force in red is used to lift the wooden floorboard.

Class 2 levers

A class 2 lever has a fulcrum at the end and the load in the middle. The effort is applied at the other end. Like a class 1 lever, a class 2 lever can magnify the effort force to generate a large load force. With class 2 levers, the effort force is upward.

In the examples shown below, can you think of a way to make this job even easier?

You guessed it! Increasing the length of the handles will increase the mechanical advantage.

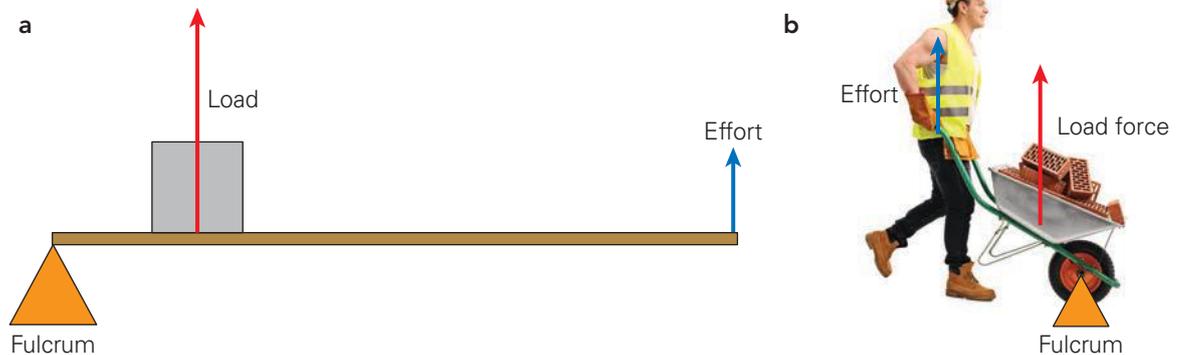


Figure 8.3 (a) A class 2 lever. The fulcrum is at one end and the load is between the fulcrum and the effort. (b) A wheelbarrow is an example of a class 2 lever. The workman does not have to apply as much effort force to lift the load. Without this simple machine, it would be nearly impossible to lift that amount of bricks!

Figure 8.4 A bottle opener is a class 2 lever. The fulcrum (shown by the orange triangle) rests on the cap and the effort force is applied to the handle. This results in a large load force on the edge of the cap, which opens the bottle. It would otherwise be difficult to open the bottle with our bare hands.



Practical 8.1: Investigation

Effect of changing the distance from the effort to the fulcrum

Aim

To investigate the effect on the effort force when changing the distance from the effort to the fulcrum.

Materials

- 1 metre ruler
- rubber stopper (alternative: eraser)
- 1 × 100 g mass
- 10 × 10 g masses

continued...

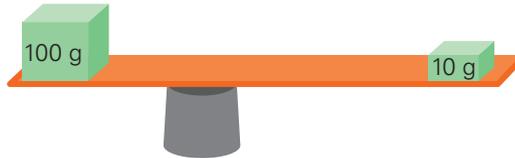
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Planning

- 1 Write a research question guided by the aim stated on page 306.
- 2 Identify the independent variable.
- 3 Identify the dependent variable.
- 4 List the controlled variables.
- 5 Read the method below and draw an appropriate results table.

Method

- 1 Place the rubber stopper under the 1 metre ruler at the 20 cm mark. The rubber stopper will act as a fulcrum.
- 2 Place the 100 g mass on top of the ruler at the 0 cm mark.
- 3 Place a 10 g mass on the 100 cm mark at the other end of the ruler. Observe.
- 4 Continue to add a 10 g mass to the 100 cm mark until the 100 g mass is lifted.
- 5 Record the mass required to lift the 100 g mass in your results table.
- 6 Move the rubber stopper to the 40 cm mark and repeat steps 1–3.
- 7 Move the rubber stopper to the 60 cm mark and repeat steps 1–3.
- 8 Move the rubber stopper to the 80 cm mark and repeat steps 1–3.



Discussion

- 1 State which class of lever was used in this experiment.
- 2 Describe any trends in your results.
- 3 Discuss whether the control variables were managed properly to ensure they did not change and affect the measurements.
- 4 Identify any changes that could be made to the method to improve the quality of the data in future experiments.
- 5 Describe how the experiment could be extended if it was done again.

Conclusion

Provide a comment about the relationship between the effort and the distance from the fulcrum based on your observations and data collected.

Class 3 levers

Class 3 levers are not force multipliers, like class 1 and 2 levers. The effort force for class 3 levers generates a load force that is smaller than it, but more speed or distance can be obtained. These levers are called **speed multipliers**. They are the special case, mentioned previously, which is the exception to the rule that load force is generally larger than effort force.

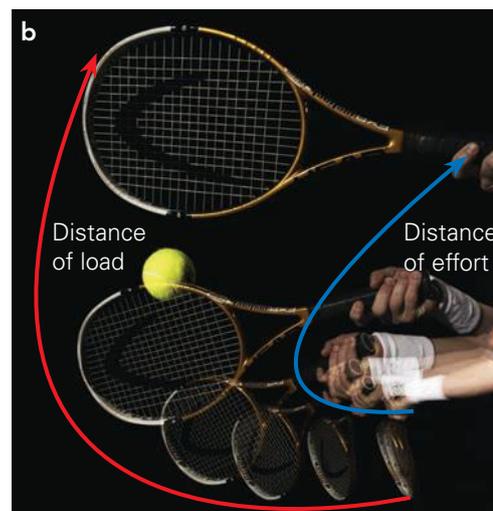
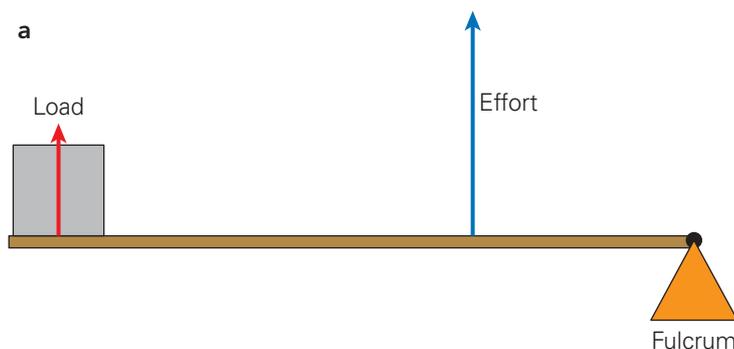
In a class 3 lever, the fulcrum is at one end and the effort force is between the load and fulcrum. Recall that class 1 and 2 levers increase the force applied to an object, but that force must be applied over a larger distance than the load moves. With class 3 levers, the load moves a much further distance than the effort, but with a smaller force. Golf clubs, paint rollers and tennis racquets are examples of class 3 levers.

speed multiplier
something that increases the speed of an object

For example, a tennis racquet can hit a ball with much greater speed than can be achieved with just your arms. Imagine trying to hit a tennis ball with your hand. It would not go very far! In a tennis racquet, the wrist acts as the fulcrum and the effort is applied by the hand

to the handle. The load is in the middle of the racquet head. The head of the racquet moves a larger distance than the hand, multiplying its speed. This is illustrated in Figure 8.5 (b). Note that the blue and red arrows are force arrows, not speed or distance arrows.

Figure 8.5 (a) In a class 3 lever, the fulcrum is at one end and the effort force is between the load and the fulcrum. (b) Sports scientists apply this knowledge of forces to help their clients improve their sporting performance. Tennis players are now able to perform serves at speeds above 250 km h^{-1}



Try this 8.2

Explore your environment to see how many levers you can find. Remember, many everyday objects can be used as levers and may be hiding in plain sight! Once you have a collection of levers, sort them into their classes.

Did you know? 8.1

There are a number of levers in the human body. Raising the forearm, for example, is a class 3 lever. The elbow is the fulcrum, the bicep muscle provides the effort force to the forearm and the hand holds the load. Other levers in nature include birds' beaks and crabs' claws.

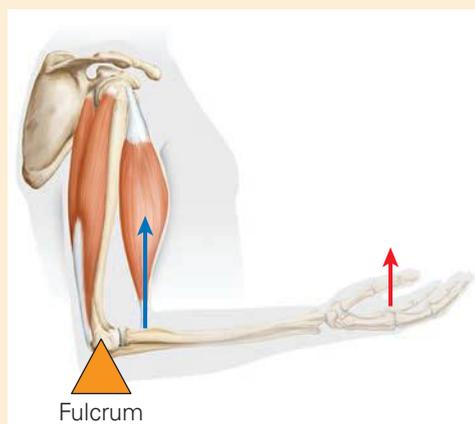


Figure 8.6 The arm is a class 3 lever.

Extension: Mechanical advantage

The mechanical advantage is related to the distances of the load and effort forces to the fulcrum. Figure 8.7 shows how to measure the distances to the fulcrum. For a class 1 lever, the closer the fulcrum is to the load and the further it is from the effort, the easier it is to move. However, this means the load moves a smaller distance.

$$\text{mechanical advantage} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$$

You also know that:

$$\text{mechanical advantage} = \frac{\text{load force}}{\text{effort}}$$

Notice that when calculating the mechanical advantage using forces, the term using load is on the top, whereas when calculating the mechanical advantage using distance, the term using effort is on the top.

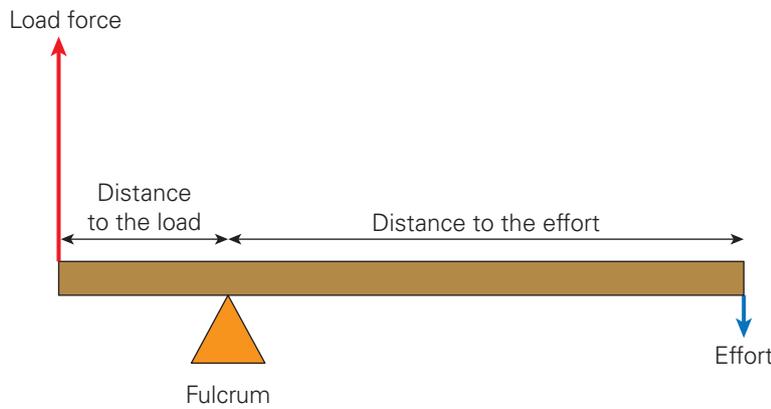


Figure 8.7 How to measure the distances to the fulcrum

Worked example 8.2 shows the use of a class 1 lever to move a load. With a short lever, an effort force applied at the end of the lever produces a large force at the other end, but it is not enough to move the load.

Worked example 8.2

Use the information in the diagram from Figure 8.8 to:

- a calculate the mechanical advantage of the lever
- b determine whether a load of 300 N can be moved by an effort force of 50 N using the lever.

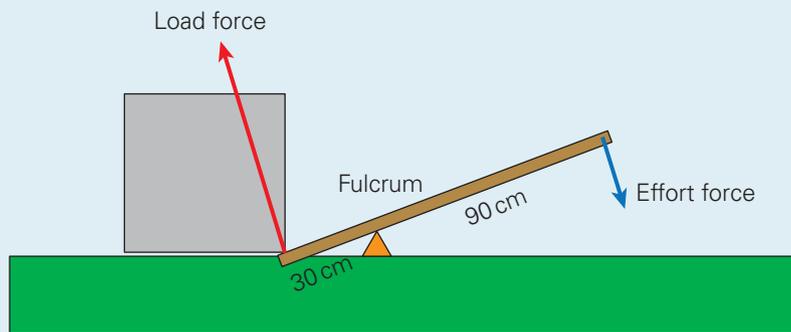


Figure 8.8 An example lever system

Working	Thinking
<p>a mechanical advantage</p> <p>We use the formula</p> $\text{mechanical advantage} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$ <p>Substitute the numbers:</p> $\text{mechanical advantage} = \frac{90 \text{ cm}}{30 \text{ cm}} = 3$ <p>The mechanical advantage is 3.</p>	<p>This means that the effort can lift a load 3 times its force.</p>
<p>b effort required to move 300 N</p> <p>We can rearrange the formula so that the effort required is on the left-hand side:</p> $\text{mechanical advantage} = \frac{\text{load force}}{\text{effort}}$ <p>Doing this gives:</p> $\text{effort} = \frac{\text{load force}}{\text{mechanical advantage}}$ <p>Substituting the numbers:</p> $\text{effort} = \frac{300 \text{ N}}{3} = 100 \text{ N}$ <p>The load will not move.</p>	<p>The effort required by this lever system to move a load of 300 N is 100 N. This is because the mechanical advantage is 3.</p> <p>This means that an effort force of 50 N will not move the load.</p>

Worked example 8.3 shows the same load is able to be moved by the same effort force if it is applied at the end of a longer rod. The longer lever produces a greater load force.

Worked example 8.3

The lever from the previous example was then replaced with a longer lever. Use the information in the diagram to determine whether an effort of 50 N could now move the same initial load of 300 N.

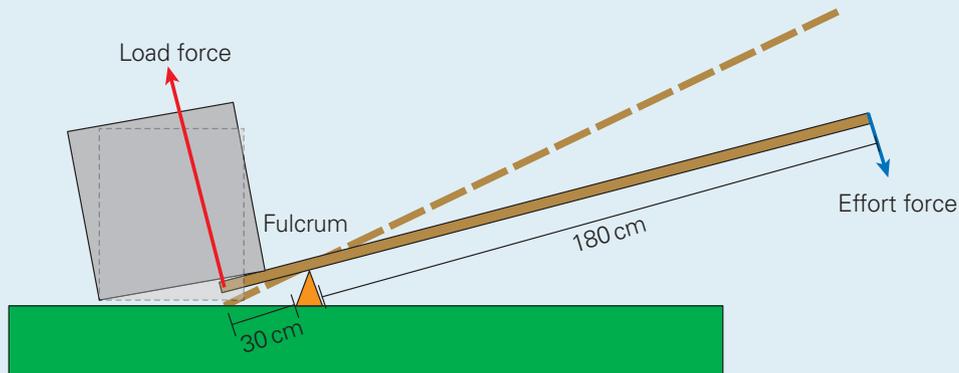


Figure 8.9 An example lever system

Working	Thinking
$\text{mechanical advantage} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$ $= \frac{180 \text{ cm}}{30 \text{ cm}}$ $= 6$ <p>The mechanical advantage is now 6. The effort required is now:</p> $\text{effort} = \frac{\text{load force}}{\text{mechanical advantage}}$ $= \frac{300 \text{ N}}{6}$ $= 50 \text{ N}$ <p>The effort of 50 N is able to move the load.</p>	<p>The distance between the effort and fulcrum has increased by using a longer lever.</p> <p>Now, an effort of 50 N is required to move the load of 300 N.</p>
<p>Alternatively, we can find the maximum load that an effort of 50 N can move with this new lever system.</p> <p>Rearrange the formula so that load force is on the left-hand side:</p> $\text{mechanical advantage} = \frac{\text{load force}}{\text{effort}}$ $\text{load force} = \text{effort} \times \text{mechanical advantage}$ $= 50 \text{ N} \times 6$ $= 300 \text{ N}$ <p>The effort of 50 N is able to move the load.</p>	<p>The maximum load is 300 N. Therefore, in this case, the effort 50 N is able to move a load of 300 N.</p>

Explore! 8.1

Spear-throwers are simple machines that were developed to help with hunting by Aboriginal and Torres Strait Islander peoples in Australia. Aboriginal peoples on the mainland did not use the bow and arrow like other early cultures, such as the Torres Strait Islander peoples, possibly due to needing a heavier weapon to hunt larger prey that were only found on mainland Australia (for example, kangaroos). Note that the choice of weapon was not just dependent on the size of the animal; it was also the landscape and whether the land was heavily wooded that determined the weapons used.

Indigenous spear-thrower devices are commonly about 50 cm long and made from hardwood timber. At one end, a hand grip is often coated with spinifex resin. At the other end is a peg, made either from wood or a large tooth, which is attached to the spear-thrower using animal sinew and resin. The peg helps hold the spear (or dart) in position, and focuses the throwing force.



Figure 8.10 The design of the spear-thrower will differ depending on where in Australia it was developed; spear-throwers are refined and altered by the people of each area to suit their own particular needs.

The spear-thrower acts as a lever, multiplying the force that a hunter can apply to the spear, as well as increasing accuracy. It allows spears of up to 3 m in length to be thrown at speeds of as much as 150 km h^{-1} .

Conduct research and watch videos of Indigenous spear-throwers being used, and answer the following questions.

- 1 Draw and label the parts of a spear-thrower and spear, showing how they connect to one another.
- 2 Identify where on the spear-thrower the load, force and fulcrum are located.
- 3 Deduce what class of lever the spear-thrower is, and explain your reasoning. Consider your answer to Question 2, and also whether it is a force or distance multiplier. Note that you and your classmates may differ in opinion.

Quick check 8.1

- 1 Define the terms 'effort', 'load' and 'load force'.
- 2 Recall an example of a class 1, 2 and 3 lever.
- 3 Describe the difference between class 1, 2 and 3 levers in terms of where the fulcrum, load and effort are placed relative to each other.
- 4 Explain the term 'mechanical advantage'.
- 5 Describe how you could make a class 1 or 2 lever more effective.
- 6 If a wheelbarrow had a mechanical advantage of 10, and the load weighs 1000 N, calculate how much effort is required to lift the load.

Inclined planes

The type of inclined plane you would be most familiar with is a ramp. A ramp is used to move heavy objects up against the force of gravity. It is much easier to push an object up a ramp than to lift it vertically upwards, especially if you can reduce friction with wheels or rollers. Just like levers, ramps provide a mechanical advantage. It requires a smaller effort force to push an object up a ramp than it would to lift it straight up. However, there is a trade-off. The effort force must be applied over a larger distance. In other words, it is easier to push the object up a ramp, but you have to push it further. Ramps are always force multipliers.

Examples of ramps include boat ramps that lift boats out of the water, playground slides and inclined roads. The closer the ramp is to the horizontal, the greater the load that can be lifted. That means that ramps that are less steep have a greater mechanical advantage than ramps which are steeper. Heavy vehicles cannot go up inclines of more than about 20° , so mountain roads on land that rises at an angle greater than 20° are designed with a series of bends to increase the horizontal length for the same rise. This results in a less steep road.

If you have ever moved house, you may have seen a removalist using a ramp to carry your belongings in and out of the truck.



Figure 8.11 Ramps are used to lift and move heavy objects.



Figure 8.12 Mountain roads have hairpin bends to reduce the incline for vehicles.

Using a ramp decreases the effort force needed to move an object from one height to another. However, the trade-off is that you must move the load through a further distance.



Figure 8.13 Using a ramp decreases the amount of effort needed to lift the object into the truck. A less steep ramp gives a greater mechanical advantage but you have to push the object further. If the truck bed is 1 m high, the mechanical advantage of the ramp on the left is $3 \text{ m}/1 \text{ m} = 3$, and of the ramp on the right is $8 \text{ m}/1 \text{ m} = 8$. If the box has a load force of 120 N, the worker needs to apply 40 N of effort force on the left, and only 15 N of effort force with the longer ramp on the right!

Practical 8.2: Investigation

Calculating the effort force

Aim

To investigate the effect of changing the ramp angle on the effort force required to pull a mass up a ramp.

Materials

- books or wooden blocks
- spring balance (10 N, 20 N, 100 N)
- 500 g weight holder
- long wooden plank
- protractor

Planning

- 1 You need to provide background information to the investigation. Complete research and write a brief paragraph to explain the key concepts of ramps and effort forces.
- 2 Create a research question, based on information in the aim.
- 3 Identify the independent variable in this investigation.
- 4 Identify the dependent variable.
- 5 Identify the controlled variables.
- 6 Read the method below and create a results table, with the independent variable in the left column and the dependent variable trials and mean in the right columns.

Method

- 1 Set up a ramp using the wooden plank and books/blocks.
- 2 Place the 500 g weight at the bottom of the ramp and attach the appropriate spring balance. (Hint: which spring balance would be the best for each ramp angle?)
- 3 Pull the 500 g weight up the ramp using the spring balance at a constant speed. The force on the spring balance will be equal to the force of friction. Record this reading in your results table.
- 4 Repeat the measurement two more times and record in your table.
- 5 Repeat steps 1–4 at four different ramp angles. Use a protractor to calculate the different angles.
- 6 Complete the results table by calculating the average effort force for each ramp angle. (To do this, you add all the readings you took for a particular ramp angle, then divide it by the number of readings you took for that ramp angle.)

Results

Draw a graph showing the relationship between ramp angle and effort load.

Discussion

- 1 Identify any trends in your results.
- 2 Identify any **anomalous** results in your graph.

anomalous
an outlying result that does not fit in with the pattern of the other results

Conclusion

Answer your research question, using evidence to support your statement.

Did you know? 8.2

Although the ramp looks like a simple device, it is capable of being used to build enormous structures. Archaeologists believe that the Great Pyramids of Giza in Egypt were built by teams of men dragging limestone blocks up giant temporary ramps into place on the pyramid.

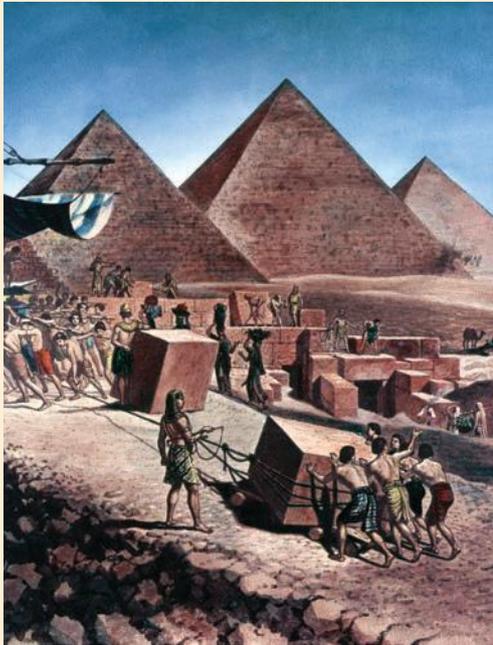


Figure 8.14 Workers on pyramids moving large stones up a ramp

You may be surprised to learn that a screw is a type of inclined plane. It is almost like a ramp wound around a cylinder. Screws are used to penetrate wood and other materials. Less effort is required to do this compared to hammering in a nail of the same size. However, for each turn of your screwdriver, the screw only goes in a little bit. That's the trade-off!



Figure 8.15 Screws and bolts are a special type of inclined plane.

Did you know? 8.3

Ancient Greek scientist Archimedes built a machine that was essentially a giant screw. The machine was used for irrigation in the Nile Delta and for pumping out water. It is still used today for pumping sewage in wastewater treatment plants.

By turning the screw, water is carried up the machine to a higher level.

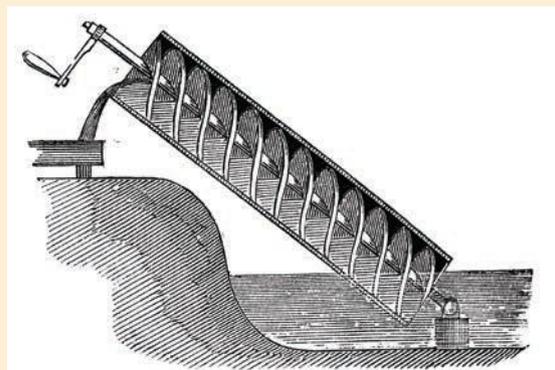


Figure 8.16 Archimedes' screw is used for lifting water.

Wedges

A wedge is a simple machine with two inclined planes, which changes the direction of force and also multiplies it. As shown in Figure 8.17, the vertical force applied to the wedge by a hammer is changed to two forces that are almost horizontal, which prise the layers of wood apart. Wedges can also be used to split layered material into sheets, or to prise apart glued or laminated sheets.

Another use of a wedge is to raise very heavy objects, such as large blocks of concrete, enough to be able to pass a lifting strap or rope underneath them, which can then be attached to a crane. The wedge is placed horizontally on the ground with the sharp edge touching the edge of the block. It is then tapped with a hammer so that it is driven under the block and raises it off the floor.

A wedge with a long, thin cross-section requires less effort than one with a short, thick cross-section to create the same load force, so it has a higher mechanical advantage.

Other examples of wedges are axe heads, doorstops, and the pointed ends of nails and pins.

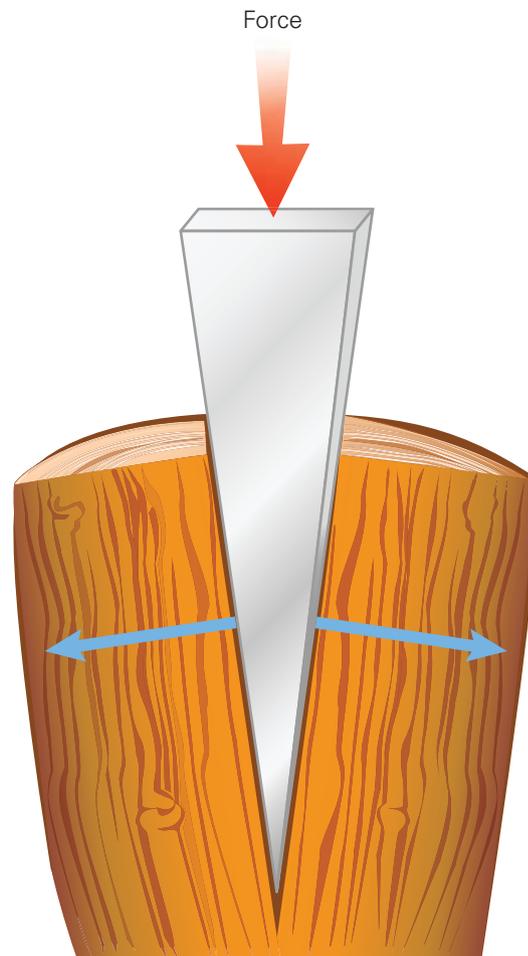
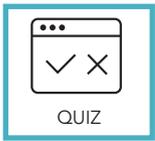


Figure 8.17 A wedge used to split a block of wood is placed with the sharp edge on the end of the block, parallel to the wood grain (its natural layers). It is then tapped with a hammer, driving it into and splitting the wood.

Quick check 8.2

- 1 Recall three examples of inclined planes.
- 2 Explain the effect of an inclined plane on the effort required to complete a task.
- 3 Explain how inclined planes are used to enable vehicles to drive up mountains.
- 4 Describe what happens to the mechanical advantage of a ramp and the effort required to push a load to the top as it becomes less steep.

Section 8.1 questions



Remembering

- 1 **Identify** the missing words in the following sentence: To calculate mechanical advantage, you must divide _____ by _____.
- 2 If the mechanical advantage is 3, **calculate** the maximum load if the effort is 25 N.
- 3 If the mechanical advantage is 4, **calculate** the minimum effort required to lift a load of 120 N.

Understanding

- 4 **Classify** each of the following as a class 1, class 2 or class 3 lever.

a Crowbar



b Wheelbarrow



c Seesaw



d Chopsticks



e A screwdriver used to open a can



Applying

- 5 Most schools and public buildings now have ramps designed for wheelchair access. Apply your knowledge of ramps and forces to **explain** why the maximum gradient of these ramps is about 5°.

Analysing

- 6 **Distinguish** between a class 1, 2 and 3 lever, what they magnify and the trade-offs.

Evaluating

- 7 Consider whether the lower beaks of birds are levers. Examine the parrot skull in Figure 8.18 and use your knowledge of simple machines to **justify** your answer. Note that there is one kind of lever to open the beak, and another kind to close it.

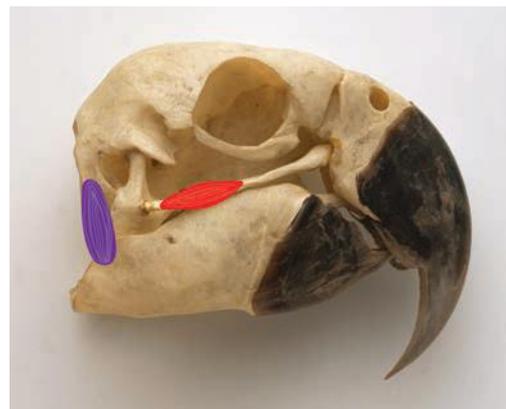


Figure 8.18 The lower beak is pulled up (beak closed) by the contraction of muscles shown in red. It is moved down (beak opened) by the muscles shown in purple.

8.2 Simple machines with rotating parts

Learning goals

- 1 To be able to describe how pulleys are useful.
- 2 To be able to describe how gears are useful.



Pulleys

Pulleys can be used to lift heavy objects. The most common example is a single-pulley system. A single fixed pulley does not decrease the effort needed to lift the object, it only changes the direction of the force. It is easier to pull down on a rope than lift something up because you can put your weight into it. This type of pulley system is used for opening blinds that cover windows.

To decrease the effort force needed to lift an object, more pulleys need to be added. The more pulleys that are added to a pulley system, the higher the mechanical advantage. If a pulley system has a mechanical advantage of 2, that means that it takes half the effort to lift an object compared to if a pulley was not used. However, the trade-off is that the rope will have to be pulled twice the distance to lift the load.

Pulleys are often found on sail boats, where heavy objects need to be lifted and held high up in the air. Imagine trying to lift and hold a sail up all by yourself! With pulleys, you simply need to pull on the rope.



Figure 8.19 A single fixed pulley system can be used to lift heavy objects. It does not give a mechanical advantage, but it changes an upwards lifting force into a downwards pulling force, which is easier.

Practical 8.3: Teacher demonstration

Observing the effect on effort force of more pulleys

Aim

To observe the effects on the effort force after adding more pulleys to a pulley system.

Materials

- 2 compound pulleys
- string
- 500 g mass
- ruler
- 500 g spring balance

Planning

- 1 You need to provide background information to the investigation. Complete research and write a brief paragraph to explain the key concepts of pulleys. Ensure you reference this appropriately.
- 2 Create a research question, based on information in the aim.

Method

- 1 Set up the four pulley systems as shown in Figure 8.20 or by the teacher.
- 2 Draw up a results table in your science book and label it appropriately.
- 3 Hook a 500 g mass to the load part of the pulley.
- 4 Attach the spring balance to the effort part of the pulley.
- 5 Observe the amount of force required to lift the mass at a constant rate by pulling on the spring balance. Record.

Results

Independent variable	Dependent variable	
	Load	Effort
Set-up 1		
Set-up 2		
Set-up 3		
Set-up 4		

Discussion

Identify any patterns, trends or relationships in the results.

Conclusion

Answer your research question, using evidence to support your statement.

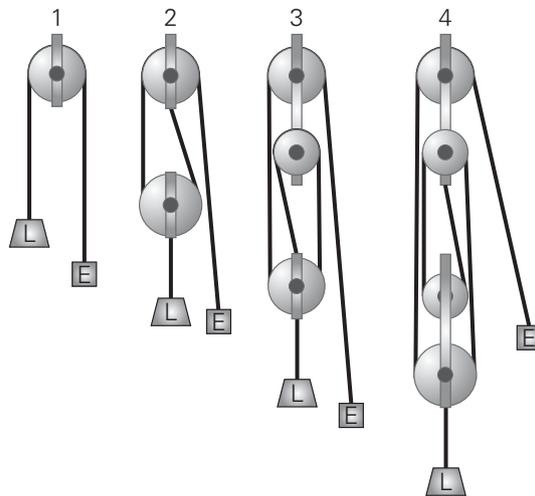


Figure 8.20 L represents the load force (the weight of the mass attached) and E represents the effort force required to lift the mass.

Extension: Mechanical advantage of pulleys

Let us investigate mechanical advantage further.

$$\text{mechanical advantage} = \frac{\text{number of strings supporting the load}}{\text{number of effort ropes}}$$

In Figure 8.22, when the effort rope (blue) is pulled, each of the two load ropes (red) is shortened. As there are two load ropes and one effort rope, the mechanical advantage of this system is 2.

In Figure 8.23, when the effort rope (blue) is pulled, the load ropes (red) are shortened. As there are four load ropes and one effort rope, the mechanical advantage is 4.

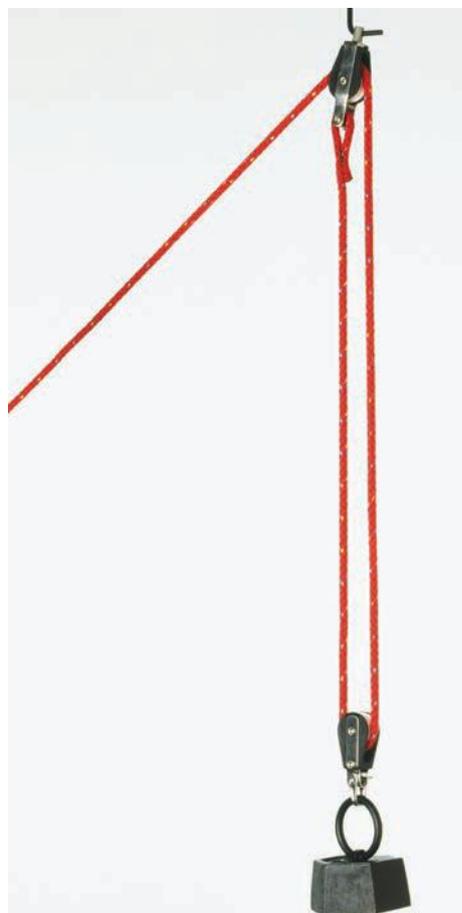
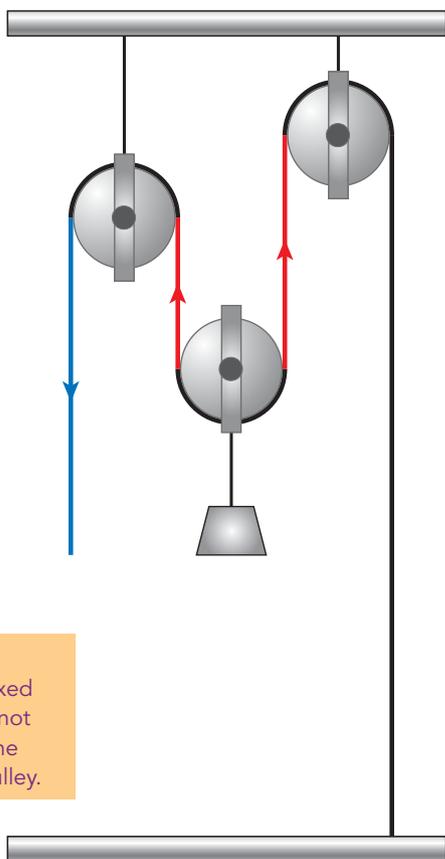
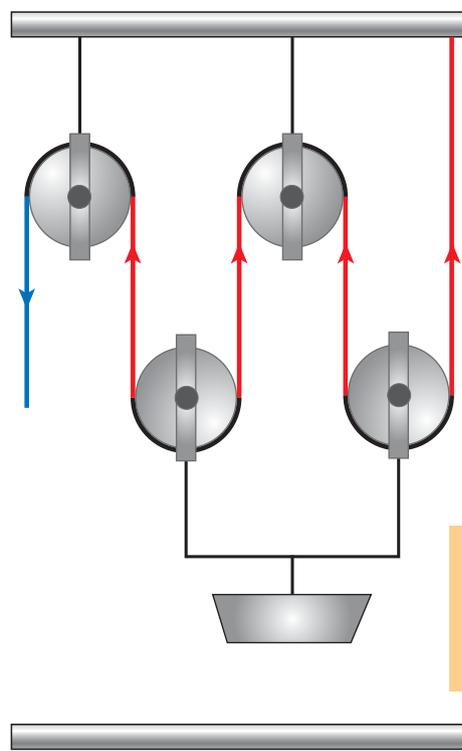


Figure 8.21 A two-pulley system



Note the black ropes have a fixed length and do not contribute to the effect of the pulley.

Figure 8.22 A pulley system with a mechanical advantage of 2



Note the black ropes have a fixed length and do not contribute to the effect of the pulley.

Figure 8.23 A pulley system with a mechanical advantage of 4

Quick check 8.3

- 1 Identify the mechanical advantage of the pulley system shown.

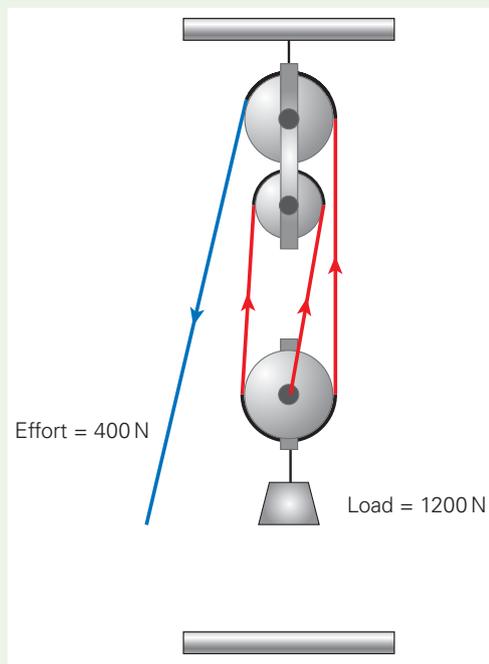


Figure 8.24 A pulley system

- 2 Calculate the maximum load that could be lifted if an effort force of 40 N was applied to the system in the previous question.
- 3 Explain why, in practice, the actual load that can be lifted may be less than the value calculated in Question 2.

Gears

Another type of simple machine is a special type of wheel called a **gear** or cogwheel. They are essentially wheels with **cogs** (teeth) that transmit force from one wheel to another.

gear
a device consisting of connecting sets of wheels with teeth

cog
one of the tooth-like parts around the edge of a wheel

driving gear
the gear connected to the source of the force

driven gear
the gear that rotates due to the rotation of a driving gear

You may recognise gears in bikes or clocks. In a bike, the gears are connected by a chain, whereas in a clock they are called ‘meshed’ gears because the teeth fit into each other.

When gears of different sizes are used, they can be either speed or force multipliers. In a gear system, the

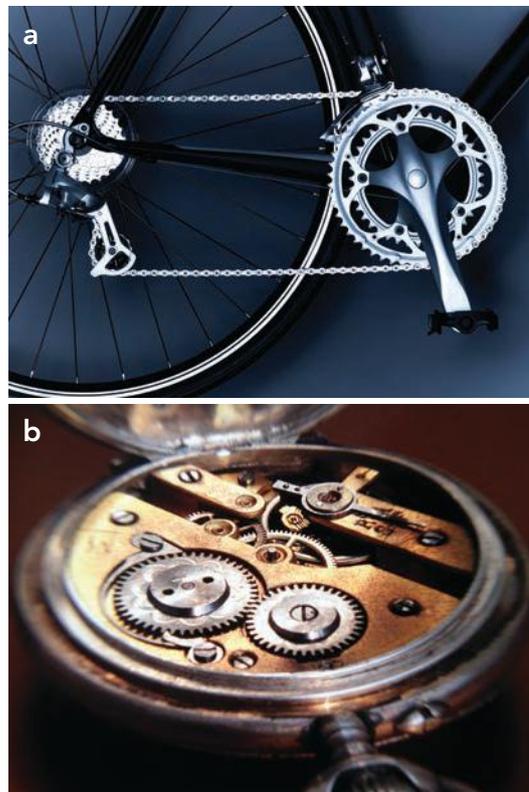


Figure 8.25 (a) Chained gears in a bicycle, (b) meshed gears in a pocketwatch

driving gear (the gear to which the effort is applied) turns the **driven gear**. If the driving gear is the larger of the two, then you have a speed multiplier. This is because for each turn of the large driving gear, the smaller driven gear turns more times. A motor can be attached to the gear to produce a turning force. An old-fashioned egg beater is an example of this sort of gear system in use.

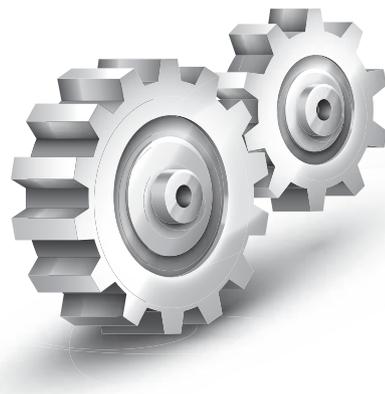


Figure 8.26 Every time the larger driving gear turns once, the smaller driven gear turns multiple times, spinning faster.



Figure 8.27 A manual egg beater. The handle turns the large gear, which in turn spins smaller gears that cause the beaters to spin fast.

In this case, you turn the larger gear using the handle and the beaters spin faster than you are turning the handle. A road bike works in the same way.

The other type of gear system is a force multiplier, where the smaller gear is the driving gear. For every turn of the driving gear, the driven gear does not turn as many times, so it turns more slowly, but it turns with more force. This sort of arrangement provides a mechanical advantage. These are found on mountain bikes.



VIDEO
How is a bicycle a complex machine?



WIDGET
Gear ratios

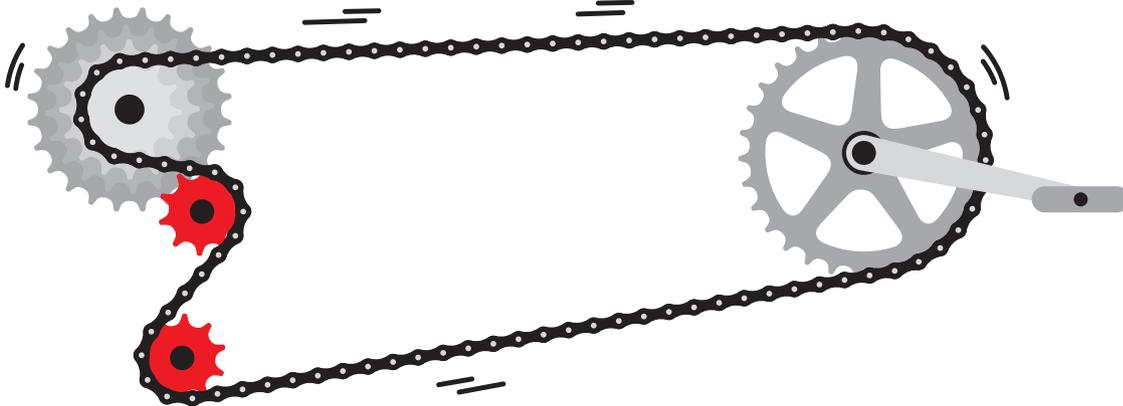


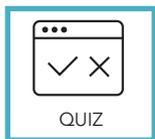
Figure 8.28 When pushing the pedals on a bike, force is applied to the larger gear by turning the pedal with your foot. This turns the smaller rear gear many times, allowing you to ride your bike with speed!

Try this 8.3

You will need either a hand beater or a hand drill.

- 1 Count how many small gears and large gears are present in your simple machine.
- 2 Either measure the diameter of each gear or count the number of teeth.
- 3 Use the handle to operate your beater or drill. Draw a diagram of the gear set-up to show how the machine works. Be sure to label the driving gear and driven gear.
- 4 For every full rotation of the driving gear, how many times does the driven gear turn?
- 5 Explain whether this is a speed or force multiplier.
- 6 How could you make the machine turn faster? How could you make your machine turn with more force?

Section 8.2 questions

**Remembering**

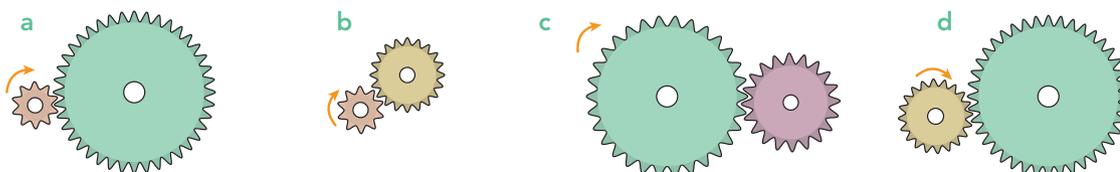
- 1 List some everyday objects that use gears.
- 2 Illustrate the gear set-up most commonly used in bikes.

Understanding

- 3 Explain the difference between a speed multiplier and a force multiplier for gears.
- 4 Describe when you would use a speed multiplier and when you would use a force multiplier.

Applying

- 5 State whether the following gears are speed or force multipliers. The arrows indicate the driving gear.



- 6 An experiment was done with the pulley system shown in Figure 8.29 and the results are shown in the table below.

Use the formula given to complete the table and hence **calculate** the average mechanical advantage.

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

Load (N)	Effort (N)	Mechanical advantage
30	88	
40	121	
50	147	
60	185	
Average		

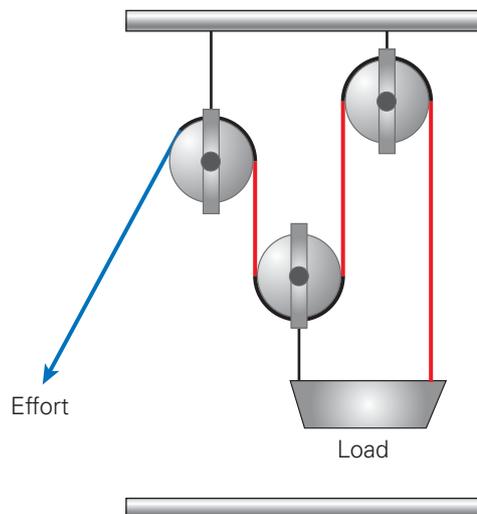


Figure 8.29 A load system

Analysing

- 7 Analyse the bike gear system in Figure 8.30. Explain why a bike might have a number of different-sized driven gears.

Evaluating

- 8 A gear system has a driving gear with 30 teeth and a driven gear with 25 teeth. Identify whether it is a force multiplier or a speed multiplier and state how it could be made more effective; that is, how it could be made to multiply speed or force more.



Figure 8.30 Bike gear system

Chapter review

Chapter checklist

In the Interactive Textbook, the success criteria are linked to the review questions and will be automatically ticked when answers are correct. Alternatively, you can download this checklist from the Interactive Textbook to complete it.

Success criteria	Linked questions	Check
8.1 I can recall some simple machines and how they work.	8	
8.1 I can describe 'mechanical advantage'.	5	
8.1 I can recognise class 1, class 2 and class 3 levers.	7	
8.2 I can describe how pulleys are useful.	4	
8.2 I can describe how gears are useful.	2	

Review questions

Remembering

- 1 **Recall** the different classes of lever.

Understanding

- 2 **Describe** the two different types of gears in a gear system: driving gear and driven gear.
- 3 **Explain** how simple machines allow us to do something that would otherwise be difficult.

Applying

- 4 A pulley system has a mechanical advantage of 4 but is less than 100% efficient. If an effort force of 80 N was applied, **explain** whether the maximum load that could be lifted would be less than 320 N or more than 320 N.
- 5 Extension: The mechanical advantage of a lever is given by:

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}} = \frac{\text{fulcrum to effort distance}}{\text{fulcrum to load distance}}$$

Use the formula to analyse the lever in Figure 8.31 and **calculate** the maximum load that can be moved with this lever.

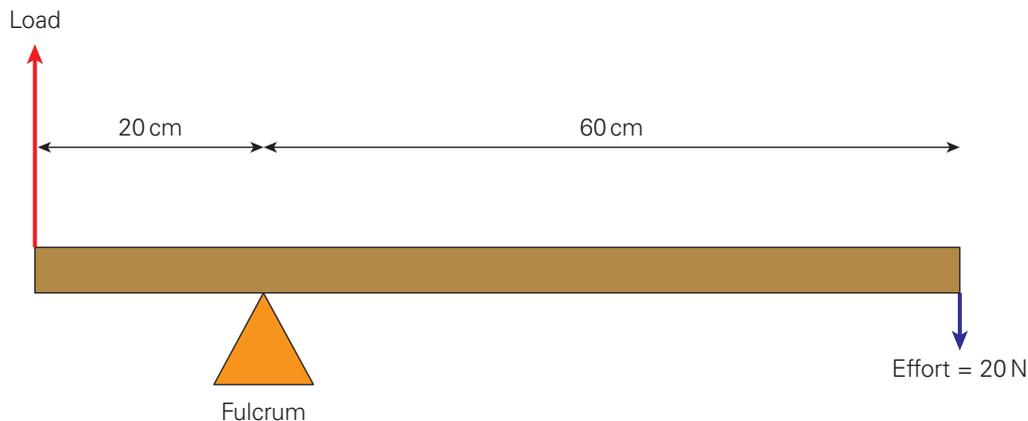


Figure 8.31



- 6 Extension: Analyse the pulley system in Figure 8.32 and state the mechanical advantage. Use your result to **calculate** the maximum load that can be lifted by an effort force of 80 N.

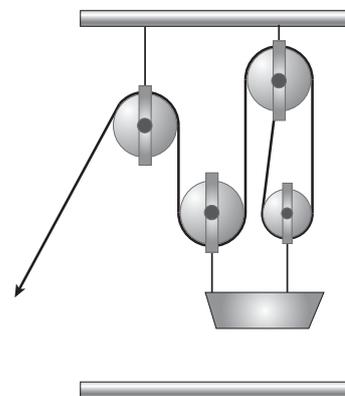


Figure 8.32

Analysing

- 7 Analyse the following and **classify** the objects as either class 1, 2 or 3 levers.

- a Screwdriver opening a lid of paint b Fishing rod c Scissors



- d Wheelbarrow

- e Claw hammer

- f Nutcracker



- g Pliers

- h Crowbar

- i Barbecue tongs



- j Seesaw

- k Broom



Evaluating

- 8 You have the choice of a ramp that is 6 m high and 10 m long, or a ramp that is 6 m high but is 20 m long. **Explore** the advantages and disadvantages of each situation.

Data questions

The ancient Greek engineer, Archimedes, is supposed to have said, 'Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.' In this activity you will assess the results of the experiments by a group of Year 7 students. They designed systems to lift a 10 kg bucket of water using a series of pulleys (Table 8.1) and also using a 2-metre class 1 lever with the bucket at different distances from the fulcrum (Table 8.2).

Number of pulleys	Effort (N)
1	100
2	50
3	33
4	25
5	20
6	17

Table 8.1 Effort force (N) for lifting a 10 kg bucket of water with respect to a number of pulleys used

Distance of bucket from fulcrum (m)	Mechanical advantage
0.4	4.0
0.8	1.5
1.0	1.0
1.2	0.7
1.6	0.3

Table 8.2 Mechanical advantage for lifting a 10 kg bucket of water using a 2-metre class 1 lever with the load (bucket) a varying distance from the fulcrum

- Identify** the number of pulleys in Table 8.1 which requires the least effort force to lift a 10 kg bucket of water.
- Calculate** the mechanical advantage for using a pulley system with five pulleys.
- Use the data from Table 8.2 to **determine** the distance of the bucket from the fulcrum which would require the least effort force to lift the 10 kg bucket.
- Identify** the trend in Table 8.2 between the distance of the bucket from the fulcrum and the mechanical advantage.
- Use data in Table 8.1 to **identify** the relationship between the number of pulleys used and the mechanical advantage.
- Deduce** how the students could gain a greater mechanical advantage using the class 1 lever.
- Compare** the mechanical advantage of a five-pulley system, to that using a 2-metre class 1 lever with the bucket 40 cm from the fulcrum, and describe which simple machine would use less effort force.
- Extrapolate** the data presented in Table 8.1 to estimate the effort force (N) used in a 10-pulley system.
- Predict** whether mechanical advantage would increase or decrease in Table 8.2 if a 4 m lever was used instead.

STEM activity: Designing and prototyping a mechanical arm

Background information

A machine is an apparatus that applies energy to exert forces for a particular action. In the real world, machines help us do a variety of things. An example of a machine is a forklift. Forklifts can be used to move loads that a human cannot move. The average human would get tired carrying around a 20 kg load for several minutes (please

do not try this!), but a forklift can carry 1000 kg without breaking a sweat!

Simple machines reduce the force required to do a task, like lifting a heavy object. There are various types of simple machines that can be used to perform tasks, including levers, ramps, wedges, pulleys, gears and screws. Two or more simple machines can be combined together to form a compound machine.

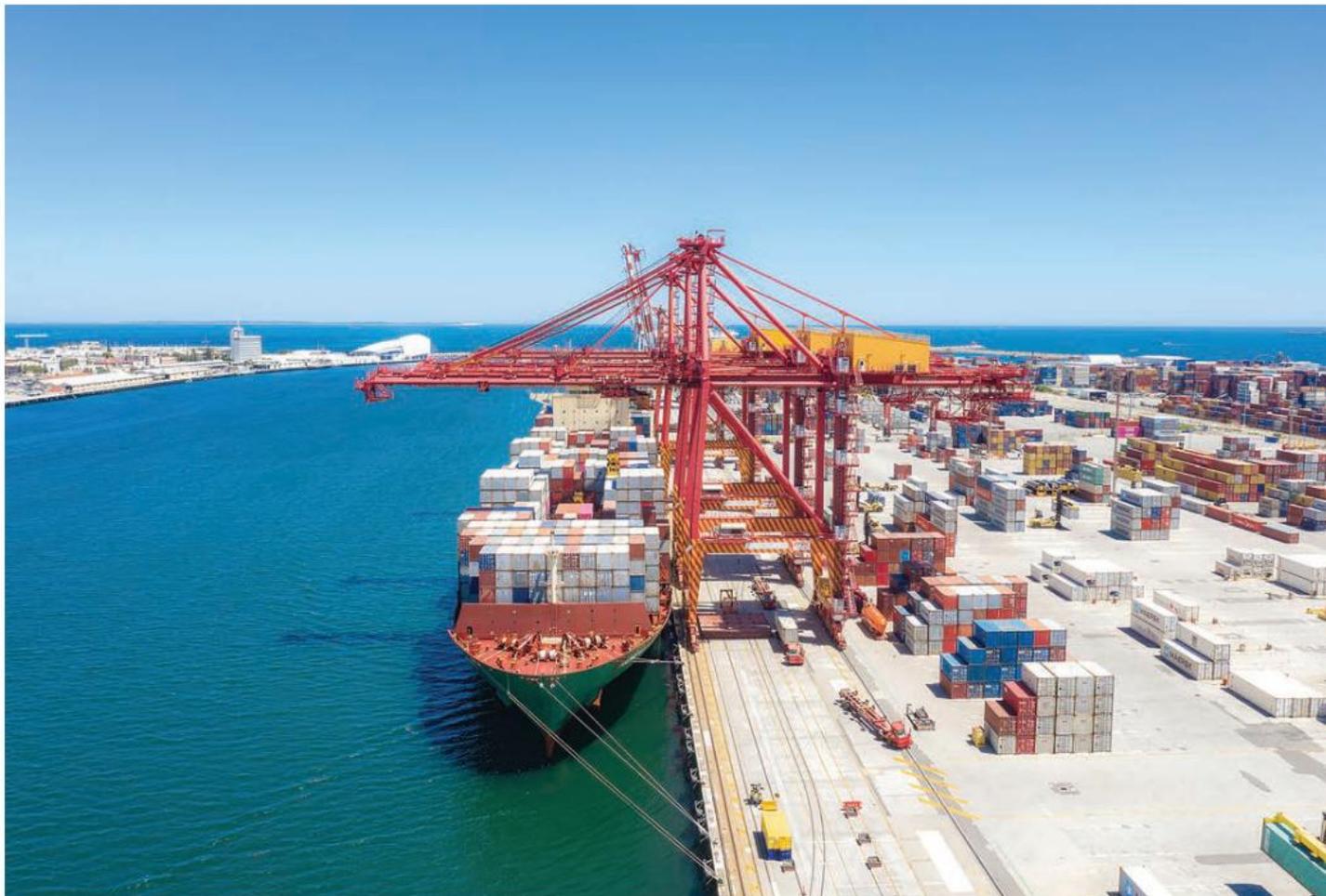


Figure 8.33 A crane used to move storage containers at Fremantle Harbour. A crane uses pulleys and may also use levers, and is an example of a compound machine.

Design brief: Design and build a mechanical arm that can lift and move the greatest weight.

Activity instructions

Your team has been assigned a task to construct a compound machine that involves at least two simple machine mechanisms to lift a load at least 30 cm vertical distance and move it at least 30 cm horizontal distance. You will provide the power to move the machine and provide the effort to lift and move the load. You must be able to control the machine by staying put in the same spot while the machine moves around and hooks the load.

As an engineer, you should investigate different kinds of mechanical arms that can be created without a motor. You will draw a design and prototype using cardboard and a number of different materials that will be provided by your teacher. Finally, you will test your prototype(s) by lifting different loads starting from the lightest to the heaviest.

Suggested materials

- four weights – 50 g, 100 g, 250 g, 500 g
- pulleys
- ruler and tape measure
- scissors
- cardboard
- string
- straws
- icy-pole sticks
- sticky tape
- wire

Research and feasibility

- 1 Research and list all the ways that mechanical arms are useful.
- 2 List the construction materials and the components used in cranes. Record the explanation for each. A table has been constructed as an example.

Materials	Components	Explanation
Steel lattice	Mast – upright steel lattice structure	The mast uses triangular steel structures bolted to each other.

- 3 Explain which simple machine types are involved in a crane and how they contribute to the motion of the arm.

Design

- 4 List the materials you have available for construction and how they would be useful.
- 5 Design a mechanical arm that you could build using your available materials. Ensure you have included in your design the capacity to move a load 30 cm both vertically and horizontally.
- 6 Label the design and include measurements for construction.

Construction

- 7 Build your mechanical arm. At several points during the construction process, check that the structure continues to meet the design constraints. You may wish to test the mechanical arm's strength and ability to lift the load during construction in case you need to make refinements.

Evaluate and modify

- 8 Discuss the challenges that you have encountered throughout this activity. List the strategies or actions that enabled you to overcome each one.
- 9 Propose ways that your prototype could be improved if you had more time and resources available.
- 10 Predict what would happen if the prototype was used on a heavier load and test if possible.

Glossary

Chapter 1

accuracy how close a measurement is to the true value

analyse examine something in order to find meaning, what it is made of or a relationship with other things

claim a statement with no evidence provided that is evaluated and then either supported or not supported by the collection of thorough evidence

concave a surface that curves inwards

controlled variable the variable or variables that are kept the same during an experiment

convex a surface that curves outwards

data facts or statistics gathered to answer a question or for further analysis

dependent variable a variable that is tested or measured during an experiment (as it responds to the independent variable)

DNA deoxyribonucleic acid, a chemical present in cells of living things that carries genetic information

experiment a controlled situation where data is gathered to answer a question

fair test an experiment where the independent variable is changed, and other variables are controlled

hypothesis a proposed explanation or prediction of an event (e.g. an experiment) based on research and current knowledge

independent variable the variable that is changed during an experiment

infer to link an observation with past knowledge and assign meaning to the observation

inference applying a reason or explanation to an observation, based on past experiences and known facts

knowledge the understanding of information

meniscus the surface of a liquid in a container

observe use senses and tools to gather information/data

parallax error an error caused by not reading liquid measurements at eye level, which leads to measurements being too high or too low

peer-review to read, check, and give an opinion about something that has been written by another scientist or expert working in the same subject area

precision how close measurements are to each other

predict to make an estimate about a possible future event or outcome

qualitative a form of data that is a descriptive measurement

quantitative a form of data that is a numerical measurement

random error an error that is random and caused by factors that cannot be easily controlled by the experimenter

research question a question that can be answered practically through scientific investigation or through research to evaluate a claim

systematic error an error that causes measurements to differ from the true result by a consistent amount, often due to faulty or uncalibrated equipment

trend a pattern in data that shows the general direction/shape of the relationship between the independent and dependent variables

variable a component of an experiment that changes or can be changed

Chapter 2

anomalous an outlying result that does not fit in with the pattern of the other results

autotroph an organism that produces its own food from light, carbon dioxide, water or other chemicals

bilateral symmetry organism can be divided into two symmetrical halves

binomial nomenclature a system of naming in which two names are used to identify an individual genus and species of an organism

botanist a scientist who studies plants

characteristic a feature or quality of something

class the taxonomic ranking below phylum and above order

classification the grouping of similar objects or organisms together

dichotomous key a tool for scientists to identify an organism from a series of choices between two characteristics

DNA deoxyribonucleic acid, a chemical present in cells of living things that carries genetic information

domain the highest taxonomic rank above kingdom and even more broad

ectothermic a cold-blooded organism that cannot regulate its internal temperature

endothermic a warm-blooded organism that can regulate its body temperature

family the taxonomic ranking below order and above genus

genre a category used to group media such as music, art or books

genus the taxonomic ranking below family and above species

heterotroph an organism that cannot make its own food, instead relying on other organisms for energy

invertebrate does not have a backbone

key a tool used to identify organisms

kingdom the highest classification on the Linnaean taxonomic rankings and the most broad

metamorphosis the process of transformation from an immature form to an adult form

microbiologist a scientist who studies very small living things like bacteria

morphology the study of the size, shape and structure of organisms

non-vascular not containing veins or specialised fluid vessels

order the taxonomic ranking below class and above family

organism a living thing

parasite an organism that lives in or on another organism and takes its food from its body

phylum the taxonomic ranking below kingdom and above class

qualitative a form of data that is a descriptive measurement

quantitative a form of data that is a numerical measurement

radial symmetry organism is symmetrical around a line drawn through the centre in more than one position

sessile an organism that is fixed in its location and does not independently move but may move its body parts

species the most specific taxonomic ranking below genus

spore a single-celled reproductive unit

taxonomy a branch of science that groups organisms

unicellular consisting of one cell

vascular containing veins or specialised fluid vessels

vertebrate has a backbone

Chapter 3

10% rule when energy is passed from one trophic level to another, only 10% of the energy will be passed on

abiotic relating to the non-living things in an ecosystem

abundance the number of individuals of a species within a community or ecosystem

algae small protist organisms (see Chapter 2) without leaves or roots; a valuable food source in aquatic ecosystems

apex predator a predator at the top of a food chain

barnacle small sea creature with a shell that sticks to rocks and the bottom of boats

biodiversity the number and types of plants and animals that exist in an area

biological control the practice of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

biotic relating to the living things in an ecosystem

calicivirus a disease that damages a rabbit's internal organs and can cause bleeding

carnivore an animal that eats only meat

cellular respiration the chemical process by which cells release energy from food

chemotroph an organism that obtains energy through chemical processes in its environment

community a group of animals or plants that live or grow together

consumer an organism that obtains food from consuming other organic material

decomposer an organism such as a bacterium or fungus that makes dead plant and animal material decay

deforestation clearing a wide area of trees or natural land

detritivore an organism that feeds on dead or decaying organic matter

detritus waste or debris

ecosystem the living and non-living components of a specific area and their interactions

endemic plants plants found widely throughout specific regions

energy the ability to do work by producing heat or motion

environment the biotic and abiotic conditions that affect an organism in its location

firestick farming the burning of areas of bush in stages, by the application of firesticks, to encourage new growth

food chain the flow of food energy through an ecosystem passing from plants and bacteria to consumers

food web a group of interweaving food chains

habitat the natural home of an organism

herbivore an animal that eats only plants

invasive species an organism that is not native to an environment and causes harm to native organisms

microorganism a living thing that on its own is too small to be seen with the naked eye

omnivore an animal that is naturally able to eat both plants and meat

pathogen an organism that can cause illness

photosynthesis the process by which a plant uses the energy from the light of the Sun to produce its own food

population all organisms of a particular species or group who live in one area

primary consumer an animal that eats plants

producer an organism capable of producing food from photosynthesis

scavenger an organism that feeds on dead animals that it has not killed itself

secondary consumer an animal that eats other animals

symbiotic a relationship between two types of living things that helps at least one of them survive

tertiary consumer an animal that eats secondary consumers

trophic level refers to an organism's level or position in a food web. It is based on an organism's feeding habits, where producers occupy the first trophic level, primary consumers the second trophic level, and secondary consumers the third trophic level, etc.

Chapter 4

aqueous solution solutions where the solvent is water

centrifuge a device that uses speed to separate substances based on mass

chromatography a technique to separate substances based on movement at different rates due to solubility

colloid a mixture where particles of one substance will not dissolve but remain distributed through another substance

concentrated a solution with a large amount of the solute

crystallisation solidification of a substance into a highly structured form

decantation the process of separating by using gravity

dilute a solution with only a small amount of the solute

dissolve cause to become mixed in a substance so that it cannot be seen

distillate the condensed liquid product from distillation

distillation a technique to separate substances in a liquid using evaporation (boiling) and condensation

emulsion a colloid of two or more liquids

evaporation when liquid changes to a gaseous state

filtrate the substance that passes through the filter

filtration separating a mixture by passing through a filter

flocculant a substance that causes particles to clump together

flotation separating a mixture based on the capacity to float

heterogeneous mixture a mixture that can be easily separated into its parts, and those parts retain their original properties

homogeneous mixture a mixture where components are evenly distributed

insoluble substances that cannot dissolve

matter anything that has mass and occupies space

mixture material made up of two or more different substances that are mixed together

physical property measurable property such as density, size, colour, magnetism, mass, melting point or texture

pure substance material that is made up of just one type of particle

residue the substance that is left in the filter

saturated a solution with the maximum amount of solute dissolved

smog a mixture of smoke, gases and chemicals, especially in cities

soluble substances that can dissolve

solute the component of a solution being dissolved

solution a mixture where one substance is evenly dissolved in another

solvent the component in a solution capable of dissolving another substance

suspension a mixture where one substance will eventually settle out of the solvent

Chapter 5

annular eclipse an event when the Moon blocks the Sun but the Moon is further away and the outer edge of the Sun is still visible

apogee the point in the Moon's orbit when it is furthest from Earth

blood moon a name given to the Moon during an eclipse while it is completely in Earth's shadow

dawn the time of day when the Sun rises over the horizon or night turns into day

dusk the time of day when the Sun drops below the horizon or day turns into night

elliptical oval shaped

equator an imaginary line drawn around the middle of Earth equidistant between the North and South poles

far side the face of the Moon that is always turned away from Earth; also called the dark side

geocentric model a model where Earth was the centre of the universe

gravitational field the region around an object where another object can experience its gravity or pull

heliocentric model a model with the Sun as the centre of the solar system

horizon the point where the sky appears to meet the land or the sea

leap year a year that happens every four years and has an extra day on 29 February

lunar eclipse a full Moon becomes dark as it enters Earth's shadow

mass the amount of substance in an object that never changes, even in space

Northern Hemisphere the half of Earth north of the equator

orbit the curved path of a celestial object or spacecraft round a star, planet or moon

partial eclipse an event when the Sun is partially blocked by the Moon

penumbra the region in a shadow where the light is partially blocked

perigee the point in the Moon's orbit when the Moon is closest to Earth

revolution one complete orbit

solar eclipse an event when the Sun partly or completely disappears from view, while the Moon moves between it and Earth

Southern Hemisphere the half of Earth south of the equator

sunspot feature on the Sun's surface that moves very slowly across the surface

synchronous rotation occurs when the rotation of an orbiting body is the same length of time as its revolution around a larger body

syzygy the occurrence in astronomy of three or more objects moving into a straight line

telescope an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

time zone Earth is divided into 24 time zones, each about 15 degrees of longitude and each one representing a time difference of 1 hour

total eclipse an event when the Sun is completely blocked by the Moon

umbra the region in a shadow where the light is completely blocked

waning the period of about two weeks where the illuminated part of the Moon is decreasing from a full moon to a new moon

waxing the period of about two weeks where the illuminated part of the Moon is increasing from a new moon to a full moon

Chapter 6

barrage a dam to generate electricity from tidal power

biomass plant and animal material suitable for using as fuel

blackwater wastewater from toilets

catchment a natural drainage basin that catches and directs water flow into a single lake or outlet to the sea

condensation when heat is lost causing a gas to become a liquid

drought a prolonged period of unusually low rainfall that leads to a shortage of water

energy the capacity to do work

erosion the process by which broken rock particles are carried away by the action of wind and water

evaporation when liquid changes to a gaseous state

fossil fuel fuels, such as gas, coal and oil, that were formed underground from plant and animal remains millions of years ago

geothermal energy energy from the heat inside Earth

greenhouse gas gases that trap heat in the atmosphere

greywater water that has already been used for washing, which can be stored and used again for other uses such as toilets

groundwater water that collects beneath Earth's surface

hydroelectricity electricity produced by the force of fast-moving water

impermeable not allowing liquid or gas to go through

infiltration to move slowly into a substance

mineral substance formed naturally in the ground

non-renewable existing in limited quantities that cannot be replaced after they have all been used

nuclear energy the energy obtained from changes within the atomic nucleus from nuclear fission or fusion

ocean energy energy harnessed from the movement of the ocean such as waves and tides

percolation the process of a liquid moving slowly through a substance that has very small holes in it

permeable allows liquids or gases to go through it

pervious a substance that allows water to pass through via cracks or defects in the rock

photovoltaic able to produce electricity from light

precipitation water that falls from the clouds towards the ground as rain or snow

renewable replenished by natural processes within a human lifetime

resource something that is useful

runoff water that flows away from high areas to low areas

solar energy the energy from the Sun used to produce electric power or to heat water

transpiration the movement of water upwards through a plant to its leaves, from where the water evaporates

urban water cycle a water cycle that includes the consequences of increased development

water cycle the way that water is taken up from the sea, rivers, lakes and soil and then comes back down as rain, snow or hail

weathering the process by which rocks are broken down through natural means



Chapter 7

air resistance the frictional force of the air

alloy a substance composed of two or more metals

anomalous an outlying result that does not fit in with the pattern of the other results

applied force force that is applied to an object by another object or person

balanced forces forces of the same size but which act in opposite directions

brittle a material that is likely to break or snap when subject to a big enough force

buoyancy force the force experienced by an object that is partially or fully submerged in a fluid, e.g. water or air

drag the frictional force of a liquid or gas

elastic elastic materials bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

electromagnet a magnet made by passing electricity through a coil of wire

electrostatic force a non-contact force between positive and negative charges; opposite charges attract, like charges repel

field a region in space in which an object is affected by a force

force a push, pull or twist in a specific direction

friction a contact force opposing motion due to the interaction between two surfaces

gravity a non-contact force describing the pull of any object with mass

impact force a contact force, which sometimes only lasts for a short time; often impact forces change an object's speed

magnetic field the space around a magnet where the magnetic force acts

magnetic force a non-contact force between a magnet and another magnet or magnetic metal

mass the amount of substance in an object that never changes, even in space

mouldable soft enough to be shaped

muscle tissue in the human body capable of exerting a force

net force the sum of all forces acting on an object

newton the unit of force; one newton is roughly equal to the force you need to keep a 102 g apple from falling

pull to exert a force towards something

push to exert a force away from something

repel to force back or apart

rotate to turn or spin on an axis

static electricity a build-up of electric charge

streamlined designed to minimise air resistance or drag

tension the force in a wire, cable or string when being stretched

turning force a force that makes an object start or stop rotating

twist to turn something

unbalanced forces a combination of one or more forces that has an overall effect, and which changes an object's motion

weight the force of gravity on an object; it is measured in newtons and changes in space

Chapter 8

anomalous an outlying result that does not fit in with the pattern of the other results

class 1 lever a lever in which the fulcrum is between the load and effort

class 2 lever a lever in which the fulcrum is at one end and the load is between the fulcrum and the effort

class 3 lever a lever in which the fulcrum is at one end and the effort is between the fulcrum and the load

cog one of the tooth-like parts around the edge of a wheel

driven gear the gear that rotates due to the rotation of a driving gear

driving gear the gear connected to the source of the force

effort the input force to a simple machine

force multiplier something that increases the size of a force

fulcrum the point on a lever where a bar is supported; the lever turns about this point

gear a device consisting of connecting sets of wheels with teeth

lever a rigid bar that moves around a fixed point so one end can be pushed or pulled to move the other end with a greater or smaller force

load the object that is to be moved

load force the output force of a simple machine

mechanical advantage the ratio of the output force to the input force

pulley equipment consisting of a grooved wheel (or wheels) with a rope or chain attached to an object to be moved

ramp an inclined surface connecting a higher and a lower level

simple machine a basic mechanical device for applying a force and changing either its size or direction

speed multiplier something that increases the speed of an object

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