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Welcome



To me, science represents a never-ending journey of learning, exploration and discovery. It is science that has allowed us to understand and explain the forces underpinning the world around us, enabling us to extend the frontier of human knowledge and develop new tools and technologies to enrich our lives.

Yet, we have barely scratched the surface of what is out there to be discovered, and in an era of information technology and big data, we have more questions than ever to grapple with, but also an array of new resources at our disposal to tackle previously unsolved problems.

It is an exciting time to be studying science. Good luck and enjoy the journey ahead!

Anand Bharadwaj is currently a Chancellor's Scholar at the University of Melbourne, studying for a Bachelor of Science degree in Mathematics and Statistics. In 2017, while in Year 11, Anand attained the highest VCE aggregate in the state of Victoria, achieving a perfect ATAR of 99.95. He has been a passionate and high-achieving student in mathematics and science over the years, winning several major bursaries in the Victorian Science Talent Search and receiving highest honours in national-level Olympiads in Physics, Chemistry, Biology, Informatics, Mathematics and Linguistics.

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Victoria Shaw has been committed to sharing her love for science with Year 7–12 students for the past 18 years and previously studied pharmacology. She was Head of Science at an independent school for a few years and volunteers as an educator for Wildlife Victoria. She has also been an assessor for the VCAA and IBO and runs workshops in Biology and Psychology.



Evan Roberts

Evan Roberts is a keen biologist and prior to teaching worked in conservation and environmental management. He has taught in both public and private schools and is dedicated to instilling his passion for science into his students. He believes that education, just like science, should be dynamic, exciting and forever changing to keep up with the world around us.



Christopher Humphreys

Chris Humphreys is currently Head of Mathematics and Physics at a college for international students. He graduated from Nottingham University in the UK and completed his MSc in Physics at the University of Waikato in New Zealand. He has over thirty years' experience as a teacher in the UK, New Zealand, Qatar and Australia.



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Jonathan Blair graduated from the University of New South Wales with a Bachelor in Science, majoring in Pharmacology. He has worked in both research and commercial laboratories, specialising in cardiac regeneration and vaccine manufacturing, respectively. Jonathan is currently working as a laboratory technician for an independent school.



Sarah Chuck

Sarah Chuck teaches Science in Years 7–10. She completed a Biomedical Science degree at Monash University and Master of Teaching Practice at RMIT. During her studies, Sarah worked in a genetics laboratory at the Australian Regenerative Medicine Institute, modelling disease in organisms, such as the zebrafish. She hopes students will also find their experiences in science to be extremely interesting and rewarding.



Paulo da Silva

Paulo da Silva is a passionate STEM Educator with a varied background in ICT, Earth Sciences and STEM Curriculum Design. Paulo encourages students to use their curiosity and creativity to design, prototype, discover and innovate, in pursuit of the product developments and ideas of tomorrow. He also vocally campaigns for STEM Education opportunities for students from low socio-economic backgrounds.

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How to use this book

Overview of the print book

These are short facts that contain interesting information.

Did you know?

These provide quick checks for recalling facts and understanding content.

Quick check

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

Explore!

Short activities encourage a hands-on approach to concepts that are currently being covered.

Try this

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



VIDEO

Videos are found in the Interactive Textbook.



WIDGET

Widgets are found in the Interactive Textbook.

Practical

Practical investigations consolidate student learning.

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.

Science as a human endeavour

Section questions

Review questions to check students' understanding and application of the section content.

78 Chapter 2 CLASSIFICATION

STEM activity: APPLYING BIOMIMICRY TO SOLVE A HUMAN PROBLEM 79

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 their sticky 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 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.

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

Suggested materials

- paper
- pens, pencils
- ruler

Evaluate and modify

Include the following in your engineering design report:

- Explain the human problem you produced a solution for.
- Identify your plant, animal or insect and its scientific name.
- Describe the unique features of your organism. Are there characteristics related to its classification?
- Describe how you copied the material, colour, and structure of the organism to design something new.
- Describe the process that helped you come up with the design.
- List the materials and their physical properties required to realise your design.
- Describe how each material was used and for what purpose.
- Create a scale drawing of your invention, including a front and side view of your invention.
- Describe your design by listing the special features of your design and which aspect of your organism inspired those features.
- Evaluate your design and the ability to solve the problem you identified. What improvements would you make?

Figure 2.68 Shovel suits were designed to mimic shark skin. They are made from a silicon ribbing fabric that reduces drag and oil-absorbing membranes.

Figure 2.69 A simple shell could be your inspiration for an eco-friendly sustainable house.

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

Overview of the Interactive Textbook (ITB)

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

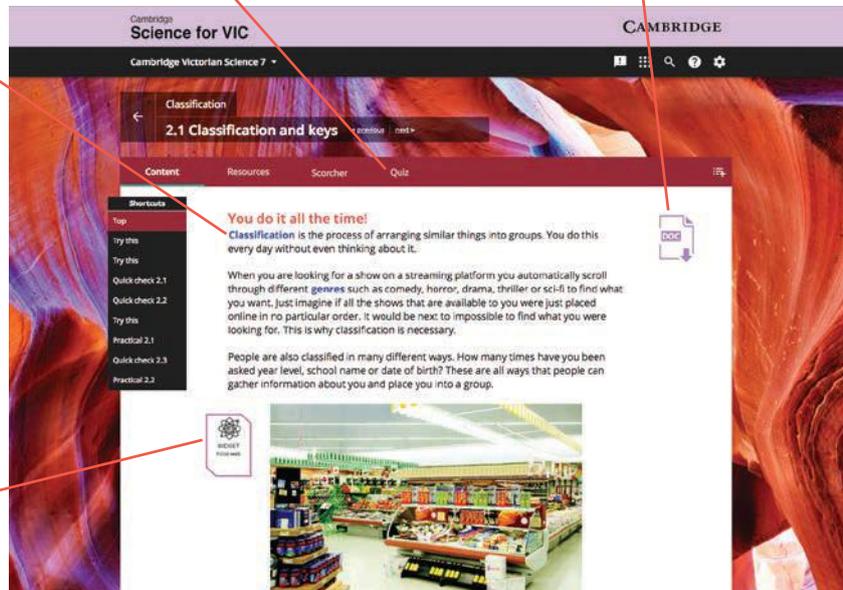
Definitions pop up for key terms in the text

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 observations



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

Practical 1.1: Self-design

Aim

You will work in groups, allocating each person with at least one role covered in this chapter. Your group will act as a team of consultant engineers, working towards finding a solution to a problem by using the engineering design loop.

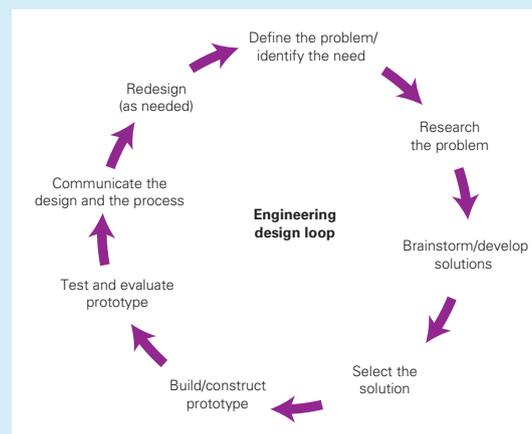
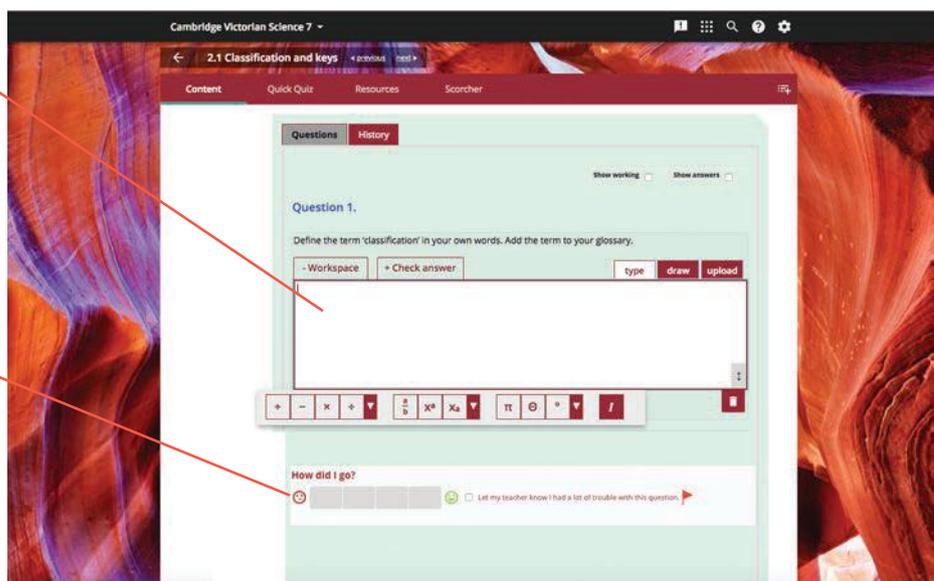


Figure 1.9 The engineering design loop

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.

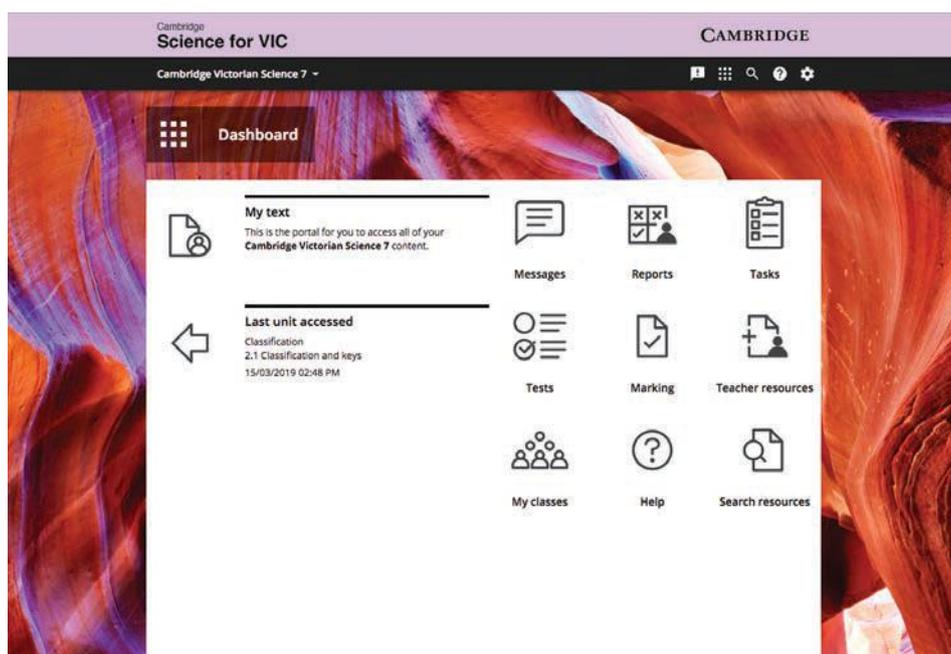
Self-assessment tools enable students to check answers, mark their own work, and rate their confidence level in their work. This helps develop responsibility for learning and communicates progress and performance to the teacher. Student accounts can be linked to the learning management system used by 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** and downloadable Word document **guides** to Practicals and STEM activities



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Chapter 1 Science skills

Chapter introduction

You may have heard of some scientists and studied aspects of science in primary school, although you might not have realised it. 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 a scientist does, 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.

Curriculum

Identify questions, problems and claims that can be investigated scientifically and make predictions based on scientific knowledge (VCSIS107)	1.1
Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (VCSIS108)	1.3
In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (VCSIS109)	1.2
Use scientific knowledge and findings from investigations to identify relationships, evaluate claims and draw conclusions (VCSIS111)	1.2
Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (VCSIS112)	1.2

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Glossary terms

analyse

concave

convex

data

experiment

hypothesis

infer

inference

knowledge

meniscus

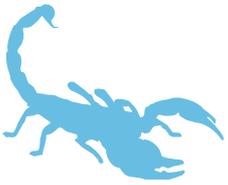
observe

predict

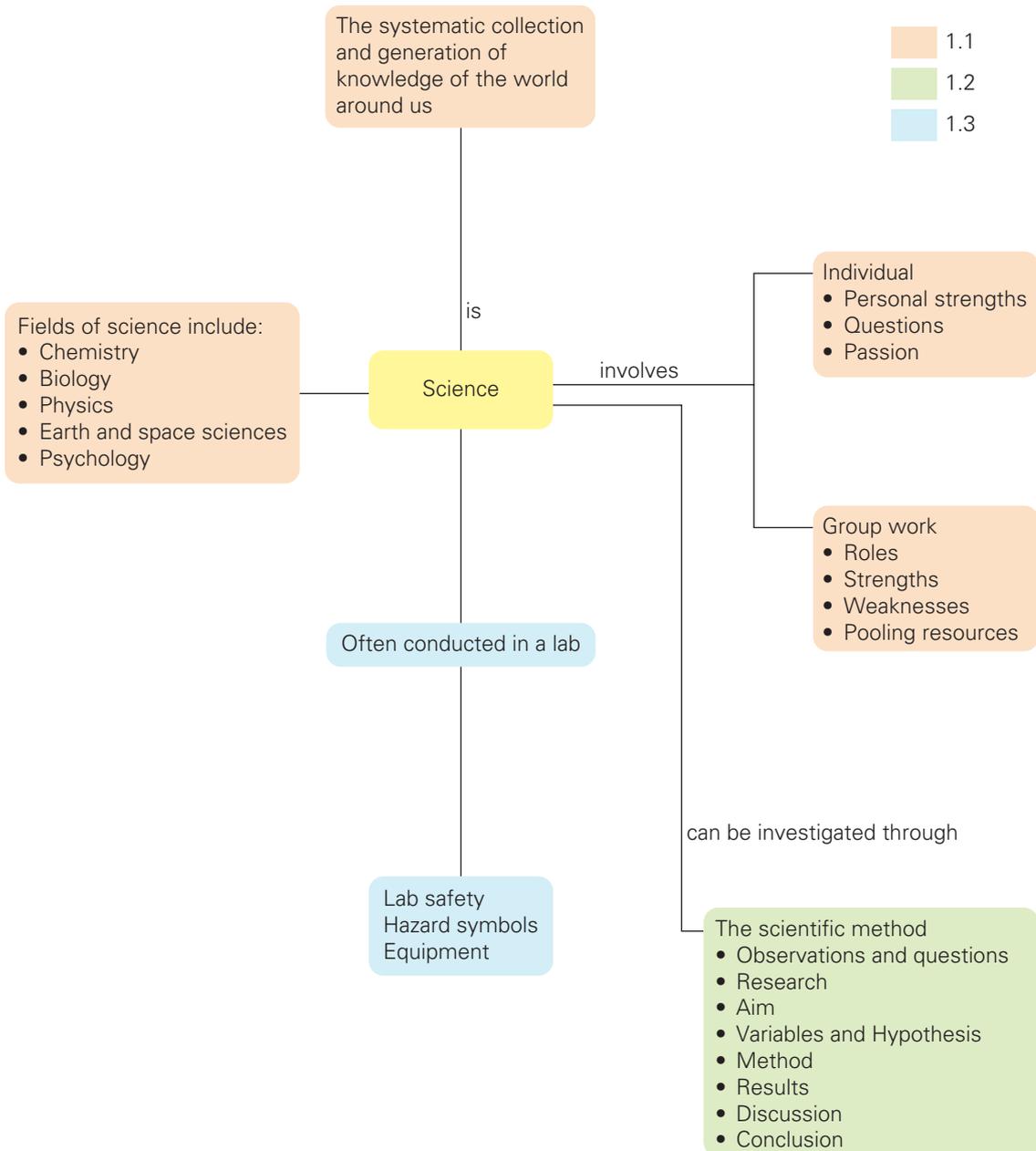
qualitative

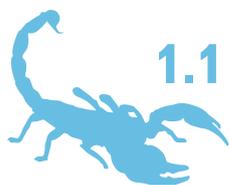
quantitative

variable



Concept map





1.1 What is science?

Science is **knowledge**, literally. The word for 'science' comes from the Latin word for 'knowledge', *scientia*. That is because science is the practice of systematically collecting and generating knowledge by studying the world around us.

knowledge
the understanding of
information

This process is used every day to answer questions about how things work, solve problems and create new amazing technologies.

In science, you are constantly asking questions about the universe, how things work, why they work that way and what happens if you 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 some 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 solve the problem of the moths. This is science in action!



WORKSHEET

Scientists often use **experiments** to collect data. **Data** is the term used to group together anything they observe 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.

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

Fields of science

Just as there are many types of questions, there are many fields of science. Science groups together different areas of science depending on what is being studied. 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 that studies biology is known as



Figure 1.1 Caterpillars eating a broccoli plant



Figure 1.2 Biologists taking samples from the ocean

a biologist. Within the field of biology, there are many smaller specialised fields such as zoology (study of animals), botany (study of plants) and ecology (study of ecosystems).

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 study of tiny particles, molecules and substances that make up the world around us. Sometimes these things are called chemicals hence the term *chemistry*.

A person who studies chemistry is known as a chemist. Branches of chemistry include organic chemistry (chemicals found in living things) and nuclear chemistry (study of radioactive chemicals).



Figure 1.3 A chemist in action

These are some questions a chemist might ask.

- Why is one metal stronger than another?
- What solvents are best for removing stains?
- What are the components of this liquid?

Physics is the study of forces and energy. 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), nuclear physics (study of atoms and elements) and astrophysics (study of space).



Figure 1.4 Physicists working on the Large Hadron Collider in Geneva

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



Figure 1.5 Geologists mapping an area

study rocks, stars, volcanos 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?

Careers in science

Although biology, chemistry, physics, and Earth and space sciences 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! In some Australian states, **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 some research to find five other scientific specialist areas or careers that have not been mentioned in this chapter.

Explore! 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 test variables.
- 4 Suggest the field of science that would study:
 - a an endangered animal
 - b minerals found in rocks
 - c the composition of a new drug.

Quick check 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 the case of the slender rat.

One of the most exciting parts about being a scientist is making a new discovery. This is exactly what happened when scientists from Australia, Indonesia and USA worked together to identify a new species of rat on the Indonesian island of Sulawesi.

The molecular biologist Dr Kevin Rowe from Museum Victoria, along with the international team, have discovered four new species of rodent on the island since 2011. These species are extremely varied; some are specialised for swimming and others for only life on land. Dr Rowe has **predicted** that there are many more new rodents to be discovered on the island.

inference

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

predict

to make an estimate about a possible future event or outcome

Science as a human endeavour 1.1



Figure 1.6 Inside Museum Victoria

continued...

...continued

As a molecular biologist, Kevin spends time in the laboratory working with chemicals and machines

analyse

to interpret data gathered during an experiment in order to detect trends and patterns, and draw conclusions

to **analyse** the genetic components of different animals. He also spends lots of time out in the field

exploring rain forests to discover new species of animals. The life of a scientist can be extremely varied and exciting.

Figure 1.7 An artist's impression of the slender root rat, *Gracilimus radix*



- 1 Describe what you think of when you think of a scientist at work.
- 2 Explain how varied the job of a scientist could be.
- 3 Outline what fields of science might be involved with the discovery of a new species.
- 4 Suggest why scientists from different countries need to work together.

Quick check 1.2

What 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 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.

A good group has:

- a clear understanding of everybody's roles
- each member having shared responsibilities, equitable participation

- 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 1.8 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 important 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.

- 1 List some qualities about yourself that contribute to group work.
- 2 Identify which categories of roles you fall into.
- 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 role you have stated in question 3.

Quick check 1.3



Figure 1.8 Roles in groups

Practical 1.1: Self-design

Aim

You will work in groups, allocating each person with at least one role covered in this chapter. Your group will act as a team of consultant engineers, working towards finding a solution to a problem by using the engineering design loop.

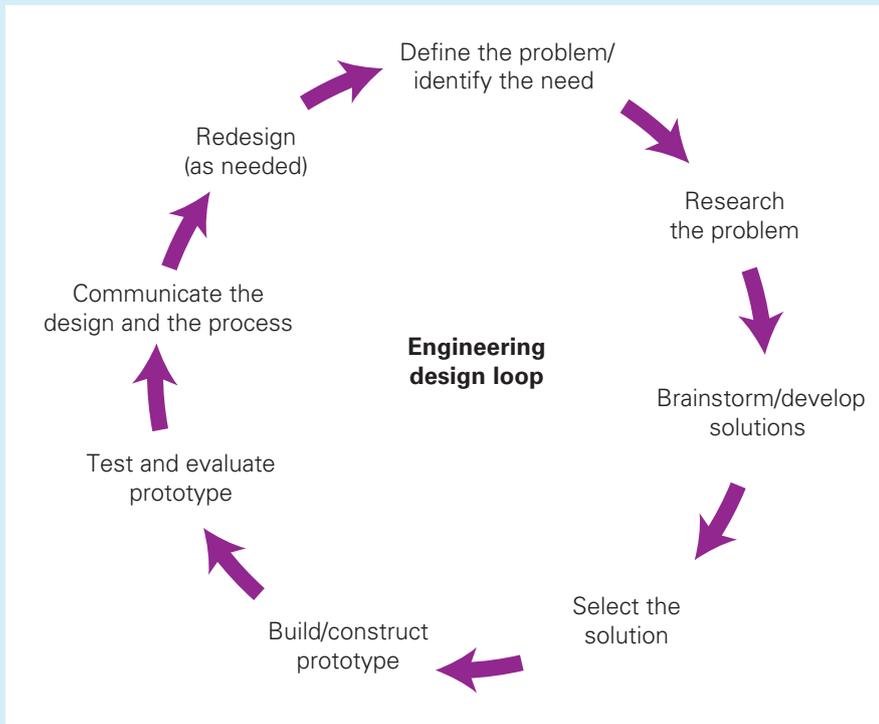


Figure 1.9 The engineering design loop

When brainstorming, remember these rules.

- Focus on quantity – come up with as many ideas as you can.
- Encourage wild ideas – don't put down or criticise ideas that are wild as they may lead to innovative designs.
- Record all ideas – have a scribe who can write everything down.
- Combine and build ideas – discuss and elaborate on the ideas of other students.
- Focus – don't get off topic!

Design a hand-washing station

Problem

People in developing nations have a limited amount of clean water they can use each day. Often, they must travel long distances to collect the water they need. Clean water needs to be used for drinking, cooking, cleaning and hygiene.

In your group and using only the materials provided, design a hand-washing station that can be used hands-free and only uses a small amount of water each time.

Criteria (limitations)

- Must be hands-free
- Must use a minimum amount of water
- Must be completed in the time your teacher decides (2–3 lessons recommended)
- Can only use the materials provided

continued...

...continued

Materials

- 4 × 50 cm bamboo sticks
- 2 × small cubes of modelling clay (1 to use as soap, 2 to use as building equipment)
- 5 m string
- plastic bottle with lid
- an A4-sized piece of cardboard
- scissors

Method

- 1 Allocate a role to each person in the group as discussed in the chapter.
- 2 Follow the engineering loop, starting with researching possible solutions to your problem.
- 3 Brainstorm all possible solutions to the problem, including drawings of your design.
- 4 Create and test a prototype.
- 5 Improve your prototype.
- 6 Use the discussion questions below to help you talk about the process you followed.

Evaluation

- 1 Explain how you came up with your design.
- 2 Identify any other pieces of equipment you would ask for if you could do it all again or had to improve your design.
- 3 Outline the hardest part of the process for you.
- 4 Identify the role you played in your group.
- 5 Discuss how you will approach the research and design process next time you conduct a similar task.

Section 1.1 questions

Remembering

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

Understanding

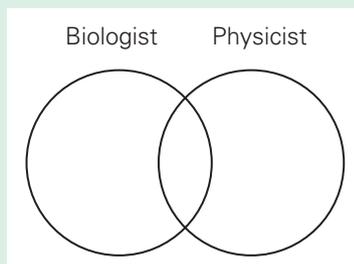
- 4 Explain how science has affected your day so far.

Applying

- 5 Propose the field of science that would study asteroids.

Analysing

- 6 Compare, using a Venn diagram, the work of a biologist to that of a physicist.



Evaluating

- 7 Some fields of science can overlap. Suggest what fields of science a biochemical engineer might study.



QUIZ



1.2 What do scientists do?



WORKSHEET

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.

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 notice something significant

For example, the government might collect some health data about the population and task a scientific organisation with finding a solution to the problem.

An epidemiologist (a person who tracks diseases) might come up with a **hypothesis** about the cause of the problem. A public health advisor might design a program to test the hypothesis, and a team of health professionals, such as doctors and exercise physiologists, might

conduct the experiment; for example, an exercise program. Biomedical research scientists might **observe** the experiment, collect the data and analyse it, while a pathologist might collect blood samples from the patients and test these. In the end, a nominated person would gather all the findings and publish the results in a scientific journal. Science is a 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 and allows other people to understand your findings and replicate (repeat) the experiment.

The scientific method may differ slightly from one area of science to another, but often it involves coming up with a hypothesis and testing it. Here is a basic outline of how the scientific method works.

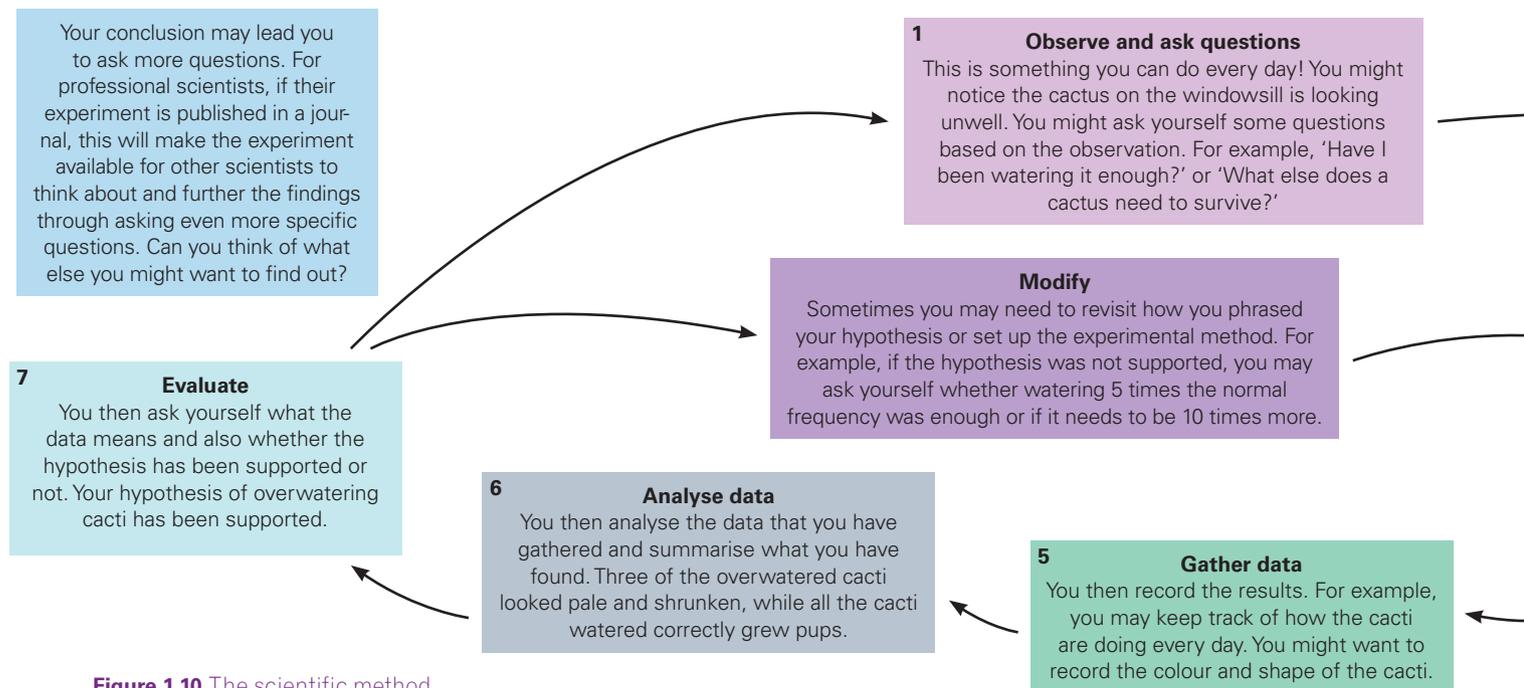


Figure 1.10 The scientific method

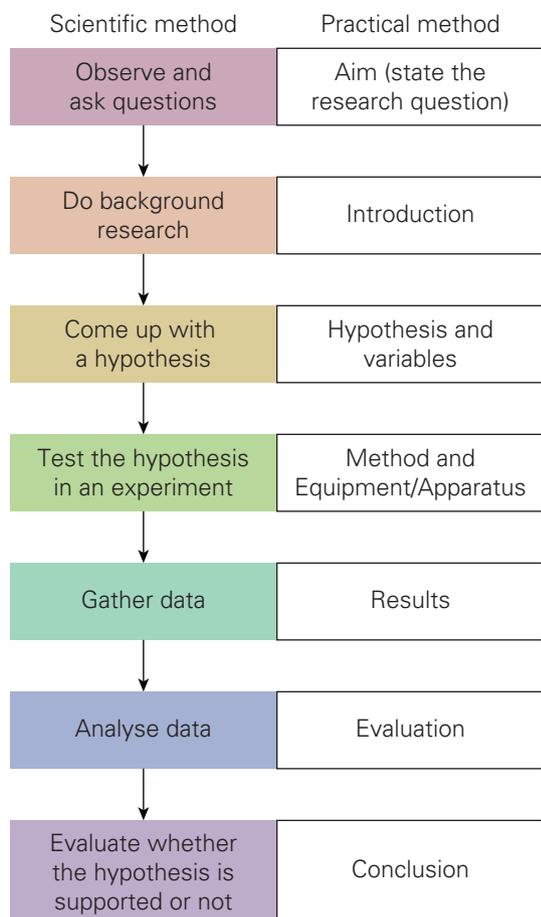


Figure 1.11 The scientific method matched to sections of a lab report

Observe and ask questions

The first step in the process is often based on an observation. Scientists continuously 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.

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.

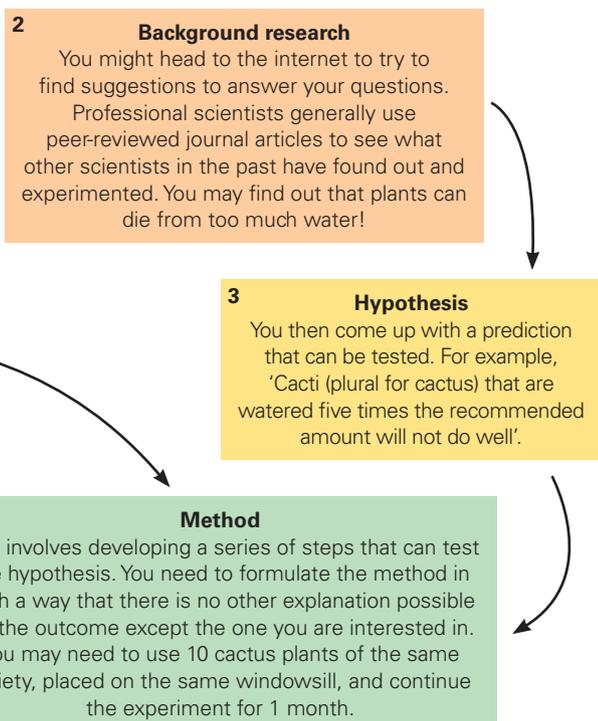
What is an inference?

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 the observation. Inferences are based on your past experiences and knowledge you have gathered throughout your life.

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.
- There is an adult standing at the front of the classroom; it must be the teacher.

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



Practical 1.2

Observing pasta

Aim

To develop observations and inferences based on a simple task.

Materials

- pasta
- beaker
- hot plate
- sieve
- water

Method

- 1 Observe the pasta before heating and record at least three observations in the results table.
- 2 Bring 200 mL of water to boiling point in a beaker on a hot plate.
- 3 Add a small amount of pasta.
- 4 Boil for 10 minutes.
- 5 Turn off the hot plate and use beaker gloves to pour the water and pasta into a sieve over a sink.
- 6 Observe the pasta after heating and record at least three observations in the results table.
- 7 Now you have your observations make inferences to explain each observation based on your prior knowledge or experiences.

Results

	Before	After
Observations	1	
	2	
	3	
Inferences about observations	1	
	2	
	3	

Be careful

Ensure appropriate signage is displayed during and after hotplate usage.

Conducting a fair experiment

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 the 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**.

variable

a component of an experiment that changes or can be changed

For example, a boy wants to see if a towel will take the same amount of time to dry after a shower if it is laid out on the ground or it is hung up on a rack.

In this example, the boy is:

- changing the place where the towel is left
- measuring the time it takes for the towel to dry.

To prove 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.

Collecting data: Types of data

qualitative

a form of data that is a descriptive measurement

quantitative

a form of data that is a specific numerical measurement

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

- 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.

Quick check 1.4

- 1 State the type of observation that is gathered using tools.
- 2 State the type of observation that is written in numbers.
- 3 Outline possible strengths of using qualitative data.
- 4 Suggest a reason that might be useful for repeated observations.

Quick check 1.5

Data type	Qualitative	Quantitative
Definition	Qualitative observations are descriptive and usually come from our senses.	Quantitative observations involve precise numbers and involve 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 Arnav and Noah 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 is 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.

Table 1.1 Comparing qualitative and quantitative observations

Practical 1.3

Quantitative versus qualitative

Aim

To collect quantitative and qualitative data regarding the temperature of water.

Materials

- 3 × 250 mL beakers
 - beaker A with ice water
 - beaker B with warm water
 - beaker C with tap water
- thermometer

continued...

...continued

Method

- 1 Place each type of water into each beaker.
- 2 Use your senses to make observations about the water.
- 3 Add descriptive words to the table below in the 'Qualitative observation Group 1' column.
- 4 Measure the temperature of each beaker with the thermometer.
- 5 Record the temperature in the table below in the 'Quantitative observation Group 1' column.

Results

Beaker	Qualitative observation		Quantitative observation (°C)	
	Group 1	Group 2	Group 1	Group 2
A				
B				
C				

Evaluation

- 1 Pair up with another group and compare your quantitative and qualitative observations by completing the 'Group 2' column of the results table.
- 2 Identify one similarity and one difference in your observations.
- 3 Suggest a reason why a scientist would use qualitative measurements.
- 4 Suggest a reason why quantitative measurements are more accurate.

Collecting data: Measuring tools

When scientists use tools to make observations, it is called 'taking measurements'. It is important to collect accurate data in a scientific experiment because collecting specific numerical measurements increases this accuracy.

There are many tools that you can use to measure certain features, depending on the size that you want to focus on.

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.

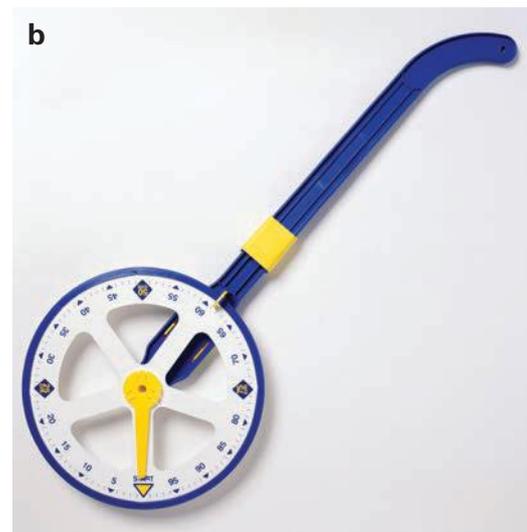


Figure 1.12 (a) A measuring tape and **(b)** a trundle wheel. Generally, to measure the length of an object, you use the units millimetre (mm), centimetre (cm), metre (m) or kilometre (km).

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.

Volume

Volume of a liquid is measured using different-sized measuring cylinders. Volume is measured in millilitres (mL) and litres (L).



Figure 1.13 A measuring cylinder

Temperature

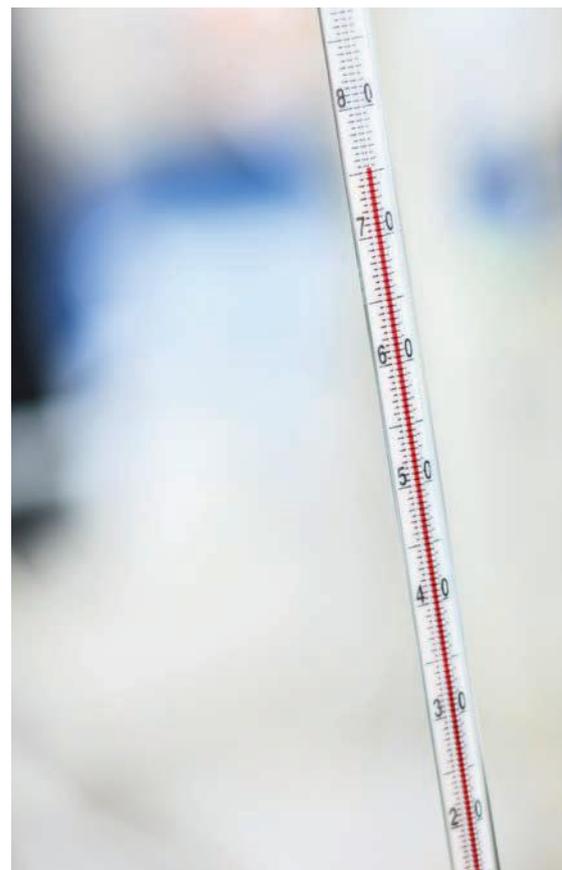
Digital thermometers, liquid in glass thermometers and data logger probes are used to measure the temperature of different objects. The unit of degrees Celsius ($^{\circ}\text{C}$) is used to measure temperature. Thermometers generally have a maximum

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.



Figure 1.14 A data logger probe

Figure 1.15 The liquid in 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. What are the differences? When did Australia start using Celsius?



Time

Stopwatches are an accurate way of gathering data about time. The units of seconds (s) and milliseconds (ms) are used most in science; however, minutes, hours and days could also be recorded for long-term experiments.

Weight

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

Practical 1.4

Reading equipment

Aim

To practice 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

Method

Station 1

- 1 Place the mass onto each spring balance and measure the weight of the mass in grams.
- 2 Record your results in the table below.

Station 2

- 1 Measure the weight 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 weight.

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 your results in the table below.

continued...

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Station 4

- 1 Attempt to stop the stopwatch at exactly 2 seconds.
- 2 Record the results from each attempt.

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 your result in millimetres.

Results

Station	Person 1 reading	Person 2 reading	Person 3 reading	Average
1 (g)				
2 (g)				
3 (°C)				
4 (s)				
5 (mm)				

Evaluation

- 1 Station 1: Suggest 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 times when measuring temperature.
- 4 Station 4: Explain why doing multiple trials and averaging the results is important to improve accuracy.
- 5 Station 5: Discuss why millimetre units were used rather than metres when measuring the piece of paper.

Minimising error

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 precise 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.

meniscus
the surface of a liquid in a container

concave
a surface that curves inwards

convex
a surface that curves outwards

Concave and convex meniscus

The reason that a concave meniscus forms is because the water is more attracted to the container than it is to its own molecules. A convex meniscus is formed when the

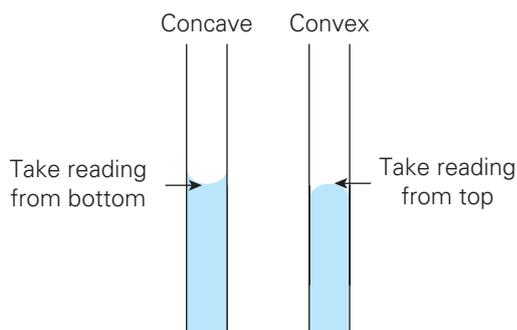


Figure 1.16 Reading a meniscus

molecules are more attracted to themselves than the container they are in.

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 of the data you are gathering.

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 you try to take the reading from above or below the measuring cylinder. 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.

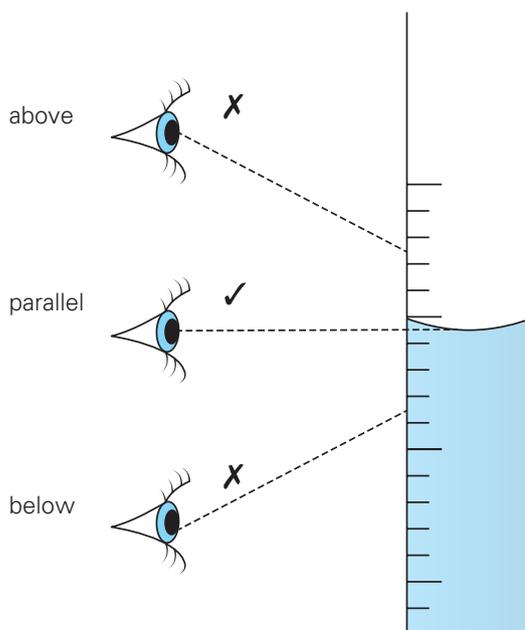


Figure 1.17 Example of parallax error

- 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 Outline how you would minimise parallax error.

Quick check 1.6



QUIZ

Section 1.2 questions

Remembering

- 1 How is an observation 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 The number of times a gorilla ate in a 24-hour period was recorded.

Applying

- 4 Look around you. Record one observation and make one inference from this observation.

continued...

...continued

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.
- Identify the error in the scientist's method.
 - What effect does this have on the findings?

Evaluating

- 6 For the pot plant experiment detailed in question 5, what could the scientist have done differently to ensure the experiment was 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?

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, 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 1.19 on page 22, 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 the following page.)



Figure 1.18 This scientist was protected by his personal protective equipment when the tomato exploded!



Figure 1.19 Good lab safety is essential.

Spot the difference answers: did you find all the lab safety issues?

- Always wear safety glasses over your eyes (not on your head) when you are handling chemicals or glassware. Chemicals can be corrosive to your eyes or broken glass could potentially cut you.
- 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 the 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.
Bacteria 	Biological material, such as organs for dissection, bacteria cultures, microbes or plants, are studied in the lab.	Any living or dead specimen could contain micro-organisms 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

Symbol	Name	Meaning	Examples
	Corrosive	This chemical attacks and destroys living tissue, such as eyes and skin!	Sodium hydroxide Sulfuric acid
	Irritant	This can cause red itchy skin or minor blisters.	Many dilute acids and alkalis
	Flammable	This chemical will catch fire easily.	Ethanol Propanone
	Harmful to the environment	The chemical will cause damage to all living things if it enters the waterways.	Copper sulfate
	Explosive	This chemical will explode if it is near a naked flame like a Bunsen burner.	Potassium Lithium
	Oxidising	These chemicals produce oxygen, which causes other substances to burn more.	Potassium manganate
	Toxic	This substance will cause severe illness or death if it enters the body.	Cyanide Mercury Lead
	Biohazard	This symbol indicates a dangerous substance produced from a living sample.	Dissections Bacterial growths

Table 1.3 Chemical hazard symbols

- Quick check 1.7**
- 1 State the first thing you should do if you see a hazard in the Science lab.
 - 2 State when you should wear a lab coat.
 - 3 Recall the name of the name of safety equipment that will protect your eyes.
 - 4 How does your school label 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. Below are several pieces of equipment used to hold and work with liquids, and their purpose.

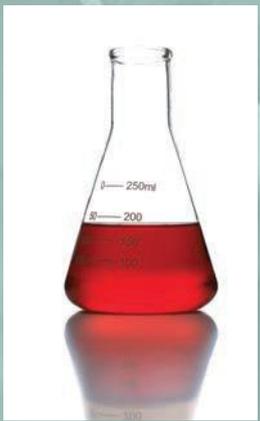
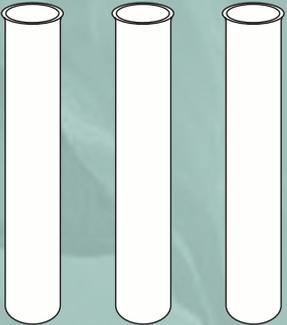
What it is used for	How it looks	How it is drawn
A beaker is a common piece of equipment found in most labs. It comes in many sizes and is generally used for holding, stirring and heating liquids.		
A conical flask is similar to a beaker but the shape of its neck is different to reduce the likelihood of liquid spilling. It can be used to swirl liquids and prevent hot liquids from boiling over.		
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.		

Table 1.4 Some common lab equipment

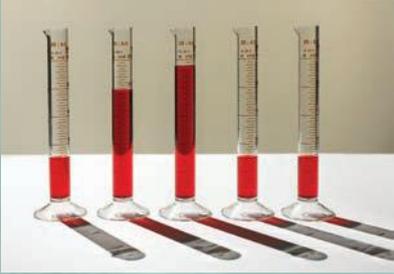
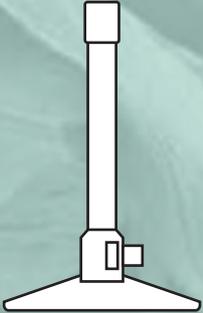
What it is used for	How it looks	How it is drawn
<p>A measuring cylinder is used to accurately measure specific volumes of liquids. It must not be used to mix or heat liquids.</p>		
<p>A Bunsen burner is a common device used to add a controlled amount of heat to an object.</p>		
<p>A tripod is used to hold an object above a Bunsen burner flame while it is being heated.</p>		
<p>A retort stand and bosshead clamp are used to hold objects in place while testing.</p>		

Table 1.4 (Continued)

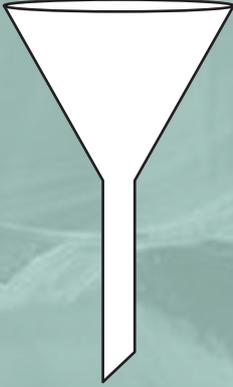
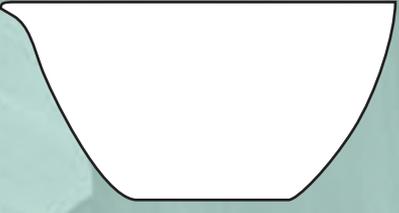
What it is used for	How it looks	How it is drawn
A funnel can be used to separate mixtures or make it easier to transfer liquids from one container to another.		
An evaporating dish is used to heat up and evaporate small amounts of liquid.		

Table 1.4 (Continued)

You may have noticed that next to each image of the equipment above, 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 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. 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 1.20.

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.

The Bunsen burner

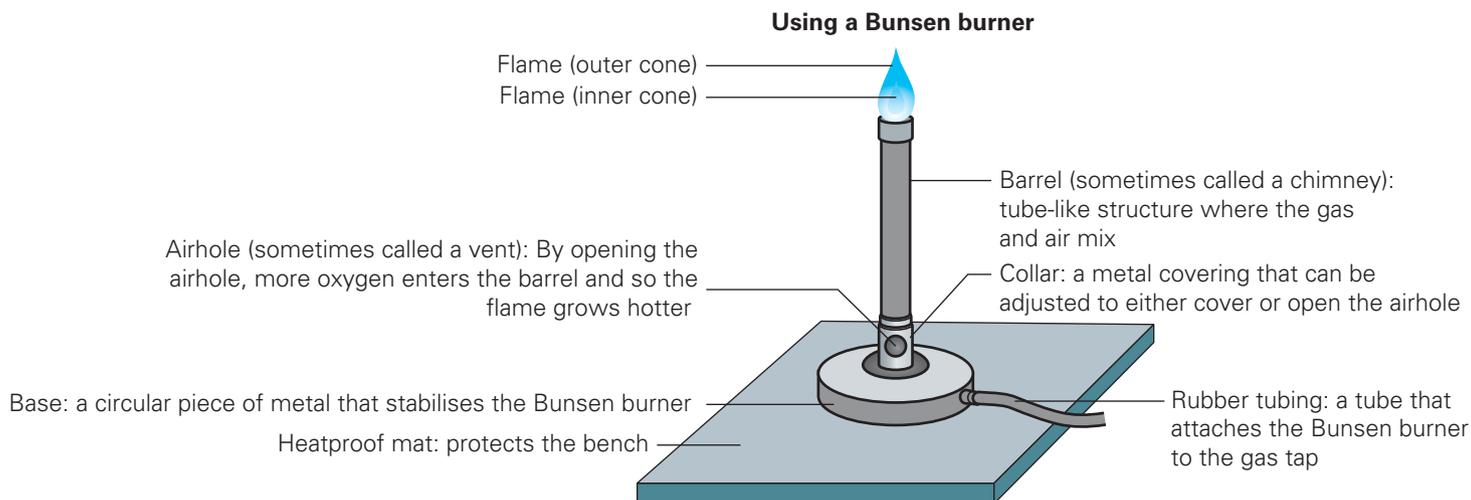


Figure 1.20 A Bunsen burner

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.

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 because the airhole is closed and so the gas inside the barrel does not mix with much oxygen. 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 1.21 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 1.5

Using a Bunsen burner

Aim

To practise the safe procedure for lighting a Bunsen burner.

Materials

- Bunsen burner
- matches
- heatproof mat

Method

- 1 Attach the Bunsen burner rubber tubing to a gas tap.
- 2 Ensure the Bunsen burner hole is closed to give a safety flame.
- 3 Strike a match away from your body.

Be careful

Ensure general fire safety is observed.

continued...

...continued

- 4 Turn on the gas.
- 5 Bring the match up towards the tip of the barrel mouth.
- 6 Shake out the match and place on the heatproof mat.
- 7 Twist the collar to open the airhole and produce a blue flame.
- 8 Twist the collar to close the airhole and produce a safety flame.
- 9 Turn off the gas.

Evaluation

- 1 Suggest why the airhole is closed before turning off the Bunsen burner.
- 2 Propose why the match is struck away from the body.
- 3 Explain why a blue flame must be used to heat an object.

Practical 1.6

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
- wooden tongs

Method

The diagrams in Figure 1.22 show how to set up your equipment for each test.

Be careful

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

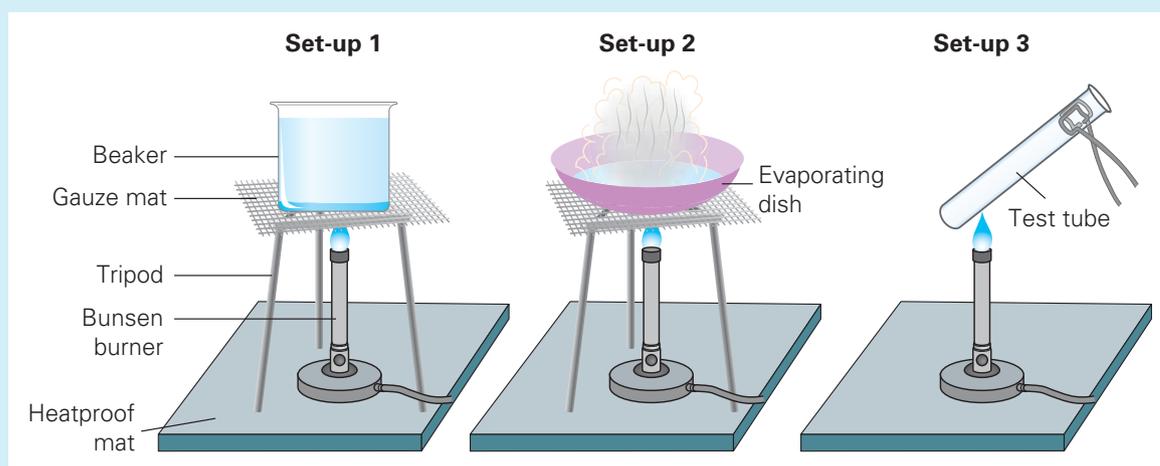


Figure 1.22 Experimental set-ups

continued...

...continued

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 Repeat steps **1–3**, replacing the beaker with an evaporating dish.

Set-up 3

- 5 Add 50 mL of water to a large test tube.
- 6 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.
- 7 Record your results in the table below.

Results

Container	Maximum volume of equipment	Risks when heating	Time taken to reach boiling point	How is the heat from the flame spread?
Beaker				
Evaporating dish				
Test tube				

Evaluation

List the advantages and disadvantages of using each vessel for heating liquids.



QUIZ

Section 1.3 questions

Remembering

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

Understanding

- 2 Explain 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 when you would use a conical flask and a beaker.

Evaluating

- 5 Billy wanted to test the absorbance of different paper towels. Design a risk assessment and equipment list for a possible experiment he could conduct.

Review questions

Remembering

- 1 Recall the units used to measure volume.
- 2 State two pieces of equipment used to measure length.
- 3 Recall three science safety rules.
- 4 List four different fields of study in science.

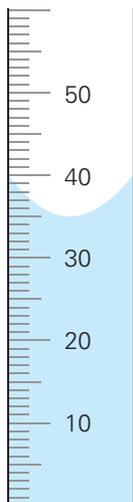


Understanding

- 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 Identify the amount of liquid in the container shown below and explain your answer, with reference to the meniscus. The gradations are in mL.



- 9 Suggest a reason why mercury forms a convex meniscus in a test tube.

Analysing

- 10 Anisha set out to test paper-plane wing size and the distance the plane travels.
 - a Describe the variable she is changing (testing) and how it might be measured.
 - b She notices that planes with larger wing sizes appear to float higher, and yells out to her brother Chris, 'They must capture more wind!'. Is this an observation, an inference or both?
 - c Anisha records distance flown in metres, using a tape measure. Is this qualitative or quantitative data?
 - d Chris remarks that the testing is not fair as they took it in turns to fly the planes and he is a better thrower. How could they improve this experiment to make it fairer?
- 11 Suggest a reason the airhole of a Bunsen burner is closed when it is not in use.

Evaluating

- 12 Construct a flow chart showing the stages of the scientific method. Rename each step using your own words.

Chapter 2 Classification

Chapter introduction

Whether you are answering questions about what food you would like to eat, what music you like or what movie 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.

Curriculum

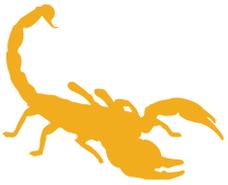
There are differences within and between groups of organisms; classification helps organise this diversity (VCSSU091)

- | | |
|--|----------|
| • grouping a variety of organisms on the basis of similarities and differences in particular features | 2.1 |
| • classifying using hierarchical systems, for example, kingdom, phylum, class, order, family, genus, species | 2.3, 2.4 |
| • using scientific conventions for naming species | 2.2 |
| • using provided keys to identify organisms surveyed in a local habitat | 2.1 |

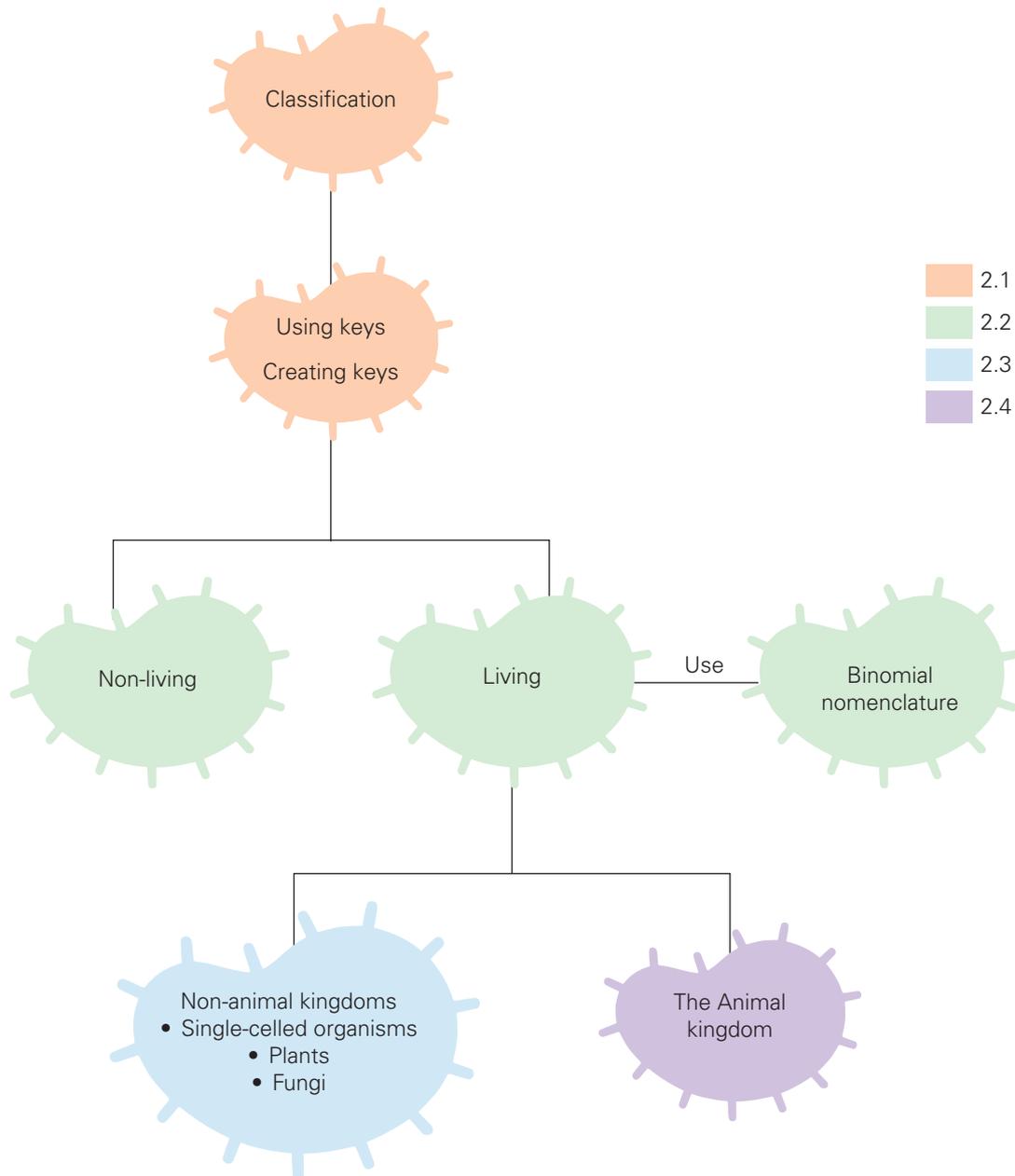
Victorian Curriculum F-10 © VCAA (2016)

Glossary terms

anther	genre	qualitative
bilateral symmetry	genus	quantitative
binomial nomenclature	invertebrates	radial symmetry
botanist	key	sepal
carpel	kingdom	sessile
characteristic	metamorphosis	species
class	microbiologist	stamen
classification	non-vascular	stigma
dichotomous key	order	style
DNA	organism	taxonomy
domain	ovary	unicellular
ectothermic	ovule	vascular
endothermic	parasite	vertebrate
family	phylum	



Concept map





2.1 Classification and keys

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.

classification
the grouping of similar objects or organisms together

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

When you are looking for a show on a streaming platform you automatically scroll through different **genres** such as comedy, horror, drama, thriller 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.



Figure 2.1 Supermarkets are another example of where classification is really important – otherwise, how would you be able to run in and out in 5 minutes with your microwave popcorn for movie night?

Give one, get one – Try this 2.1 Classification

Procedure

- 1 Copy down the grid below into your notebook.
- 2 Write one example of something that you classify in the top-right box.
- 3 Get up and 'give' your idea to another student and 'get' one idea from them.
- 4 Continue to do this one on one exchange with different people in your class until you have all your boxes filled.
- 5 Once you have filled out your grid, return to your chair and share the ideas you have gathered with the class.

Things you classify in everyday life



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 wouldn't 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
something possesses

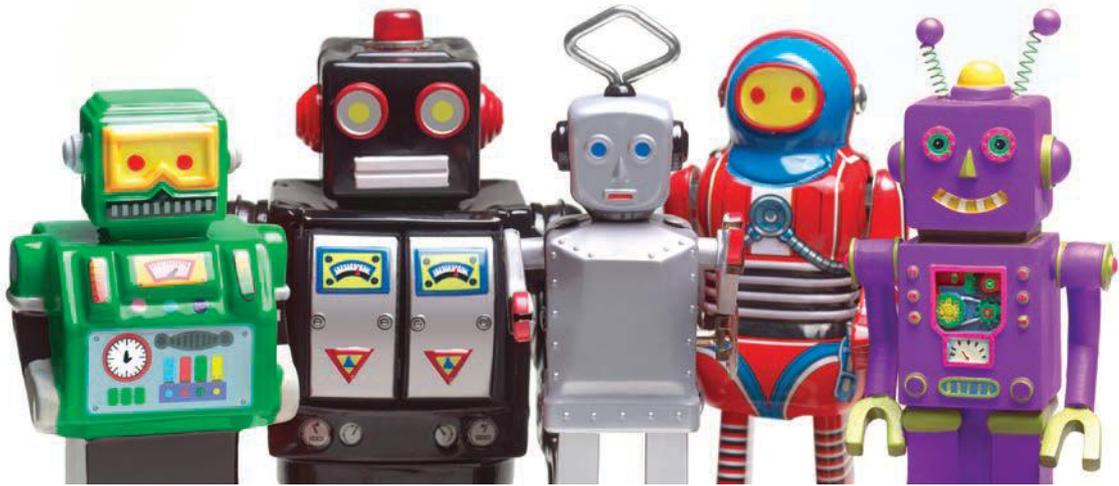


Figure 2.2 Even robots can be classified based on their observable characteristics.

Let's practise observing the different characteristics or features of the following objects and living things. Make a list of what you see and compare with your classmates. Have you observed the same features?

Try this 2.2



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 and since it fits in with neither, it has been classified in a unique group of its own.

Did you know? 2.1

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

- 1 Define the term 'classification' in your own words. Add the term to your glossary.
- 2 Name three examples of classification systems that you named in *Try this 2.2* on page 36 and explain how they demonstrate classification.
- 3 What are the three key steps involved in classifying something?
- 4 Explain why it is important that scientists all use the same language of classification.

Quick check 2.1**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. In Figure 2.5 on the next page, there are six different types of made-up creatures that have theoretically been found under the ice of Europa, one of Jupiter's moons. You can use the key to determine their names.

key
a tool used to identify organisms

Pluto used to be considered a planet.

Explore! 2.1

Investigate why Pluto was reclassified as a dwarf planet. State the criteria that disqualified Pluto from being a planet.



Figure 2.4 Dwarf planet Pluto

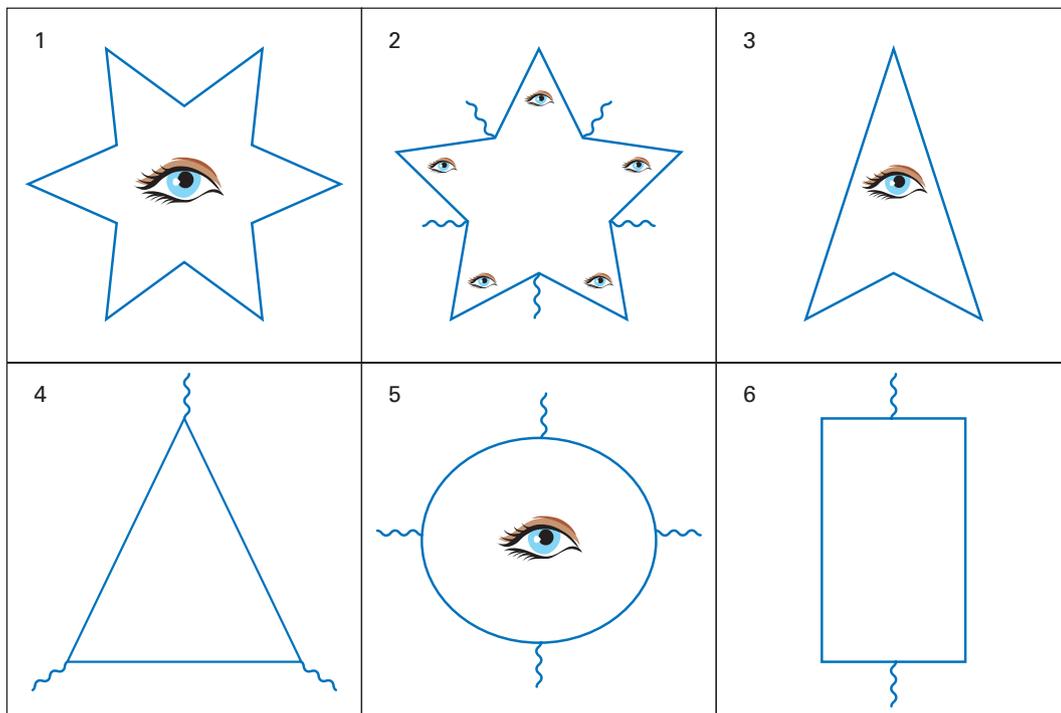


Figure 2.5 Imaginary European creatures being studied. Use the key in Figure 2.6 to identify them.

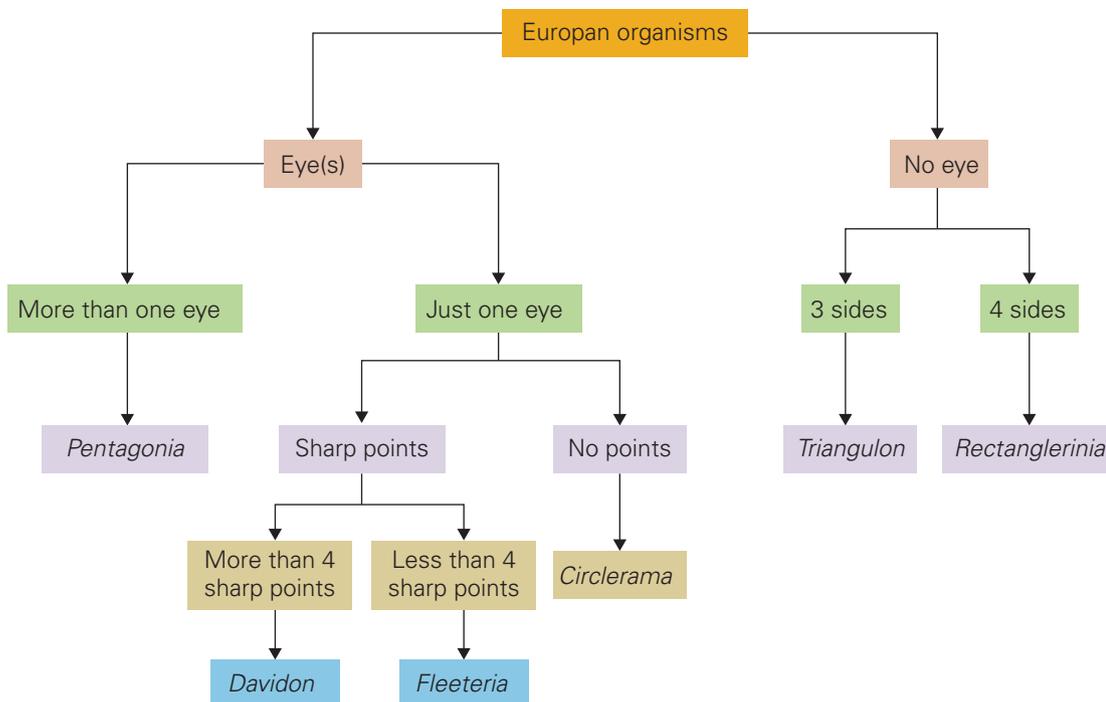


Figure 2.6 A branching dichotomous key for classifying the European organisms in Figure 2.5

Using keys

Imagine you are a scientist wanting to focus your research on the creature called the *Davidon*. You have a sample of creature 1 as shown in Figure 2.5 but are not sure if it is the *Davidon*. To determine if you have the correct creature, you must use the key in Figure 2.6.

Can you work out if the name of creature 1 is *Davidon*? Start at the top and at each step in the process, make a yes/no decision.

The key that you just used is known as a **dichotomous key**. This is a simple key

dichotomous key
a tool that allows a scientist to identify an organism from a series of two option choices

to use and create as at each stage it gives you just two options based on the objects you are looking at and allows you to narrow down the possible choices. The word dichotomous literally means 'to cut in two'. 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. Check you get the same answer using this key in table 2.1 as using the branching key.

1a	eye(s)	Go to Question 2
1b	no eyes	Go to Question 5
2a	more than one eye	<i>Pentagonia</i>
2b	just one eye	Go to Question 3
3a	sharp points	Go to Question 4
3b	no points	<i>Circlerama</i>
4a	more than 4 sharp points	<i>Davidon</i>
4a	less than 4 sharp points	<i>Fleeteria</i>
5a	3 sides	<i>Triangulon</i>
5b	4 sides	<i>Rectanglerinia</i> in Figure 2.6

Table 2.1 Dichotomous key drawn as a table to identify European creatures

- 1 Explain the purpose of a key.
- 2 Define the term 'dichotomous key' and describe how it works in your own words. Add the term to your glossary.
- 3 Using the dichotomous key of European creatures in Table 2.1 and Figure 2.6:
 - a list the characteristics of the *Circlerama*
 - b identify creatures 1 to 6 in Figure 2.5.

Quick check 2.2



WIDGET
Classifying
Australian
animals

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.

Try this 2.3

Practical 2.1

Creating a dichotomous key for leaves in your local area

Aim

To construct a dichotomous key using leaf samples from a variety of plants found around the school.

Materials

- at least 6 different leaves
- hand lens
- plant/leaf identification guide

Method

- 1 Collect at least six different types of leaves from a walk around your school grounds, recording the name of the plant they come from.
- 2 Observe the different leaves you have gathered and decide what characteristics you will use to classify the leaves – size, shape, colour, texture, veins etc.

continued...

...continued

- 3 Use the main difference between all the types of leaves to separate them into two groups.
- 4 Continue to do this until there are only individual leaves left (i.e. no groups of more than one leaf).
- 5 Use the differences you have identified to construct a dichotomous key for the plants.
- 6 Pass the key to a classmate and get them to use it on your plants to make sure it is easy to follow.
- 7 After you have tested the key, make any alterations that you need to for it to work.

Results

Present your dichotomous key in table form.

Evaluation

- 1 Outline the main difficulties you faced when deciding on the differences between the leaves.
- 2 Discuss the reason for any changes you made after testing the key with a classmate.
- 3 Compare your key with other students' classification keys. Identify the different terms used to classify the leaves in other groups.

Conclusion

From this activity we can claim that leaves _____. This is supported through observations that _____. This means that _____.

Creating a key

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

Will the characteristics change over time?

Sometimes characteristics, like colour, size and behaviour, are not so useful for making a key as they can change over the lifetime, or even a year. 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 on the ground, while in summer it completely changes colour to brown!

Are the characteristics specific?

You might have noticed that the European creatures key focused on specific observable characteristics of each creature at each stage of the key. This is very important to remember when constructing a key as otherwise scientists will get muddled 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

Figure 2.7 This is an image of a stoat with its winter coat and summer coat. It could be two different animals!



VIDEO

How quickly do these animals change appearances?



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.

qualitative

a form of data that is a descriptive measurement

quantitative

a form of data that is a specific numerical measurement

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 it is a yes/no question and the answer is clear. The term **quantitative** is used when a characteristic is measured or described using numbers.

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?

Top-bottom: zebra, tiger and okapi.

- 1 Summarise the key points to remember when creating a key.
- 2 Define the terms 'qualitative' and 'quantitative' in your own words. Add these terms to your glossary.
- 3 When making a key, do the characteristics need to be qualitative or quantitative? Explain.
- 4 In the table below, turn the following qualitative descriptions into quantitative descriptions.

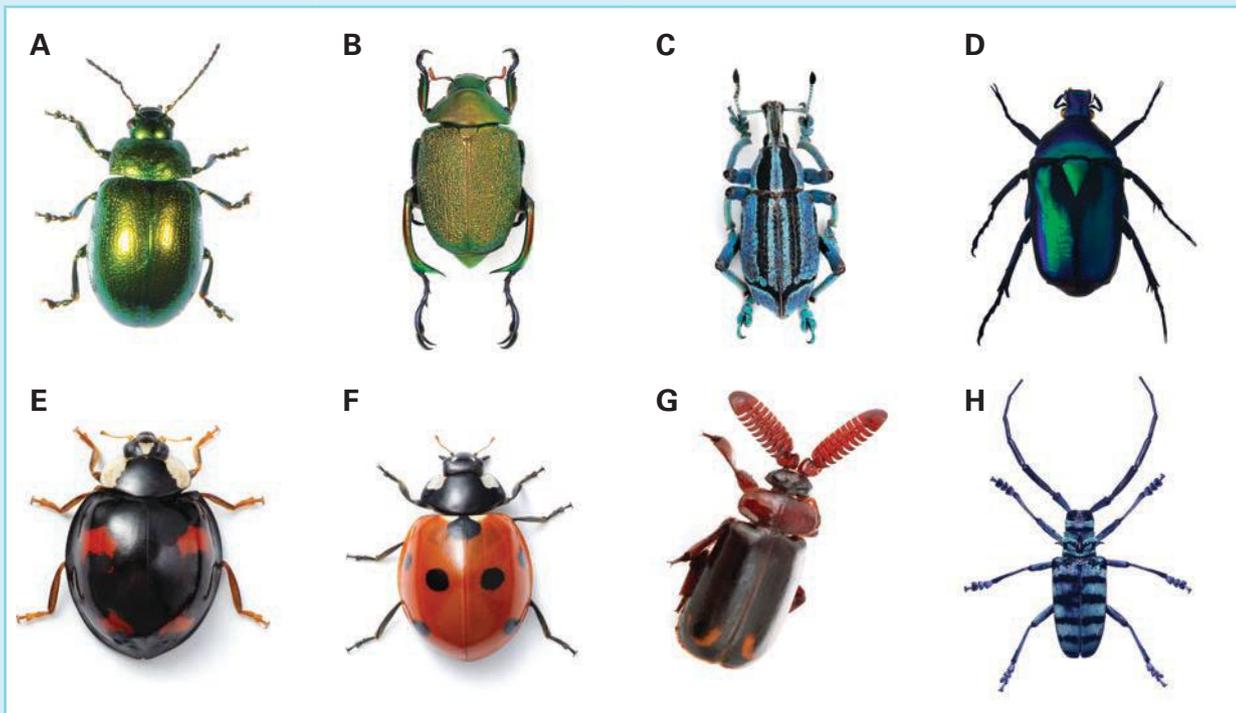
Quick check 2.3

Characteristic	Qualitative	Quantitative
Height	Tall	
Antennae	Heaps	
Fur length	Short	
Wing size	Big	

Practical 2.2

Creating a key for some insects

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



Aim

To construct a dichotomous key for the different insects in the images above.

Materials

Images of beetles above. (This practical could also be done on insects gathered from around the school.)

Method

- 1 Observe the different insects and describe their main differences.
- 2 Use the main difference between the insects to separate them into two groups.
- 3 Continue to do this until there are only individual insects, i.e. no groups of two or more.
- 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.
- 6 After you have tested the key, make any alterations that you need to in order for it to work.

Results

Present your dichotomous key in table and branching form.

Evaluation

- 1 Explain the main difficulties you faced when you constructed your key.
- 2 Discuss the reason for any changes you made after testing the key with a classmate.
- 3 Suggest some pieces of information, other than the pictures provided, that would have been helpful when making your key.
- 4 Working through your dichotomous key backwards, list the characteristics of one of the insects.

Conclusion

From this activity we can claim that insects _____. This is supported through observations that _____. This means that _____.



QUIZ

Section 2.1 questions

Remembering

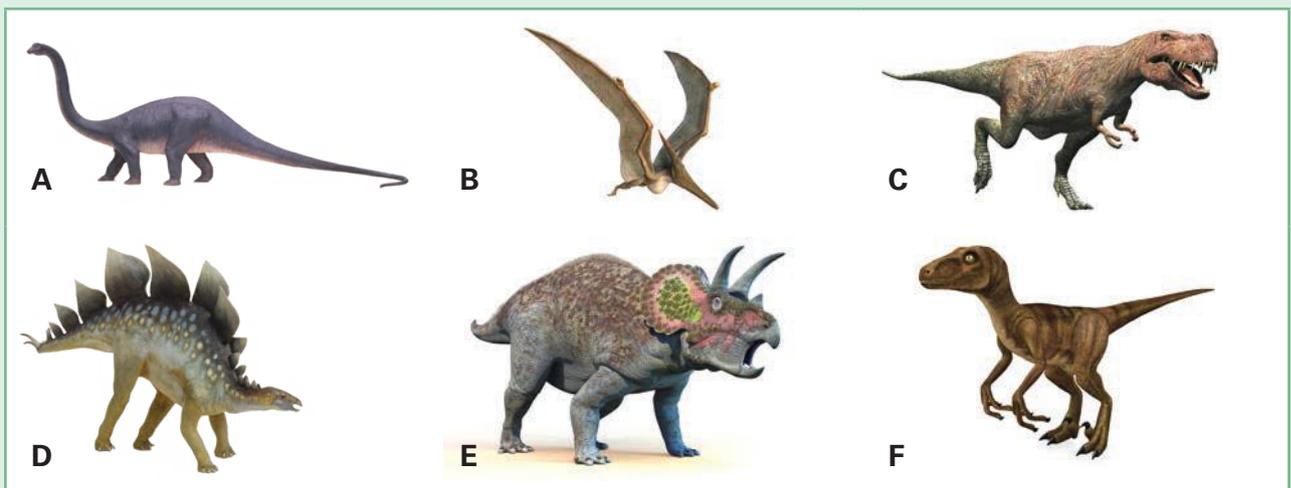
- 1 Define the term 'classify'.
- 2 Outline why scientists need to classify things.
- 3 Recall the term given to a key that has two possible options at each stage.

Understanding

- 4 Which of the following characteristics would be best to use when making a classification key for birds?
 - 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 Identify 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 Copy and complete the results table on page 44 using the images and dichotomous key below.



Dinosaur dichotomous key:

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

continued...

...continued

Results

Dinosaur	Species
A	
B	
C	
D	
E	
F	

Analysing

- 8 a Classify the foods below into two groups based on a specific characteristic. Outline the features of each food that led you to your classification.
- b Now use the images again to classify these objects but this time into three groups. Outline the features of each food that led you to your classification.
- c Ask to see the groups your classmates came up with – are they the same as yours or different? Identify why this is the case.



- 9 Distinguish between qualitative characteristics and quantitative characteristics.
- 10 When you are older, you may be interested in buying a second-hand car. Most likely, you will jump online to a car sales website and begin your search. The state you live in might be one of the first things you enter to narrow down your search. Suggest other features or characteristics you may need to use to refine your search. Justify your choices, saying if you think everyone would follow the same pathway as you.

Evaluating

- 11 Copy and construct the following table. Decide whether the features are good or weak descriptors to use in a dichotomous key for humans. Justify your choices.

Feature	Good or bad descriptor	Justification
Blue or brown eyes		
Long hair		
150–160 cm tall		
Likes cats		
Size 6 shoe		



2.2 Classifying living things

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 doesn't 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); or internal movement, such as movement of sap, or movement seen inside cells with a microscope.

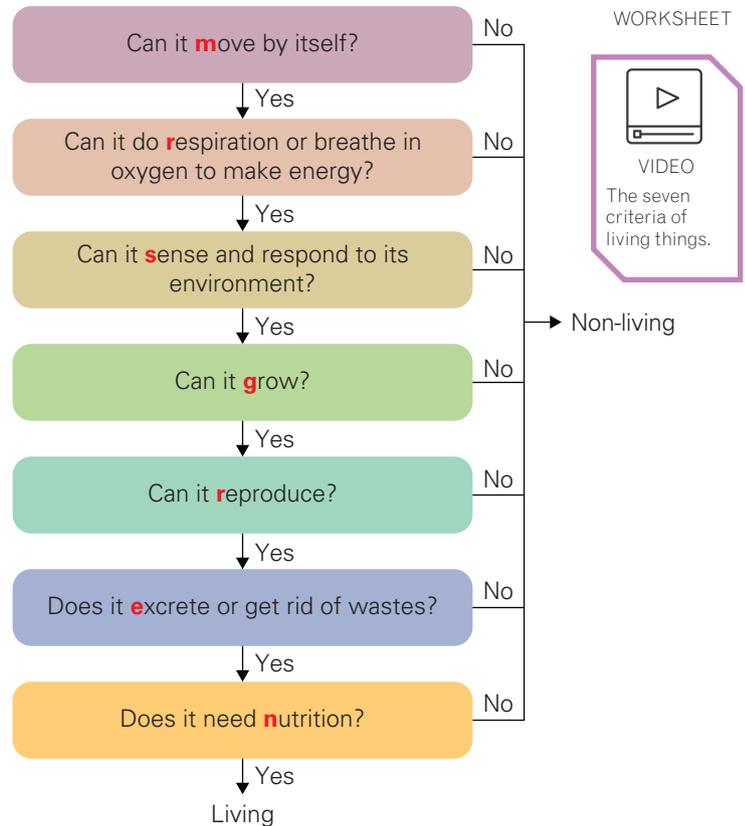


Figure 2.10 Unless all seven criteria are met, a thing cannot be classified as 'living'.

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

Explore! 2.2

- 1 List 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 on page 46:
 - Tick if the characteristic is present.
 - Define the object as living, non-living or dead.

Quick check 2.4

continued...

...continued

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								

You are related to a banana!

Did you know? 2.2

Every living organism on this planet is related to every other organism. 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. Can you see how classifying by DNA might not be the only answer?

DNA

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



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!

organism
a living creature

taxonomy
a branch of science that groups organisms



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

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 in all countries as the standard system to use.

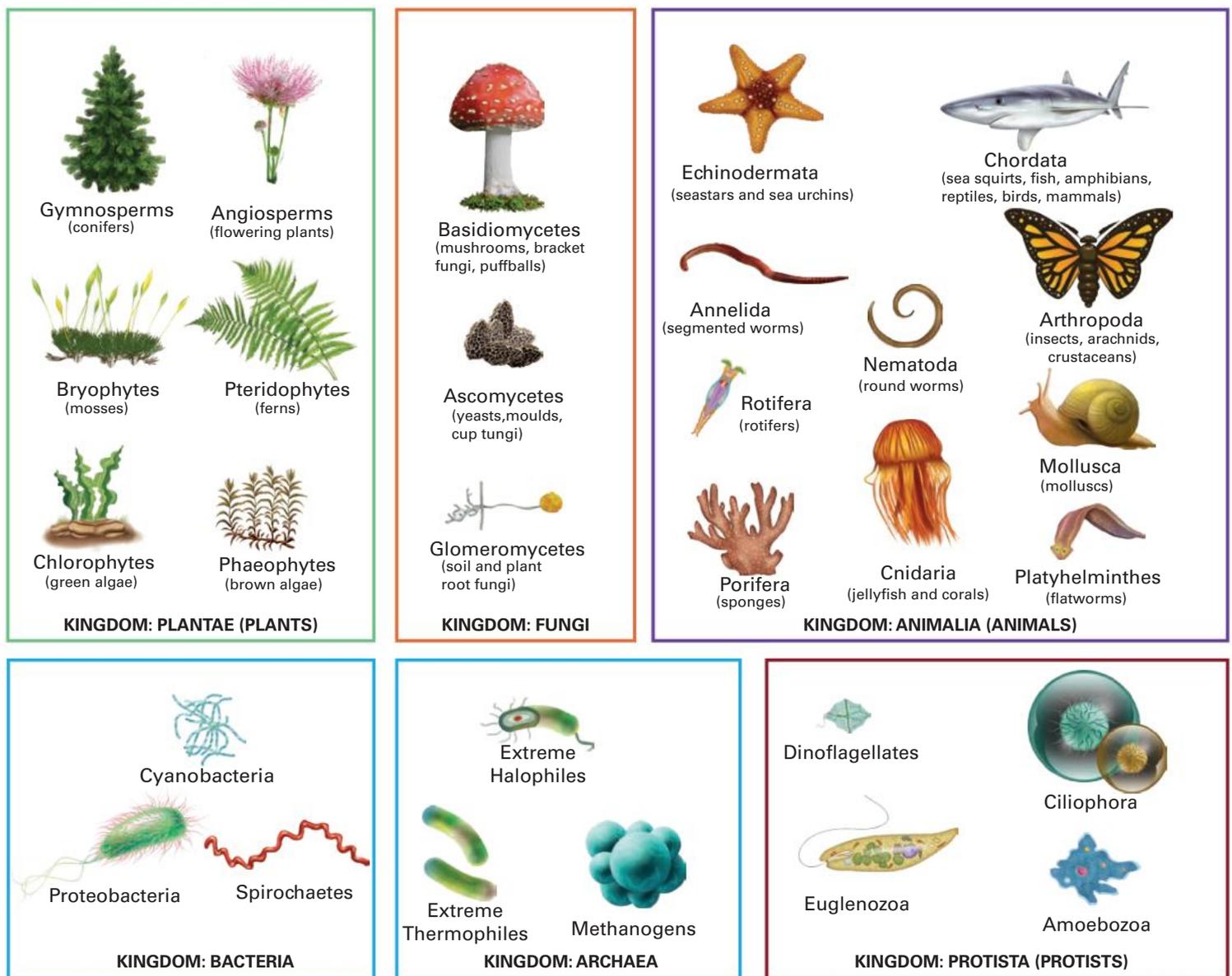


Figure 2.13 The six-kingdom classification of living organisms, with some representative groups within each. Note that there are many more groups than the ones shown, especially in the kingdoms Bacteria, Archaea, Protista and Fungi.



Figure 2.14 Linnaeus on a scientific expedition

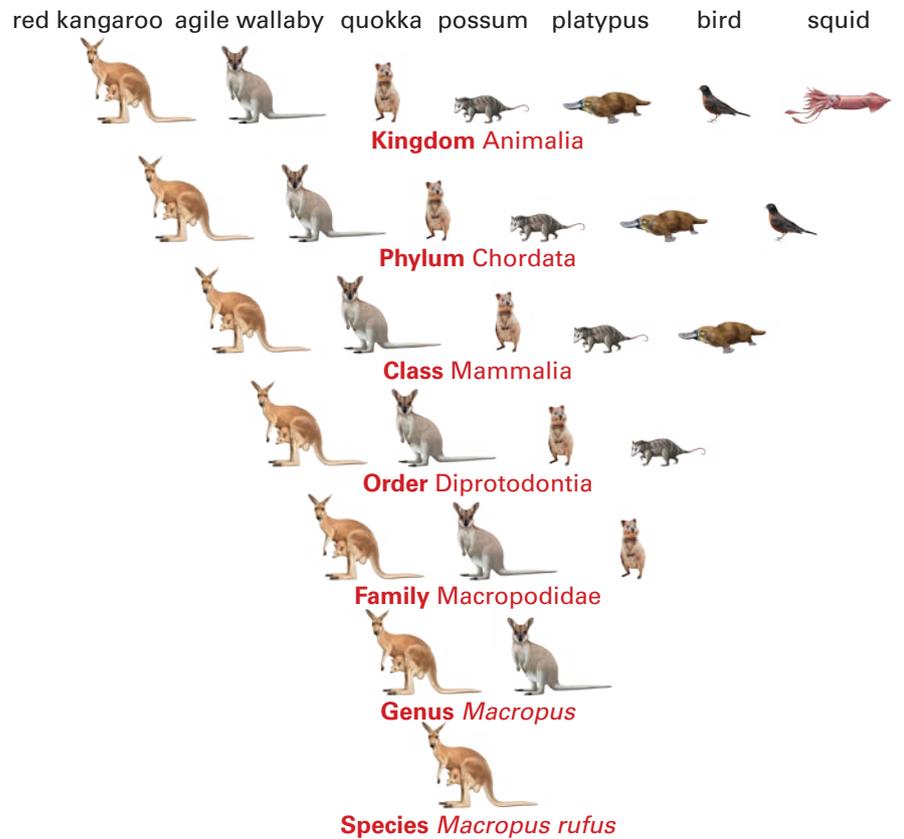


Figure 2.15 Linnaeus' classification hierarchy: at each level as you go down the organisms share more characteristics and are more similar

Carl Linnaeus

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

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.

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.

The order and names of Linnaeus' different

Try this 2.4

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.

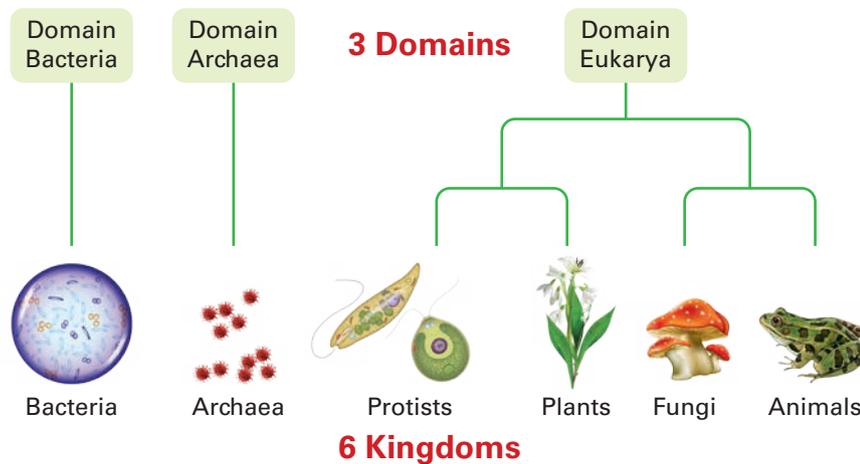


Figure 2.16 The links between Woese's domains and kingdoms

Carl Woese

In addition to the original levels that Linnaeus suggested, a higher, broader level was proposed by Carl Woese (a **microbiologist**) in 1990.

microbiologist

a scientist who studies very small living things like bacteria

domain

the highest taxonomic rank

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.

How often do the kingdoms change? Explore! 2.3

Linnaeus proposed two kingdoms, animals and plants, this grew to five, and then Woese proposed six kingdoms. Research online the historical groupings of organisms and create a timeline to indicate the changes that have taken place throughout history. Make a prediction on the next change.

- 1 Define the term 'taxonomy' in your own words. Add the term to your glossary.
- 2 Explain why the classification system is constantly being updated.
- 3 What are the names of the six kingdoms?
- 4 How did Woese's proposal change the way organisms are classified?

Quick check 2.5

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 kelloggi* 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 all 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 naming

Linnaeus is also responsible for the two-part naming system described above, which is known as **binomial nomenclature**. This replaced much longer names such as the one for the tomato plant given on page 48.

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



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

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 the *Harry Potter* books – ‘*Macropus giganteus*!’ – (that’s an eastern grey kangaroo!).

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

Table 2.2 *Macropus giganteus* taking a nap, and its classification

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?

Try this 2.5

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.

Did you know? 2.3

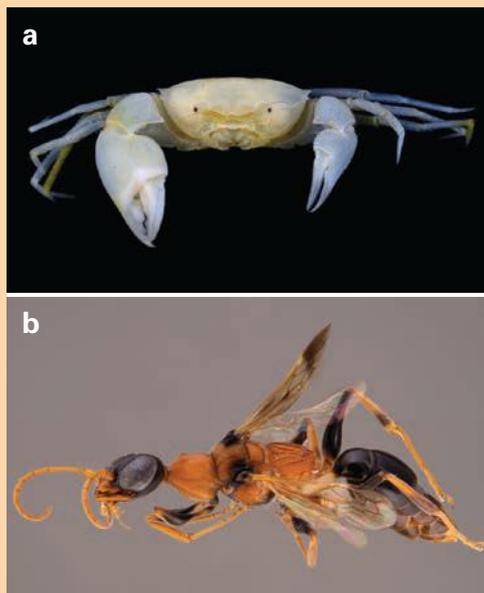


Figure 2.18 (a) *Harryplax severus* (b) *Ampulex dementor*

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) 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. It is not scientific.

Australia once had lions!

Explore! 2.4

In 2017, Australian scientists discovered a new species of extinct marsupial lion that roamed in Queensland 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 researchers determine whether an organism belongs to a new or existing species.



Figure 2.20 British magpie

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

Quick check 2.6

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 1798, 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.

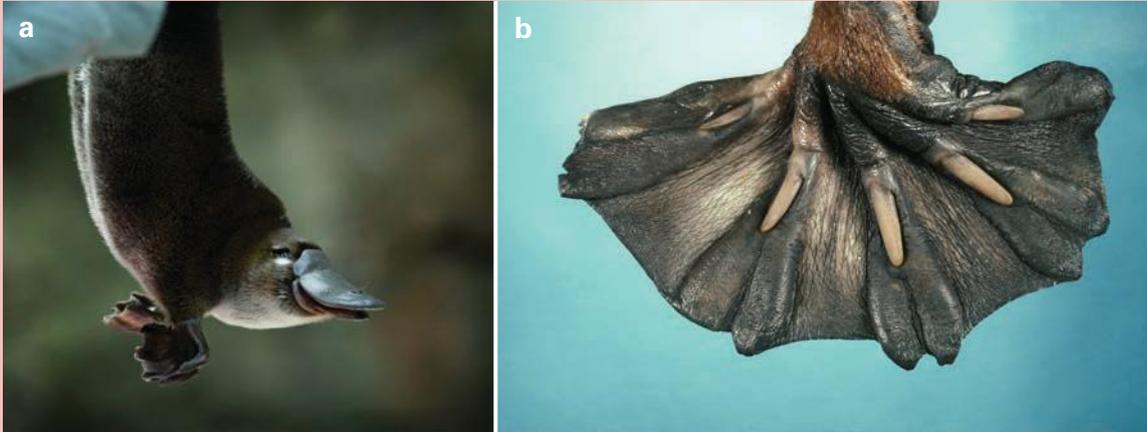


Figure 2.21 The platypus. (a) Platypus young displaying their duck-like bill (b) Webbed platypus foot

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 2.6**Practical 2.3****Creating an animal****Aim**

To create a new animal and classify the animal under the current classification system.

Materials

Access to a digital device and the internet.

Method

- 1 Use your preferred web browser to search 'make new animals'.
- 2 Use an animal building tool to create a new animal with features of many different types of animals (e.g. Switchzoo). Alternatively, you can sketch your animal creation instead of using an app or browser game.

continued...

...continued

Results

- 1 Take a screenshot of your creation and then create a description of the animal.
- 2 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

Evaluation

Using your description, justify into which group of animals (insects, birds, mammals, reptiles) you would classify your new animal.



QUIZ

Section 2.2 questions

Remembering

- 1 Name the person who is called the 'father' of modern taxonomy.
- 2 List the six kingdoms.
- 3 What are 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*. For which country or countries does this name apply?
- 6 Outline the main problems with the classification system that was used before the Linnaeus system.
- 7 Summarise what you have learned about scientific names.

Applying and Analysing

- 8 Imagine you saw a platypus in the wild for the first time. Describe how you would classify it and why.

Evaluating

- 9 Predict how closely related the fish in Figure 2.23 are with the clownfish on the bottom left based on physical characteristics. Justify your prediction.



Figure 2.22 Male common bluetail damselfly



Figure 2.23 Tropical fish



2.3 Non-animal kingdoms



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

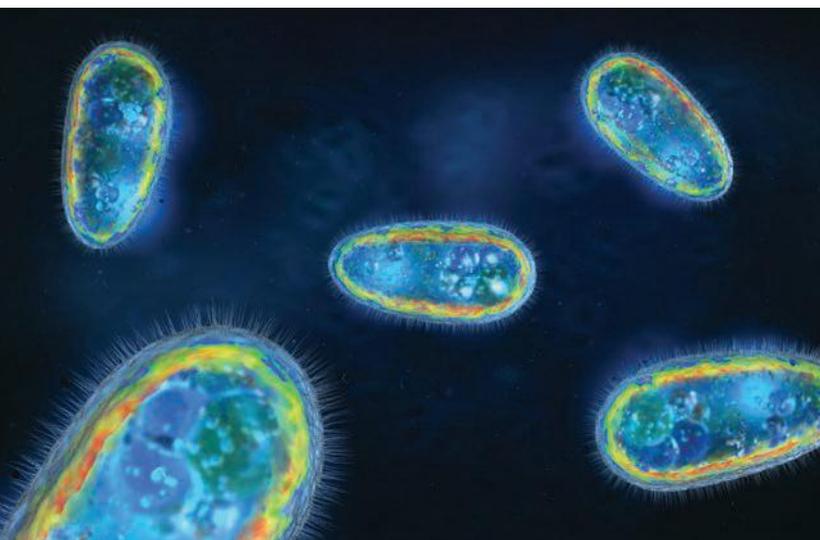


Figure 2.24 Unicellular organisms have only one cell, which performs all the cellular functions.

Archaea

- 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

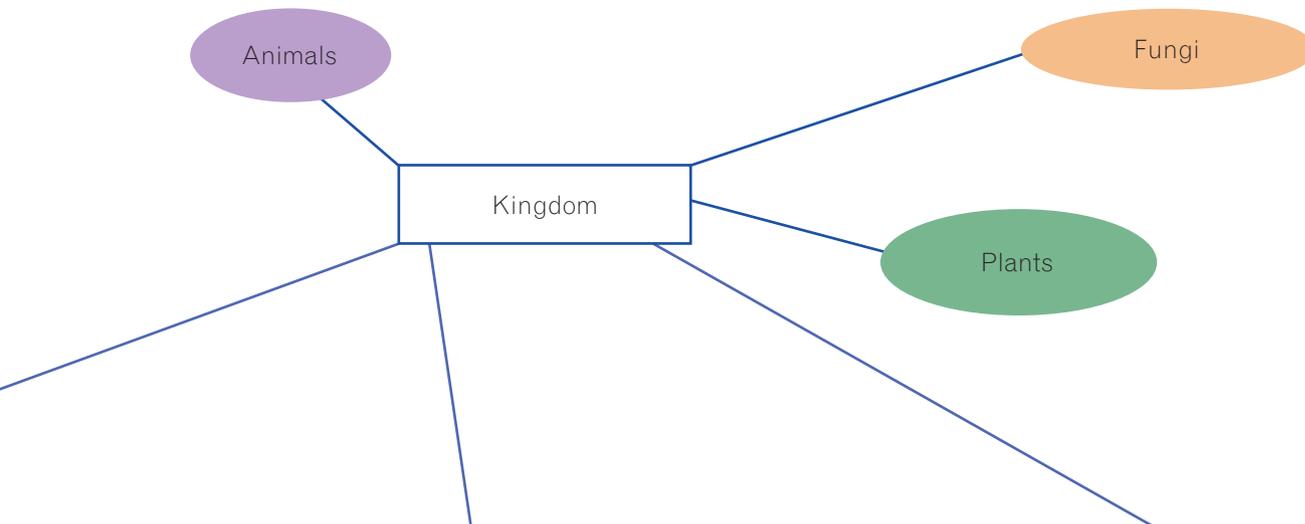


Figure 2.25 Archaea can be found in inhospitable (harsh) environments like these geothermal hot springs or even toxic oil wells.

We have one kind of archaea

Did you know? 2.4

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

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

Protista

- Single cells like bacteria and archaea but complex in comparison
- Do not always have a cell wall and can be tiny or quite big
- Organisms that do not fit into the other kingdoms gets placed in the Protista
- 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 soil.



Figure 2.27 These *Phacus* euglenoids can swim and make sugars by a process called photosynthesis, just like plants can.

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

Quick check 2.7

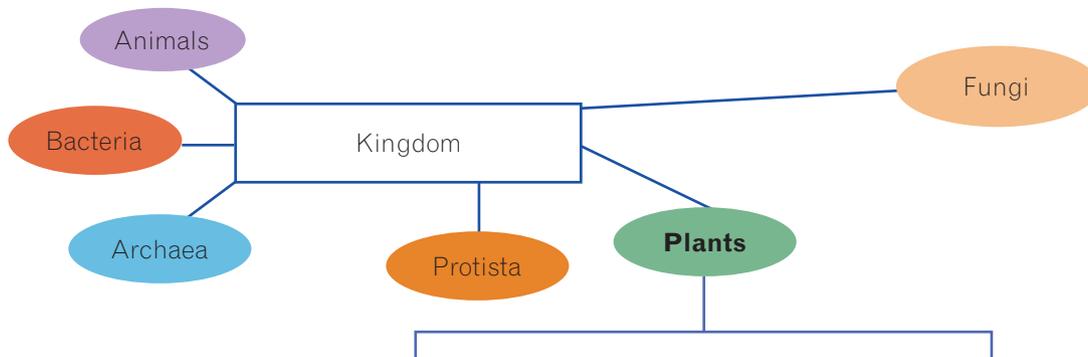
Plants

Plants do incredible things for us! They turn the toxic greenhouse gas carbon dioxide into the very useful gas oxygen that allows us to stay alive. Plants have been on Earth for millions of years longer than animals and spent that time transforming the atmosphere into the one that can be breathed. They are also the primary food source for all life on land, converting the

energy from the Sun into useful sugars that can be digested.

Figures 2.28 to 2.32 show how the Plant kingdom is divided into four main groups based on whether they have:

- vascular tissue
- no vascular tissue
- seeds
- no 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).
- Includes mosses, liverworts and hornworts, and some algae



Figure 2.28 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 2.29 Veins that you see on leaves are special pathways for water and nutrients to flow.

non-vascular
not containing veins or specialised fluid vessels

vascular
containing veins or specialised fluid vessels

Flowering plants

- Use brightly coloured flowers and sweet nectar to lure insects, birds and other animals to the flower
- These organisms help spread the flowers' pollen to produce seeds
- Seeds develop inside the 'fruit', which in botany includes pods, capsules and all 'fruiting bodies'
- The fruit of some plants is edible and attractive, so when animals eat the fruit, they spread the seeds over large distances.



Figure 2.30 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 2.31 Ferns mainly grow in moist, humid areas.

Non-flowering plants

- Examples include cycads and conifers
- Reproduce using seeds, which are a complex way of reproducing as seeds contain multiple cells, not just one. These cells are protected by a waterproof layer much like the hard shells of reptiles and birds, and it prevents the seed from drying out
- Conifers 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 2.32 The Wollemi Pine is an ancient non-flowering, seed-producing plant that is only found in Australia.

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

Quick check 2.8

Characteristics	Non-vascular	Vascular		
		Ferns	Non-flowering	Flowering
Roots and stems				
Grow tall or only short				
Spores or seeds				
Flowers or no flowers				
Other key points				
Examples				

Practical 2.4**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. Glycerol can be used to slow 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, using a sharp pencil.

Evaluation

- 1 State whether the euglena is a multicellular or unicellular organism.
- 2 Discuss why you believe a coverslip was used in this experiment.
- 3 Euglena can make sugars like plants can, has a simple 'eye' spot (sensitive to light, not a true eye) and can also move, as you have observed. From your observations, justify whether you believe euglena is more similar to animals or plants.

Conclusion

From this activity we can claim that euglena is a _____. This is supported through observations that _____. This means that _____.

Be careful

Ensure proper microscope handling and use is observed.

Practical 2.5

Dissecting a flower

Aim

To identify and label the parts of a flower.

Materials

- 1 whole flower (lily, gladioli or tulip)
- 1 single-sided razor blade or craft knife (would be safer)
- magnifying glass
- chopping board
- sticky tape

Method

- 1 While holding the flower, choose one side to be the back and one to be the front.
- 2 Carefully pull off the **sepals** and the petals from the front of the plant.
- 3 Copy the results table into your notebook and stick the petal in the petal section.
- 4 Draw the exposed centre of the flower.
- 5 Use the diagram in Figure 2.33 to help you to identify the parts of your flower.
- 6 Label your drawing.
- 7 Remove one of the **stamens** and stick it to your results table.
- 8 Observe the pollen on the **anther** of the stamen using your magnifying glass.
- 9 Identify the **stigma**, **style** and **ovary** (the style may be absent in some flowers so stigma is on the ovary)
- 10 Use your single sided razor blade to cut the **carpel** in half (from top to bottom).
- 11 Draw the carpel and label the **ovule** if you can locate it.

Be careful

Extreme care is to be taken when handling the razor blade

sepal

one of the leaf-like parts forming the outer part of a flower, which surrounds the petals and are usually small and green

stamen

the male part of a flower, consisting of a thin stem that holds an anther

anther

the part of a flower that produces and releases pollen

stigma

part of the flower that receives pollen

style

an extension of the ovary supporting the style

ovary

the container of the ovules

carpel

the female part in a flower, made of the ovary, stigma and style

ovule

the container of female reproductive cells or 'egg', inside the ovary that will form a seed

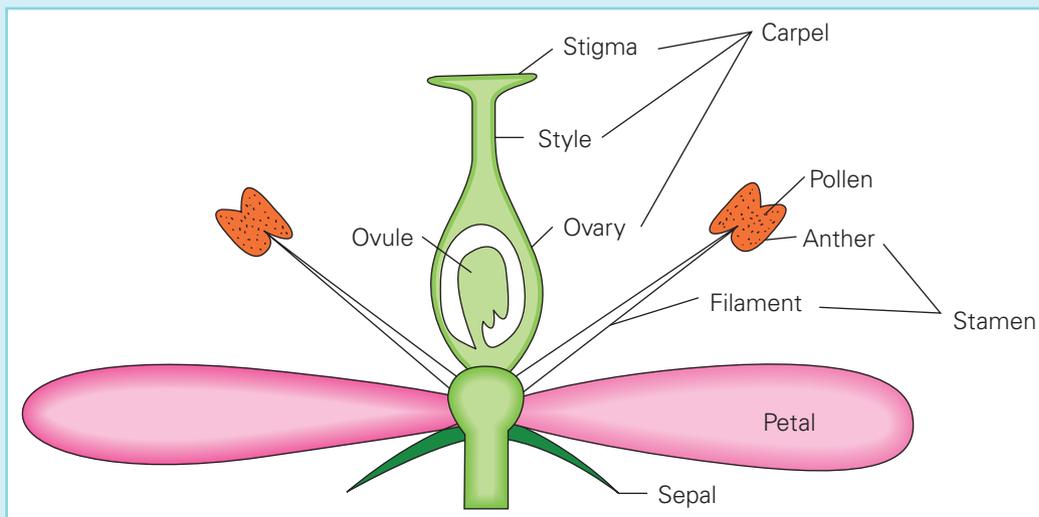


Figure 2.33 Features of a flower

Results

Copy this table into your notebook. Leave enough room in it to stick in parts of the flower.

Part of flower	Stick structure	Description
Petal		
Stamen		
Carpel		

continued...

...continued

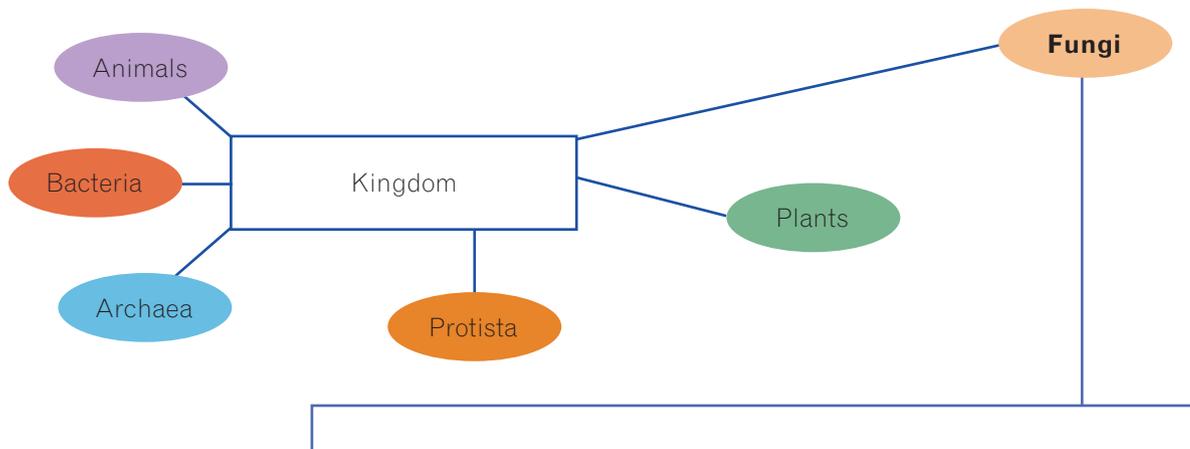
Evaluation

- 1 If you have access to more than one type of flower, do some have more stamens than others? Do all the stamens have pollen on them? Suggest why there may be differences between the flowers.
- 2 Pollen is very fine and can stick to surfaces easily. Explain why this could be useful for the plant.
- 3 The ovule is the part of the flower that forms the seeds. Explain why this part of the flower can vary in size in each flower.
- 4 Insects and birds are attracted to brightly coloured petals. Propose a reason that this would be beneficial to flowers.

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.



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*.



Figure 2.35 *Penicillium* mould growing on an orange

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 them to be recycled in the circle of life. 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



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

frog extinctions and ten rapidly declining frog species in Australia. Currently, there is no cure or method of controlling this disease in the wild.

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.

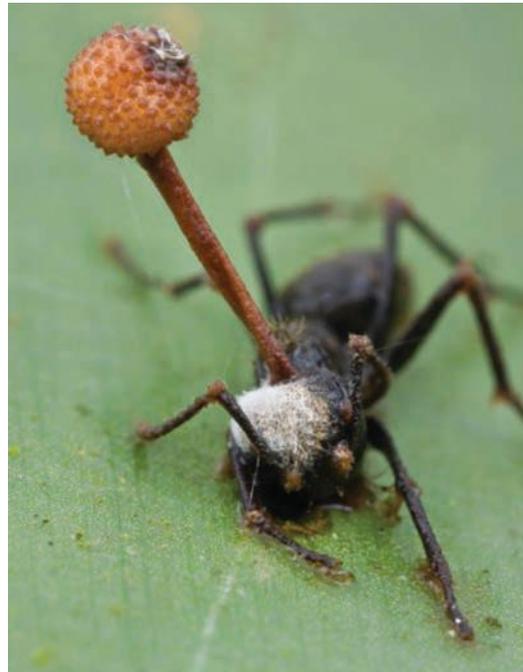


Figure 2.38 Fungi sprouting out of the brain of an ant!

Can trees talk?

Explore! 2.5

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 List the characteristics of fungi.
- 2 What are the characteristics that plants and fungi have in common?
- 3 Do some research and find some examples of how fungi can be both beneficial and dangerous to humans.
- 4 What conditions are best for mould or fungi to grow?

Practical 2.6: Self-design

Spores are all around us

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. Food, on the other hand, does not have an immune system, and fungi that land on it can grow very easily. Most of the fungi that grows on food is known as mould.

Be careful

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

Aim

To design an experiment that will allow you to determine the conditions that are best for the growth of fungi on bread.

Materials

- 4 slices of bread (near 'best before' date)
- 4 zip-lock bags
- paper towels
- sticky labels
- permanent markers

Time period

around 1 week

Method

- 1 Begin by brainstorming what conditions you think might encourage the growth of fungi on bread. Share your ideas with your classmates.
- 2 Select the condition you want to investigate and identify the variables for your experiment: the thing you change is the independent variable; the thing you will be measuring is the dependent variable; the things you want to keep the same are called the control variables.
- 3 Design your experiment by constructing a detailed method to explain the procedure you will follow. Set it out in step-by-step form. Remember, another scientist should be able to read this procedure and replicate your experiment exactly, so be precise.
- 4 Create a hypothesis or prediction of the results.
- 5 After checking your method with your teacher, carry out your experiment.

Results

Construct an appropriate results table to document your experimental results.

Evaluation

- 1 What do your results show? Explain.
- 2 Did your experiment prove or disprove your hypothesis?
- 3 Did something go wrong that you did not control for?
- 4 How would you alter your experiment next time to prevent this?

Conclusion

From this activity we can claim that for fungi to grow, _____. This is supported through observations that _____. This means that _____.

Classification super-challenge!**Try this 2.7**

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 with ovules and pollen inside them and 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.		





QUIZ

Section 2.3 questions

Remembering

- 1 State 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.
- 7 Identify why animals depend on bacteria and fungi.

Analysing

- 8 Place each one 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. Suggest 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 Propose some examples of variables she kept the same or controlled.
 - d Suggest two other variables she could test with a similar experiment assessing the growth of mould.





2.4 The Animal kingdom

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
- 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.

sessile

an organism that does not independently move its location but may move body parts

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, you will notice 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 backbone or an external backbone or 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.



WORKSHEET

vertebrate

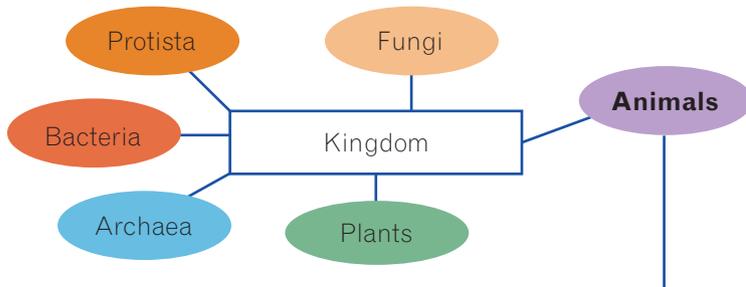
has a backbone

invertebrate

does not have a backbone

ANIMAL KINGDOM		
Phyla (scientific name in brackets)	Examples	Backbone or no backbone
Poriferans (Porifera)	Sponges	Invertebrates
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)	Seastars, 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. Note that eight of the nine phyla contain animals with exoskeletons i.e. no backbone.



The Animal kingdom is divided into many phyla; Figures 2.40 to 2.48 show the nine key ones. Animals are also divided informally into two large groups: invertebrates and vertebrates.

Invertebrates

Poriferans

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

- 'Pore-bearers', have holes
- Use filters to obtain food
- No organs
- Sessile (do not move)
- Simple animal, no specialised organs
- Includes sponges.

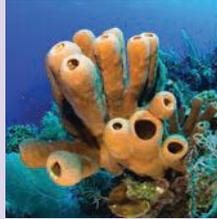


Figure 2.40 A sponge with its simple tube form for filtering water

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
- Includes anemones, coral and jellyfish.



Figure 2.41 The box jellyfish, whose venom is strong enough to kill humans, can be found in the Northern Territory or 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
- Includes all flatworms.



Figure 2.42 Flatworms display many vibrant colour combinations.

Nematodes

parasite

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

(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 2.43 Many nematodes are parasites.

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
- Includes earthworms.



Figure 2.44 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 scaping device for eating
- Includes 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
- Contains 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
- Includes 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
- Includes sea urchins, sea cucumbers, brittle stars.



Figure 2.48 When a starfish loses a limb, it can grow back.

Vertebrates

Chordates

(pron. *core-dates*)

The Chordate phylum contains the most complex group of animals – they all have a spinal cord. The spinal cord is a long nerve that connects the brain of the animal to the rest of the body. This nerve is usually, but not always, protected by bones that are called vertebrae. Run your fingers down your back to feel your vertebrae that are protecting your spinal cord. You may remember that animals with such bones are called vertebrates. Humans, all other mammals, fish, reptiles, amphibians and birds all belong to the Chordate phylum but are further grouped into classes based on their similar characteristics.



Figure 2.47 Elephant seals and penguins are both examples of chordates.

Some scientists believe they have found an

Explore! 2.6

immortal jellyfish (*Turritopsis dohrnii*). Research how the scientists explain this immortality and propose whether the same measure could ever be used by humans.

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.

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

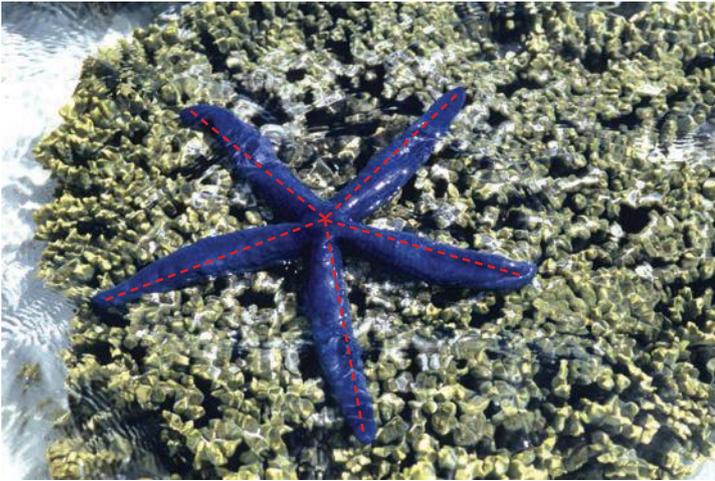


Figure 2.49 The blue seastar shows radial symmetry.



Figure 2.50 Victoria's brown falcon shows bilateral symmetry.

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

Explore! 2.7

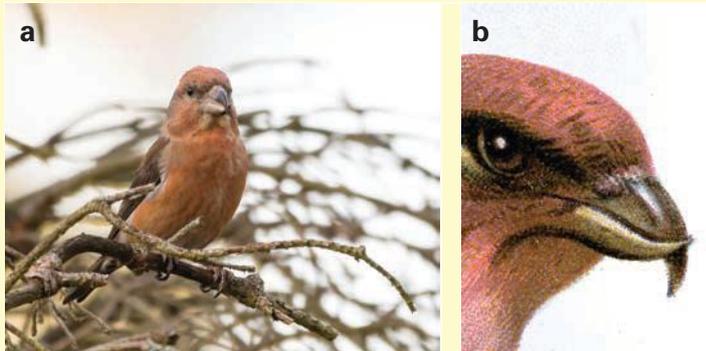


Figure 2.51 (a) A male crossbill; (b) Close up of its crossed bill

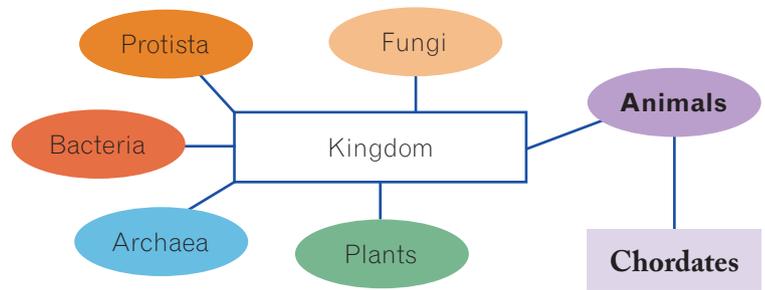
Look at each of the following animals then decide whether they show radial symmetry, bilateral symmetry or no symmetry.

Try this 2.8



Animal classes

Kingdoms are divided into phyla and the next grouping down after phylum is Class. You will now take a closer look at the 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
- Includes 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
- Includes sharks, skates and rays.



Figure 2.53 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)
- Includes salmon, tuna, eels, trout and clownfish
- **Ectothermic** (cold-blooded) – the temperature inside their bodies is controlled by the temperature of their environment.

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



Figure 2.54 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
- Includes toads, frogs, newts and salamanders.

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



Figure 2.55 White's tree frog found in Australia

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.

Explore! 2.8

Reptilia (reptiles)

- Have waterproof scales as covering
- Most lay eggs, but have a leatherier shell than amphibian eggs and do not dry out
- Ectothermic
- Have lungs for breathing
- Includes snakes, lizards, turtles and crocodiles.



Figure 2.56 Frilled lizards use their frill to catch more heat from the sun to warm up.

Aves (birds)

(pron. *ab-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
- Includes all living birds.

endothermic

a warm-blooded organism that can regulate its body temperature



Figure 2.57 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 2.58 Dogs are not only very good friends, they are also placental mammals like us!



Figure 2.59 Quokkas are very friendly marsupials found on Rottnest Island 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 amongst 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 rare in the rest of the world.



Figure 2.60 Mother giraffe with her newborn offspring



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

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 phyla 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 breath 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 about 1 metre away, they will then use their vision and a special thermal sensor to detect their prey.

Did you know? 2.5

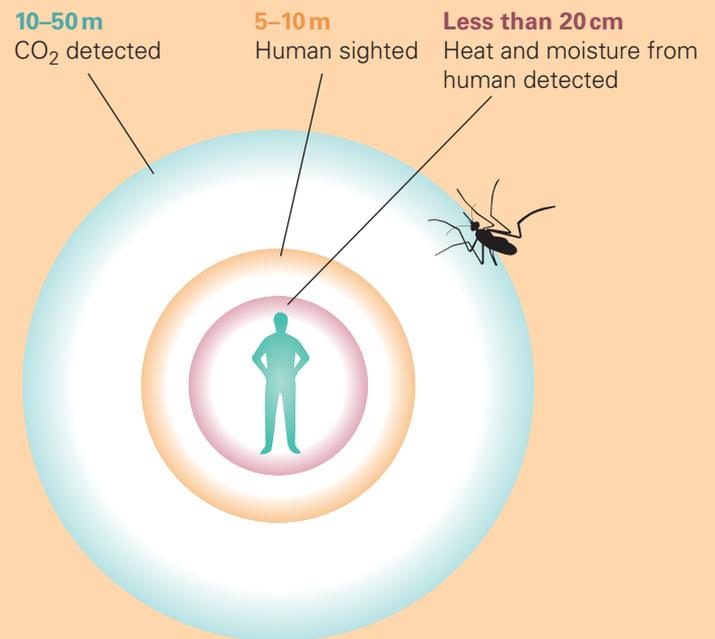


Figure 2.62 Zones of human detection for mosquitoes

Practical 2.7

Dissecting a squid

Aim

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

Materials

- 1 squid
- dissecting tray (plastic chopping board)
- dissecting scissors
- probe
- newspaper
- 11 toothpicks
- 11 sticky labels
- gloves
- lab coat
- Optional: dissecting microscope

Be careful

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

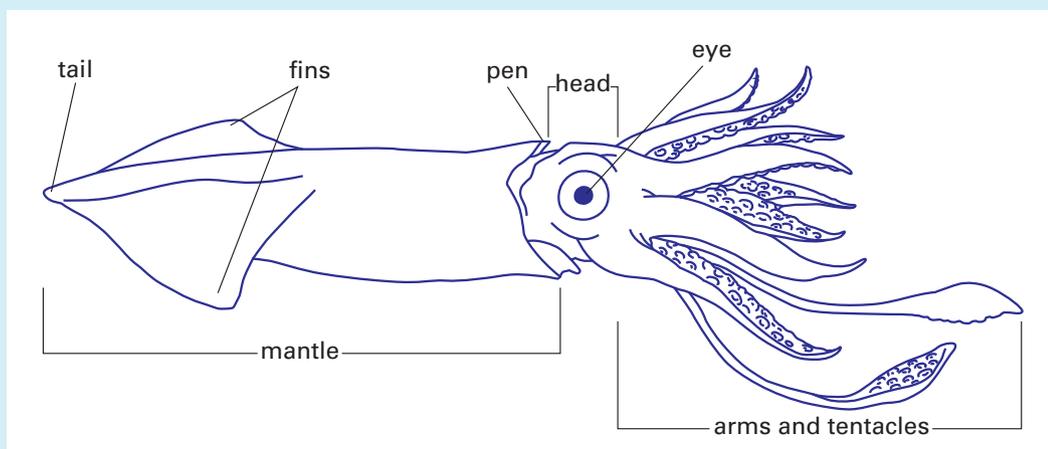


Figure 2.63 External anatomy of the squid

continued...

...continued

Method

- 1 Create 11 toothpick label flags with the toothpicks and sticky labels. 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 and use 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. You will notice that they are longer than the arms and only have suction pads at the end of each tentacle.
- 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 Once you have removed the ink sac from the squid, try popping it using a toothpick and writing 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.

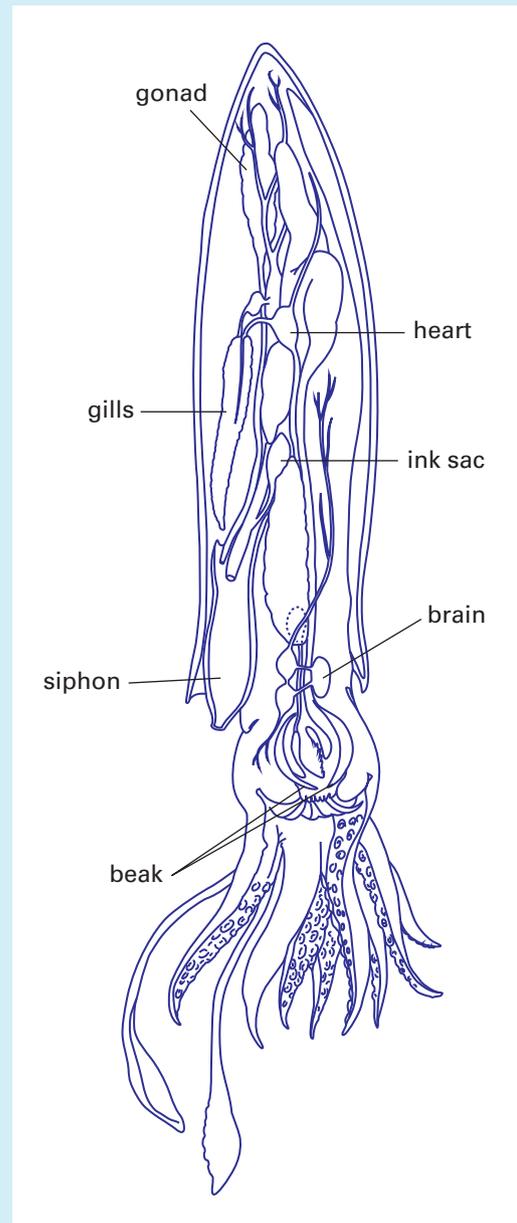


Figure 2.64 Internal anatomy of the squid

continued...

...continued

Results

List the purpose of each of the following features. You may need to do some research.

- | | | | | | |
|------------------|----------------|--------------------|-----------------|-----------------|-----------------|
| a heart | c gills | e tentacles | g mantle | i fins | k gonads |
| b ink sac | d arms | f eyes | h pen | j siphon | |

Evaluation

- 1 State how many arms the squid has.
- 2 State how many tentacles the squid has.
- 3 Explain the reason why the squid is a mollusc but does not have a shell.
- 4 Propose a reason why it would be beneficial for a squid to be able to produce ink.

Which phylum?

Quick check 2.10

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 arbuscular* 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.

Reptile roadkill

Did you know? 2.6

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.

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

Quick check 2.11

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.

Did you know? 2.7

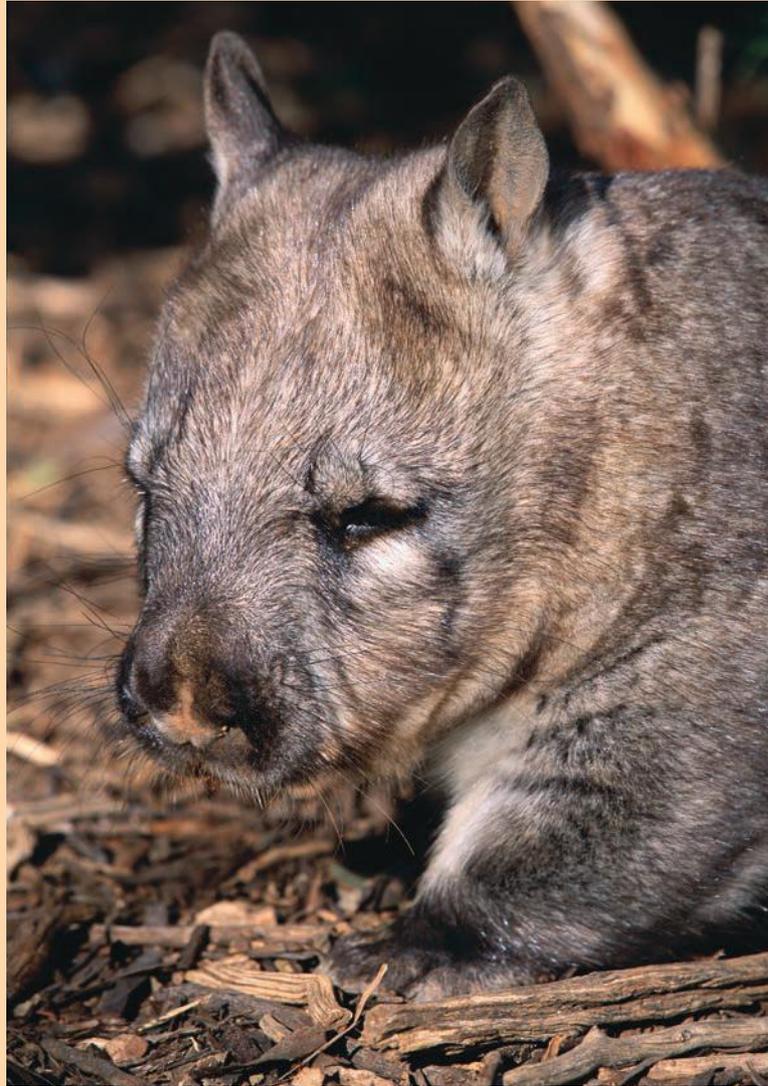


Figure 2.66 Southern hairy-nosed wombat popping out of its burrow

Which 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.

Quick check 2.12

Practical 2.8

Exploring the Animal kingdom

Aim

To research and gather information on the features of two invertebrate and two vertebrate species that interest you.

Materials

- access to the internet and a digital device
- notebook

Method

- 1 Use your preferred web browser to research your two chosen vertebrates and invertebrates.
- 2 Copy the following table format into your notebook and use the information you find on the website to complete the table.

Results

Common name	Genus species name	Phylum	Characteristics of the phylum	Three features of the species	Three interesting facts

Evaluation

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, try it with your teacher!

Conclusion

From this activity we can claim that _____. This is supported through observations that _____. This means that _____.

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.

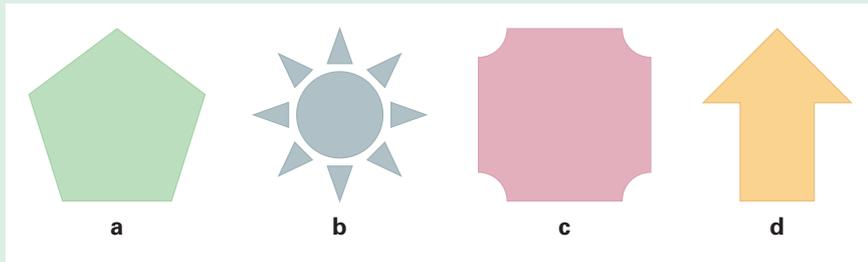
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QUIZ

...continued

4 Identify whether each of the following shapes has bilateral or radial symmetry:



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.
 a Which animal phyla does the sea pig share features with?
 b Which phyla do you believe the sea pig belongs to and why?



Figure 2.67 A sea pig

Evaluating

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

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 Scientific names for genus and species names are mostly taken from which language?
- 4 Show the correct way to write the genus and species name of the domestic cat. *Hint*: the unformatted name is felis catus.



Understanding

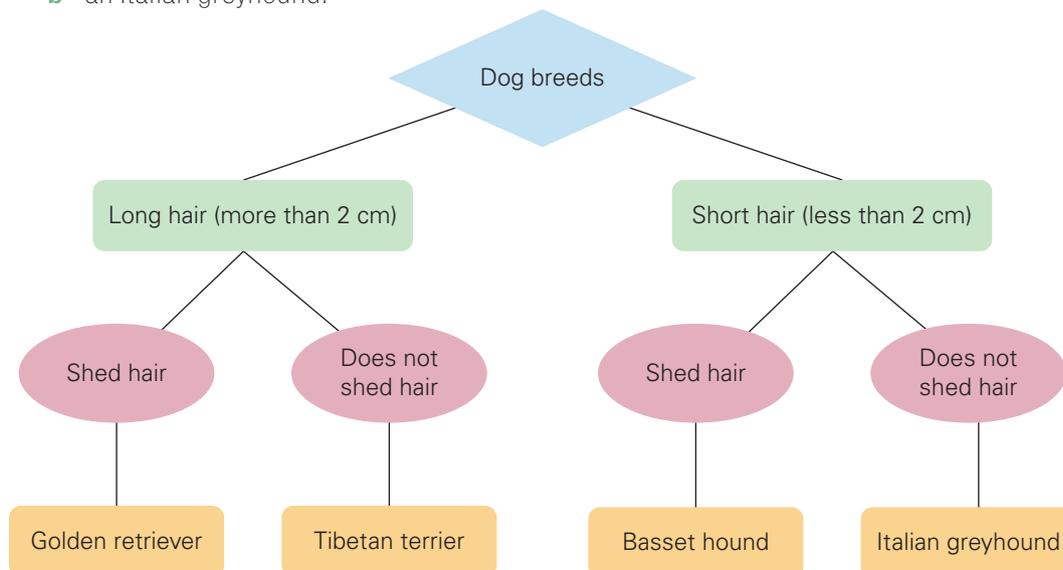
- 5 Outline why it is useful to classify organisms and give them a unique universal name.
- 6 Predict the effect of using qualitative descriptions in a dichotomous key.

Applying

- 7 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	

- 8 Create a dichotomous key to classify the contents of your pencil case.
- 9 Moss and fungi both produce spores. Describe two differences between these organisms.
- 10 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.



Analysing

- 11 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.
- 12 Predict what would happen if all the decomposers in the world were suddenly to die out.

Evaluating

- 13 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.
- 14 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.

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.

VCSSU091

VCDSTS043

VCDSTC048

VCDSC0049

VCSIS113

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 2.68 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 animals, to develop and design a sustainability-related invention that solves a human problem.



Figure 2.69 A simple shell could be your inspiration for an ethically sustainable house

Examples of problems you may like to look at could be transportation, building design, lighting, landscaping, water use etc. 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 animal, plant or insect inspired those features. Remember to ask yourselves throughout the process: 'What would nature do here?'

Suggested materials

- paper
- pens, pencils
- ruler

Evaluate and modify

Include the following in your engineering design report.

- Explain the human problem you produced a solution for.
- Identify your plant, animal or insect and its scientific name.
- Describe the unique features of your organism. Are these characteristics linked to its classification?
- Describe how you mimic the material, colour, and structure of the organism to design something new.
- Describe the process that helped you come up with the design.
- List the materials and their physical properties required to realise your design.
- Describe how each material was used and for what purpose.
- Create a scale drawing of your invention, including a front and side view of your invention.
- Describe your design by listing the special features of your design and which aspect of your organism inspired those features.
- Evaluate your design and its ability to solve the problem you identified. What improvements would you make?

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.

Curriculum

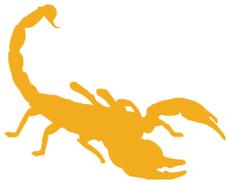
Interactions between organisms can be described in terms of food chains and food webs and can be affected by human activity (VCSSU093)

- | | |
|---|----------|
| • constructing and interpreting food chains and food webs to show relationships between organisms in an environment | 3.1, 3.2 |
| • recognising the role of microorganisms within food chains and food webs | 3.3 |
| • researching examples of human impacts on specific ecosystems, for example, the use of fire by traditional Aboriginal people, the effects of palm oil harvesting, deforestation, agricultural practices or the introduction of new species | 3.4 |

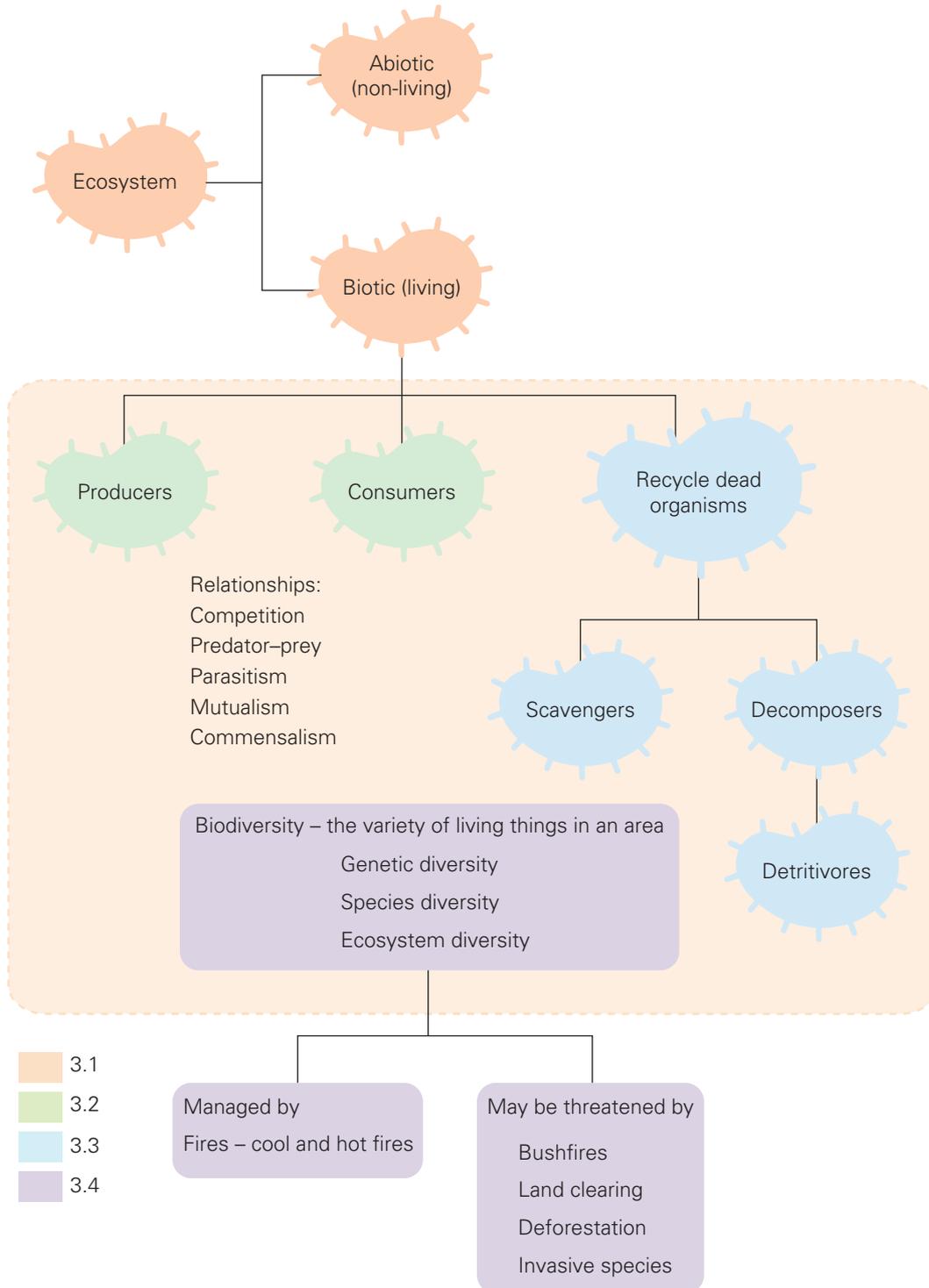
Victorian Curriculum F–10 © VCAA (2016)

Glossary terms

abiotic	consumer	invasive species
abundance	decomposer	microorganism
algae	deforestation	omnivore
apex predator	detrivore	photosynthesis
barnacle	ecosystem	population
biodiversity	energy	primary consumer
biological control	environment	producer
biotic	firestick farming	scavenger
calicivirus	food chain	secondary consumer
carnivore	food web	symbiotic
cellular respiration	habitat	tertiary consumer
community	herbivore	



Concept map





3.1 Ecosystems

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.

Give one, get one – Ecosystems

Complete a 'Give one, get one' activity. Write one example of an ecosystem in the top right box of the grid below and then follow the instructions from the Classification Try this in section 2.1.

Try this 3.1

An example of an ecosystem		



Figure 3.1 An example of many ecosystems in one area

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 abiotic conditions that affect an organism in its habitat. For example, the temperature, amount of light, amount of rain, type of soil and other organisms that live there affect an organism.



WORKSHEET

ecosystem
the living and non-living components of a specific area

biotic
relating to the living things in an ecosystem

abiotic
relating to the non-living things in an ecosystem

environment
the air, water and land conditions in which an organism lives

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

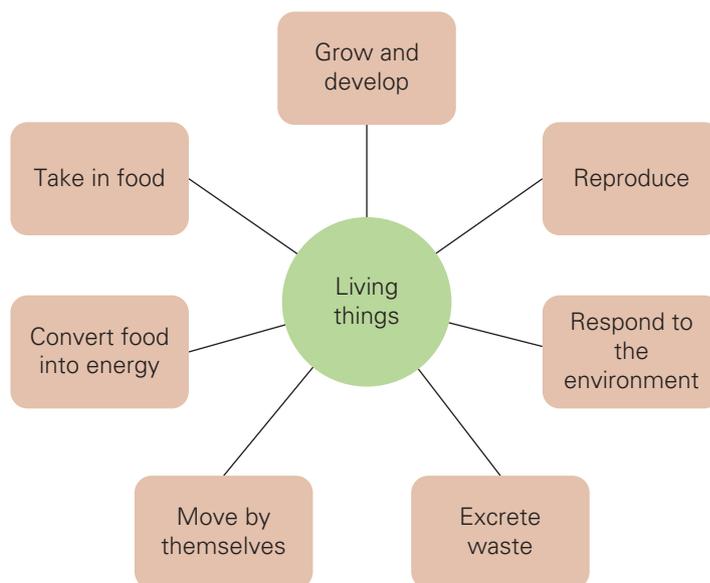


Figure 3.2 All living things demonstrate these processes.

If you are trying to decide if 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.

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 below 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.

Try this 3.2



Figure 3.3 Three images of the beautiful ecosystem that is our Great Barrier Reef

Habitats

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

habitat
the natural home of an organism

Figure 3.4 Penguins searching for their ideal habitat



- 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.

- Quick check 3.1**
- 1 Define these terms in your own words: ecosystem, biotic, abiotic and habitat. Add the terms to your glossary.
 - 2 List four different types of ecosystem.
 - 3 Name three examples of biotic and three examples of abiotic components of an ecosystem.
 - 4 What is it that makes a habitat a home for a particular organism?

Explore! 3.1

Look at the following image. 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?

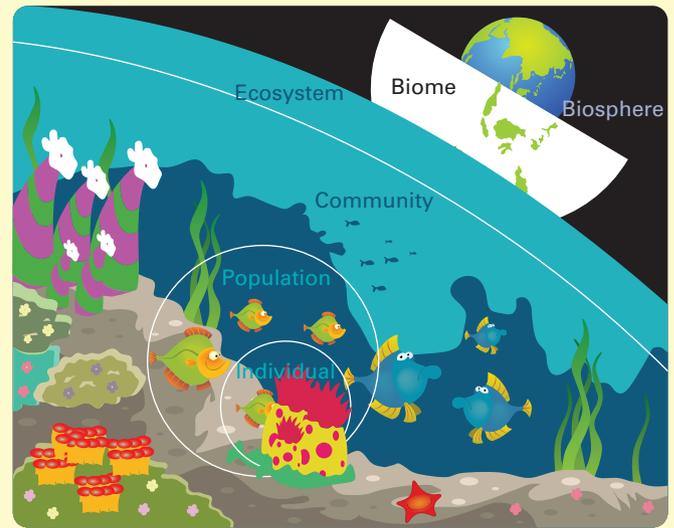


Figure 3.5 Levels of organisation

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.

community

a group of animals or plants that live or grow together

population

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

abundance

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

Level of organisation	Description
Community	A group of different organisms that live in the same area. For example, the community that is below Melbourne's West Gate bridge consists of mangrove trees, which provide shelter for the young and adults of many fish species. They also provide roosting and feeding opportunities for birds and bats. Their root network provides a habitat for crabs, snails, worms and insects.
Population	A group of the same species of an organism living in the same area. Their total number is called their abundance . For example, there is a population of the Baw Baw frog living in alpine and sub-alpine regions of the Baw Baw Plateau.
Individual	One living organism.

Table 3.2 The levels of organisation in an ecosystem

Demonstrating the organisation of ecosystems

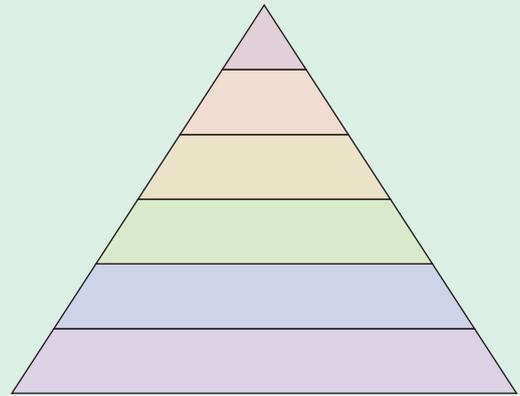
Try this 3.3

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 this process as you work through the levels of organisation, all the way up to biosphere.

If you choose to study an ecosystem, you can decide whether to look at a very small sample or an extremely broad area. For example, if you study a community you might observe how a bird eats the fruit from a specific plant. However, a scientist could also study the effects of a bushfire on an entire habitat, which would include many living and non-living features.

Quick check 3.2

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



Ecosystem case study: Saving the Great Barrier Reef

Science as a human endeavour 3.1



Figure 3.6 Aerial photo of the magnificent Great Barrier Reef

continued...

...continued

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. Due to the clean waters, light can penetrate to a depth of around 20 metres.

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.

barnacle

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

algae

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

One example of a reptile found at the reef is the green turtle.

There are around 16 000 green turtles found on the reef. These turtles can carry **barnacles** and **algae**, which some fish in the community feed on.

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. So, the stressed algae move out of the coral. This means the coral loses its major source of food and becomes pale and sick. In 2016, the result was a 30% loss of corals, and a further 20% loss in 2017.

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 so much more hope for being able to save the Great Barrier reef.



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



Figure 3.8 A beautiful sea turtle supporting a community of other living things.

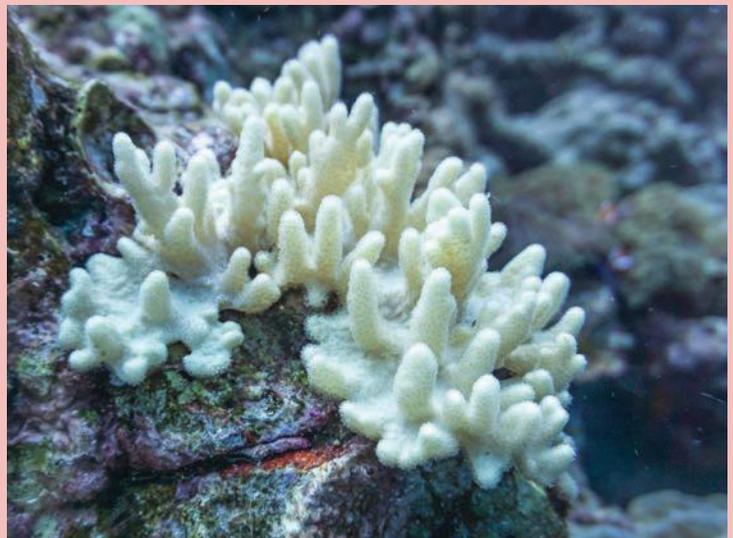


Figure 3.9 A coral that has undergone coral bleaching

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 **sympiotic** relationships

are all examples of different types of interactions between organisms.

Symbiosis means ‘to live together’, and 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.

sympiotic
a relationship between two types of living things that help at least one of them survive

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 prey on and eat 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 sugarbird feeds on the nectar from the king protea flower. As they reach the nectar, pollen gets stuck on their beak, so helping the flower to pollinate.
Commensalism	Benefit	No effect	One organism benefits and the other is unaffected.	The remora, also called a sharksucker or suckerfish, rides sharks and other fish 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 sympiotic interactions.



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

What is the interaction?**Try this 3.4**

Look at each of the following images and with a little research, decide which 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

QUIZ

Remembering

- 1 List the components of an ecosystem, from largest to smallest.
- 2 List some environmental features found at the Great Barrier Reef.
- 3 List three biotic features of the Great Barrier Reef.
- 4 Define the terms 'parasitism', 'mutualism' and 'commensalism'.

Understanding

- 5 Name a population in the reef and state its abundance.
- 6 Define the term 'habitat'.
- 7 Provide examples of organisms in symbiosis and explain whether they are in parasitism, mutualism or commensalism.

Applying

- 8 Using what you have learned about interactions in ecosystems, think of 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

continued...

...continued

Analysing

- 10 Compare the terms 'ecosystem' and 'environment'.
 11 Using a Venn diagram, compare and contrast abiotic and biotic factors in an ecosystem.

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.'
 Do you agree with this statement? Give reasons for your decision.



3.2 Food chains and food webs



WORKSHEET

Energy

We have a lot in common with all the living creatures around us, such as dogs and fish and even a slug, 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 to eat but because they do not have mouths 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 the food, it then needs to turn this food into energy. It does this by breaking down the sugars in food, called glucose, in a process called **cellular respiration**.

This is the cellular respiration word equation:

glucose + oxygen → energy + carbon dioxide + water



energy
the ability to do work producing heat or motion

cellular respiration
the chemical process by which cells release energy from food to be used



Figure 3.13 We all need to eat.

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. Add the term to your glossary.
 - 2 Explain what energy is needed for.
 - 3 Cellular respiration is a necessary process carried out by plants and animals; explain why.
 - 4 List the inputs and outputs of the process of cellular respiration.

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 the Sun's light and water them 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



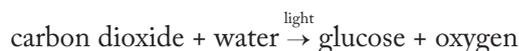
Figure 3.14 Green leaves absorb light energy from the Sun to make food.

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.

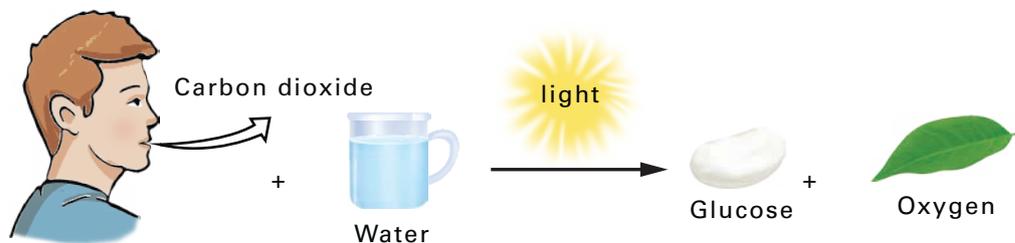
photosynthesis
the process by which a plant uses the energy from the light of the Sun to produce its own food

producer
an organism capable of producing food from photosynthesis

This is the photosynthesis word equation:



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



Practical 3.1

Observing photosynthesis

Aim

To investigate how light energy affects photosynthesis by placing a plant in the light and a plant in the dark and observing the change in colour of bromothymol blue indicator.

Materials

- aquatic plant
- bromothymol blue solution (acts as an indicator to show if photosynthesis is occurring)
- 3 conical flasks
- 500 mL beakers
- large measuring cylinder
- straws
- plastic wrap or stopper
- foil
- tray

Method

- 1 Pour 250 mL of water into a 500 mL beaker.
- 2 Add enough drops of bromothymol solution to turn the water a pale blue colour.
- 3 Using a straw, GENTLY blow into the solution causing it to bubble for approximately 1 minute. Record your observations. Note:
 - bromothymol blue + CO₂ = *green colour*
 - bromothymol blue + no CO₂ = *blue colour*
- 4 Label three conical flasks: 1, 2, and 3
 - Flask 1 will be the control (no aquatic plant)
 - Flask 2 will be the aquatic plant in the dark
 - Flask 3 will be the aquatic plant in the light
- 5 Pour 75 mL of the bromothymol blue + water solution from step 3 into each of the three conical flasks.
- 6 Cover flask 1 with plastic wrap or stopper.
- 7 Add a 7 cm piece of the aquatic plant to flask 2. Using your straw, GENTLY push the aquatic plant to the bottom of the flask. Then completely cover flask 2 with tinfoil.
- 8 Add a 7 cm piece of the aquatic plant to flask 3. Using your straw, GENTLY push the aquatic plant to the bottom of the flask. Cover the flask with plastic wrap or a stopper.
- 9 Place the labelled flasks onto a tray and leave next to a window until next lesson.
- 10 Complete the following sentence. This will form your hypothesis (prediction) which is based on the variables we are changing (plants in the light or the dark) and measuring (the colour change of bromothymol blue) during this experiment.
 It is predicted that the aquatic plant in flask 3, because it is exposed to the light energy, will carry out photosynthesis and use up the carbon dioxide in the water. This will turn the bromothymol blue _____ colour.
 It is predicted that the aquatic plant in flask 2, because it is not exposed to the light energy, will not carry out photosynthesis and therefore not use up the carbon dioxide in the water. This will mean the bromothymol blue is _____ colour.
- 11 Record your observations of the bromothymol blue colour in your next lesson.

Results

Colour of bromothymol blue

continued...

...continued

Flask	Colour day 0	Colour next lesson
Flask 1 (light, no aquatic plant)		
Flask 2 (dark)		
Flask 3 (light)		

Evaluation

- 1 Describe your results for flasks 2 and 3 in sentences.
- 2 Reread your hypothesis. State whether your results support your hypothesis (that is, they agree with each other). Explain why you think this happened.
- 3 Flask 1 is called a control flask. Find out what a control is and then outline why it is important to have this flask with no aquatic plant.
- 4 State at least three variables that you kept the same in this experiment to ensure it was a fair experiment.
- 5 Remind yourself of the key terms 'qualitative' and 'quantitative', then state whether your results were qualitative or quantitative.
- 6 Devise a version of this experiment where the results would be quantitative.

Conclusion

From this activity we can claim that light _____. This is supported through observations that _____. This means that _____.

- Quick check 3.4**
- 1 Discuss why plants are called producers. Add the term 'producer' to your glossary.
 - 2 Explain why photosynthesis is a process carried out by plants.
 - 3 List 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, 'how come we don't 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



Figure 3.15 A giraffe consuming a producer

of the energy we would need. This would not give us much time to do anything else!

consumer
an organism that obtains food from consuming other organic material

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

Producers and consumers

Look at the pictures of Australian organisms in Figure 3.16 and sort them into producers and consumers.

Try this 3.5



Wattle



Quokka



Fruit bat



Eucalyptus



Koala



Bottlebrush



Kangaroo paw



Kangaroo

Figure 3.16

Life deep under the sea

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. 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.

Did you know? 3.1



Figure 3.17
Examples of life around a deep-sea hydrothermal vent

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

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

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.

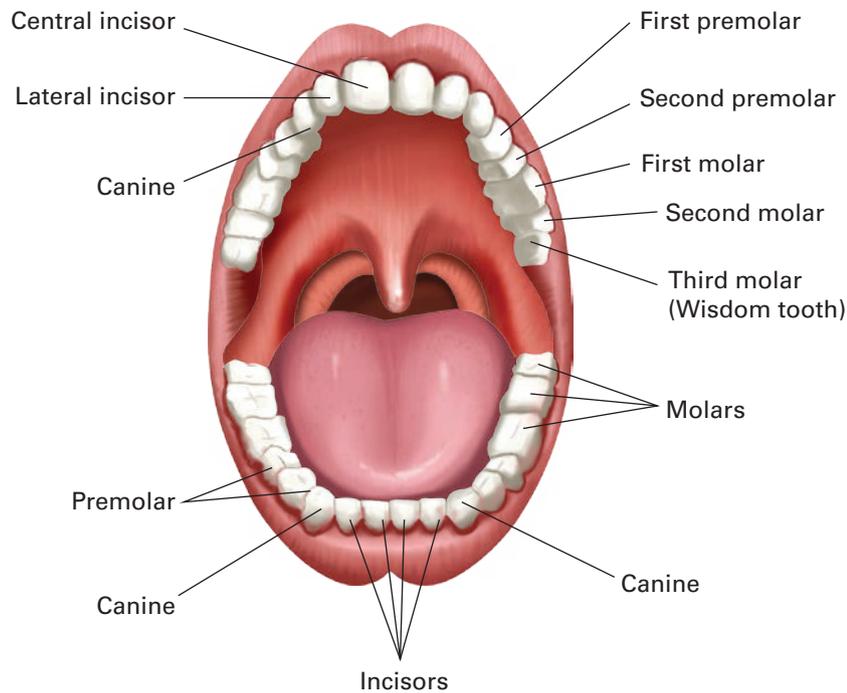


Figure 3.18 Human teeth identify us as omnivores.

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, as they are used constantly they tend to wear down. Due to this, the

incisors of animals like 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.



Figure 3.19 A rabbit's incisors keep growing throughout its life.



Figure 3.20 A leopard showing off her impressive canines

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.



Figure 3.21 A cow using her molars to chew some grass

Herbivores have large molars that allow them to grind plant material into very small pieces before swallowing.

Animal teeth

Try this 3.6

Ask your teacher if you can view a random selection of animal skulls. You may be able to identify some of the animals you see but take on the role of a scientist and check their teeth. Do they have incisors? Canines? Molars? Can you confirm what the animal might eat and therefore have more evidence as to what the animal is? You may like to tabulate your observations and then compare with your class mates.

- 1 Define the term 'consumer' in your own words. Add the term to your glossary.
- 2 There are three main types of consumer.
 - a List the three types.
 - b Define what each group eats.
- 3 Examine the images in Figure 3.22 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.

Quick check 3.5

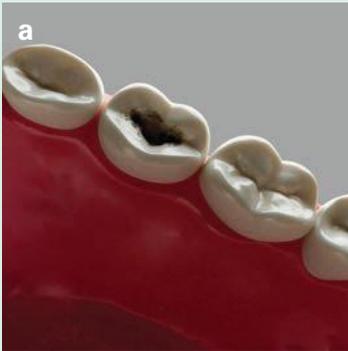


Figure 3.22



VIDEO

Create the food web for one of these animals.

Food chains: Who eats whom?

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**.

food chain

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

An example of a simple food chain would be:

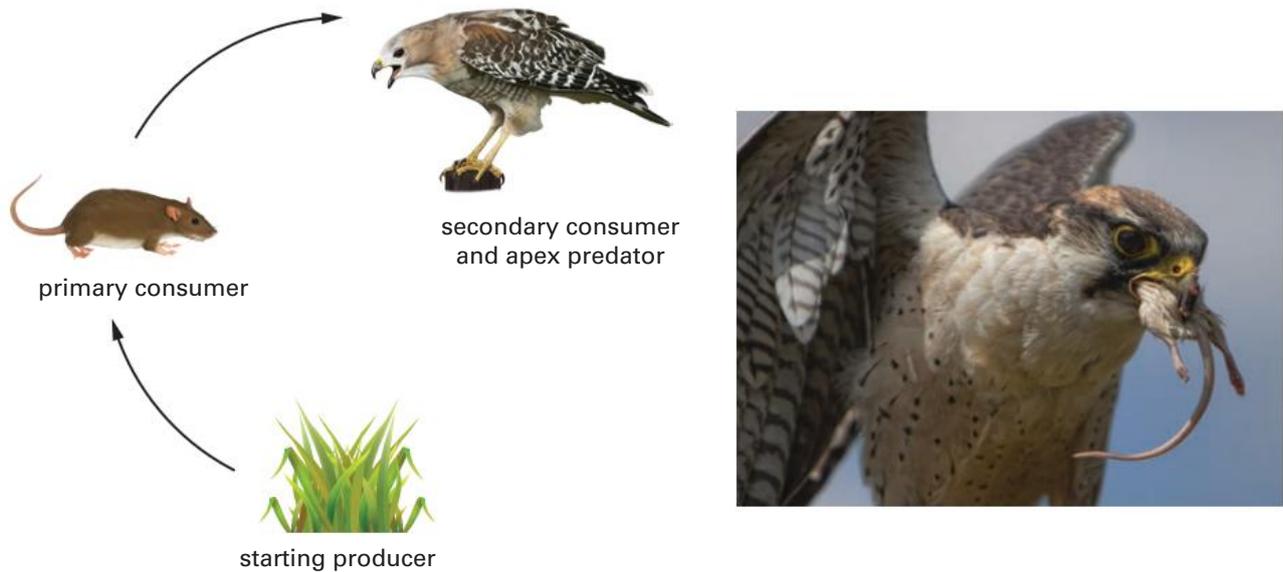


Figure 3.23 A hawk is an example of an apex predator as it has no natural predators.

The food chain in Figure 3.23 introduced some new terms, which are explained in Table 3.4.

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. Can be a carnivore or omnivore.	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

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

Table 3.4 Consumers can be classified into these groups, based on their position in 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 pancake food chain and also the burger food chain.

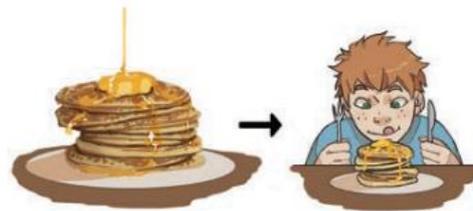


Figure 3.24 Pancake food chain

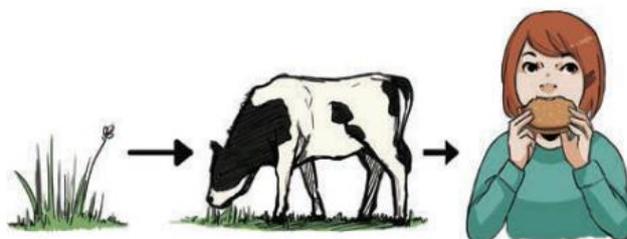


Figure 3.25 Burger food chain

What food chains can tell us

Try this 3.7

Consider the food chain in Figure 3.26 to answer the questions.

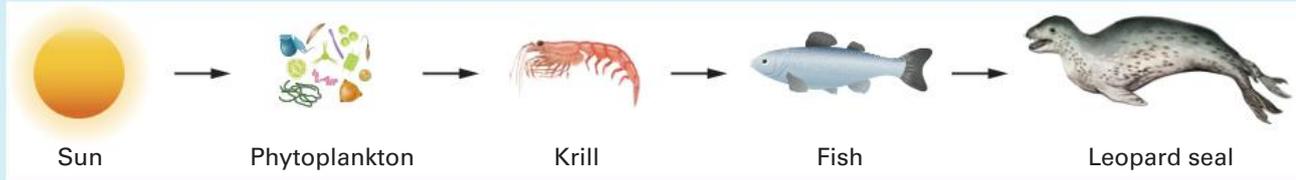


Figure 3.26 What does this food chain tell us?

- 1 What do the arrows show the flow of?
- 2 Where does all the energy originally come from?
- 3 Label the producer, first consumer, second consumer, tertiary consumer and apex predator.
- 4 Identify who is the herbivore.
- 5 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 kill all the phytoplankton?

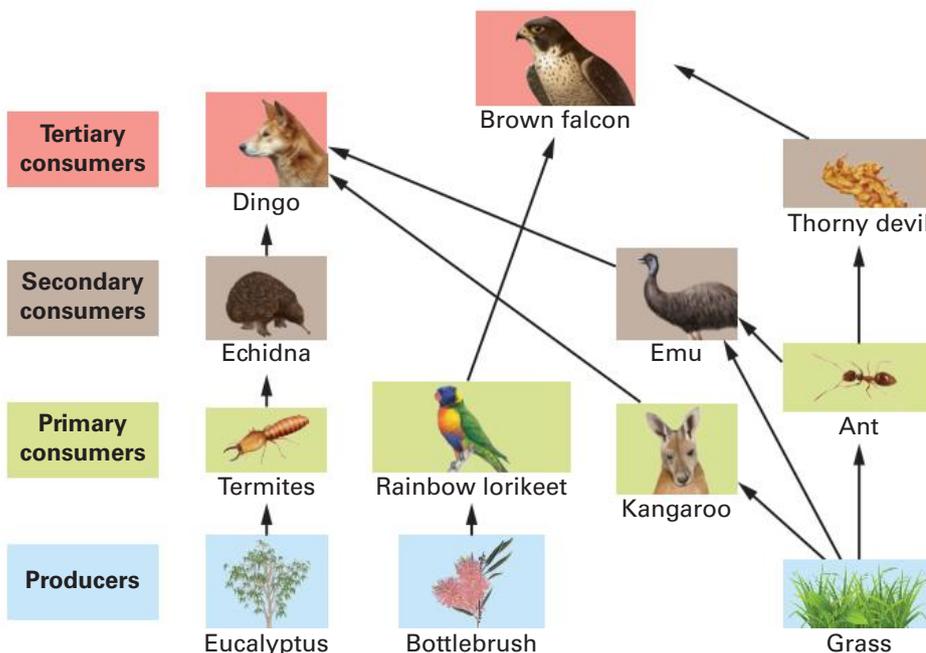
- 1 Define the term 'food chain' in your own words. Add the term to your glossary.
- 2 What do the arrows represent in a food chain?
- 3 Where should the Sun go in a food chain and why?
- 4 Draw an Australian food chain of your choice and identify the producer, primary consumer, secondary consumer, tertiary consumer and apex predator.
- 5 What sort of information can you find out from looking at a food chain?
- 6 What is a food web?

Quick check 3.6

Food webs

There are many different types of organism in any habitat. There are also many food

chains that are interlinked. These interlinked food chains are known as a **food web**.



food web a group of interweaving food chains

Figure 3.27 An example of an Australian food web

If you look at the food web in Figure 3.27, 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 level of the food chain as it passes from the Sun to the producer and consumer. Each organism uses up most of the energy it consumes in the following ways:

- carrying out processes like growing, moving and reproducing
- lost as heat when the organism uses the food to fuel its living processes such as respiration
- lost 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 3.28 shows this loss of energy. Note that kcal is a unit of energy. It is equal to about 4000 joule.

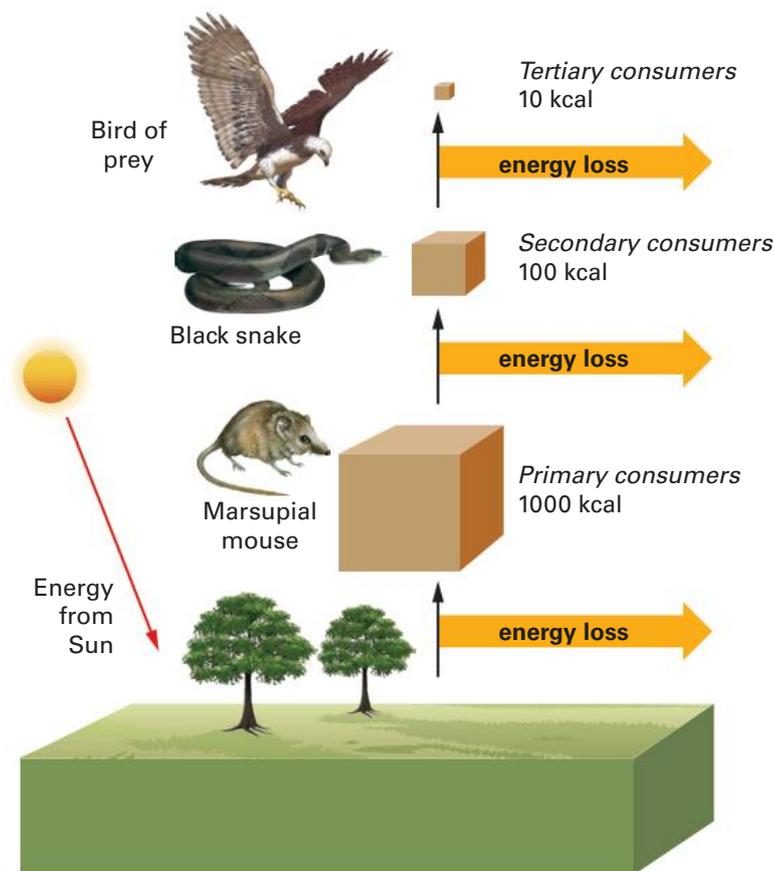


Figure 3.28 The energy flow and loss through a food chain

- 1 What do organisms need energy for?
- 2 How is energy lost from an organism or a food chain?
- 3 What do you notice about the amount of energy (kcal) that is passed on from the producers to the primary consumers and from the primary consumers to the secondary consumers?
- 4 **Challenge question:** Can you work out how much energy is passed on as a percentage of the original kcal?

Quick check 3.7

Practical 3.2

Food web model

Aim

To model the flow of energy in food webs from producer to consumers.

Materials

- photos of producers, primary consumers, secondary consumers, tertiary consumers and apex predators
- different coloured balls of wool
- scissors

Method

- 1 Each of you will be allocated a photo.
- 2 Stand in a circle as a class and pass the end of a piece of wool to a producer. The piece of wool will represent the flow of energy along the food chain.
- 3 Ask the producer what primary consumer it wishes to be eaten by.
- 4 Pass the wool to the primary consumer and ask them to choose the secondary consumer they wish to be eaten by. Repeat this process with the secondary consumer.
- 5 When the wool reaches the apex predator, cut the line but make sure you keep hold.
- 6 Repeat this process many times starting with different producers.
- 7 A complex web will form between you and your class mates.
- 8 Discuss the complex nature of the food web you have produced as a class.
- 9 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.

Results

Take a photo each time a food chain is made, so that the development of the web can be seen.

Evaluation

- 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. Is this the same or different to losing a consumer from the food web? Explain.
- 3 Suggest why an ecosystem with many types of organisms would be able to cope with the loss of one species.
- 4 Assess whether your model of a food web accurately depicts a real ecosystem.
- 5 Propose one way in which this model could be improved.

Conclusion

From this activity we can claim that energy _____. This is supported through observations that _____. This means that _____.

How wolves changed the course of a river

Explore! 3.2

Yellowstone National Park is a national park 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.



Figure 3.29 Grey wolf in Yellowstone National Park

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



Figure 3.30 Elk crossing a river

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



Figure 3.31 Loss of habitat for beavers

continued...

...continued

to drop. 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 even out water flow when storms hit and provide cold shaded water for fish and as there are more willows, there are more trees to provide habitats for birds.

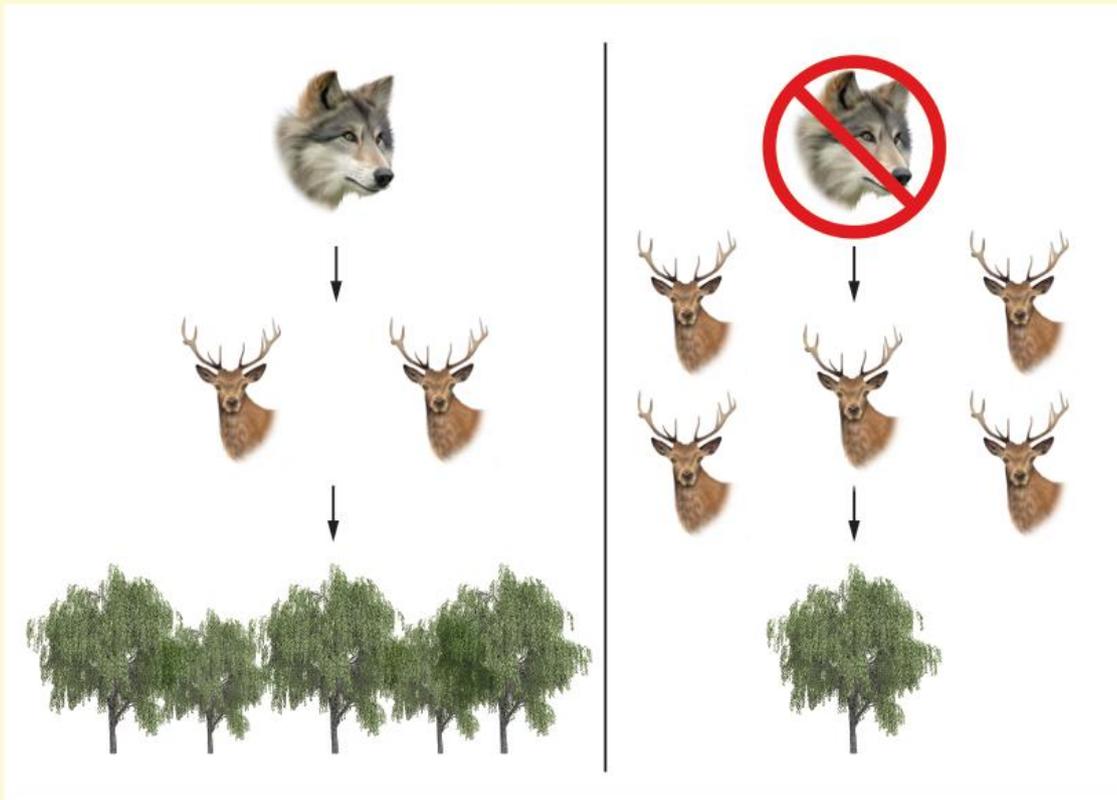


Figure 3.32 A pictorial representation of how the wolves have brought balance back to Yellowstone National Park.

Do some research into this amazing change brought about by the reintroduction of wolves.

- 1 List 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.' Assess this statement and give your opinion.



QUIZ

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.

continued...

...continued

Understanding

- 4 Define these terms:
 - a carnivore
 - b herbivore
 - c omnivore.
- 5 Outline why all food chains must contain a producer.

Applying

- 6 Look at the food web in Figure 3.33.
 - a Identify and draw 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 Are there any organisms that are secondary and tertiary consumers?
 - e Describe the impact on this ecosystem if a fungus killed all the grasses.

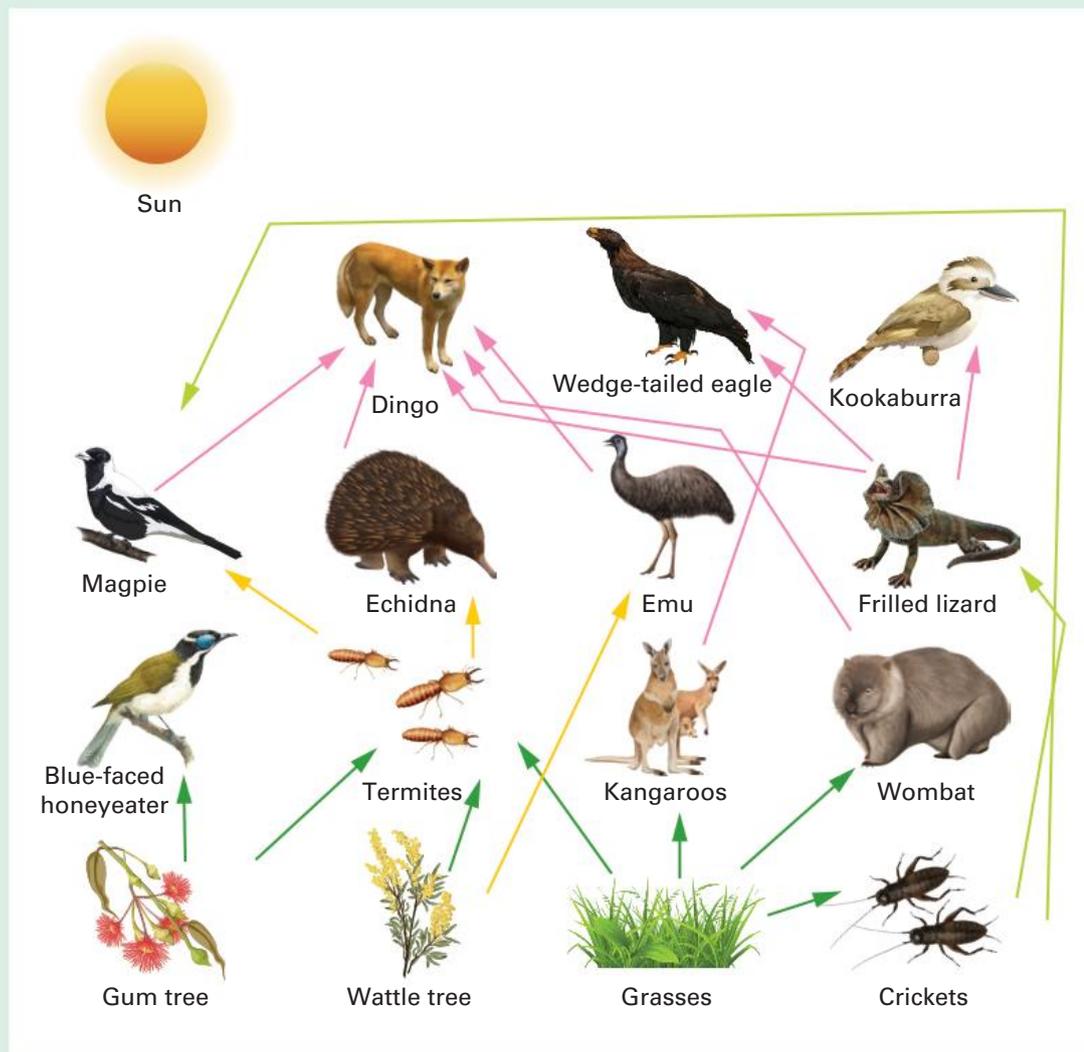


Figure 3.33 A food web

continued...

...continued

Analysing

- 7 Compare a herbivore to 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 3.34 and decide which one is more likely to survive an environmental disaster. Explain your choice.

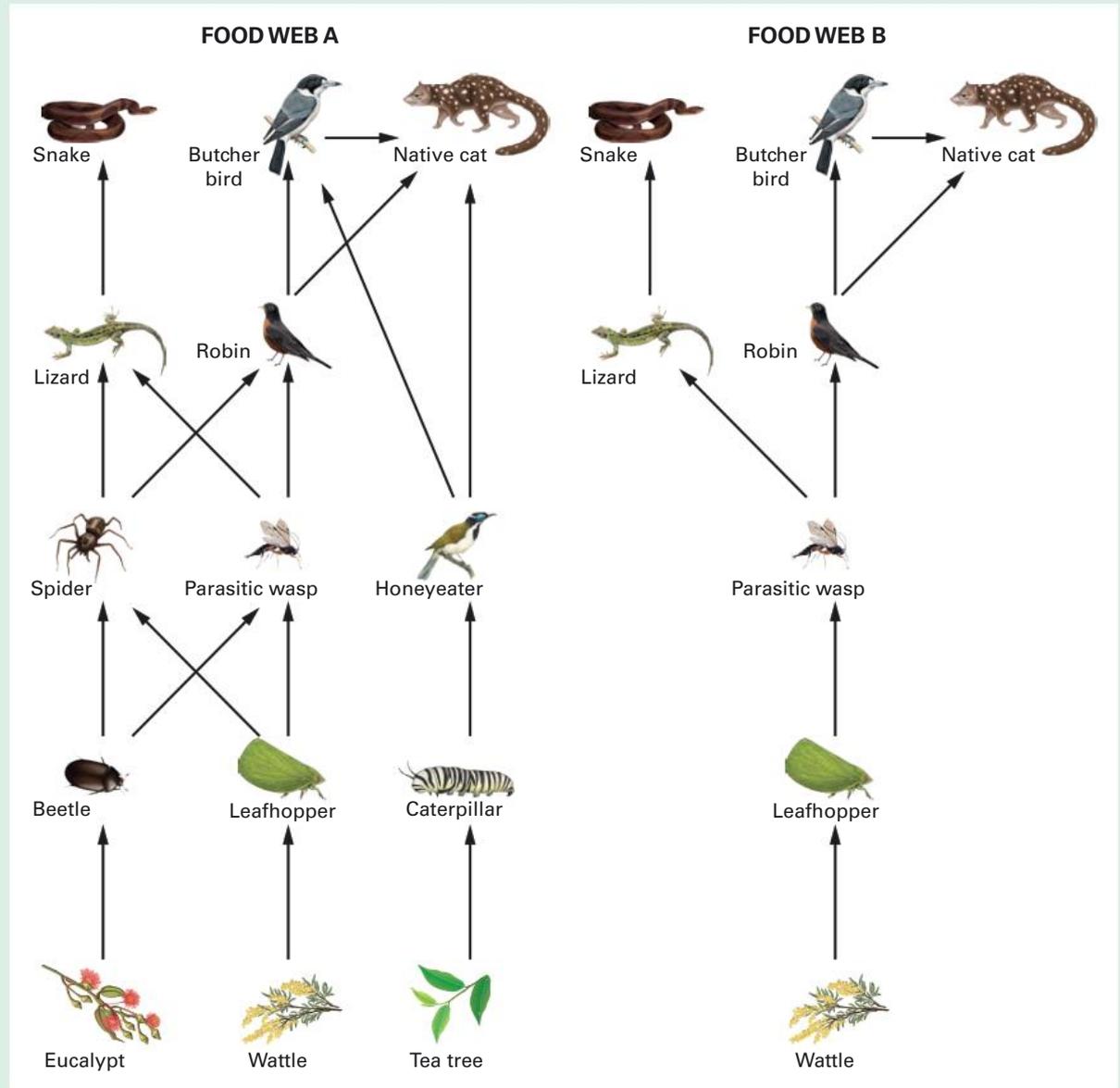


Figure 3.34 Two different ecosystems support these two food webs.

Evaluating

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



WIDGET
Food web



3.3 Recycling in ecosystems

All living things within an ecosystem fall into three categories:

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

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 Australian 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 spend energy to kill their prey, but they use their sense of smell to find their food.



WORKSHEET

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



Figure 3.35 Scavengers: a hooded crow in Ukraine and dingoes in Australia

Decomposers

Decomposers gain their energy by breaking down already dead organisms. Decomposers are found in most living kingdoms. For example, slugs and worms are decomposers in the Animal kingdom whereas mushrooms are decomposers found in the Fungi kingdom.

Decomposers break down dead organisms, which 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 3.36 Decomposers hard at work

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

Detritivores

Detritivores are a group of decomposers that do not consist of microorganisms. They help speed up decay by feeding on detritus (dead and decaying material) by ingesting it, and thereby increasing the surface area available for

detritivore

an organism that feeds on dead or decaying organic matter

microorganisms like bacteria and fungi to feed off. Detritivores include insects such as beetles, flies, slugs, snails and earthworms. Marine detritivores include crabs, lobsters, sea stars and sea cucumbers.

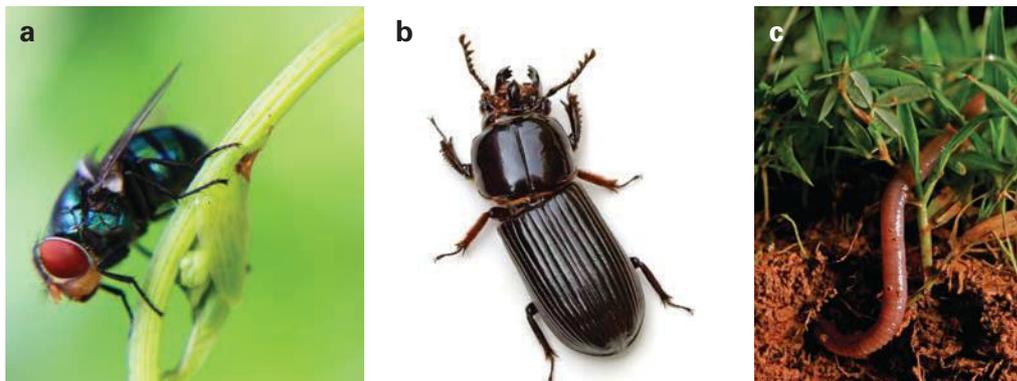


Figure 3.39 Examples of detritivores: (a) flies, (b) beetles and (c) earthworms.

We need bacteria in our bodies!

Did you know? 3.2

Although it is a myth that we have many more bacteria cells in our bodies compared to our own cells recent research has show that we have nearly an equal amount.

Bacteria help our bodies in the following ways:

- competing with invaders for space and nutrients
- producing compounds which kill harmful bacteria
- lowering the pH so that other bacteria cannot grow
- producing vitamins we are unable to produce such as vitamin B12
- helping us digest food.

Some people even take pro-biotics, which are drinks that contain beneficial bacteria

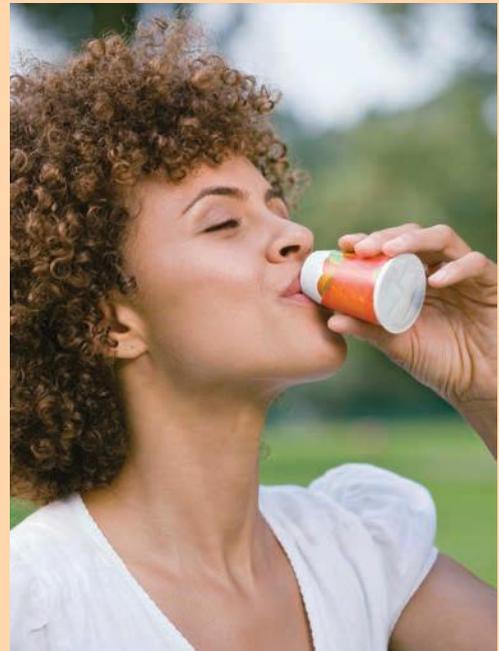


Figure 3.38 Beneficial bacteria can be ingested in foods like yoghurt or pro-biotic drinks.

- 1 State what happens to an organism in an ecosystem after the organism dies.
- 2 Define the terms 'scavenger' and 'decomposer' in your own words. Add the terms to your glossary.
- 3 List five examples of decomposers.
- 4 Define the term 'detritivore'.
- 5 Explain why plants rely on decomposers.
- 6 Distinguish between scavengers and decomposers.

Quick check 3.8**Practical 3.3: Self-design****Friendly bacteria****Aim**

To observe if 'friendly' bacteria found in yoghurt can prevent harmful bacteria in mould from growing on different decaying food surfaces.

Materials

- yoghurt solution (made with Greek yoghurt starter powder containing live cultures)
- apple, melon and carrot peel (10 cm strips)
- 1 slice of bread
- takeaway food containers
- small paint brush

Method

- 1 Paint 5 cm of the fruit and vegetable peel with the yoghurt solution on the flesh side. Leave the other 5 cm blank to use as a control (comparison).
- 2 Paint half of the slice of bread with the yoghurt solution. Keep the other half clean. This will be your control.
- 3 Place all food into takeaway food containers with the yoghurt side face-up.
- 4 Cover the container and label the side with your group name.
- 5 Write a hypothesis or prediction about what you expect the growth of mould to be like on each food item, and whether the yoghurt will prevent its growth.
- 6 Observe the growth of microorganisms in the container over 12 days and record your observations in the results table below.
- 7 Keep a photo log of the experiment to compare the changes observed over the 12 days.

Results

Food tested	Observation 1 (day 3)	Observation 2 (day 6)	Observation 3 (day 9)	Observation 4 (day 12)

Be careful

Do not open the container once closed and do not consume any food product. Ensure all materials are disposed of in the appropriate manner.

continued...

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Evaluation

- 1 Outline how effective the bacteria in the yoghurt was at preventing other microorganisms from growing.
- 2 Compare the growth of microorganisms on each food type. Assess which food is likely to spoil quicker.
- 3 If you repeated this experiment keeping the food the same but changing the dilution of the yoghurt mixture, what would be your independent variable?
- 4 Develop a hypothesis for the experiment outlined in question 3.
- 5 Suggest some sources of error in this experiment and how you might be able to reduce them in the future.

Conclusion

From this activity we can claim that certain bacteria _____. This is supported through observations that _____. This means that _____.

Brown food chain

You already know consumers get their energy from producers or other consumers, and that 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 by photosynthesis. What might surprise you is that only 10% of plants are eaten while they are alive. This 10% of living plants forms the base of the green food chain.

But what happens to all the energy stored in the other 90% of plant material that does not get eaten? It becomes detritus and forms the base of the 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, we are rather squeamish when it comes to dead and rotting material as we did not evolve eating waste and it

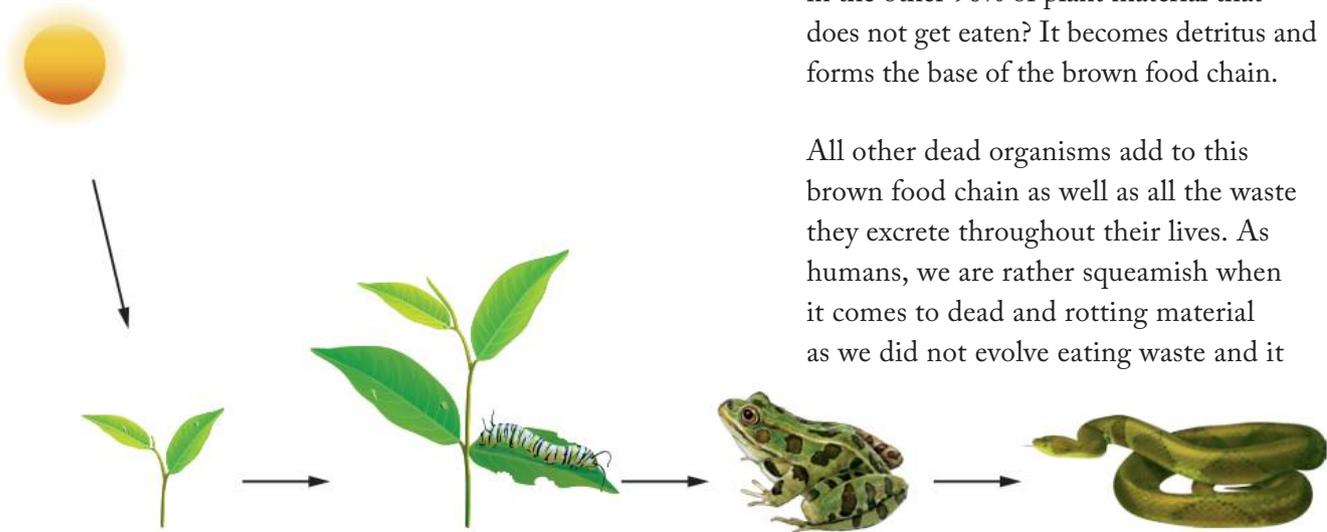


Figure 3.40 Green food chain

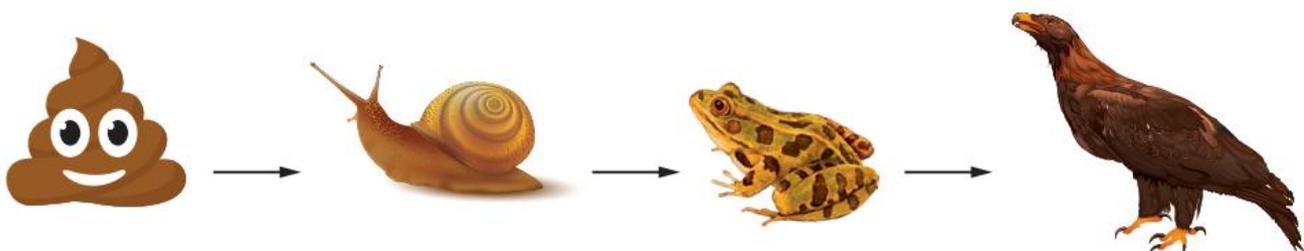


Figure 3.41 Brown food chain

can make us very sick. However, many organisms on Earth get at least some of their energy directly from detritus. This is why dogs sometimes eat faeces (poop) and do not get sick if they eat meat that is slightly passed the use by date.

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 3.42 Some dogs eat their faeces and do not get sick.

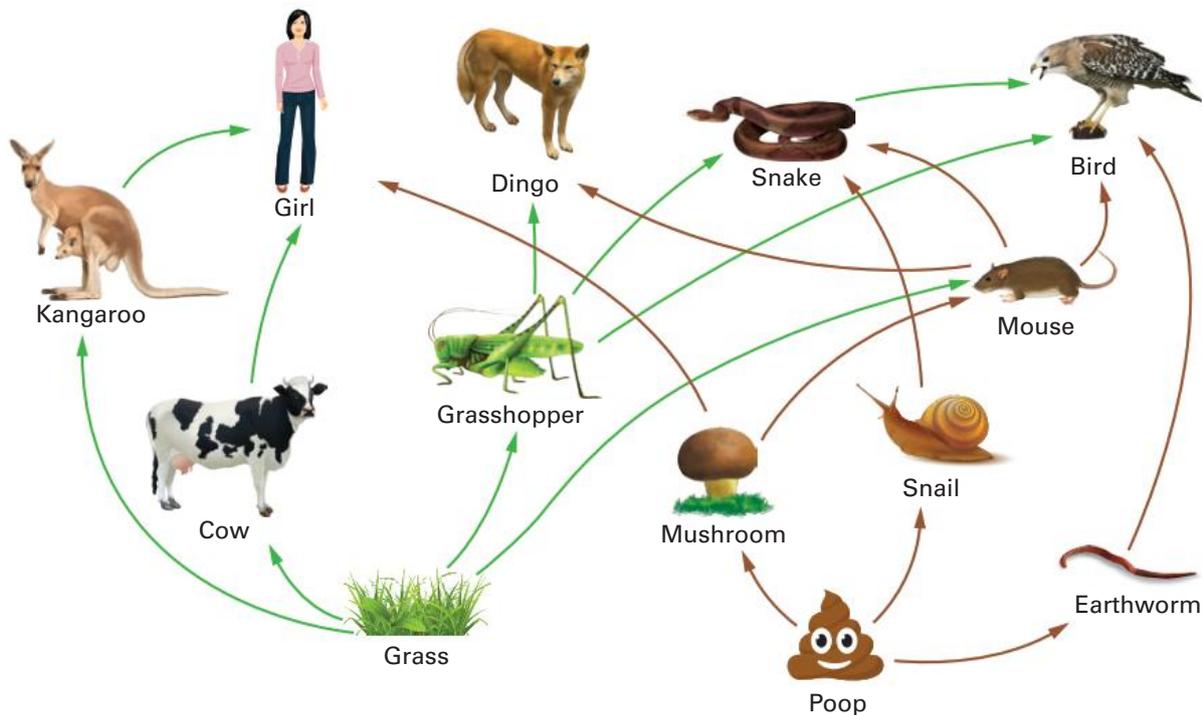


Figure 3.43 Combined green and brown food webs

Practical 3.4: Self-design

Designing an investigation into the role of decomposers

Aim

To determine if a type of fungi called yeast are needed to decompose organic material in an ecosystem.

Materials

- zip-lock bags
- 1 banana (organic material)
- dry yeast (a type of fungi)
- camera

Be careful

Do not open the container once closed and do not consume any food product. Ensure all materials are disposed of in the appropriate manner.

continued...

...continued

Method

- 1 Brainstorm with your classmates how you could find out if fungi are needed to decompose organic material in an ecosystem. Look at the list of the materials you have access to as this may help.
- 2 Identify the variables in your experiment.
 - What are you deliberately changing? (independent variable)
 - What are you measuring? (dependent variable)
 - What are all the other factors that could change but you need to control (keep the same)?
- 3 Construct a detailed method to explain the procedure you will follow in your experiment. Set it out in step-by-step form. Remember, another scientist should be able to read this procedure and replicate your experiment exactly, so be precise.
- 4 Write a hypothesis or prediction based on what you are trying to find out; for example, do you think fungi are needed to break down organic matter in an ecosystem?
- 5 Show your teacher your plan, and with their approval, carry out your experiment.

Results

Construct an appropriate results table to document your findings.

Evaluation

- 1 Describe what your results show.
- 2 Did your experiment results support or not support your hypothesis? Explain.
- 3 Did anything go wrong that you did not control for?
- 4 How would you alter your experiment next time to prevent this?

Conclusion

From this activity we can claim that yeast _____. This is supported through observations that _____. This means that _____.



QUIZ

Section 3.3 questions

Remembering

- 1 State the percentage of plant matter that is decomposed.
- 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 Design 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 Summarise the role/s that scavengers can play in an ecosystem. Are they only scavengers or can they have other roles too?
- 8 Look at Figure 3.44 and using your knowledge of decomposers, describe what is happening.

continued...

...continued



Figure 3.44

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 Consider 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

Biodiversity

When scientists look at all the different types of animals found in an area, they start to talk about **biodiversity**. Biodiversity

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

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, shades 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.



WORKSHEET

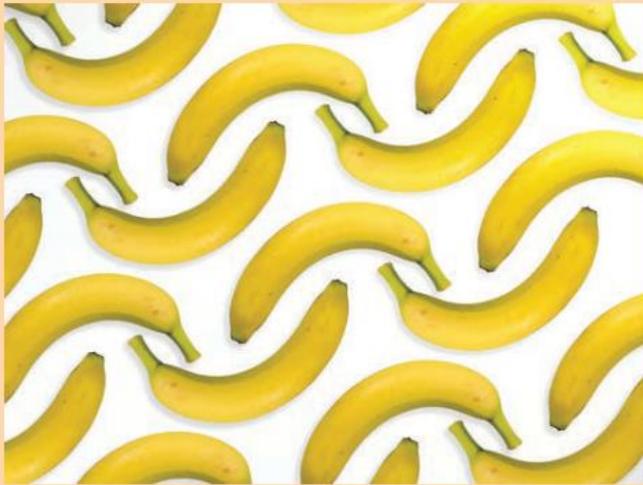


Figure 3.45 Many bananas are clones.

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.

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. Around 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 around 73% of all animal species.

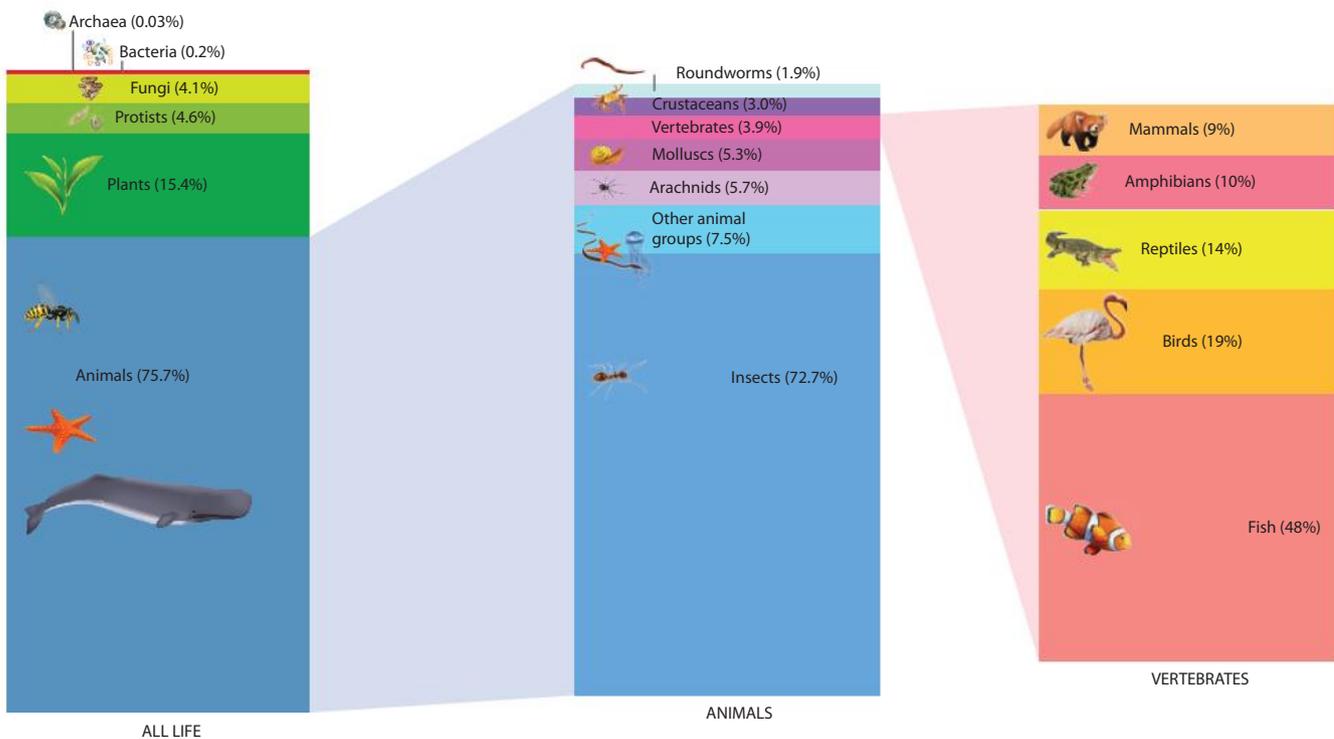


Figure 3.46 Species biodiversity on our planet

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 3.5

Assessing the biodiversity at your school

Aim

To assess the biodiversity of two areas in your school.

Materials

- butterfly net
- individual whiteboard
- pole (similar to a broom handle)
- large zip-lock bags
- poles or posts
- metre ruler
- string
- tweezers
- magnifying glass
- small paint brush

Method

- 1 Choose two different areas to assess within your school, such as a grassy area and a garden.
- 2 Rope off a 1 metre square section of the first area using your metre ruler, poles or posts and string. This square is called a quadrat (survey area).
- 3 Use the three methods below to gather invertebrates from each area. Once you have gathered all the invertebrates from each section, return to your classroom to identify them.

Butterfly net

- 1 Swish your butterfly net over any vegetation in your quadrat, lightly tapping the tip of the net on the corners of the plants.
- 2 Use a gentle continuous swooping motion until you have covered your entire quadrat.
- 3 When you have finished, hold the net near the opening to prevent any invertebrates from escaping.
- 4 Open your large zip-lock bag and carefully turn the net inside-out inside the bag to remove any invertebrates you have gathered.
- 5 If you gather any stinging insects, ask your teacher for assistance.
- 6 Remove the net and seal the bag.

Tree tapping

- 1 If you have any trees or bushes in your survey area, use the whiteboard and pole for this method.
- 2 Place the whiteboard at arm's length under a tree or bush and have a partner tap the tree or bush with the pole to shake loose any insects.
- 3 Be careful that no insects fall onto you.
- 4 Observe the insects you collect on the whiteboard and brush them into a zip-lock bag using the paint brush.

Quadrat

- 1 Subdivide your quadrat into four sections and allocate each section to a group member.
- 2 Get on your hands and knees and use the magnifying class and tweezers to pick up any invertebrates you find in your section.
- 3 Place these into a zip-lock bag.

continued...

...continued

Results

- 1 Combine your results with the whole class and produce a results table for each of the survey areas.

Area description	Species found	Number of individuals
Example: school oval	Example:	
	Large ant	10
	Green beetle	1
	Snail	1
	Ladybird	3
	Aphid	8
	Total number of species	5
	Total number of individuals	23

- 2 Calculate the biodiversity index (how biodiverse an area is) for each survey area by using the following equation:

$$\text{Biodiversity index} = \frac{\text{Number of species in an area}}{\text{Total number of individuals}}$$

For example, in the school oval survey above:

$$\begin{aligned} \text{Biodiversity index} &= \frac{5}{23} \\ &= 0.22 \end{aligned}$$

Evaluation

- 1 Outline the level of biodiversity in each survey area, referring to the biodiversity index you calculated.
- 2 Suggest a reason for any differences you found when comparing the two survey areas.
- 3 Propose a reason that quadrats were used in this experiment.
- 4 Assess the strengths and weaknesses of each collection method in a table.

Conclusion

From this activity we can claim that in the areas of interest _____. This is supported through observations that _____. This means that _____.

Aboriginal land management

Bushfires are common in Australia. With 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.

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 is less common than lightning as a cause. Humans can light fires either deliberately or accidentally.



Figure 3.47 Lightning naturally starting a bushfire

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

firestick farming

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

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 hide behind, the 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 animals in the area new sources of food.

Two types of fires were used for firestick farming.

- **Cool fires** were low intensity and happened regularly to clear the undergrowth. They did not damage the larger plants and were used to clear paths and promote the growth of food plants for both humans and grazing herbivores.



Figure 3.48 Regrowth of plants after a bushfire

- **Hot fires** were used more sparingly as they burnt areas of thick vegetation including trees and shrubs, which are important habitats for animals. These fires were very dangerous and destructive, killing everything in their path. Because of this, they were only used in overgrown areas where vegetation was struggling to thrive to revitalise the area.



Figure 3.49 Devastating hot fire

- 1 List some causes of fire in Australia before Aboriginal and Torres Strait Islander peoples arrived.
- 2 Outline 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 prevent natural bushfires in summer. Suggest a problem with disrupting this natural event.

Quick check 3.9



VIDEO

Name one danger of prescribed burning.

Science as a human endeavour 3.2

Firefighting in virtual reality

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 3.50 A helicopter 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 ‘hot spots’ 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 of Victoria is destroyed. Some of the biggest rainforests closest to Australia can be found in Borneo and Sumatra. These rainforests contain some of the world’s last remaining pygmy elephants, Sumatran tigers, rhinoceroses and orangutans. The main threat to these species and the rainforests is palm oil farming.



Figure 3.51 Orangutans are treated as pests by farmers in Borneo and Sumatra.



Figure 3.52 Huge area being cleared for palm oil

You may not know it, but you will probably have eaten or used 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 extremely poor, so palm oil farming is crucial for jobs and the economy of these countries.

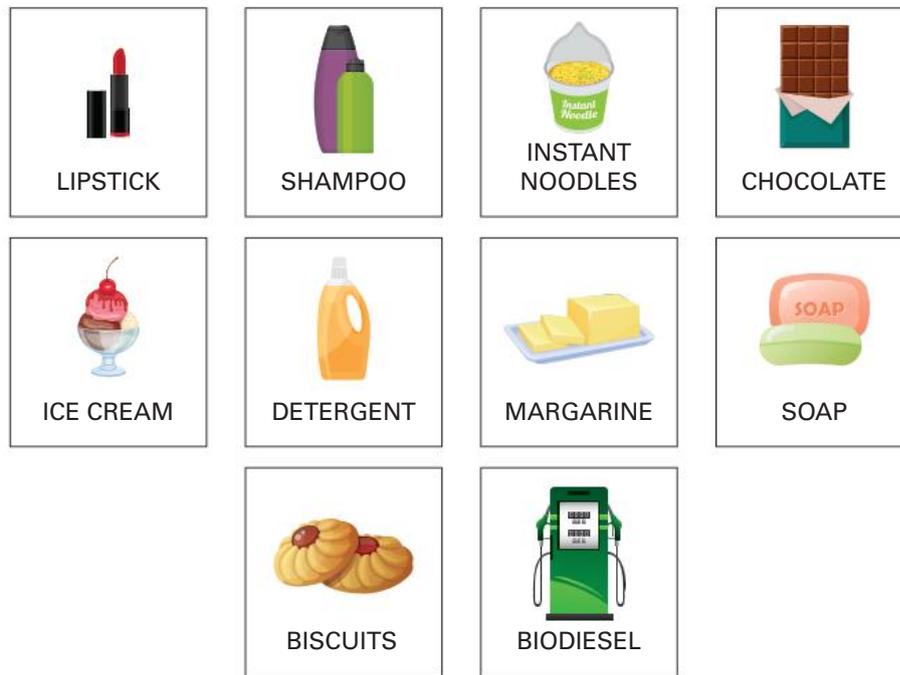


Figure 3.53 These everyday products are likely to contain palm oil.

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 Sumatra 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 3.54 Sumatran tiger

By removing plants and their roots, the thin 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.

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.

deforestation
clearing a wide area of trees
or natural land

The **deforestation** is also a threat to the environment of these areas.



Figure 3.55 Dangerous clearing fires

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:
- 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 the following logo:



Figure 3.56 Can you spot the various things palm oil may be labelled under?

All of these can be labels for palm oil.



Figure 3.57 Sustainable palm oil logo

- 1 Explain why rainforests are referred to as 'Earth's lungs'.
- 2 List 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 List three ways in which you can help reduce the use of palm oil.

Quick check 3.10**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.

Science as a human endeavour 3.3

Figure 3.58 Palm oil seeds

Deforestation in Australia

The logging industry has been cutting down ancient old growth forests in Victoria for over 150 years. This has led to a massive loss of habitat for the Leadbeater's possum and has also put Melbourne's clean water supply at risk.

Professor David Lindenmayer is a landscape ecologist and conservation biologist. He is campaigning for a new national park in the central highlands of Victoria to help protect the remaining forests there. If this national park is approved, it will mean a loss of jobs from local logging companies but might mean a boost in tourism.

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

Explore! 3.3



Figure 3.59 Leadbeater's possum (*Gymnobelideus leadbeateri*)



Figure 3.60 Old growth forest

Invasive species

An **invasive species** is an organism that has been introduced to a new ecosystem by humans and does not originally come from that ecosystem. 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**.

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

biological control
the practise of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

Rabbit-proof fences

calicivirus

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

Rabbits are considered a major pest in Australia. 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.

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 3.62. 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 to attempt to control the rabbit population. Summarise your findings.



Figure 3.61 Rabbit-proof fences were built to try and limit the devastation caused by rabbits.

Explore! 3.4

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 wild in 1935 in Australia their population exploded, and they quickly became a huge pest. Cane toads have many ecological impacts such as competing with



Figure 3.62 A cane toad

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.

Effective control

Not all examples of biological controls 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.



Figure 3.63 Prickly pear plant

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

Try this 3.8

Name	Areas found	Main problems caused	Control measures

Table 3.6 Information on pest animals found in Australia

Section 3.4 questions

Remembering

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

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 phyla 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 an effective biological control.
- 8 Suggest some of the impact that humans are having on oceanic ecosystems.

Analysing

- 9 Compare the use of 'hot fire' and 'cool 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 could be the Orangutan Foundation.

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. Suggest how this might damage the ecosystem.
- 12 Create a pros and cons list on the role of invasive species.



QUIZ



Review questions

Remembering

- 1 List two natural and two human threats to an ecosystem.
- 2 Name the type of teeth that most herbivores are missing.
- 3 State what incisors are used for.
- 4 Recall the characteristics of all living things.

Understanding

- 5 Define 'community' in an ecosystem.
- 6 Describe how energy is lost along a food chain.
- 7 Explain how high biodiversity could be a sign of a healthy ecosystem.
- 8 Summarise the key interactions between species in an ecosystem. For each interaction, provide an example not mentioned in the text.

Applying

- 9 Outline a named example of an organism affecting the abiotic features of an environment.
- 10 Identify some reasons why palm oil farmers treat local wildlife as pests.
- 11 A producer is always part of a food chain. Explain how a producer fits into the brown food chain.
- 12 Using the pictures of organisms in Figure 3.64, create a food web.



Figure 3.64

Analysing

- 13 Copy Figure 3.65 into your notebook.
 - a Use arrows to show the interactions between each organism.
 - b Label each organism as producer, consumer and decomposer. Each organism may have more than one label.
 - c Identify (if any) the herbivores, carnivores, omnivores or detritivores.



Figure 3.65 Various organisms

14 Compare and contrast the roles of decomposers and consumers.

Evaluating

15 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.

16 Look at the food web in Figure 3.66. Explain what would happen if the mouse was removed from the food web.

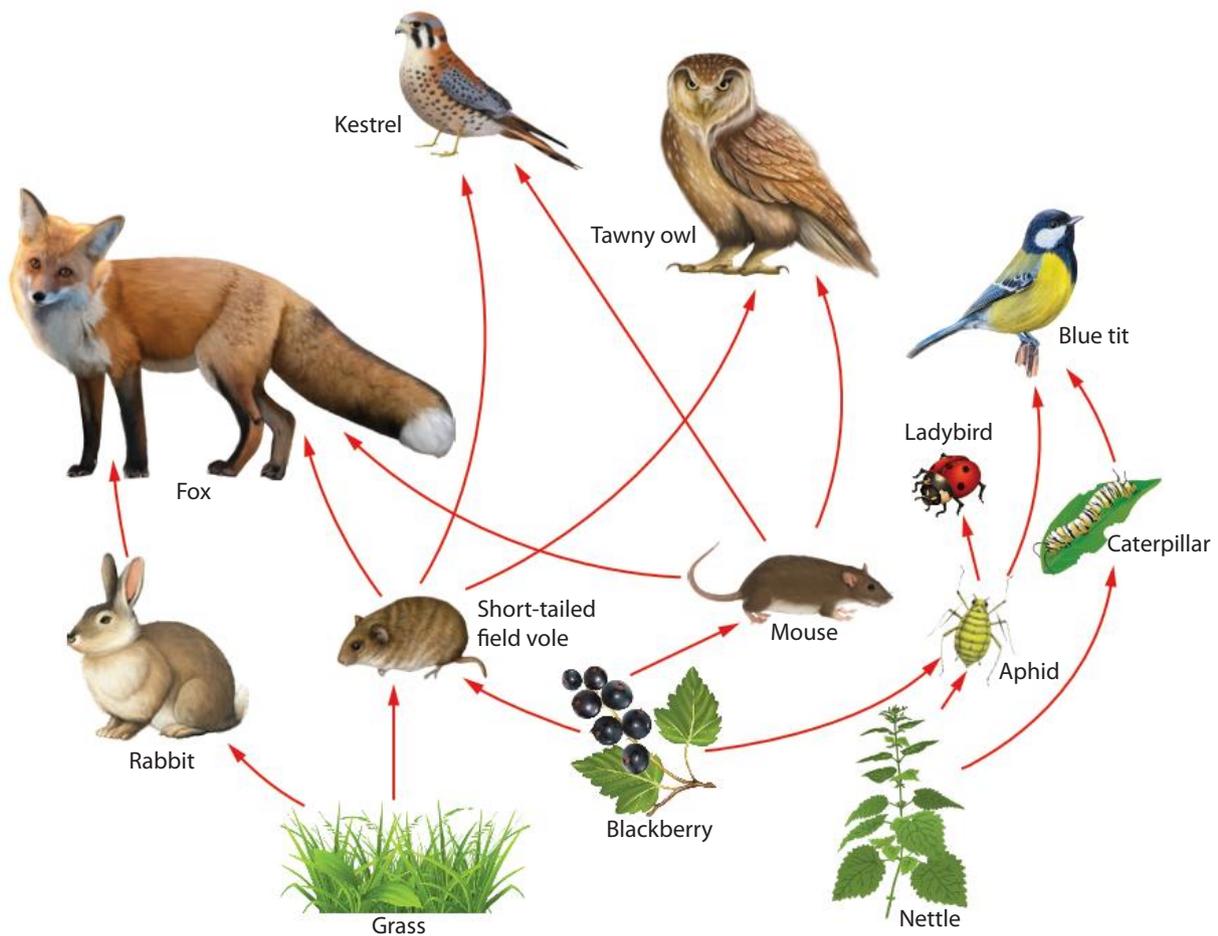


Figure 3.66 A food web

STEM activity: Designing a wildlife crossing

Background information

We could not live without roads and train lines. They have become incredibly important for the way that humans live. However, every time a new road is built, it fragments (splits up) ecosystems and the animals living within those ecosystems are affected in a number of detrimental ways. These effects can include the loss of habitat from the construction of the road, animals being killed by cars and trucks, and animal populations being separated from one another. Wildlife–vehicle collisions also pose a serious threat to motorists and often involve damage to cars as well as drivers and passengers.

In recent years, wildlife crossings have been developed to conserve habitats and allow animals to safely cross human-made barriers. Wildlife crossings (sometimes called animal bridges or eco-passages) can be tunnels, overpasses, canopy bridges and even fish ladders. Engineers have designed the bridges to suit the animals (or groups of animals) that need to use them.

Engineers need to consider many factors when designing a tunnel, overpass or bridge. The biggest consideration is how it will be supported. The best way to build a sturdy bridge is to use triangles. The design of a truss bridge demonstrates this principle. Another common bridge design is the suspension bridge, where cables or ropes support the bridge.

Design brief: Design, construct and test a model wildlife crossing.

Activity instructions

In small groups, choose an animal or group of animals to focus on. Some suggested animals are:

- Christmas Island crab
- pygmy possum
- long-nosed bandicoot
- kangaroo and wallaby
- hairy-nosed wombat
- eastern long-necked turtle

VCSSU093

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VCDSCD049

VCDSCD051

VCSIS113



Figure 3.67 A wildlife overpass in Singapore (top) recently after it was constructed in 2014, and one from Canada (bottom). Wildlife overpasses attempt to reduce wildlife mortality on roads.

- your own choice (needs to be approved by your teacher).

You will need to think about how your animal moves and decide on the most appropriate type of wildlife crossing. These are some questions to think about.

- What is the size of your animal?
- Can your animal climb?
- Will only one animal be crossing at a time or will it be more of a migration (many animals at a time)?

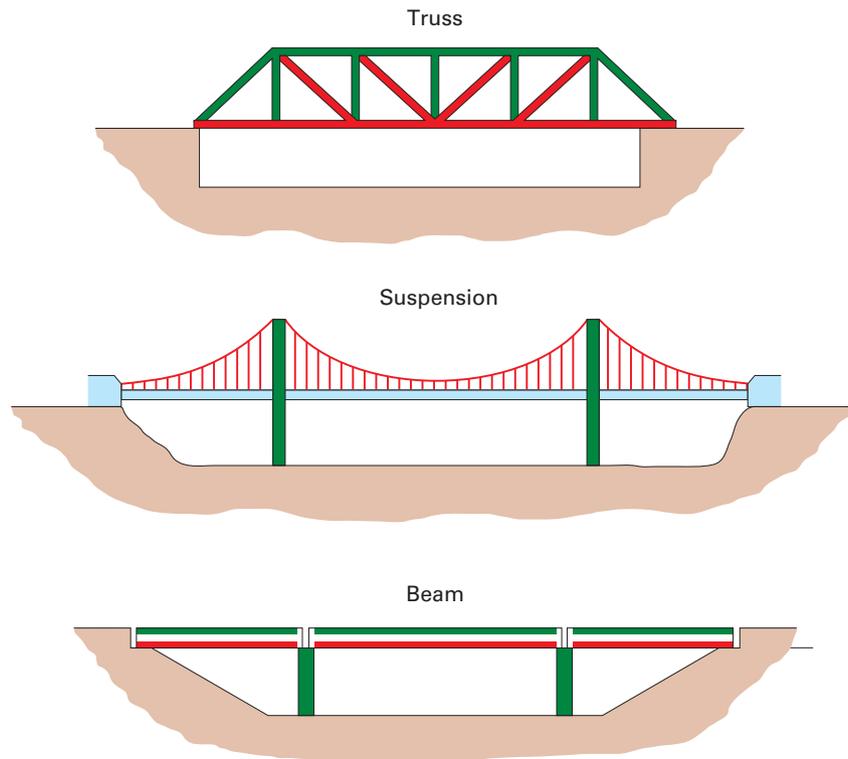


Figure 3.68 Truss, suspension and beam bridges are three of many types of bridges. The red parts of the bridge highlight areas that undergo tension (stretching), and the parts in green experience compression (pressed together).

- How will the animals be 'herded' toward your crossing?
- Is your animal a predator, or escaping from predators?
- Will you need to cater for other animal populations?

Draw a diagram of your suggested bridge/tunnel/overpass and label the different features. Ask your teacher to approve your design before you begin construction.

Suggested materials

- cardboard
- scissors
- string
- glue
- icy-pole sticks
- straws
- sticky tape
- masses

Evaluate and modify

- 1 Find out what other animals live in the same ecosystem as your chosen animal.
 - a Predict which other animals may also benefit from the wildlife crossing you have designed.
 - b Predict which animals could not use your design, and their possible futures as a result of not having a safe crossing.
- 2 Test your wildlife crossing for structural integrity by placing several masses on top of it. The masses will represent the mass of the animals (on a canopy bridge), the mass of the soil, plant life and animals (on an overpass) or the mass of cars and trucks (on top of a tunnel). Film the test so that it can be watched back in slow motion to determine where and why it failed (destructive testing).
- 3 Discuss any problems you encountered while constructing your crossing and describe how you overcame them. This may include problems with tools, materials and working as part of a team.
- 4 Evaluate the potential effectiveness of your wildlife crossing and suggest some improvements to your design.

Chapter 4 States of matter

Chapter introduction

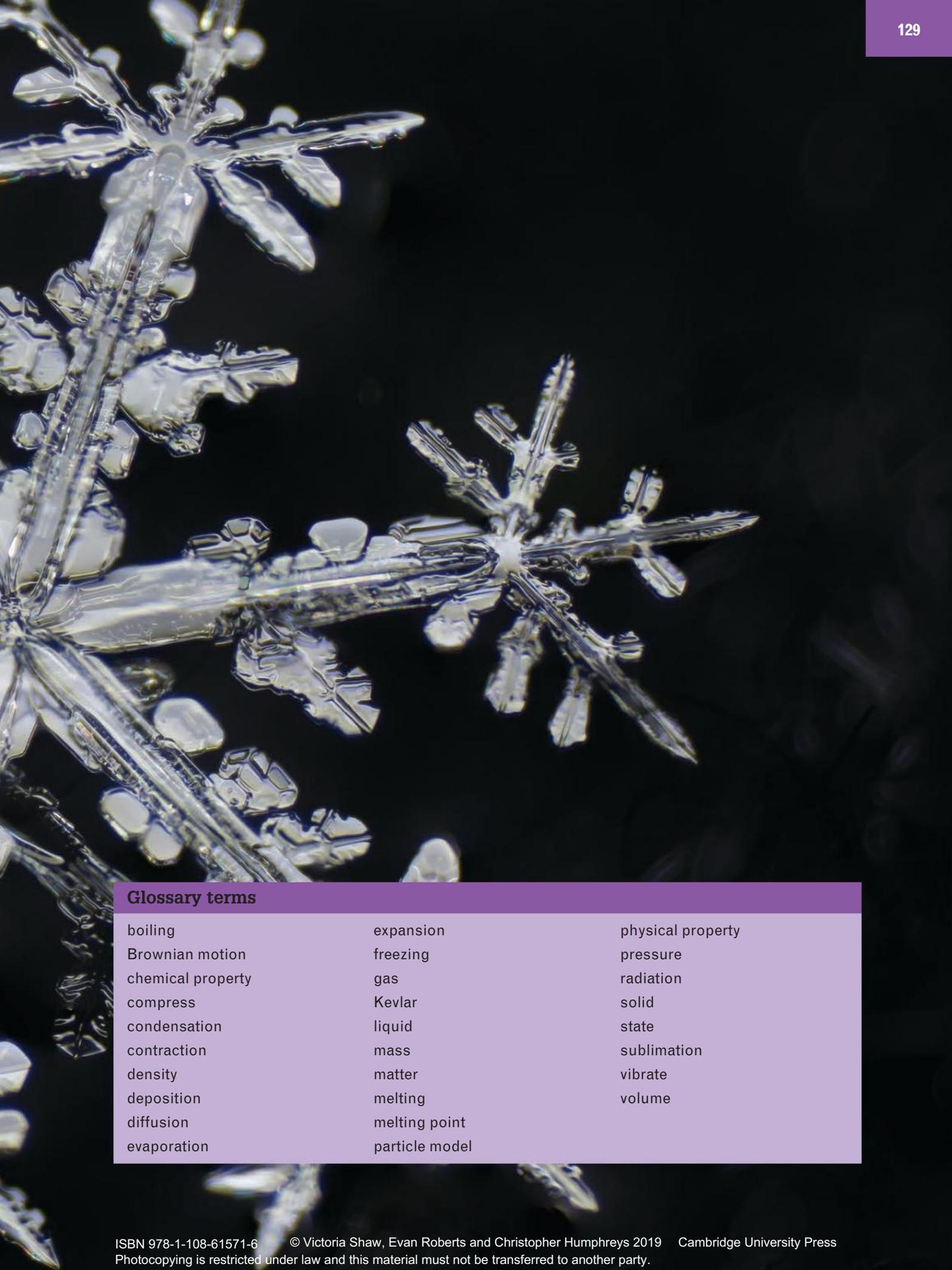
This chapter will introduce you to the amazingly minute world of particles and the idea that everything in our universe is made up of them – yes everything! You will focus on the three states of matter (solids, liquids and gases) and investigate how the particle model can explain not only their changes in state, but also the properties they exhibit.

Curriculum

The properties of the different states of matter can be explained in terms of the motion and arrangement of particles (VCSSU096)

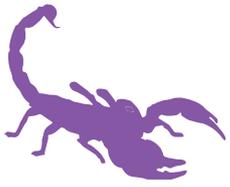
- | | |
|---|----------|
| • modelling the arrangement of particles in solids, liquids and gases | 4.1, 4.3 |
| • using the particle model to distinguish between the properties of liquid water, ice and steam | 4.2, 4.3 |

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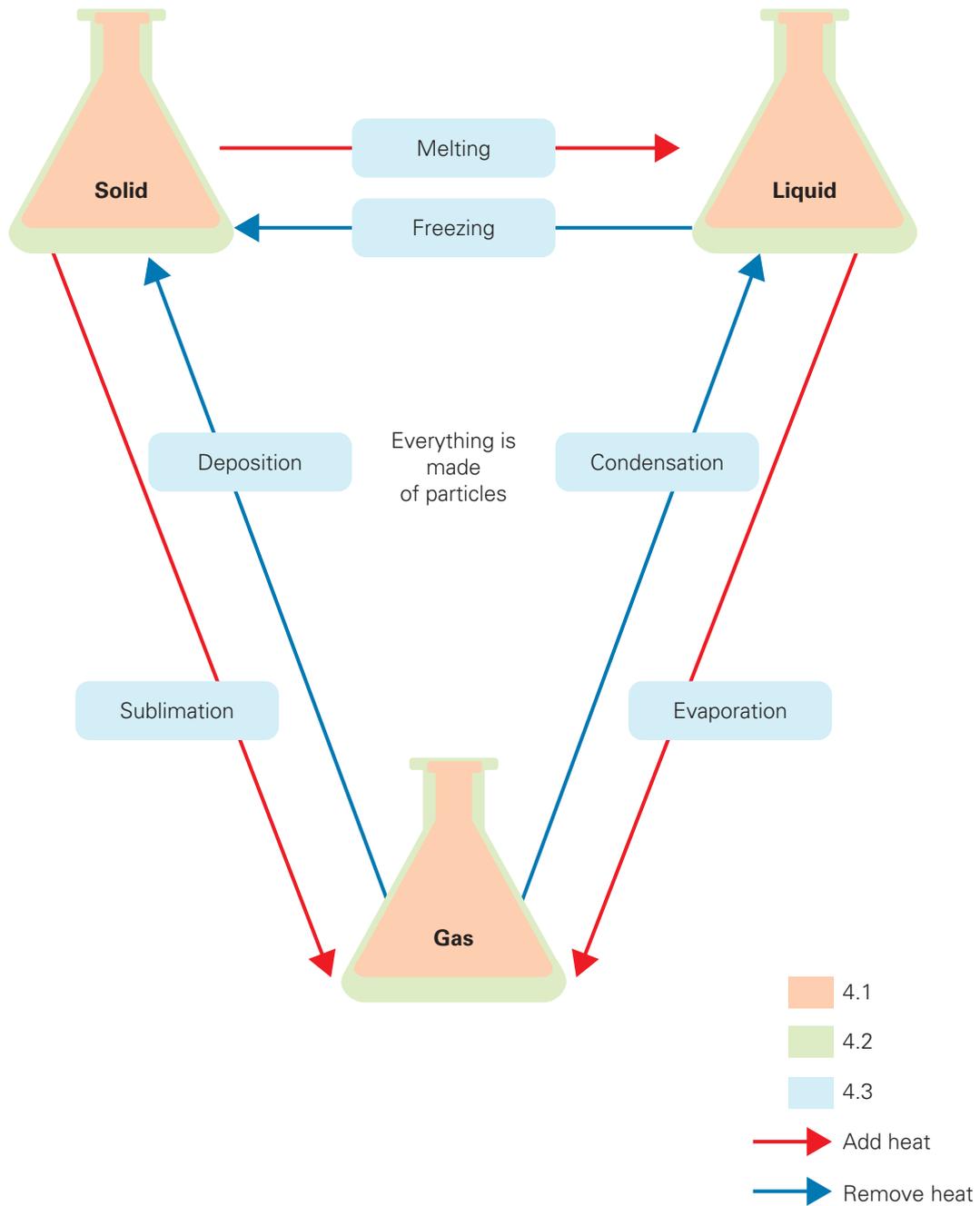
A detailed microscopic image of snowflakes, showing their intricate, six-fold symmetrical crystalline structures. The snowflakes are translucent and appear to be composed of many smaller, interconnected ice crystals. The background is dark, making the white and light blue tones of the snowflakes stand out.

Glossary terms

boiling	expansion	physical property
Brownian motion	freezing	pressure
chemical property	gas	radiation
compress	Kevlar	solid
condensation	liquid	state
contraction	mass	sublimation
density	matter	vibrate
deposition	melting	volume
diffusion	melting point	
evaporation	particle model	



Concept map





4.1

Particle model and states of matter

What do cars, milk and oxygen have in common? They all have matter! **Matter** is essentially anything that takes up space and has a **mass** and **volume**. Mass is the amount of matter in a substance or object, and volume is the amount of space the substance or object takes up. There are three **states** of matter that scientists talk

about: **solids**, **liquids** and **gases**. Look at the images in Figure 4.1, and identify the solids, liquids and gases. What do the solids all have in common? What do the liquids all have in common? What do the gases all have in common? What makes them different?



WORKSHEET

matter

anything that has a mass and volume

mass

the amount of substance in an object that never changes, even in space

volume

the space an object occupies

state

one of the distinct forms matter can exist in

solid

a substance that is firm and stable

liquid

a substance that flows freely but has constant volume

gas

a substance that expands freely to fill space



Figure 4.1 States of matter: solids, liquids and gases. What are the similarities and differences between the three states of matter illustrated above?

Other states of matter

You have heard of solids, liquids and gases but there is one other naturally occurring state of matter that is common in the universe: plasma! Plasmas are highly energised gases that are not common here on Earth, but stars, including the Sun, are covered in plasma. Plasma can be created by lightning strikes and is even used in plasma TVs in the form of ionised gas. There are actually other 'extreme' states of matter that can be created under experimental conditions and are very rare in the universe. Can you find these?

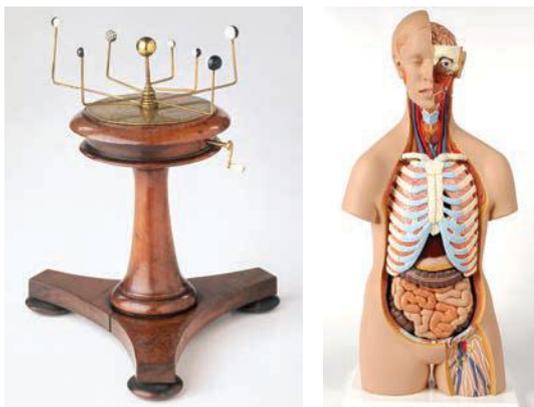
Did you know? 4.1**The particle model**

The ancient Greeks wondered what would happen if you could keep dividing matter up into smaller and smaller pieces. Would you eventually come to a particle that you could not split? Although they had no way of observing them, they assumed that these particles existed and must explain some of the properties of matter. The **particle model** was born!

particle model
all matter is made of particles that behave differently depending on whether they are solid, liquid or gas

Before you get into the nitty gritty, it is important to clarify what a model is. In science, models are used to represent different aspects of real-world objects (like models of trains and cars) and phenomenon (like the Earth circling the Sun). Sometimes though, scientists make models to test out ideas, like making model bike helmets and seeing how well they prevent an uncooked egg from breaking when dropped. And other times, scientists use models to represent what they cannot see to try and

Figure 4.2
Models: a model of the solar system from the 18th century and a modern model of the human body used in schools



explain how it might work. This is the case with the particle model.

So, to better understand what makes a solid a solid or a gas a gas, you will need to begin by looking at the particle model. This model suggests that all matter is made up of extremely small particles that are invisible to the naked eye. These particles are not only different sizes in different substances, but are also arranged differently in solid, liquids and gases. The closer the particles are to one another, the stronger the attraction between them. This helps us understand why each state of matter has different properties.

According to the particle model, the particles that make up matter are always moving because of the energy they have; for example, the more energy they have, the faster they will move. Heat can also increase the energy of particles and therefore make them move faster. Particles will always have some energy and so will always move, even if it is just a little bit. The way particles move is totally random and in science, this is called **Brownian motion**.

Brownian motion
the random movement of particles in fluids

Brownian motion is named after the botanist Robert Brown, who first observed this in 1827. Do some research on the internet to answer the following questions.

Explore! 4.1

- 1 Explain how Robert Brown first discovered that substances are made up of invisible particles.
- 2 Who also studied Brownian motion? What did they determine about this random movement of particles?

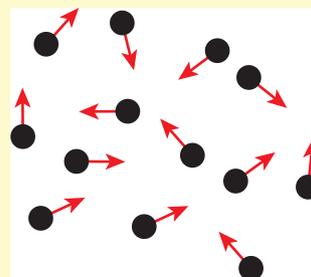


Figure 4.3 A representation of particles randomly moving

- 1 What is matter? What are the three traditional states of matter?
Add the terms to your glossary in your own words.
- 2 Summarise the key points of the particle model by completing the following sentences.
 - a All matter is made up of tiny _____.
 - b Solid and liquid particles are _____ towards other particles around them.
 - c The particles are always _____.
 - d Particles move faster if the substance is _____.

Quick check 4.1**States of chocolate****Try this 4.1****Figure 4.4** One of the states of chocolate**Be careful**

No chocolate is to be consumed
in a laboratory classroom.

Aim

To demonstrate the three states of chocolate.

Materials

- chocolate buttons
- small beaker
- large beaker
- boiling water

Method

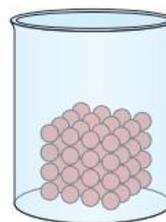
Heat the chocolate in a small beaker surrounded by boiling water in a large beaker.

Evaluation

- 1 After a few minutes, some of the chocolate will be partially melted. How many states of matter can you see?
- 2 What do you think is happening to the particles as they are heated up?

Solids

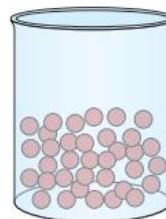
In a solid, the particles are packed tightly together. Due to their close proximity, the attraction between particles is very strong. Because of this, the particles in solids cannot move freely; instead, they **vibrate** in one spot, which is called a fixed position.



vibrate
periodic motion of particles

Figure 4.5 Diagram showing the arrangement of particles in a solid. Particles in a solid are very closely packed together and just vibrate in one spot.**Liquids**

In liquids, particles are held together by attraction. As the particles are not as close together as in solids, these attractions are not as strong. This means that the particles do not vibrate in a fixed position, they can move freely.

**Figure 4.6** Diagram showing the arrangement of particles in a liquid. Particles in a liquid are packed closely together but can still move about and slide over one another. Gravity pulls the liquid into the shape of the container.

Gases

The particles in a gas are in constant motion as they have much more energy than those in solids or liquids. The attraction between the particles in a gas is weak because the particles are so far apart, so the particles spread out to take up any space that is available. The way that the gas particles move to fill a container is called **diffusion**.

diffusion

when substances spread out to occupy a larger area

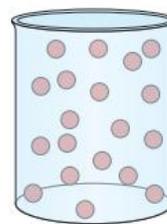


Figure 4.7 Diagram showing the arrangement of particles in a gas. Gas particles are always moving and spread out to fill any space they are in.

What state are you in?

Working with your classmates, role-play what a solid, liquid and gas look like. Make sure you can explain what the particles are doing in each state of matter.

Try this 4.2

Modelling the three states

Use polystyrene balls and pipe cleaners to make a model of each state of matter. Draw diagrams of what the three models look like.

Try this 4.3

Copy and complete the following table.

Quick check 4.2

State of matter	Describe and explain the strength of attractions between particles	Describe and explain the movement of particles	Diagram of particle arrangement
Solid			
Liquid			
Gas			

Practical 4.1: Self-design

Diffusion

Aim

To firstly investigate diffusion, the movement of liquid and gas particles as they spread out in another liquid or gas. Then design an investigation into how quickly particles can diffuse through water at different temperatures.

Materials

- aerosol deodorant/perfume
- food colouring
- eye dropper
- 4 × 250 mL beakers
- iced water, cold tap water and hot tap water
- thermometer
- stopwatch

Be careful

Check to ensure that no one suffers from any respiratory issues when using the aerosol deodorant/perfume.

continued...

...continued

Method

- 1 Spray some aerosol deodorant/perfume in one corner of the room. Move to the opposite corner of the room and record the time it takes for the scent to reach you.
- 2 Put one drop of food colouring into a beaker of tap water. Observe how the colour spreads and record the time it takes for the colour to spread evenly in the water.
- 3 Design an experiment to determine if the diffusion of food colouring occurs faster in warm or cold water. In science experiments, every variable is kept the same except for the one being investigated. What will you be keeping the same? What will you be changing? Consider what you will need to record and how you can do it.
- 4 Write a prediction about what you think might happen. This is called a hypothesis.
- 5 After checking your design with your teacher, carry out your experiment and record your results.

Results

- 1 Draw a diagram showing how the deodorant/perfume particles moved through the air.
- 2 Draw a diagram showing how the food colouring particles moved through the water.
- 3 Draw up a table that summarises your results from your self-designed experiment.

Evaluation

- 1 How do you think the particles of the food colouring were able to spread out through the water? Use the terms you have learned in class about the particle model and diffusion.
- 2 Explain why changing the temperature affected how fast diffusion occurred.
- 3 Many industries use diffusion to dispose of their waste products either as gases into the air or as liquids into rivers and the sea. Explain whether you think this is sustainable or not in the long term.
- 4 Were there any possible sources of error? How might you prevent these from occurring again?

Conclusion

From this activity we can claim that diffusion is affected by _____. This is supported through observations that _____. This means that _____.

Balloon pressure

Try this 4.4

Blow up a balloon slowly. You know the particles of air inside the balloon are gas particles, so they would move in all directions. They collide with one another and with the inside wall of the balloon. The collisions with the balloon wall exert an outward pressure on the wall. As more particles are added, the wall of the balloon will stretch until it cannot stretch anymore. What happens when you let go of the fully inflated balloon? Try to use the words 'gas particles' and **pressure** in your explanation.

pressure
putting force (push or pull) onto a substance

Microwave ovens Did you know? 4.2

Microwave ovens heat your food by using **radiation**. The radiation (in this case called microwaves) is absorbed by water particles in the food, which causes them to vibrate. This means they get hotter. The hotter the water particles, the hotter the food next to them, and it is this heat that cooks the food.



Figure 4.8 Microwave ovens work by causing the water particles in food to vibrate and heat up.



VIDEO
Animation of water particles in three states.

radiation
energy from heat or light that you cannot see, different from nuclear radiation

Heating and cooling

The particle model suggests that if you heat up a substance, the particles will gain more energy and so they will begin to move more. As the particles start to move more, the distance between the particles increases and they begin to take up more space. Because the particles are further apart the attraction between the particles decreases. This process of getting larger is called **expansion**.

expansion

when substances get larger

When heat is applied, gases can usually expand more than solids



Figure 4.9 A hot air balloon over the city of Melbourne. The heated air expands, becomes lighter than the air outside the balloon, so the balloon rises.

Are temperature and pressure related?

Try this 4.5

Take an empty plastic drink bottle, remove the lid, squeeze in the sides and put the lid back on. Now use some tongs to hold the bottle under the hot-water tap and then under the cold-water tap. Observe what happens to the dents you made in the bottle before starting. What is happening? Where is the pressure coming from? Can you explain what is happening in terms of the particle model?

and liquids because the particles are not restricted to a fixed volume, and particles are less packed.

So how does it work when a substance is cooled? The reverse of the process of expansion occurs; the substance cools down, the particles lose energy, they slow down, and the distance between the particles gets smaller. Because the particles are closer, they become more strongly attracted to one another except in a gas. This process of getting smaller is called **contraction**.

contraction

when substances occupy a smaller volume

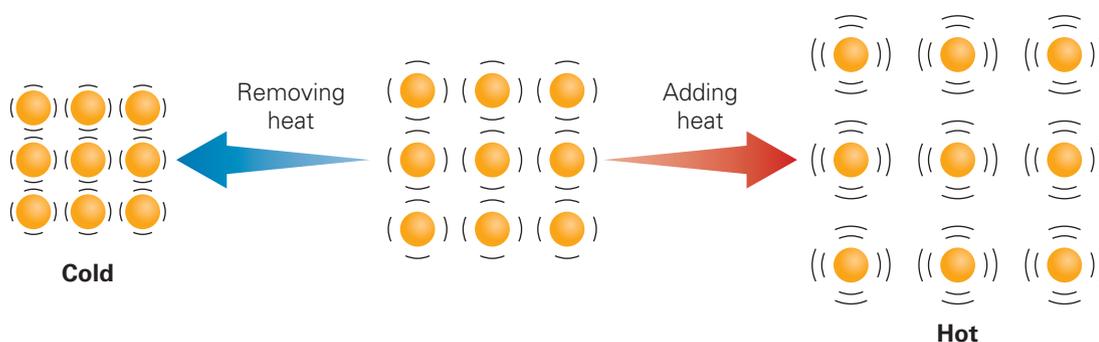


Figure 4.10 Diagram showing the changes experienced by particles with heating and cooling

Building bridges

Architects must work with engineers when designing and constructing bridges and railway lines. They must allow for the expansion and contraction of the materials they use.

- 1 Explain what is done to allow for the expansion and contraction of bridges and railway lines.
- 2 Discuss why it is important for engineers to carefully select the materials they choose for building bridges and railway lines with.

Explore! 4.2

- 1 Compare the distance between particles in a liquid, a gas and a solid.
- 2 What happens when a substance gains heat?
- 3 The particles of a substance in a sealed container are investigated at two different temperatures.
 - At temperature A, the particles are very close together but move about freely at moderate speed in the bottom of the container.
 - At temperature B, the particles are distant from one another and move about freely and very fast in all parts of the container.What is the state of the substance at temperature A and at temperature B?

Quick check 4.3**Practical 4.2****Expansion and contraction****Aim**

To observe and explain the expansion and contraction of solids and gases.

Materials

- ball and ring apparatus
- tongs
- Bunsen burner
- bimetallic strip
- 2 metal bars of same size but different material
- wax candle
- stopwatch
- 1 balloon
- felt-tip pen
- ruler or tape measure
- coin
- bucket of ice water
- bucket of hot water

Method

- 1 Play with the ball and ring apparatus. Does the ball fit through the ring when it is cold? What do you predict will happen when you heat the ball? Heat the ball using the Bunsen burner and see if it still fits through the ring. What happens if you heat the ring and not the ball?
- 2 Look at the bimetallic strip – predict or hypothesise what will happen when you heat it. Now, heat the bimetallic strip. Describe and explain what happens.
- 3 Attach a coin to one end of the metal bar with the wax from a candle. Hold the metal bar using tongs and heat the other end of the metal bar with a blue Bunsen flame. Time how long it takes before the coin falls off.
- 4 Hypothesise what might happen if you used another metal bar of the same length and size but made of a different material. Test this hypothesis by repeating step 3 with the new metal bar.
- 5 Inflate a balloon. Draw two felt-tip pen lines exactly 10 cm apart on the balloon. Place the balloon in the bucket of ice water. What happens to the lines? Place the balloon in the bucket of warm water. What happens to the lines?

continued...

...continued

Results

Record all observations and descriptions from **each** step of the method.

Evaluation

- 1 Write a sentence explaining your observations from **each** step of the method, referring to the particles, their energy, their movement, strength of their attraction etc.
- 2 Do you think a balloon can be used as a thermometer to measure temperature? Find out about how gas thermometers are made and used.
- 3 Were there any possible sources of error along the way? How might you reduce these errors?

Conclusion

From this activity we can claim that temperature _____. This is supported through observations that _____. This means that _____.

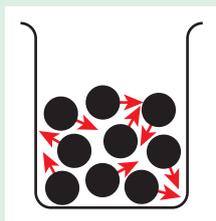


QUIZ

Section 4.1 questions

Remembering

- 1 Recall the four key points of the particle model.
- 2 In which state are the particles only able to vibrate in a fixed position?
- 3 Which state is shown in the diagram below?



- 4 Which state cannot flow from place to place?
- 5 In which state do particles have the strongest attractions?
- 6 Define the term 'diffusion'.
- 7 What word describes the change you expect to see when a metal is heated?

Understanding

- 8 At room temperature, which state do the particles of a substance have the most energy? Provide evidence for your answer.
- 9 Describe what happens when you heat up particles.

Applying

- 10 Construct a table that distinguishes solids, liquids and gases. Include a diagram to model the different states. Compare the closeness of the particles, the speed at which they move and list some examples.

Analysing

- 11 Use the particle model to explain why food colouring and water mix together but food colouring and ice do not.

Evaluating

- 12 Determine how a mercury thermometer works.



4.2

Properties of solids, liquids and gases

physical property

the way a substance looks and acts

chemical property

the behaviour of a substance when it reacts with another substance

density

how compact a substance is

Scientists often refer to properties when they talk about the different states of

matter, but what does that mean? The two types of properties scientists refer to are **physical properties** and **chemical properties**.



	Property	
	Physical	Chemical
Definition	The way substances look and act	The behaviour of a substance when it reacts with another substance
Examples	Colour, size, solubility, melting point, hardness, boiling point, conductivity, shape and density	Burns or explodes in oxygen, rusts or corrodes, acidity, biodegradable and combustibility
Picture		

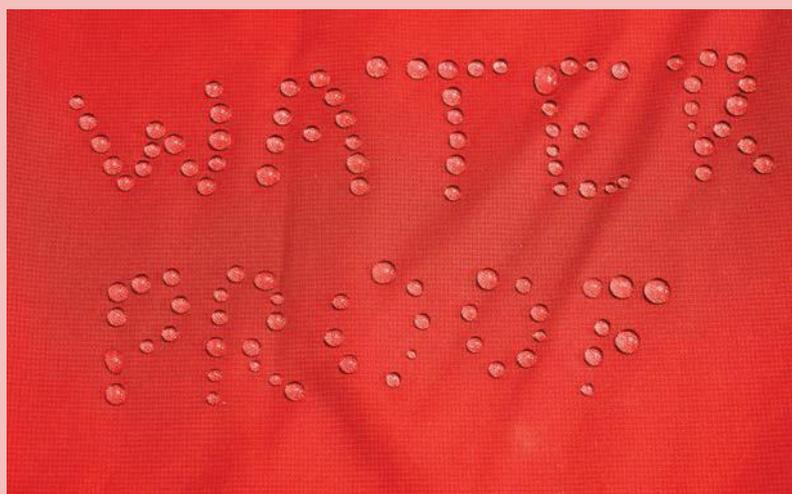
Figure 4.11 The two types of properties investigated when looking at matter.

Waterproof coating

It is the properties of substances that allow them to be used in certain industries in certain ways. In 2016, a new spray-on substance with a remarkable ability to repel water was developed by Australian researchers. This new protective coating could eventually be used to waterproof mobile phones, prevent ice from forming on aircrafts and protect boat hulls from corroding.

Figure 4.12 The properties of substances are used by scientists to design new materials with specific purposes.

Science as a human endeavour 4.1



Practical 4.3

Investigating the properties of solids, liquids and gases

Aim

To determine and compare the physical properties of solids, liquids and gases.

Materials

- plastic syringe
- beaker of water
- balloon
- ice-cube
- metal spoon

Method

- 1 Have a play with each solid, liquid and gas that you have access to and answer the following questions in the table in the results section.
 - a Shape: is the shape of the substance fixed? Does it fill any container it is put in? Or does it just stay in part of a container?
 - b Compression: using the metal spoon, syringe, and balloon, consider if the substance can be **compressed**, that is can the particles be squashed closer together?
 - c Flow: can the substance flow? Can the particles in the substance move past one another? Can the substance be poured into a container?

compress
squeeze to make smaller

Results

	Solid	Liquid	Gas
Shape – fixed/container/part of container?			
Compression – compresses easily/not easily?			
Flow – particles can flow easily/not easily?			

Table 4.1 Results showing the observed properties of solids, liquids and gases

Evaluation

- 1 Do you think the results you found will apply to all solids/liquids/gases? Explain.
- 2 How could you explain each of these properties using the particle theory? Write a couple of sentences on each state of matter using the terms you have learned so far.
- 3 Where there any possible sources of error during this Practical? How might you reduce these errors?

Conclusion

From this activity we can claim that the properties _____. This is supported through observations that _____. This means that _____.

If you have had a chance to explore the properties of solids, liquids and gases in the previous practical, you will have figured out a number of the key properties

of solids, liquids and gases on your own! Let's just run through them and explain them using what you already know from covering the particle model.

Solids

Earlier in this chapter you learned that, the particles in a solid are packed so tightly together and the attraction between particles is so strong that the particles in solids cannot move freely; they are fixed. This is why solids usually have a shape and volume that cannot be changed and why they are hard to break apart. This also explains why solids cannot

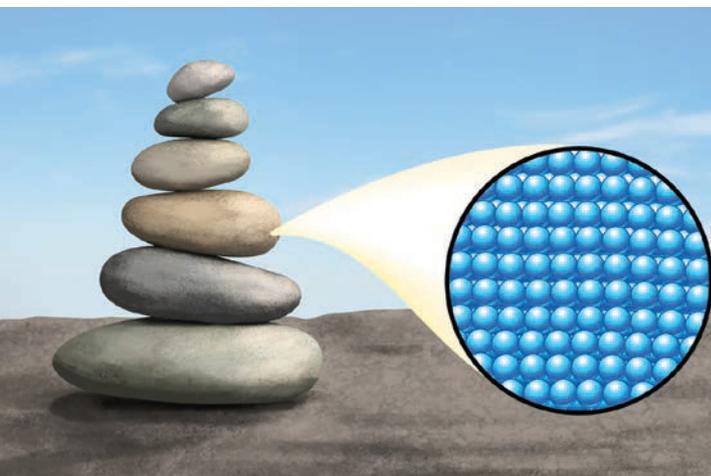


Figure 4.13 Consider these rocks and the arrangement of their particles shown in the diagram. Are their shapes fixed? Can they be compressed? Is their volume fixed? Can they flow?

easily be compressed (squashed) and cannot be poured.

Density

You may have noticed density was mentioned in the table at the start of this section. Density is an exciting physical property as it allows us to determine whether an object will float or sink. It describes how heavy or light something is for its size, but it is not the same as its weight or mass. For example, 1 kg of steel always weighs the same as 1 kg of feathers (they are both 1 kg), but the space they take up is very different. Density can therefore be defined as the measurement of how compact a substance is; that is, how much matter (or mass) fits in a certain amount of space (or volume). So, the more dense an object is (like steel), the more mass there is in a particular volume. The relationship between density, mass and volume is written in this way: $\text{density} = \frac{\text{mass}}{\text{volume}}$.

This is called a scientific equation.

Practical 4.4: Self-design

Calculating density

Aim

To design and conduct an investigation to measure the mass and volume of different objects. Then use this information to calculate the density of the objects and determine whether they would float or sink in water.

Materials

- ruler
- large measuring cylinder
- 8 small random objects

Method

When you design your experiment, consider the following questions.

- What measurements do you need to be able to work out the density of an object?
- How will you measure the mass of the random objects you have access to?
- How will you measure the volume of the random objects you have access to? What will you do with objects of regular and irregular shape?
- How will you record your data? Perhaps a table would help?

continued...

...continued

- How will you calculate density?
- What is your prediction for the results? Which items do you expect will float and which will sink? What can you do to work this out?

Before beginning, your teacher will show you how to determine volume using the water displacement method. You will then write up your intended method step by step, as though it was going to be published in a textbook. Then check with your teacher that you can begin your investigation.

Results

- 1 Record your prediction.
- 2 Write your method step-by-step.
- 3 Record your measurements in a table.
- 4 Using the equation for density, calculate the density of the objects you had access to.

Evaluation

- 1 The density of water is 1.00 g/mL. If an object has a density of less than 1.00 g/mL, it should float in water. If an object has a density of greater than 1.00 g/mL, then the object should sink when placed in water. Did your results show these statements to be true?
- 2 Were your predictions correct?
- 3 What are the advantages and disadvantages of using the water displacement method for determining volume?
- 4 Would your results be different if you used a different liquid to water? Explain your reasoning.
- 5 Were there any steps of the practical that you would do differently if you were to repeat the task? How would you fix them up for next time?

Conclusion

From this activity we can claim that _____. This is supported through observations that _____. This means that _____.

Graphene

Graphene – a two-dimensional arrangement of the particle carbon – was discovered in 2004. It has the physical properties of being extremely strong and an excellent conductor of electricity. In 2017, scientists found a way to turn this amazing material into three-dimensional structures. This may not seem very exciting, but these 3D structures are 10 times stronger than steel yet only 5% as dense! The breakthrough material can therefore help reduce the amount of steel used for infrastructure, but also excites scientists because of its applications in space programs.

Science as a human endeavour 4.2

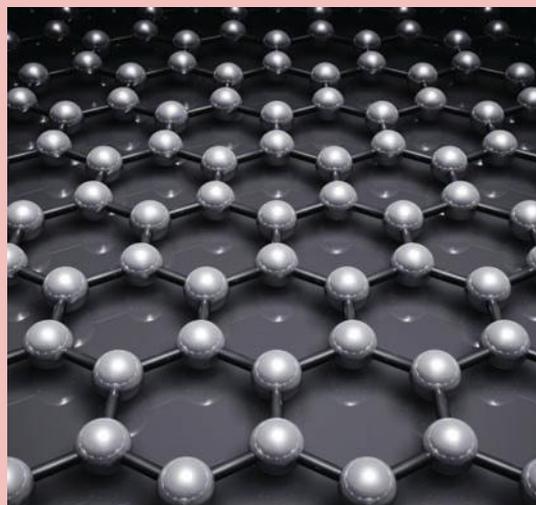


Figure 4.14 Model of the hexagonal lattice of a graphene layer

- 1 List the properties of a solid.
- 2 Copy and complete the table below by filling in the blank squares.

Quick check 4.4

Particle model explanation of a solid	Link to the properties of a solid
Packed tightly together	
	Hard to break apart
Particles in solids cannot move freely; they vibrate in one spot, which is called a fixed position.	

- 3 What about a substance like sand? It can be poured and does not have a fixed shape, so is it a solid? Explain.
- 4
 - a Explain the relationship between mass and density.
 - b Explain the relationship between volume and density.

Artificial spider silk!

Kevlar

fibres that have five times the strength of steel for the same weight and are used in a variety of clothing, accessories and equipment Dupont™ Kevlar®

In 2017, researchers at the University of Cambridge designed an extremely stretchy, artificial spider silk that is tougher than DuPont™ **Kevlar**®. It is also environmentally sustainable as it is made from a material that is 98% water! This material offers the possibility of improving products from bike helmets to parachutes to bulletproof jackets to aeroplane wings.

Figure 4.15 The properties of substances are used by scientists to design new materials with specific purposes.

Did you know? 4.3



Liquids

Since liquids are held together by attractions, but the attraction is not as strong as in solids, the particles can move more freely and flow (be poured), and therefore take on the shape of the container they are put in. Due to gravity though, the shape it takes on will always be at the bottom of the container into which it is placed. Although their shape can change, liquids have a fixed volume and mass. Like solids, they cannot be compressed into 'much' smaller spaces. The particles can actually be pushed a tiny bit closer together but it takes a massive effort and so we generally say that the particles in a liquid are so closely packed that they cannot be compressed.

Remember, you learned about the idea of density being a physical property of solids earlier in this section. Density is

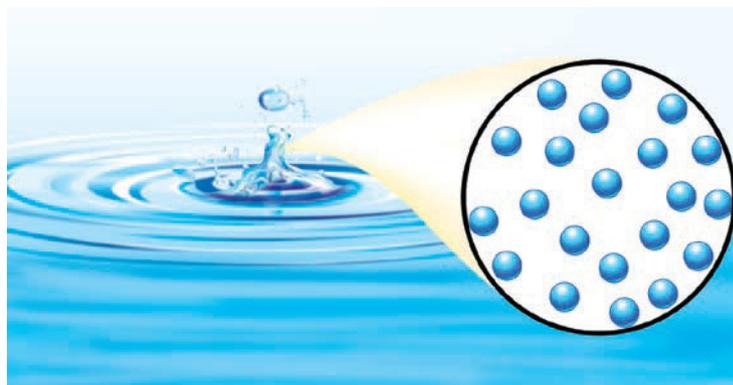


Figure 4.16 Consider the tap water and the arrangement of its particles shown in the diagram. Is its shape fixed? Can it be compressed? Is its volume fixed? Can it flow?

also a physical property of liquids (and gases)! What is interesting to note, is that the density of a liquid is affected by temperature – the hotter a liquid is, the less dense it will be. Think about what you know about the particle model; how could you explain this?

Does sugar-free help you float?**Try this 4.6**

Put an unopened can of soft drink in a deep tub/jug of water. Does it float or sink?

Put an unopened can of the equivalent diet soft drink in a deep tub/jug of water. Does it float or sink? Try to explain your findings.

Make your own lava lamp!**Try this 4.7**

Search the internet for instructions on how to make your own lava lamp at home. It is safe and easy to do. Begin by measuring the mass of a cup of oil and a cup of water (this is an equal volume). Which one is heavier? So, which one is more dense? How can you explain this using the particle model and your understanding of density? Think about how an effervescent tablet was used to power your lamp – what is used in real life? Explain how temperature affects the density of substances.



Figure 4.17 A lava lamp demonstrates density, one of the physical properties of liquids.

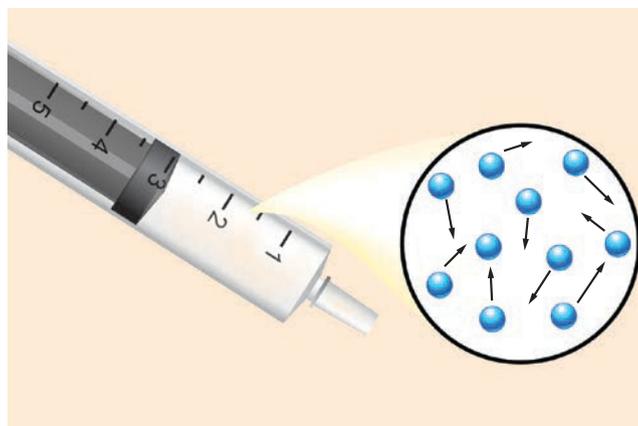


Figure 4.18 Consider the air in the first 3 cm of this syringe and the arrangement of the air particles shown in the diagram. Is its shape fixed? Can it be compressed? Is its volume fixed? Can it flow?

Gases can be compressed

Explore! 4.3

because there is a lot of space between the particles. There are lots of different places where you can see the result of such compression; for example, oxygen tanks for diving, air freshener sprays, deodorants and fire extinguishers that are filled with carbon dioxide.

- 1 Why is carbon dioxide a good choice for extinguishing fires?
- 2 Use the particle model to explain why gases can be compressed.
- 3 Explain why carbon dioxide in a fire extinguisher is under a lot of pressure.

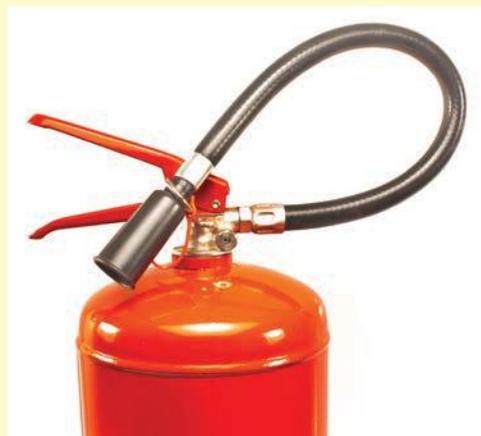


Figure 4.19 A common fire extinguisher you will find in the home and at school.

Gases

Scientists know the attraction between the particles in a gas is weak because the particles are far apart. This means that gases have no fixed shape or volume – they spread out to take up any space that is available. Keep in mind though, that if the container you put a gas in, does not have a lid, the gas particles will bounce off the walls and spread out by diffusion. Due to the large spaces between gas particles, there is plenty of space for the particles of a gas to be squashed together or compressed.



VIDEO
Why does an aerosol can get colder when sprayed?

- 1 Define the terms 'volume' and 'mass' in your own words. Add the terms to your glossary.
- 2 Compare the shape and volume of solids, liquids and gases.
- 3 Copy and complete the following table.

Quick check 4.5

State	Examples	Particle diagram	Properties
Solid			
Liquid			
Gas			

Making oobleck**Try this 4.8**

Find a recipe on the internet for making oobleck (cornflour and water) and make some to play with. Ask yourself these questions.

- Can it be rolled into a ball? Can it be stretched? Does it flow and take the shape of its container? What happens when a ball of oobleck is dropped?
- What are the physical properties of oobleck?
- So, is it a solid or liquid?

Oobleck

Have you heard of Isaac Newton? He described how 'normal' liquids behave, and he observed that they have a constant resistance to flow (called viscosity). He said that the flow of liquids does not change unless you change the temperature or pressure. For example, it doesn't matter whether water is sitting in a cup or is being stirred in a beaker, the flow/or ease of stirring, doesn't change. Most liquids are therefore called Newtonian liquids or fluids because of his work. However, what about oobleck? What did you determine were its properties in the 'Try this' activity? Oobleck is a non-Newtonian fluid, as the flow of the liquid changes depending on the amount of stress you put onto it. You may have noticed, when you try to stir oobleck, its flow changes and it becomes thicker and difficult to stir. As you remove the force and stop stirring, it becomes like a liquid again. This is because of the way the particles move and lock together when a force is applied.

Did you know? 4.4

Figure 4.20 Oobleck is a non-Newtonian fluid.

Section 4.2 questions**Remembering**

- 1 State how a liquid behaves in a container and what happens if it is put in a different container.
- 2 State how a gas behaves in a container and what happens if it is put in a different container.
- 3 State how particles in a solid behave. Use these terms in your answer: fixed, vibrate, shape, compressed, attraction.

Understanding

- 4 Summarise the properties of a gas in two sentences.
- 5 Explain why steam can be compressed but ice cannot.

continued...



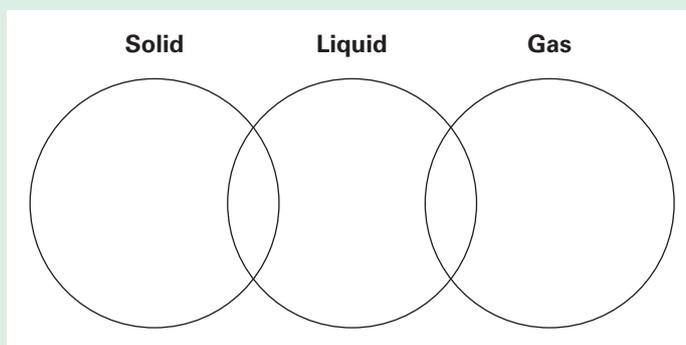
QUIZ

...continued

Applying

- 6 Copy the Venn diagram and organise the following statements into the correct place to describe solids, liquids and gases.

Strong attraction between particles that are not as close	Particles that are free to move, no strong attraction	Strong attraction between close particles
Easy to compress	Definite shape	Can be poured
Expand to fill a container	Particles in a fixed position	Difficult to compress
Fixed volume	Not a fixed shape	

**Analysing**

- 7 A plastic toy unicorn floats in liquid X but sinks in liquid Y. What does this tell us about the densities of the unicorn, liquid X and liquid Y?
- 8 The table below lists the densities of several materials. Which material will float in water? Explain your answer referring to the materials in the table as evidence.

Material	Density (g/mL)
Plastic	0.90
Water	1.00
Sulfur	2.07
Steel	7.80
Rubber	1.20

- 9 Explain two ways you could find out if a material is a solid.
- 10 The metal lid of a glass jar is stuck and cannot be undone. Kim runs the lid under hot water, and now the lid can be unscrewed. Using your understanding of the particle model and the properties of matter, explain why Kim used the hot tap.

Evaluating

- 11 Discuss how and why the properties of a liquid are different from the properties of a gas.
- 12 Office chairs, like the one shown on the right, usually have a lever on the side for adjusting their height. The stand contains a cylinder and a piston that can move up and down inside it and consequently, the chairs often feel quite springy when you sit on them. Would the cylinder contain a solid, a liquid or a gas? Give reasons for your answer.



Figure 4.21 An office chair



4.3 Changing states

Under the right conditions, all matter can change from one state to another; for example, from a solid to liquid, liquid to gas, or liquid to solid. This may occur because of a change in temperature or pressure, which may be naturally occurring or caused by humans.

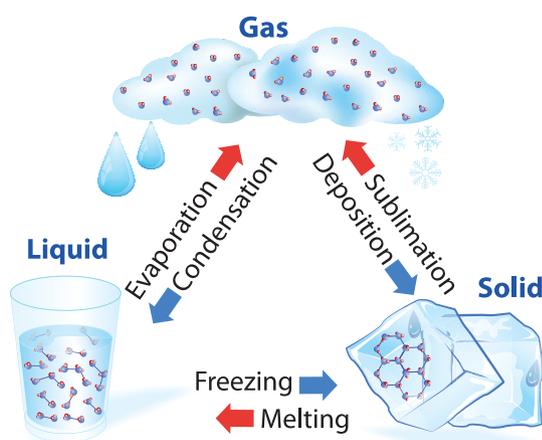


Figure 4.22 Changes in the state of water

Adding heat

You know that heating up a substance causes an increase in temperature, but, did you know that if enough heat is added, the substance can actually change its state!

Melting: when heat causes a solid to become a liquid. Remember that heating a substance gives the particles of that substance more energy and this makes the particles move or vibrate faster. Well, if you add enough heat to the particles, the edge of the solid will eventually be jiggling around so much that some of the particles will break free. The temperature at which this occurs is called the melting point of the substance.

melting
when heat causes a solid to become a liquid

Different substances respond to heat differently and so have different **melting points**. It is not surprising that when a substance changes from a solid to a liquid (by melting) its properties also change; however, the actual substance remains the same. For example, melting ice involves solid water forming a liquid form of water and the properties are very different (hardness, ability to be poured, shape), but they are both water.



WORKSHEET



WIDGET
Metals and melting points

melting point
the temperature at which a specific solid melts



Figure 4.23 Melting butter on a hot cob of corn involves a solid forming a liquid. The properties may change but it is still butter.

Evaporation (or vaporisation): where heat causes a liquid to become a gas. Adding heat, and therefore energy, to a liquid, causes the particles of the liquid to move faster, spread

evaporation
when heat causes liquid to become gas

out and this increased distance, decreases the attraction between particles. If there is enough heat added to the liquid, the particles at the liquid's surface can vibrate or move so fast they break away from the rest of the particles and form a gas. For example, at a natural hot spring, water changes state from liquid to vapour, and some of it changes back to liquid droplets forming clouds. Evaporation can, however, occur at a range of temperatures. Consider the clothes you hang on the line to dry. They will dry by the water evaporating from the surface of the clothes, faster when it is sunny and hot, but they still do dry on cooler cloudy days.

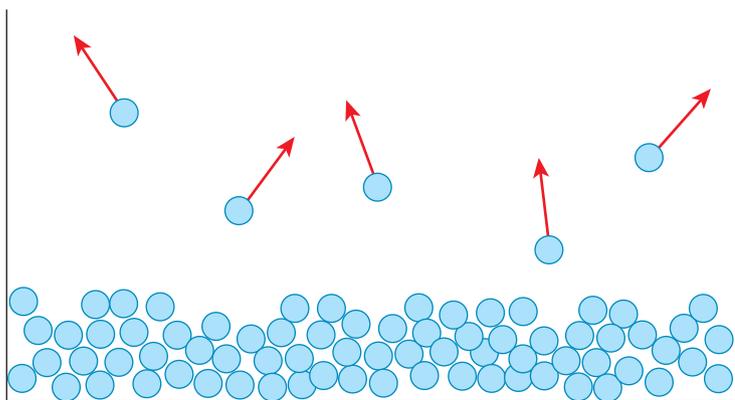


Figure 4.24 When heated, particles gain energy and spread out allowing them to break free from the liquid and form a gas.

Boiling: a special case of evaporation where heat causes a liquid to become a gas. Boiling occurs at a temperature called boiling point. When a substance reaches this temperature, it is very obvious that the substance is boiling, and evaporation is starting to occur not just on the exposed surface but at various points throughout the liquid. You may have watched water boil at 100°C in a transparent kettle or saucepan. Pockets of air (bubbles) form low down in the water, and when they expand, they rise and break at the surface.

boiling
a special case of evaporation



Figure 4.25 The bubbles of boiling of water form low down in the liquid, then expand and rise to the surface.

As with melting points, different substances have different boiling points too.

- 1 Find out the melting, boiling and freezing points of some different substances.
- 2 Draw up a table to record the melting point, boiling point and freezing point of the substances you investigated.

Explore! 4.4

Melting and boiling points can change!

Melting and boiling points depend on how far above sea level you are. The higher up you are, the lower the melting and boiling points would be. Even in Canberra, which is only around 570 metres above sea level, the boiling point of water is around 98°C . Can you think of why this is the case?

Did you know? 4.5

Sublimation: where heat causes a solid to become a gas. Most substances go through the process of melting and evaporating when heated, however there are a few rare substances that skip the liquid phase at room temperature. Dry ice (solid carbon dioxide) is an example you may be familiar with.

sublimation
where heat causes a solid to become gas

Practical 4.5: Teacher demonstration

Dry ice

Aim

To observe the behaviour of dry ice and its changes in state.

Materials

Dry ice

Method

- 1 Put some solid pellets of dry ice on a plate using tongs. Place an ice cube of water on another plate beside the dry ice. Discuss the properties of the dry ice as compared to water.
- 2 Predict what you think will happen when you put some pellets of dry ice into a beaker of water. Demonstrate this.
- 3 Put several pellets of dry ice into a new beaker of coloured water.
- 4 Put several pellets of dry ice into a new beaker of water containing a squirt of detergent.
- 5 Add 3–4 cm of water into the bottom of an empty tin that has a plastic lid. Add a scoop of dry ice pellets and securely put on the tin lid.

Results

Record your observations at each stage of this demonstration.

Evaluation

- What do you think will happen when the temperature is increased?
- Would expansion or contraction occur?
- What is sublimation? Is this occurring?
- Describe the results of each step in terms of the particle theory.

Conclusion

From this activity we can claim that dry ice _____. This is supported through observations that _____. This means that _____.

Be careful

Ensure appropriate protective equipment is worn when handling dry ice: safety gloves, tongs and protective glasses. Dry ice should be stored in NON-AIRTIGHT containers. Ensure you work in a well-ventilated area. Dry ice is extremely cold and can cause serious burns.



Figure 4.26 Dry ice is a resource that can be used on a movie set.

Removing heat

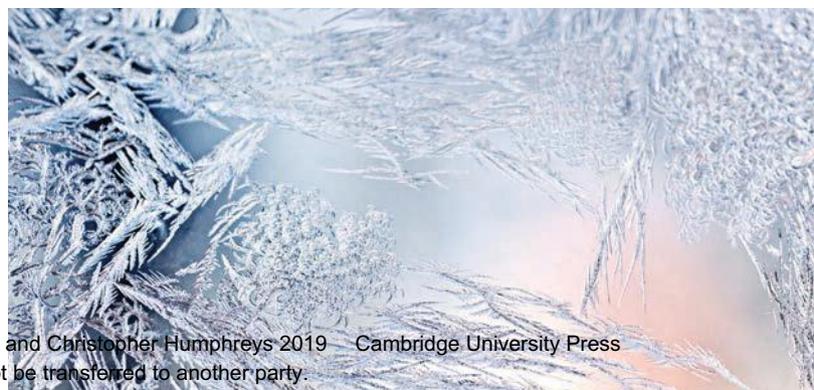
You know that cooling a substance causes a decrease in temperature, and like heating a substance, if enough heat is lost, the substance can change its state!

Freezing (or solidification): where heat is lost causing a liquid to become a solid. The process of freezing is the reverse of melting. As liquid cools, the particles lose energy and move or vibrate slower. If you remove enough energy, the particles will end up just vibrating in a fixed position and due to their

closeness, the particles will form stronger attractions with

their neighbours than before, forming a solid. The point at which this occurs is called the freezing point. Different substances have different freezing points. For example, the freezing (and melting) point of water is 0°C , while the freezing (and melting) point of oxygen is -218.8°C .

Figure 4.27 Snowflakes form when the liquid water turns into the solid ice.



freezing

where heat is lost and liquid becomes solid

Freezing water

Fill an empty plastic bottle with water (not quite to the top) and mark the water level with a waterproof marker. **Do not** use a glass bottle. Carefully place the open water bottle in the freezer and leave it to stand overnight. The next day have a look. Did the shape of the container change? Why? What might have happened if the container had been made of a hard material such as glass or stone? Explain what happened using the particle model and your knowledge of changes in state.

Try this 4.9**Ice is strange!**

Solids usually take up a smaller volume than liquids because the particles are held closer together. However, ice is a very strange solid that actually takes up a bigger volume (and is therefore less dense) than liquid water! That is why icebergs float on the sea, rather than sink to the bottom. It is also why a bottle of water put into the freezer will puff out and sometimes break because the frozen ice takes up more space than the water. It has to do with the position of the water particles when they freeze versus when a liquid.

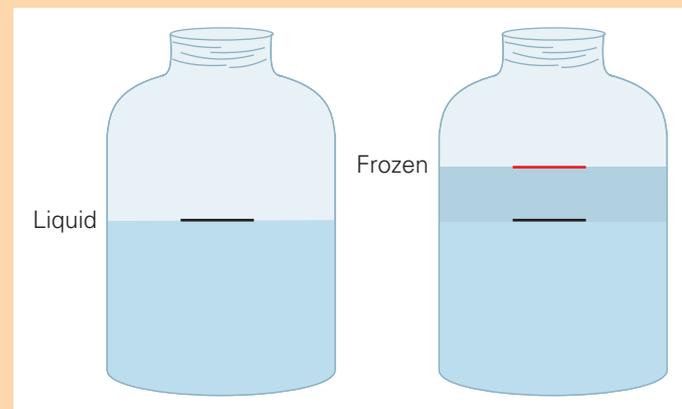
Did you know? 4.6

Figure 4.28 If you completed the 'Try this' Freezing water activity, you would have seen that water at a certain level (left image), stored in the freezer, increases its volume (right image) Weird!

Deposition (also known as reverse sublimation or desublimation): where a reduction in heat causes a gas to become a solid. Like sublimation, deposition is rare. However, it can be seen when, in sub-freezing air, water vapour changes directly to ice without first becoming a liquid.

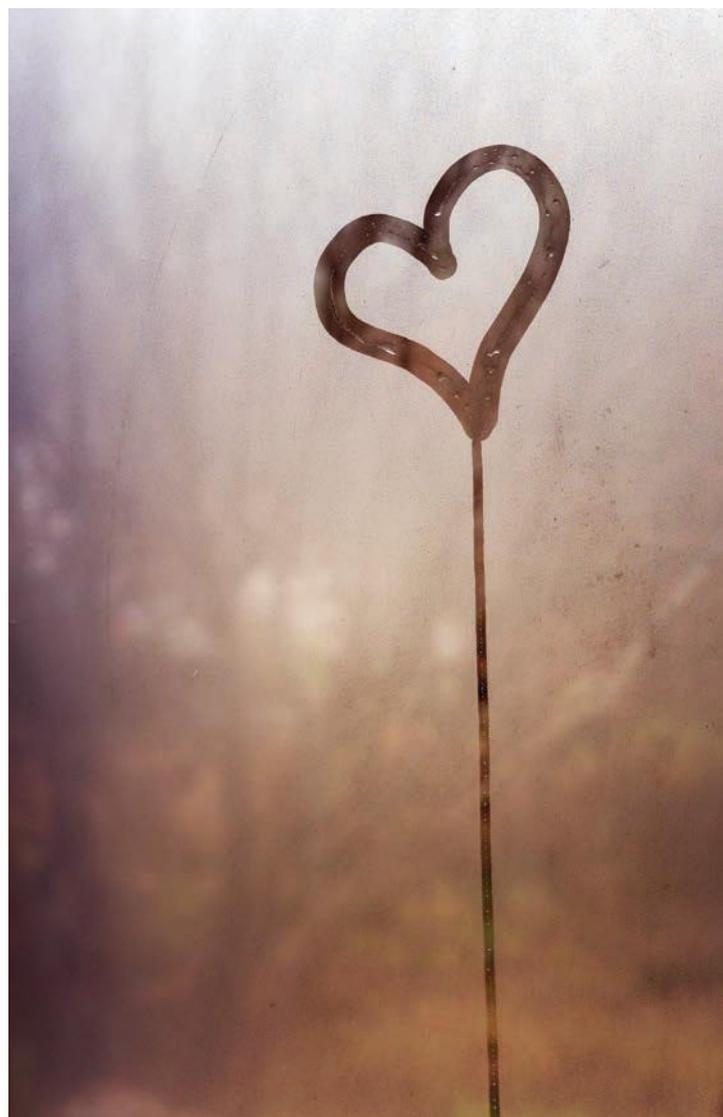


Figure 4.29 Condensation forms on a window overnight as the air cools.

Condensation: where heat is lost causing a gas to become a liquid. As a gas cools, the particles that make it up lose energy and slow down. When they have slowed down enough, the particles become close enough together that they begin to attract one another, and consequently form a liquid. An example you may see every day is when the steam from your shower condenses on the mirror of your bathroom as the water vapour (gas) cools down when it hits the mirror and forms a liquid.

condensation

where heat is lost causing a gas to become a liquid

deposition

where a reduction in heat causes a gas to become a solid

Practical 4.6: Teacher demonstration

Deposition of iodine

Aim

To observe what happens when iodine crystals are heated and cooled.

Materials

- iodine crystals
- evaporating dish
- glass funnel
- cotton wool
- Bunsen burner
- tripod
- gauze mat

Method

Be careful

To be performed in a fume hood by a teacher only. Wear safety glasses and gloves.

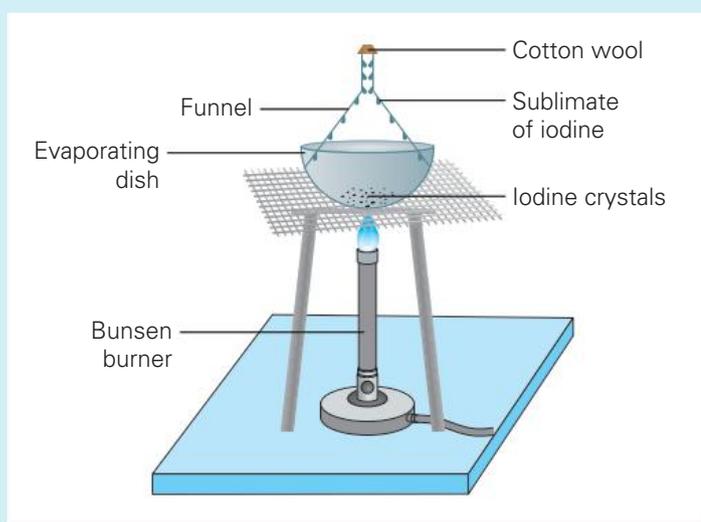


Figure 4.30 Equipment set-up

- 1 What do you think will happen to the iodine crystals as they are heated and as they are cooled?
- 2 Heat iodine crystals in an evaporating dish over a Bunsen burner, ensuring the inverted funnel is covering the crystals and the cotton plugs the top securely.

Results

Observe the iodine carefully and record what you see as the iodine is heated and cooled.

Evaluation

- 1 What do you think reverse sublimation means?
- 2 What evidence is there that this occurred in this demonstration?
- 3 What evidence is there that iodine is a solid that sublimates when heated?
- 4 Research whether iodine has a liquid phase or not and deduce what occurred in the experiment.
- 5 Explain why safety precautions were taken.

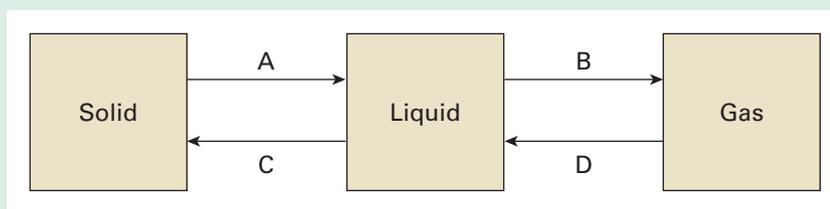
Conclusion

From this activity we can claim that heating and cooling of iodine crystals _____. This is supported through observations that _____. This means that _____.

Changing state**Try this 4.10**

Working with your classmates, role-play what heating a solid for example, (a change in state between a solid and a liquid, liquid and a gas) would look like. Make sure you can explain what the particles are doing. What would occur if you were to enact what happens when a gas cools down?

- 1 In your own words, define the processes of: melting, evaporation, boiling, sublimation, freezing, condensation and deposition. Add these terms to your glossary.
- 2 Solids, liquids and gases can change their state. In the diagram below, each arrow represents a change in state. Answer the questions below.

Quick check 4.6

- a Which letter represents melting?
 - b What is the name of the process represented by the letter B?
 - c What happens to the particles in a solid when it becomes a liquid?
 - d What is the name of the process represented by the letter C?
- 3 Use the particle theory to explain these questions.
 - a What happens when you increase the temperature of a cube of frozen juice?
 - b What happens when you increase the temperature of liquid water?

Practical 4.7**Heating curves****Aim**

To investigate and construct the heating curve for water.

Materials

- ice cubes
- cold tap water
- 250 mL beaker
- stirring rod
- Bunsen burner
- tripod
- gauze mat
- heatproof mat
- thermometer/temperature probe
- retort stand and clamp
- stopwatch
- matches
- safety glasses

Be careful

Take care when using the Bunsen burner, heatproof mat, tripod and glass thermometer. Be aware of the boiling water.

continued...

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Method

- 1 Wearing your safety glasses, set up the equipment as shown in Figure 4.31.

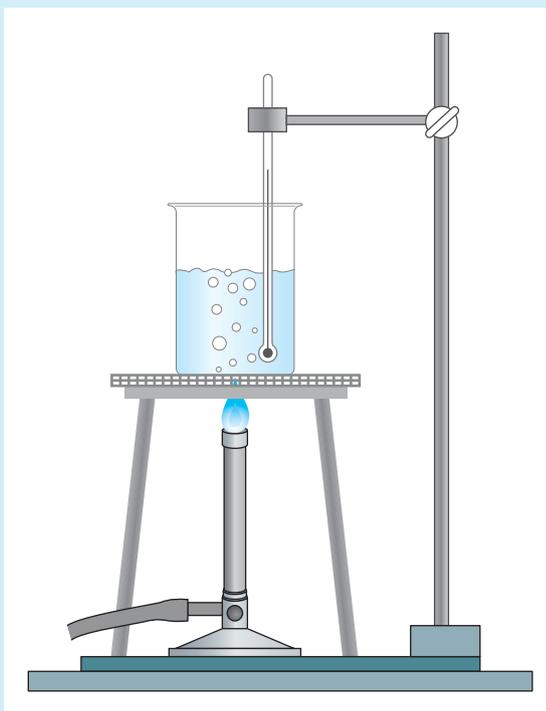


Figure 4.31 The equipment set-up you will need

- 2 Fill the beaker with 100 mL of cold tap water. Add ice cubes so that the water level increases about 50 mL.
- 3 Allow the ice–water mixture to settle and all come to the same temperature (about 5 minutes). Occasionally stir with a stirring rod.
- 4 Record the temperature of the ice–water mixture, this is time zero.
- 5 Light the Bunsen burner and gently heat the beaker of water.
- 6 Design a results table and then record the temperature of the water each minute until it is boiling. Your table should be placed under your 'Results' heading.
- 7 Once the water is boiling, continue taking measurements for another 5 minutes, then turn off the Bunsen burner.

Results

Use Excel or Desmos to draw a line graph to show how the temperature of the water changed over the total time you took measurements.

Evaluation

- 1 Mark on your graph:
 - where you had one or more of a solid, liquid and a gas
 - where the ice was melting and the water was boiling
 - where the melting and boiling points are.
- 2 Explain what is happening to the particles in the solid ice as they are melting.
- 3 Explain what is happening to the particles in liquid water as it is boiling.
- 4 Explain why parts of the graph are horizontal lines. Think about what is happening. Shouldn't the temperature be increasing if the Bunsen burner is still on? Where is the energy going?

continued...

...continued

- Would the graph look the same if you started with water vapour and cooled it down to form solid ice? Explain.
- Did your experiment work perfectly? Describe three possible sources of error for this practical and how they could be minimised in the future.

Conclusion

From this activity we can claim that heating water _____. This is supported through observations that _____. This means that _____.

Is hot water different from cold water?

Science as a human endeavour 4.3

You have just been investigating the three states of water – solid ice, liquid water and water vapour (gas). However, our understanding of the states of water is changing! In April 2016, an international team of scientists revealed that they had found signs that liquid water might actually come in two different states. The researchers were surprised to find a number of physical properties of water change their behaviour between 50°C and 60°C. This could have a massive impact on our understanding of biology and environmental science.



QUIZ

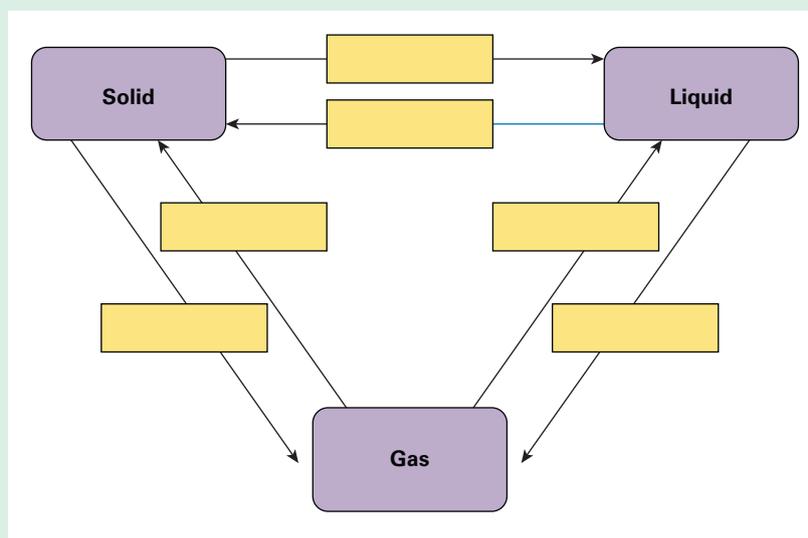
Section 4.3 questions

Remembering

- What happens to the closeness and energy of particles when you heat up something? What about cooling something instead?

Understanding

- Copy this diagram into your notebook and label the yellow boxes with the name of the process (for example, melting, evaporation). Then colour over the arrows with blue or red pen/pencil to indicate whether you add heat (red) or take it away (blue) to achieve that change of state.



continued...

...continued

Applying

3 For each of the following processes, decide whether energy is added or taken away.

- | | | |
|---------------|----------------|--------------|
| a sublimation | c freezing | e deposition |
| b evaporation | d condensation | f melting |

4 Describe the process of **a** ice melting and **b** water boiling, using the following terms:

boil	boiling point	decrease
evaporate	gas	heat
increase	liquid	melt
melting point	particle	solid
space	speed	temperature

Analysing

5 Answer the following questions using the information in the diagram below.

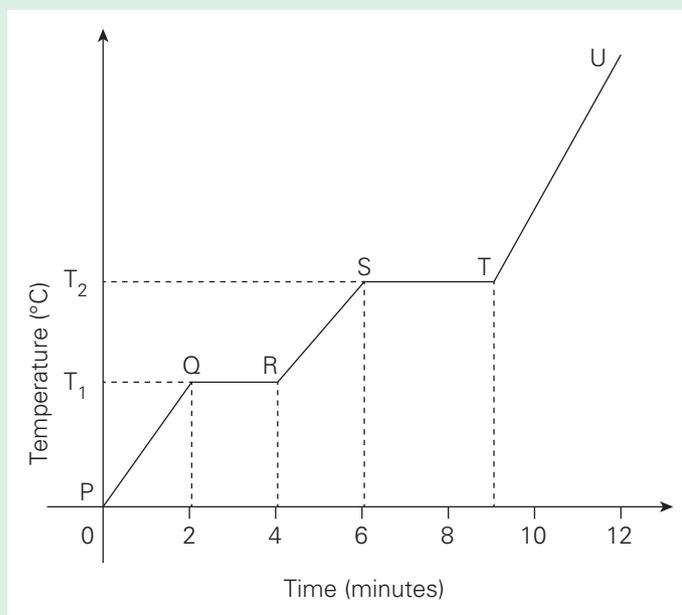


Figure 4.32 Heating curve of a substance that exists as a solid at time 0 minutes

- What process is happening between 2 and 4 minutes?
 - What is the state of matter that is present at **U**?
 - What is the temperature of the boiling point?
 - At what time is the substance all in liquid form?
- 6 Use the information in Table 4.2 on the following page to answer the following questions.
- Which substance has the highest melting point?
 - Which substance has the lowest melting point?
 - Order the substances from lowest boiling point to highest boiling point.
 - Name one substance that is a gas at 20°C.
 - Name one substance that is a liquid at 20°C.
 - Name one substance that is a solid at 20°C.

continued...

...continued

Substance	Melting/freezing point (°C)	Boiling point (°C)
Water	0	100
Aluminium	660	2467
Iron	961	2212
Alcohol	-130	78
Helium	-272	-268

Table 4.2 Melting, freezing and boiling points of different substances**Evaluating**

- 7 In cold countries, rock faces can sometimes have pockets of water trapped inside cracks after it rains. Describe what might happen if the trapped water freezes when the temperature drops.

Review questions**Remembering**

- Fill in the answers/blanks below.
 - Something you can do if you want a metal to get smaller.
 - Hot air _____ because it expands and gets less dense.
 - This metal is a liquid at normal temperatures and, because of the way it contracts and expands, can be used to measure temperature.
 - A word that means the same as evaporation.
 - The process of turning a solid into a liquid by heating it.
 - When the water vapour in the air cools down overnight, it will often _____ and form dew.
 - Hot air balloons rise because the _____ of its air increases.
- Copy and complete the following table.

	Solids	Liquids	Gases
Shape			
Volume			
Density			
Ability to flow			
Ability to be compressed			
Closeness of particles			

- What two measurements do you need to do to calculate the density of an object?

Understanding

- Explain why a solid is very difficult to compress when force is applied.
- Read each statement and determine if it is true or false, then rewrite any false statements as true ones.
 - Oobleck behaves only like a solid.
 - Oxygen can be compressed.
 - A wooden toy has a fixed shape.
 - Water will always boil at 100°C.
 - Melting points are different depending on the substance.
 - Steam changes back to a liquid at the boiling point.
 - Liquid particles have the highest speed of movement.

- h The particles in water are closer than in steam.
 i Solids and liquids have a fixed mass, while gases do not.
 6 a Match the property (A–D) with the correct behaviour of the particles (1–4).

Property
A Take the shape of the container
B Are very difficult to be compressed
C Cannot be poured
D Can spread out in all directions

Behaviour of particles
1 Because their particles are very close already
2 Because their particles are not held together at all
3 Because their particles are free to move
4 Because their particles are not free to move

- b Which of the above properties belong to gases?
 7 Temperature determines the state of a substance. Explain why.
 8 What is the likely outcome of heat being absorbed by particles?
 9 The particles of a substance are moving very fast with a lot of space between the particles. What is the substance likely to be?

Applying

- 10 Use your knowledge of the particle model to explain what happens in the following situations.
 a Decrease the temperature of steam (gas)
 b Decrease the temperature of liquid water
 11 Explain the gas pressure in a full balloon in terms of the particle theory.



Figure 4.33 Fully inflated balloons

- 12 Imagine a single grain of sand. It is hard and has a definite shape. If you scoop up a handful of dry sand, you can pour it out of your hand, which sounds like liquids, not solids. It is very difficult to build a sand castle with dry sand. However, if you wet the sand, you can shape it into a sand castle.



Figure 4.34 Sand seems to have different properties when it is wet and when it is dry.

- a Give reasons as to why you might classify sand as a solid.
 b Give reasons as to why you might also classify sand as a liquid.
- 13 Which of the following diagrams shows the particle arrangement in a solid, liquid and gas? Explain what it is about substance **B** that enabled you to identify it.

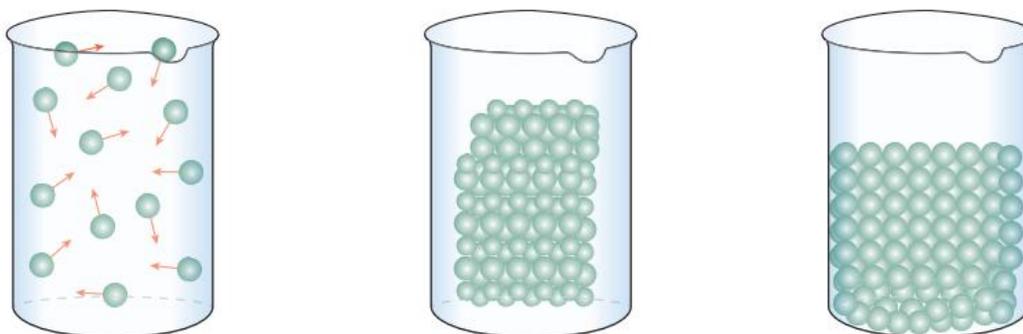
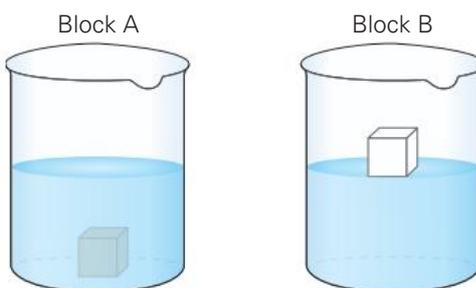


Figure 4.35 Substance A, substance B and substance C (left to right)

- 14 The particle theory of matter states that there are attractive forces and spaces between particles. Would you expect the forces of attraction to be greater or lesser for particles that are further apart from one another?
- 15 You get a can of creamy soda out of the fridge and leave it on the bench while you run to get a glass from the cupboard. When you return to your can, it has beads of water on the outside. Explain where the water came from and what change of state occurred.
- 16 Block A and block B are made of different materials. Each block is in a beaker with baby oil, as shown below.



- a Why does block A sink and block B float? The density of baby oil is 0.82 g/mL.
 b Do you expect the same or different results if you warm up the baby oil in the beaker containing block B?

Analysing

- 17 How does one gas diffuse through another?
- 18 The diagram below shows the process of diffusion occurring; that is, the movement of gases or liquids spreading out in another gas or liquid.

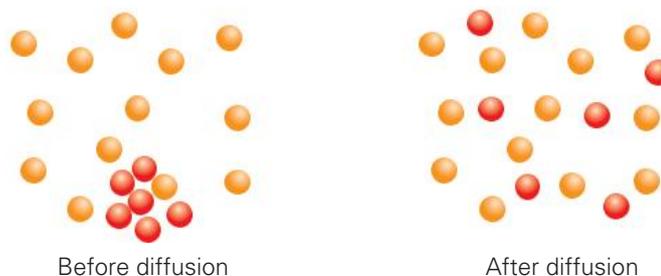


Figure 4.36 The process of diffusion illustrated as particle diagrams. The particles are constantly moving and over time, will spread through the gaps.

- a Explain what is happening to the red particles as they diffuse through the orange particles.
- b Factors like heat can affect how fast diffusion occurs. Would the red particles diffuse faster or slower in warm water? Explain making mention of the particle model.
- c The state of the substances diffusing can also affect how fast diffusion occurs. What do you think would diffuse faster – particles of perfume in the air or ink in water? Explain.
- d An effervescent tablet put into water bubbles away until it is gone and is an example of diffusion. Is it an example of a solid moving through a liquid, liquid moving through a liquid or a gas moving through a liquid? Explain.

Evaluating

- 19 Burning a fuel produces a lot of heat, and the particles formed are therefore likely to be moving very fast and are often in a gaseous state. Explain why, when solid or liquid fuels burn, the product is a gas.
- 20 When you are walking home from school, have a look at the concrete footpath. You may notice that it is not one long path but rather a series of large sections all in a row. Explain why you think concrete paths are constructed this way.
- 21 Dry ice is used in filmmaking to make creepy horror cemetery scenes. How is dry ice useful in this case?



Figure 4.37 Horror movies often utilise the properties of dry ice.

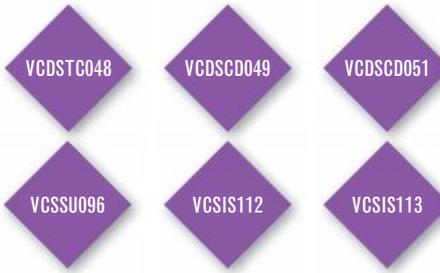
STEM activity: Prosthesis design

Background information

Your skeleton protects your organs and gives your body shape and structure. Your skeleton is necessary for you to move, make blood cells, store calcium and more! You would look very different without it. For various reasons, not everyone has all the bones that complete their skeleton. Biomedical engineers can help in this area. Biomedical engineers act to combine engineering principles and problem-solving strategies to medicine for healthcare purposes. In this case, a biomedical engineer would study the strength and durability of our bones so that they can replicate them to make prostheses (artificial devices that replace body parts).

Of course, there are criteria and constraints that a biomedical engineer needs to think about when designing, for example, a prosthetic leg. Consider what would be some important features of a good prosthetic leg.

Biomedical engineers design new ways to create prosthetic legs that have all the characteristics you have thought of, but most importantly biomedical engineers must carefully select the right materials for the project. Whenever something is made by engineers, they must consider both the chemical



and physical properties of the materials they use – their choices are key to biomedical technologies.

Design brief: Construct a lower-leg prosthesis that can assist in movement.

Activity instructions

In teams, you will become a biomedical engineer and investigate the technology of prosthetics. You will first list the characteristics and features that are important for a prosthetic leg, then design your prototype using various ordinary materials that you have selected based on their physical properties, and then create a lower-leg prosthetic prototype. Your team will then demonstrate your prosthetic's strength, analyse your prototype and make suggestions for design improvements.



Figure 4.38 Components of an artificial lower leg



Figure 4.39 An artificial limb restores functionality and independence.

Suggested materials

- ruler or tape measure
- scissors
- prosthetic structural materials from home, e.g. cardboard tubes, sponges, pants, shoes, rope
- roll of duct tape

Evaluate and modify

You are using your findings for an engineering conference presentation – include the following in your presentation:

- How you came up with the design.
- Describe the important design features of your prototype.
- List of materials and their physical properties.
- Justify why you used each material for its purpose.
- Demonstrate its use.
- Reflect upon your design: what improvements would you make to your prototype?

Chapter 5 Mixtures



Chapter introduction

Our world is an amazing place. It is made up of so many different substances like wood, food, metal, fibres, air, glass, plastic and ceramics. Some of these substances are considered pure substances, while some are mixtures of pure substances. 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.

Curriculum

Mixtures, including solutions, contain a combination of pure substances that can be separated using a range of techniques (VCSSU095)

• recognising the differences between pure substances and mixtures and identifying examples of each	5.1
• identifying the solvent and solute in solutions	5.2
• investigating and using a range of physical separation techniques such as filtration, decantation, evaporation, crystallisation, chromatography and distillation	5.3, 5.4
• exploring and comparing separation methods used in the home	5.3, 5.4

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Glossary terms

aqueous solution

centrifuge

chromatography

colloid

concentrated

crystallisation

decantation

dilute

dissolve

distillation

emulsion

evaporation

filtrate

filtration

flocculant

flotation

heterogeneous mixture

homogeneous mixture

insoluble

mixture

pure substance

residue

saturated

smog

soluble

solute

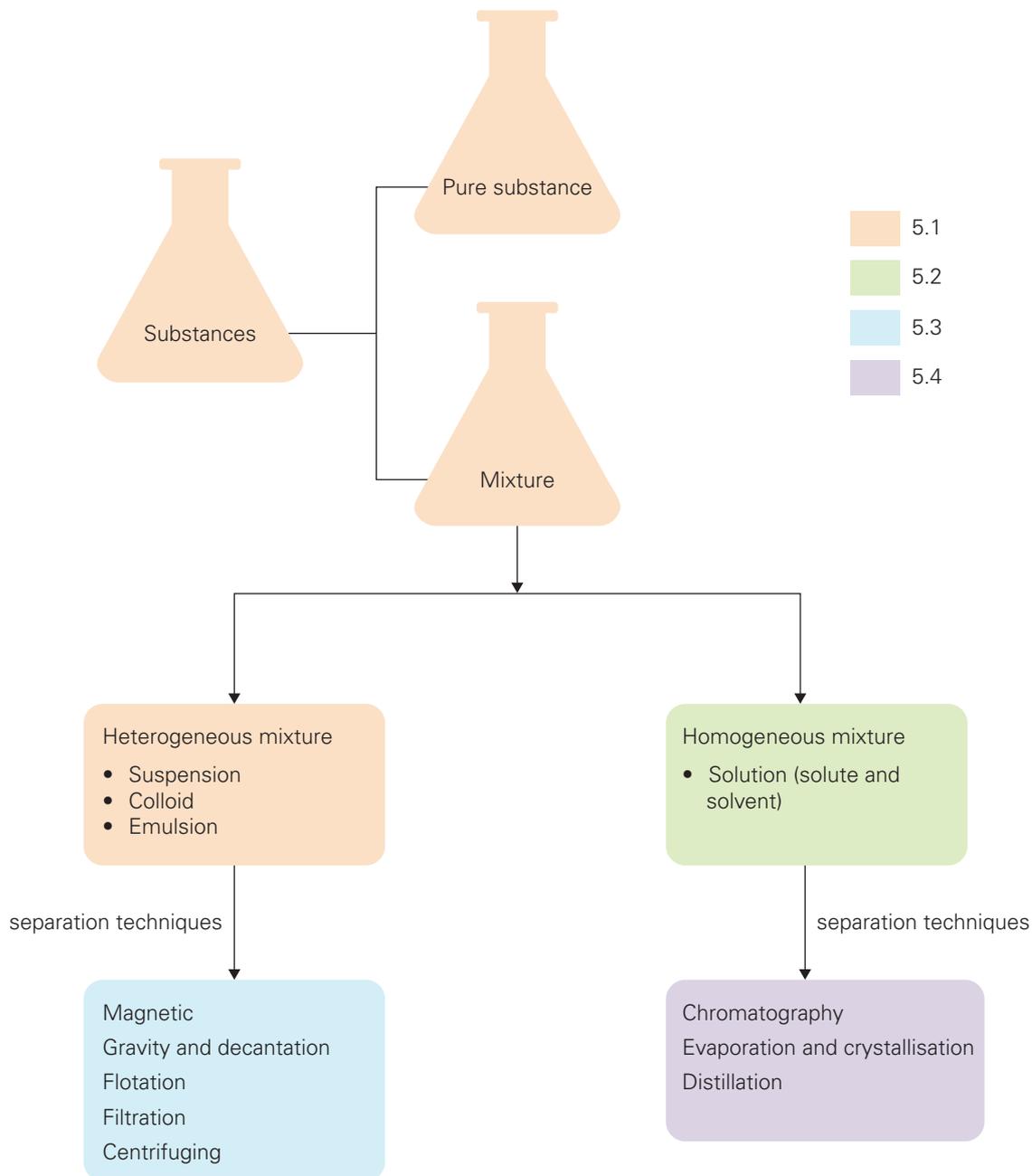
solution

solvent

suspension



Concept map





5.1

Pure substances and mixtures

Look around you. What do you see? It does not matter where you are or what you are looking at, almost everything that you can see is a mixture of different substances. In science, the area where you find out more about these substances and mixtures is called chemistry.

What is this?

Gather some everyday substances you see around you; for example, water, juice and so on. List their unique physical properties in a way that your classmates could guess the substance from the physical description.

Try this 5.1

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 one type of material or one type of particle, for example, pure water, pure gold and oxygen. Every pure substance has

pure substance
material that is made up of just one type of particle



Figure 5.1 Spaghetti bolognese sauce is a mixture you may love to eat.

unique physical properties such as different states, densities, size, magnetism, colour, mass, melting points and texture. Scientists need an understanding of these different physical properties to be able to distinguish one type of material from another.



WORKSHEET

Mixtures

Mixtures are substances made from two or more different pure substances mixed together that 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 and colouring), a cup of tea (a mixture of tea leaves and water), tap water (a mixture of water, fluoride salts, salts dissolved from ground and chlorine), spaghetti bolognese (a mixture of pasta, tomatoes, beef, garlic, chillies and thyme) and healthy fruit salad (a mixture of kiwi fruit, apples, bananas and raspberries).

mixture
material made up of two or more different pure substances

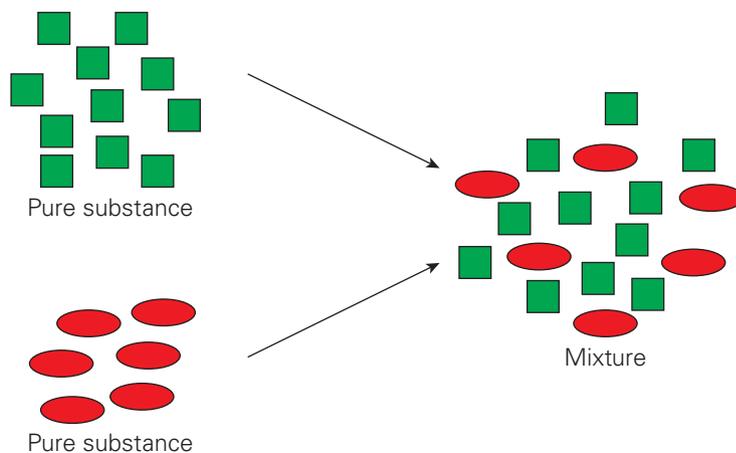


Figure 5.2 A mixture is made of two or more pure substances.

- 1** Define the terms 'pure substances' and 'mixtures' in your own words. Add them to your glossary.
- 2** Following is a list of pure substances and mixtures. Draw up a table with the headings 'Pure substances' and 'Mixtures' and write the names of the following substances into the correct column.
- | | | |
|------------|----------------|------------------|
| smoke | pen ink | iron |
| soft drink | aluminium foil | cough medicine |
| trail mix | margarine | filtered water |
| hand cream | chocolate milk | polystyrene foam |
| salt water | ice cream | cheese |
| oxygen | carbon dioxide | blood |

Quick check 5.1**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

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**.

Identifying mixtures**Try this 5.2**

Have a look at a glass of vinegar (a solution). Look at it closely and try to identify the characteristics mentioned in Table 5.1; for example, solutions are usually transparent or see-through. Then look at an example of a suspension, a colloid and an emulsion and practise identifying the characteristics that define them.

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 so it always looks cloudy.	Whipped cream (the gas air is distributed throughout the liquid cream) Hair gel Wet paint (a solid pigment distributed in liquid)
Emulsion	A type of mixture that is formed when a colloid of two or more liquids 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

dissolve

cause to become mixed in a substance so that it cannot be seen

solvent

the component in a solution capable of dissolving another substance

Table 5.1 Types of mixtures



Figure 5.3 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, or chocolate sauce – suspension; 4. tea – solution of tea and water; 5. hair gel – colloid of solid particles in water; 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 snowflakes and water; 9. muddy water – suspension of mud and water.

Copy and complete the following table and use the mixtures in the Figure 5.3 on the previous page for the 'Examples' column.

Quick check 5.2

Type of mixture	Transparent or cloudy?	Separates/settles when left to stand?	Examples
Solution			
Suspension			
Colloid			
Emulsion			

Milk used to come with cream!
Did you know? 5.1

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 5.4 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 5.5 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. Remember, physical properties are how a substance looks (size, mass, texture, shape, volume) or how it behaves around other substances (is it magnetic? dense? able to dissolve?).

Recycling sorting

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 weight and more manual sorting. The separated elements are then taken to their respective recycling companies.



Figure 5.6 Your weekly recycling is sorted using a variety of different separation techniques because of the different properties of the substances.

Creating a photo essay

Note: You need a smartphone or camera for this activity.

Create a time sequence photo essay. 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. 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?

Try this 5.3

Classifying mixtures

Mixtures can be broadly classified into two categories: **homogeneous mixtures** and **heterogeneous mixtures**.

homogeneous mixture
a mixture where components are evenly distributed

heterogeneous mixture
a mixture that can be easily separated into its parts, and those parts retain their original properties

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.

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.

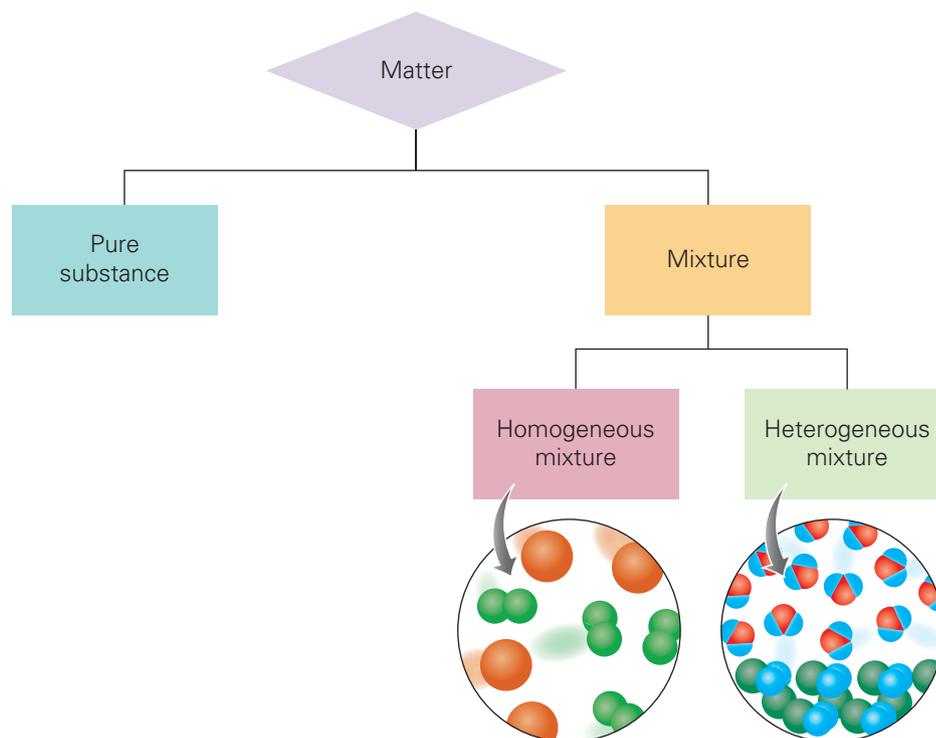


Figure 5.7 How particles may be organised in a heterogeneous mixture and a homogeneous mixture.

Heterogeneous mixtures are mixtures that can be easily separated into its 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, trail mix, 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

Observing mixtures

Observe a selection of the following mixtures, firstly 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 just like being a scientist. 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.

Try this 5.4

- 1 Define the term 'heterogeneous' and list the characteristics that allow you to identify if a mixture is heterogeneous. Add it to your glossary.
- 2 Define the term 'homogeneous' and list the characteristics that allow you to identify if a mixture is homogenous. Add it to your glossary.
- 3 Classify the following substances as either a mixture or a pure substance. If it is a mixture, deduce whether it is homogeneous or heterogeneous.
Substances: pure water, Coca Cola, iron nails, green paint, chunky salsa, silver ring, chocolate chip cookies, concrete, orange juice with pulp, table salt.
- 4 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.

Quick check 5.3**Practical 5.1****Sherbet!****Aim**

To investigate how changing the proportions of the components in a mixture can change the properties of the mixture.

Materials

- 4 samples of ingredients (labelled A–D)
- icy-pole sticks
- small zip-lock snack bags

Method

- 1 Wash your hands.
- 2 Go to your teacher and receive a small scoop of sample ingredient **A** into the *palm of your hand*, using the tip of an icy-pole stick. You are to record the taste of the ingredient before returning to your teacher to get another ingredient to sample (**B, C, D**).
- 3 Using a small snack bag, make a mixture of 1 teaspoon of each of the four sample ingredients. You are to record the taste of your mixture.
- 4 You now have three opportunities to change the taste of your mixture by changing one ingredient at a time. Record which of the ingredients you are going to change and how, collect a new snack bag and make your new mixture. Repeat until you have the best tasting mixture ever!

Results

- 1 Record the taste of ingredients **A, B, C** and **D** on their own.
- 2 Draw up a table that shows how much of each ingredient was added to your four recipes and each recipe's taste. Record your data in this table.

Evaluation

- 1 Describe which ingredients tasted good on their own and which did not taste good.
- 2 Explain why an ingredient that tastes bad on its own would be in your sherbet mixture.
- 3 Compare your recipes and the taste that you ended up with, even though the ingredients were the same, you would have noticed different taste sensations.

Conclusion

From this activity we can claim that the taste property of a mixture _____. This is supported through observations that _____. Therefore it can be concluded that _____.

Be careful

Alternative room and equipment should be used for this activity so there are no chemical or biological materials that could potentially contaminate the activity.



QUIZ

Section 5.1 questions

Remembering

- 1 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. Give two examples of each.
- 3 Outline the differences between heterogeneous mixtures and homogeneous mixtures. Give two examples of each.

Applying

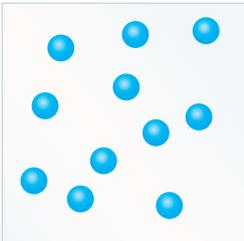
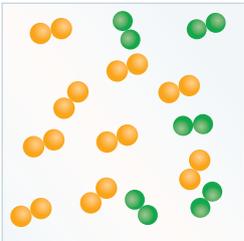
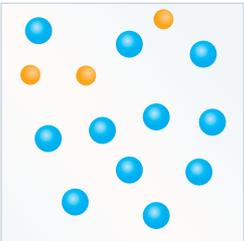
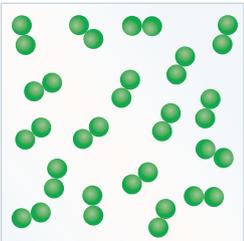
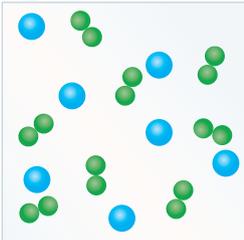
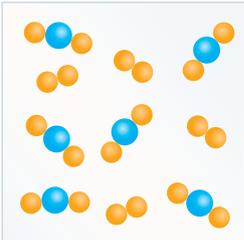
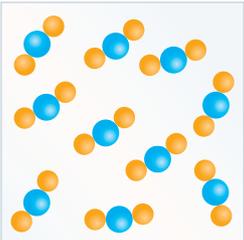
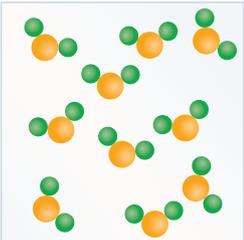
- 4 Is 100% pure carrot juice a pure substance? Explain using the definitions you have learned.
- 5 You are looking at a beaker with a substance in it. How can you tell if it is a solution, suspension, colloid or emulsion? Show your knowledge of the characteristics of the four types of mixture in your answer.

Analysing

- 6 Consider a solution and a colloid. Work out the states of matter that are possibly involved in each of these types of mixtures. As an example, a suspension is a *solid* suspended in a *liquid*.

Evaluating

- 7 Select one or two words from the following list that best describe each of the following particle diagrams:
mixture; pure substance; heterogeneous; homogeneous.



5.2

Solutes, solvents and solutions

To fully understand the properties of both a homogeneous mixture and heterogeneous mixture, 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 not only the answer to a mathematics question, but also a type of

mixture that is formed when the particles of one substance break up, separate and spread out evenly into another substance. This act of breaking up, separating and spreading out is called dissolving. 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.



WORKSHEET



Figure 5.8 Tap water is a solution as it is a mixture of chlorine, fluoride salts and more, all dissolved evenly into pure water.

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? What are the particles looking like?

Try this 5.5

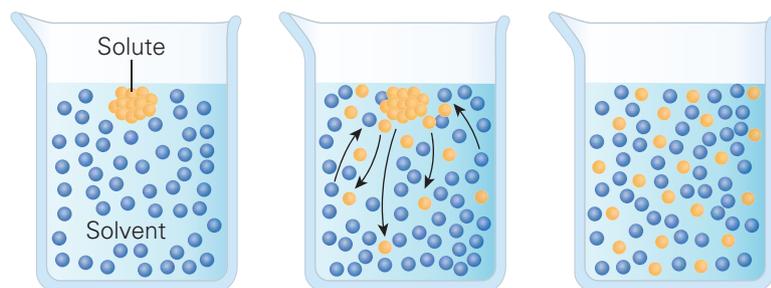


Figure 5.9 Particle diagram of a solid solute dissolving into a liquid solvent to form a solution

Examples of solutions

An everyday example of a solution is the oxygen dissolved in a fish tank water, 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. Such solutions are called **aqueous solutions**.

aqueous solution

solutions where the solvent is water

soluble

substances that can dissolve

insoluble

substances that cannot dissolve

Not everything is able to dissolve to form a solution. Substances that can dissolve are called **soluble** and those that are unable to dissolve are called **insoluble**.



Figure 5.10 Oxygen is a solute that is dissolved in the solvent water to form the solution that organisms like fish and plants live in.

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.

dilute

a solution with little of the solute

concentrated

a solution with a lot of the solute

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 5.11 The more dilute solutions are on the left, while the more concentrated solutions are on the right.

- 1 Choose from the list to 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 Update your glossary with these terms: solution, solvent, solute and aqueous solution.

Quick check 5.4

Investigating solubility**Try this 5.6**

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, bicarbonate of 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 carefully 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.

Saturation

Did you try adding more and more solute to one of your containers in the ‘Try this’ 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

Melbourne Water

is responsible for managing Melbourne's water assets on behalf of the community. They supply drinking water, catch and store water, recycle water, protect the waterways and maintain drainage systems.

Explore! 5.1

Research and find out what is added to our drinking water to make it drinkable. What is the role of each of the additives?

Practical 5.2: Self-design**Factors affecting how fast a substance dissolves****Aim**

To investigate the effect of a surface area on how quickly an effervescent tablet dissolves

OR

To investigate the effect that temperature has on how quickly an effervescent tablet dissolves.

Materials

- 2 test tubes and stoppers of the same size
- 2 effervescent tablets
- test-tube rack
- access to tap water, cool water/ice and warm water/kettle
- metal spoon
- mortar and pestle
- stopwatch or equivalent



Figure 5.12 The dissolving of an effervescent tablet (solute) into water (solvent) to form an aqueous solution.

continued...

...continued

Method

1 Choose whether you would like to investigate:

- the effect of surface area on how quickly an effervescent tablet dissolves

OR

- the effect that temperature has on how quickly an effervescent tablet dissolves.

2 Design a simple experiment using two test tubes: a crushed effervescent tablet versus an uncrushed tablet

OR

cool water versus warm water.

3 Consider what you are investigating in this experiment and so what you will need to change between the test tubes. Consider what you must keep the same.

4 Write up your method in numbered steps showing details, such as the amount of water you will add to your test tubes.

5 Show your teacher your method and ensure that you discuss any risks and how they can be prevented. This is called a risk assessment.

6 Write a hypothesis for your experiment: which effervescent tablet situation do you think will dissolve faster?

7 Carry out your experiment safely and record your results in minutes and seconds.

Results

Design a table that will allow you to record how quickly the effervescent tablet dissolves in each of your situations.

Evaluation

1 Which test tube contained the effervescent tablet that dissolved the quickest?

2 What could you conclude based on your results? Did this agree with your hypothesis or not?

3 Sometimes in experiments things may happen by accident (for example, pouring too much water into the test tube) or are beyond your control (for example, it is a really hot day on the day of the experiment), and these may affect the outcome of your investigation. Were there any sources of error in your experiment? How could you work to prevent them from occurring in the future?

4 Speak to your classmates about what they investigated and found out.

5 What would be more useful? A tablet that helps you rehydrate after playing sport or a powder that helps you rehydrate after playing sport?

Conclusion

From this activity we can claim that _____. This is supported through observations that _____.

Therefore it can be concluded that _____.



QUIZ

Section 5.2 questions

Remembering

1 Define these terms: saturated solution, aqueous solution, dilute solution, concentrated solution.

Understanding

2 Rewrite each statement in your notebook and fix them to make them true.

- Soluble is when a substance cannot be dissolved in a solvent.
- The solvent dissolves to form a solution.
- A mixture is when different substances are chemically combined.
- A saturated solution is a solution in which the minimum amount of solute has been dissolved.

continued...

...continued

- e In a solution, it is the solute that is unable to dissolve into the solvent.
- f Concentrated solutions have a lot of solute compared to the amount of solvent.
- g A suspension is a mixture in which a solute is dissolved in a solvent to form a transparent liquid.

Applying

- 3 Why is it possible to see solid salt crystals in water but not possible to see the dissolved salt particles?
- 4 What is the solvent, solute and solution in the following situations?
 - 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. How could you do this and what results would you expect?

Analysing

- 6 Compare and contrast solutions and mixtures. You may like to use a Venn diagram.
- 7 Are all solutions mixtures? Or are all mixtures solutions? Give some reasons for your choice.

Evaluating

- 8 Look at this diagram of a test tube containing a liquid substance and a soluble solid substance. Redraw and label the diagram as many times as needed 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



5.3 Separating heterogeneous mixtures

You may recall earlier in this chapter you saw that heterogeneous mixtures like fruit salad, pizza and choc-chip cookies, 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 anchovies off your pizza. 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 5.13 Magnets can be used to separate magnetic substances from non-magnetic substances.

Decantation

If you have dropped some of your hot dog in your drink at a birthday party, the hot dog will sink to the bottom of your glass.

The process of **decantation** can help you separate your drink from the hot dog.

decantation
the process of separating by using gravity

flocculant
a substance that causes particles to clump

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 or panning for gold at Sovereign Hill.

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 easy 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 safely stored and disposed of.



VIDEO
Explain how spills in the ocean are cleaned up.

flotation
separating a mixture based on the capacity to float

Figure 5.14 Booms and skimmers helping to clean up an oil spill



Practical 5.3: Teacher demonstration**Decanting, using a flocculant and flotation****Aim**

To observe a demonstration of decanting, flocculation and flotation.

Materials

- alum (potassium aluminium sulfate) or equivalent
- sand
- muddy creek/river water
- glass beaker
- 2 glass cylinders
- stirring rod or spoon
- polystyrene cup, broken up
- pasta-straining spoon or equivalent

Method

- 1 Decantation: Mix the sand in the water until the water appears cloudy. Leave the mixture to separate and the sand settle to on the bottom. Very carefully, pour the water off the top of the sand so that the sand remains in the cylinder.
- 2 Flocculation: Put muddy river water into two glass cylinders. In one cylinder, stir in 3 mL of alum flocculant solution for 2 minutes. Leave the mixture to separate for 15 minutes. Compare the two cylinders.
- 3 Flotation: Mix the polystyrene cup pieces in the water. Leave the mixture to separate and the polystyrene cup pieces to float to the top. Use a tool like a pasta-straining spoon to remove the polystyrene cup pieces from the top of the water.

Results

Describe what has happened in each situation and why.

Evaluation

Discuss possible sources of error when carrying out each of the techniques.

Conclusion

From this activity we can claim that _____. This is supported through observations that _____. Therefore it can be concluded that _____.

- 1 What should you use to separate a mixture of sand and iron?
- 2 What might prevent a magnet being useful to separate the components of a mixture?
- 3 In what situation would hand-picking 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.

Quick check 5.5

Figure 5.15 Flocculants can be used to help clean pool water.

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 name for 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



Figure 5.16 Cafes use filters when making coffee.

Combustion engines in cars have very fine filters that can trap extremely small carbon particles and stop them from polluting the atmosphere.

Did you know? 5.2

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.

filtrate

the substance that passes through the filter

residue

the substance that is left in the filter

Toothless whales have filters

Did you know? 5.3

The humpback whale, and other toothless whales, possess a unique feeding adaptation called a 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 in our hair and nails. The blades filter small animals such as krill, plankton and small fish out of the sea water.



Figure 5.17 The mouth of a humpback whale contains a baleen which allows them to filter the ocean water for krill.

Drawing a filter

Try this 5.7

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 5.4**Filtration practice****Aim**

To practise using the equipment required for filtration and to carry out a separation of chalk and water using this equipment.

Materials

- beaker containing a mixture of chalk and water
- beaker
- small filter funnel
- stirring rod
- filter paper
- retort stand and clamp
- bosshead clamp

Method

- 1 Fold your filter paper as shown in Figure 5.18.

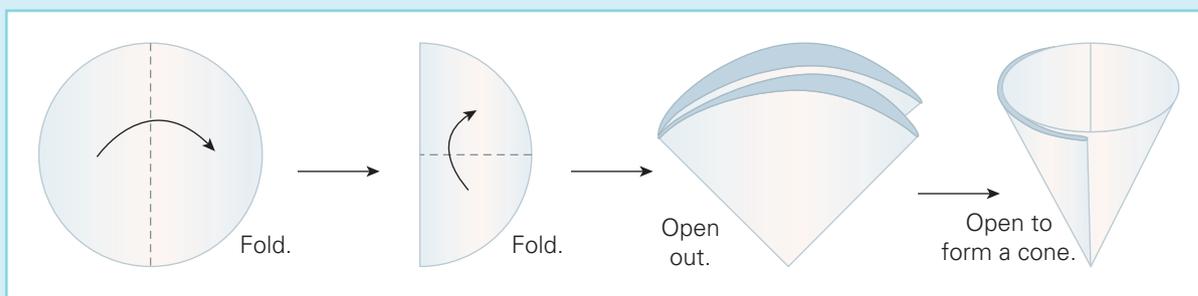


Figure 5.18 How to fold your filter paper

- 2 Set up your equipment as shown in Figure 5.19.

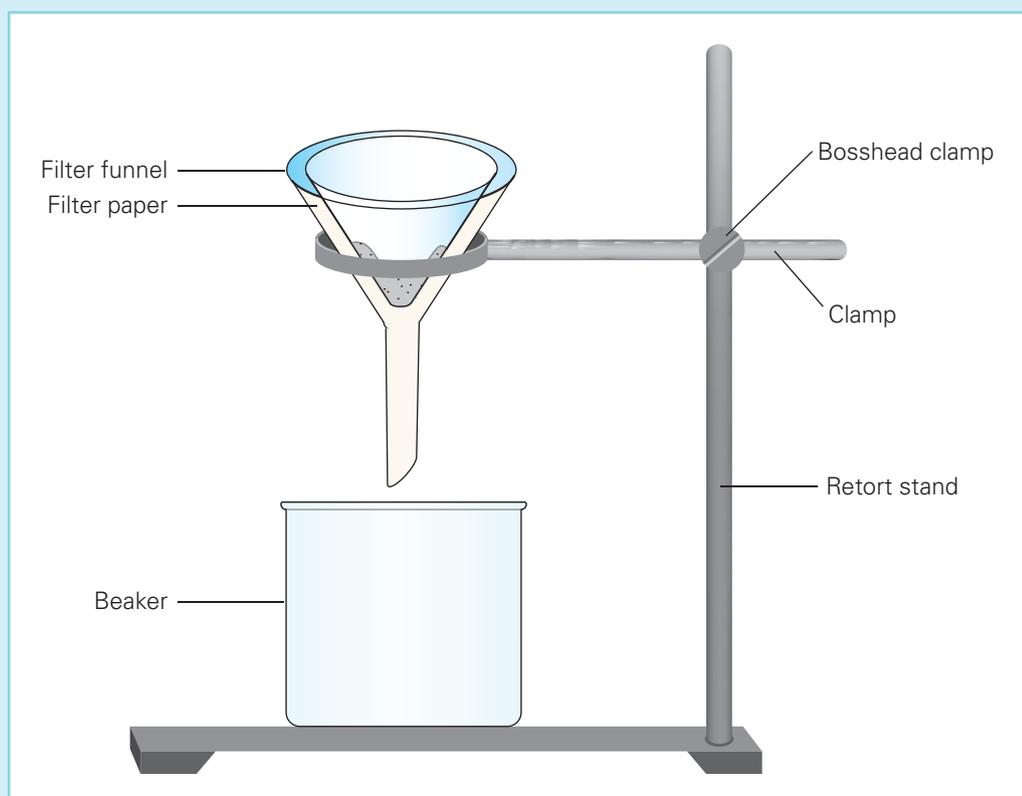


Figure 5.19 Practical set-up

continued...

...continued

- 3 You may need to dampen your filter paper with some water so that it sticks to the sides of the filter funnel.
- 4 Write your hypothesis – what do you predict will happen? Use the terms 'mixture', 'filter funnel', 'residue', 'filtrate'.
- 5 Stir or swirl your mixture and then carefully and slowly pour it into the filter paper. Take care not to fill the filter funnel up to the top, just add more mixture gradually, swirling each time.
- 6 Keep adding the mixture until it is all gone. You can add extra water to help get any of the mixture stuck on the beaker into the filter funnel.
- 7 Once all the mixture has passed through the filter paper, you can pull out the filter paper and leave it somewhere safe to dry.

Results

Record your observations. What is in the beaker? What is in the filter paper?

Evaluation

- 1 What are the physical properties that allowed the components of the mixture to be separated?
- 2 What are the names of the different components of the mixture once they have been separated?
- 3 What were possible sources of error when using this separation technique?
- 4 How could you minimise the impact of these sources of error in the future?

Conclusion

From this activity we can claim that the separation of chalk and water can be achieved through _____. This is supported through observations that _____. This means that _____.

Our kidneys have filters

After your body has processed the nutrients you consumed, 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.

Did you know? 5.4

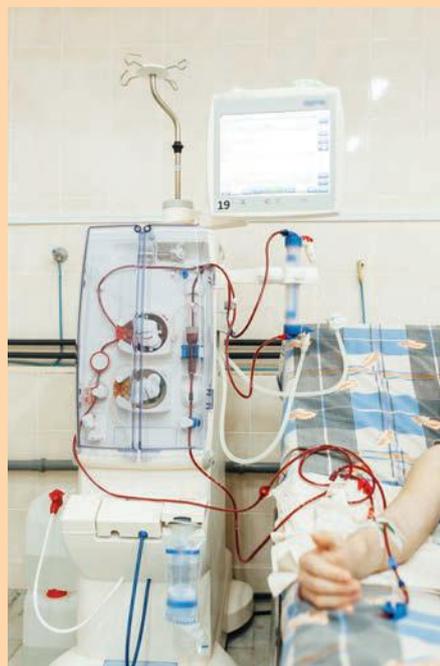


Figure 5.20 The haemodialysis machine filters blood by trying to mimic what your kidneys do.

Charcoal and salt are accidentally mixed together. The mixture is placed in water and stirred before being passed through filter paper.

Quick check 5.6

- 1 What remains in the filter paper?
- 2 What passes through the filter paper?
- 3 The filtrate is the _____.
- 4 The residue is the _____.
- 5 The residue is found in the _____.
- 6 A filter funnel can separate two substances in a mixture when those two substances have different _____.

The Victorian Desalination Project
Science as a human endeavour 5.1

In 2012, the Victorian Desalination Project in Wonthaggi was completed by a company called Aquasure. The desalination plant took three years to build and involves several filtration steps. 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 let 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.

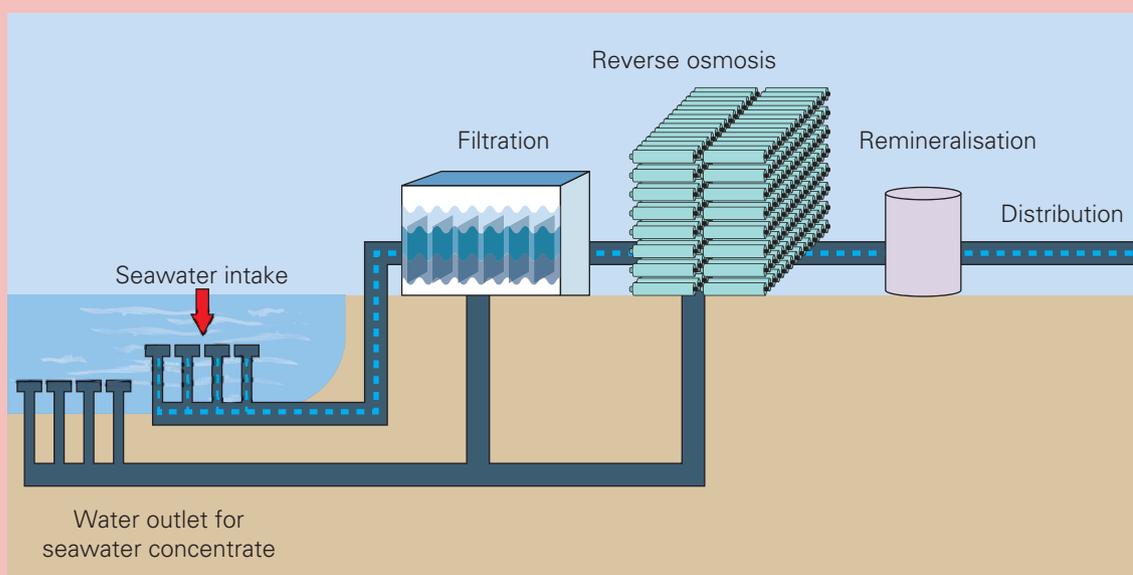


Figure 5.21 Desalination process

Melbourne Zoo has an onsite water treatment plant, which uses different mixture separation techniques to purify water that comes from the animal wash-downs, emptying of the ponds within animal exhibits, overflowing lakes, rain water and storm water.

Explore! 5.2

- 1 Research the Melbourne Zoo saving water page and list the different steps involved in the process of water purification at Melbourne Zoo.
- 2 Explain each of the steps using the separation techniques you have learned so far in this chapter.



Figure 5.22 A seal enjoying one of the benefits of the Melbourne Zoo's water treatment plant

Centrifuging

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)

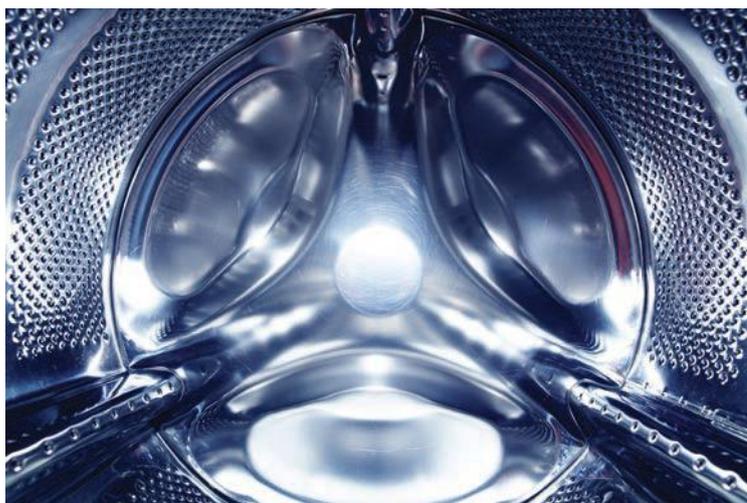


Figure 5.23 Both the inside of your washing machine and a salad spinner are designed to spin so fast that the water moves outwards through the holes, while the clothes or salad remains in the centre.

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.

Blood has different components

Did you know? 5.5

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 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?

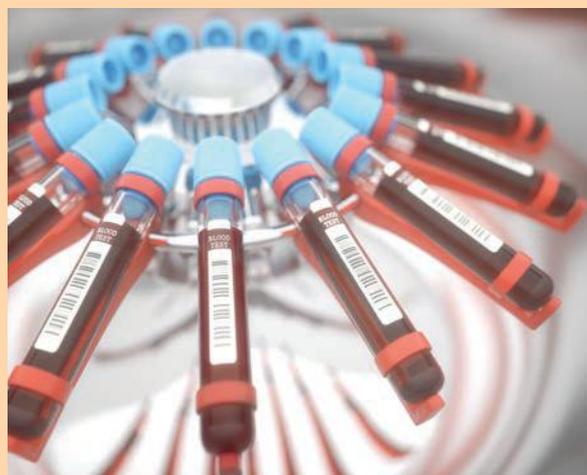


Figure 5.24 Whole blood being centrifuged to separate the components





QUIZ

Section 5.3 questions

Remembering

1 Explain how centrifugation separates the substances in a mixture.

Understanding

2 Does filtering always work? Explain why you may sometimes find flies in your house despite having flyscreens on the windows.

3 Which of the following cannot be separated using a centrifuge: components of blood; water from lettuce leaves; cream from milk; salt from sea water.

Applying

4 Why can you not filter dissolved sugar out of water? Include the terms you have learned earlier in this chapter in your answer.

5 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.

6 Explain why filtering water does not mean that it is pure.

Analysing and Evaluating

7 a All of the filters in Figure 5.26 are used in the home. For each, consider its role and state the:

- components of the mixture
- residue
- filtrate.



Figure 5.25 A modern-day gas mask

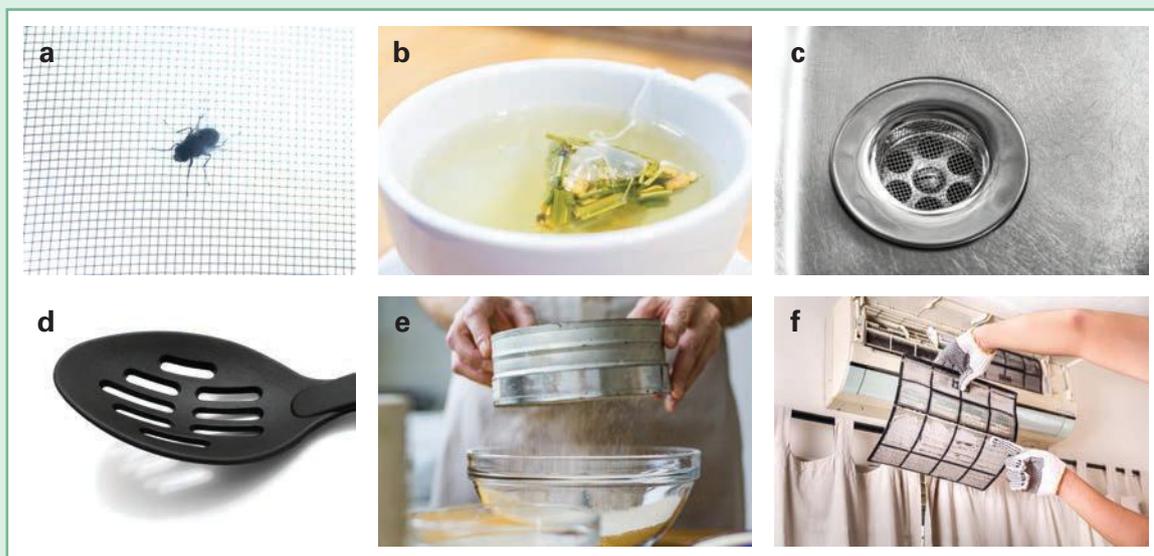


Figure 5.26 Filters

- 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.



5.4 Separating homogeneous mixtures



WORKSHEET



VIDEO

Predict what colours each ink will separate into.



VIDEO

Why is one of the yellow components longer?

chromatography

a technique to separate substances based on movement at different rates due to solubility

There are a variety of separation techniques that can be used to separate homogeneous mixtures. What does 'homogeneous' mean again?

Chromatography

Chromatography is a technique used to separate the substances in a mixture based on their solubility, that is their ability to dissolve in a solvent (and also their attraction to a solid material, for example paper). Look at Figure 5.27. 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 5.27 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 5.5

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 Place about 1 cm of the water into a beaker.
- 2 Draw a line using a pencil 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.
- 3 Using the water-soluble colour marker pen, draw a small dot onto the filter paper in the middle of your pencil line.

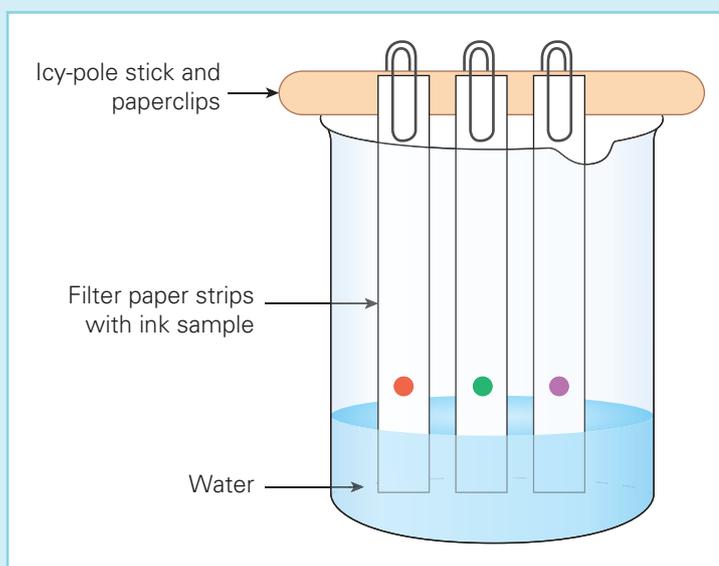


Figure 5.28 Experimental set-up

- 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.
- 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.

continued...

...continued

- 7 Leave the strips for about 10 to 20 minutes after placing the strip 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 book (or take a photo and upload it to your practical report file).

Evaluation

- 1 The chromatogram formed is unique for each type of pigment. What did you find out about the different pigments in green, red and yellow/orange pens?
- 2 What were possible sources of error when using this separation technique?
- 3 How could you minimise the impact of these sources of error in the future?

Conclusion

From this activity we can claim that pen ink _____. This is supported through observations that _____. Therefore it can be concluded that _____.

Drug screening

Gas chromatography is one of the most common methods of testing urine and blood samples for drugs. In gas chromatography, the sample is converted into a vapour in the presence of a gaseous solvent and placed into a special machine. Each component of the sample will dissolve differently in the gas and will only stay in the gas phase for a unique time, called the retention time. When the sample is analysed, it is compared to known samples of different drugs, so that specific drugs can be identified in the urine or blood samples.

Did you know? 5.6

Invisible ink

Find a recipe for 'lemon invisible ink' and write a message on some paper. Once it is dry, ask a friend to use the heat of a light bulb to read it.

Try this 5.8

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.

Did you know? 5.7

Evaporation and crystallisation

You may recall from the previous chapter that **evaporation** is a change in state from a liquid

evaporation

when heat causes liquid to become gas

to a gas, but it is also 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 the 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, washing drying in the sun on the clothes line or dehydrated baby peas in the pantry.

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

crystallisation

solidification of a substance into a highly structured form

occurs because as the solvent forms a gas, 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? Or perhaps you have visited the Pink Lakes in the north-west of Victoria?



Figure 5.29 The Pink Lakes in the Murray Sunset National Park, Victoria

Practical 5.6: Teacher demonstration

Copper sulphate crystals

Aim

To observe and explain the formation of copper sulfate crystals.

Materials

- saturated solution of copper sulfate (solid copper sulfate and hot water)
- beaker
- test tube and test-tube rack
- paperclip
- icy-pole stick
- sewing thread

Be careful

DO NOT discard the copper sulfate solution down the sink. Copper sulfate waste needs to be collected and disposed of properly.

continued...

...continued

Method

- 1 Make a saturated solution of copper sulfate in a beaker using solid copper sulfate and hot water.
- 2 Let the solution settle briefly. (Alternatively, pour the solution through filter paper in a filter funnel and then pour the solution into a test tube in a rack.)
- 3 Tie a paperclip to the icy-pole stick using the thread and suspend it in the centre of the solution as demonstrated in Figure 5.30.
- 4 Leave it to cool overnight.

Results

Describe what you found the next day.

Evaluation

- 1 Explain what formed overnight and how.
- 2 What was the purpose of the paperclip?
- 3 What substance has been lost during this experiment? How could you prevent this from happening?
- 4 How useful would this technique of separation be if the solute was a mixture of substances? Explain.
- 5 What were possible sources of error when using this separation technique?
- 6 How could you minimise the impact of these sources of error in the future?

Conclusion

From this activity we can claim that evaporation and crystallisation _____. This is supported through observations that _____. Therefore it can be concluded that _____.

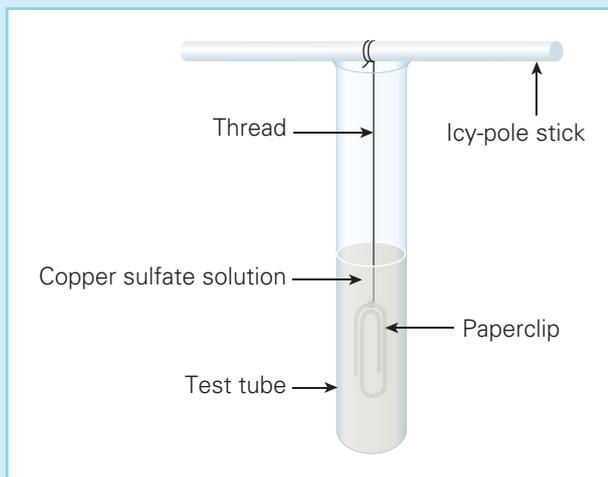


Figure 5.30 Experimental set-up

- 1 Choose the correct term from the list to complete the sentences.

filter pigments pigments solvent water

Quick check 5.7

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.

- 2 Number each of the following statements to indicate the order they occur in the process of chromatography.
 - _____ Place your sample in the centre of the pencil line.
 - _____ Place about 1 cm of water into a beaker.
 - _____ 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.
- 3 Update your glossary by defining the key terms 'evaporation' and 'crystallisation'.
- 4 How could you separate salt and ground pepper (that can float) when they are all mixed up together? Include the terms 'evaporation' and 'crystallisation' in your explanation.

Practical 5.7: Self-design

The ultimate separation

Aim

To create a mixture that will involve magnetism, decanting, flotation, filtering and evaporation to purify; and to then design and carry out a method that will separate the mixture back into its original components.

Materials and method

- 1 Provide your teacher with a list of the materials you require for both your mixture and separation design. Keep in mind the practicals, 'Try this' activities and teacher demonstrations you have done in class.
- 2 Show your teacher a diagram of the arrangement of the equipment you will use and a step-by-step method of your separation process. You may like to include a flow chart as part of your method.
- 3 Discuss with your teacher the risks associated with your experiment and how you may avoid them.
- 4 Once approved, create your mixture and carry out the subsequent separation.

Results and evaluation

- 1 List your mixture ingredients and the properties of each ingredient that made it stand out from the rest.
- 2 Summarise your separation techniques and the property they were separating the mixture based on.
- 3 Discuss your separation design and how successful it was.
- 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?

Conclusion

From this activity we can claim that _____. This is supported through observations that _____. Therefore it can be concluded that _____.

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

distillation

a technique to separate substances in a liquid using evaporation through boiling and condensation

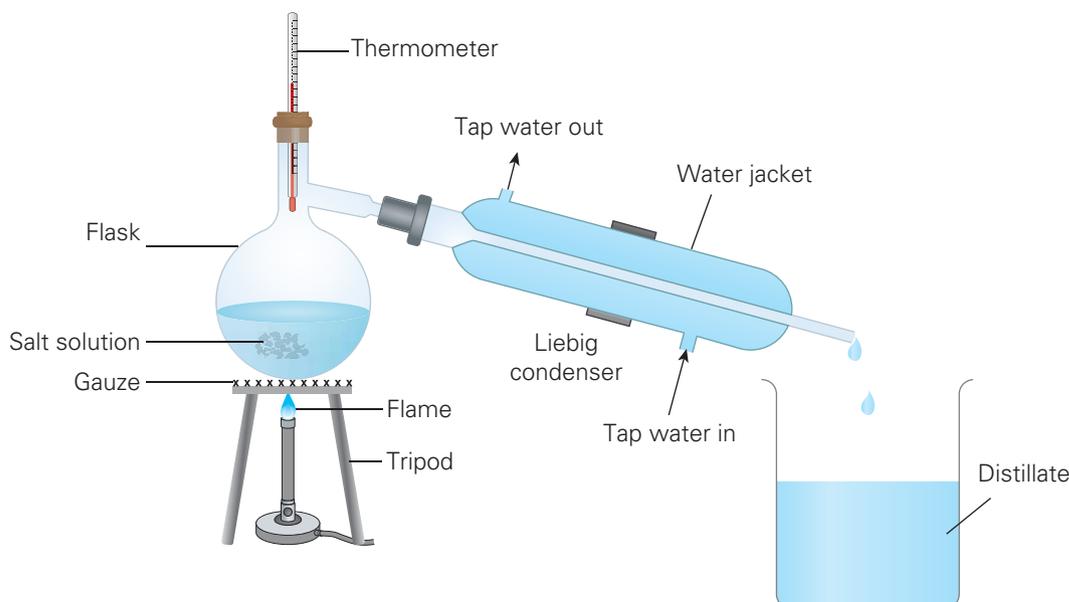


Figure 5.31 A Liebig condenser is used for the process of simple distillation.

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 as it forms the distillate in the test tube at the end.



Figure 5.32 Distillation equipment used for the food and beverage industry.

Practical 5.8: Teacher demonstration

Distillation

Aim

To observe and explain 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 5.31 on page 191.
- 2 Wearing safety goggles, put 100 mL of water into one of the beakers. (The other one will collect the distilled water.)
- 3 Use the spatula to add salt and stir.
- 4 Continue adding salt until the solution smells distinctly salty. Pour the salty solution into the round-bottomed flask of the distillation apparatus.
- 5 Turn on the water that circulates in the condenser.
- 6 Heat the salty solution.
- 7 Smell the distilled water that you collect.

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.

continued...

...continued

Results

- 1 Describe your observations of this process.
- 2 What did the distilled water smell like?
- 3 What substance is left behind in the round-bottomed flask?

Evaluation

- 1 Why was it necessary to heat the salty water solution?
- 2 Explain how the condenser works.
- 3 Why did the distilled water have a smell?
- 4 Which part is the distillate?
- 5 What were possible sources of error when using the different separation techniques?
- 6 How could you minimise the impact of these sources of error in the future?

Conclusion

From this activity we can claim that distillation _____. It was observed that _____. Therefore it can be concluded that _____.

The formation of essential oils and perfume relies on the separation technique of distillation.

Explore! 5.3

- 1 Investigate the role of distillation in the creation of essential oils and perfume.
- 2 Compare and contrast 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 5.33 To bottle peppermint essential oil, distillation of the peppermint plant must first occur.

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 and little research has been done.

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 the lowest boiling point compared to the 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.

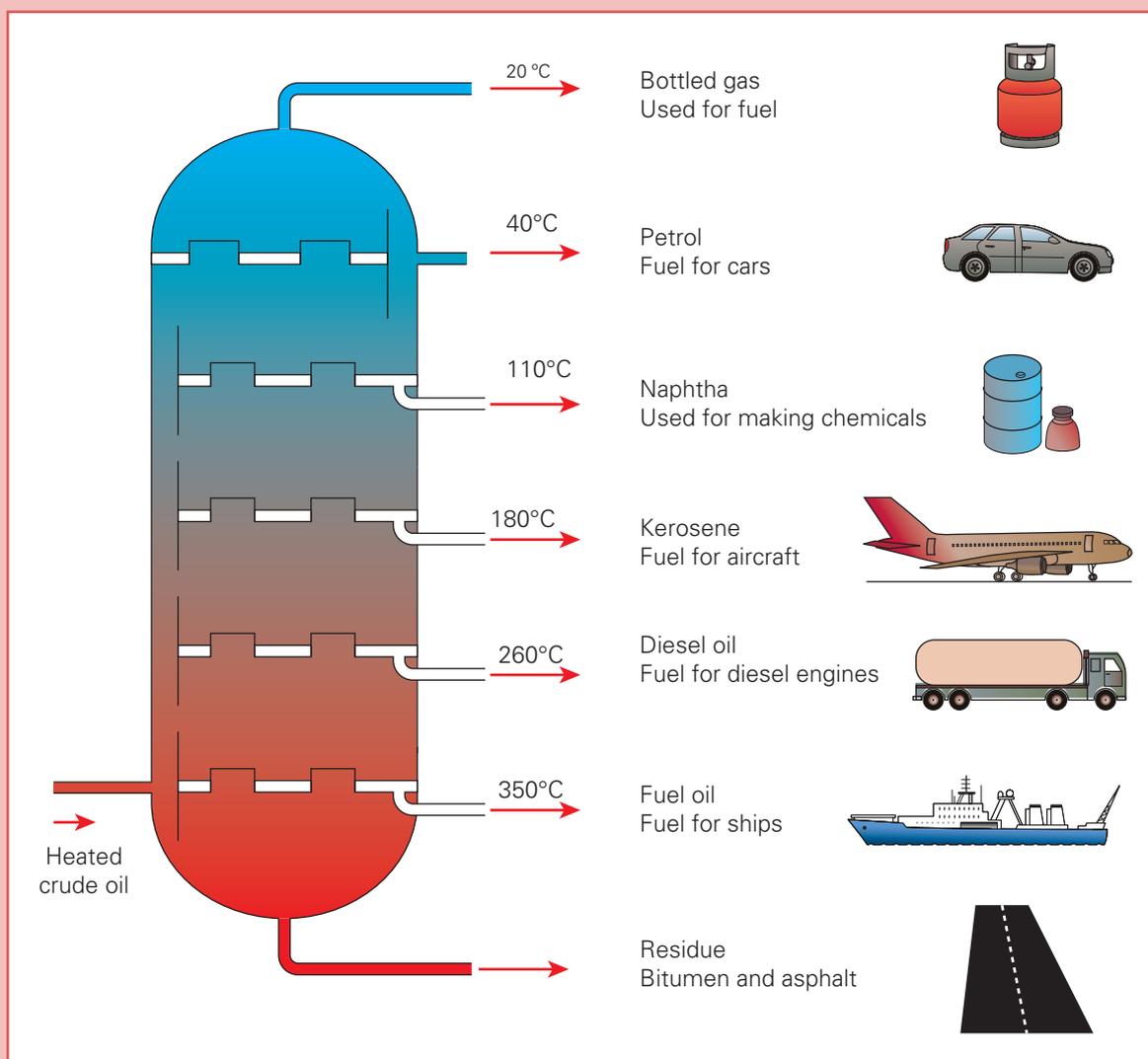


Figure 5.34 Fractional distillation of crude oil

Think about your future

Did you know that it does not matter what career you may be interested in, separation techniques will be a part of your world!

It seems unbelievable, but think about what careers and industries you have come across in this chapter.

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
Dairy industry	Dentistry	Perfume industry	Botany

Section 5.4 questions

Remembering

- 1 Copy and label the parts of the Liebig condenser and other equipment indicated in Figure 5.35.

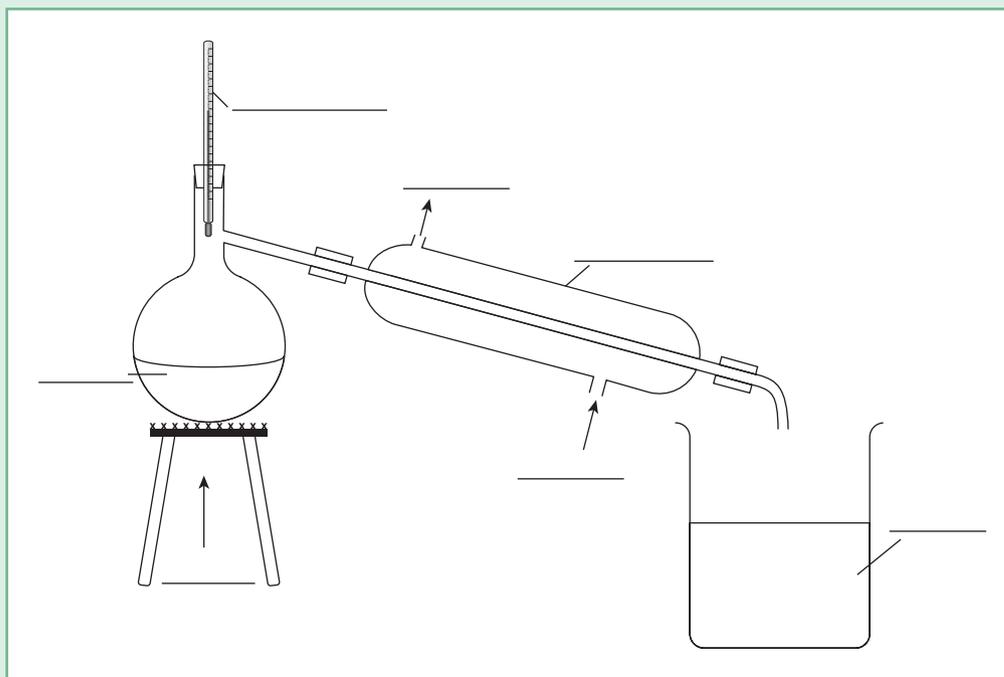


Figure 5.35 Liebig condenser and other equipment

Understanding

- 2 Define the terms 'distillation' and 'evaporation'.
- 3 What are the similarities and differences between distillation and evaporation?

continued...



QUIZ



WIDGET

Choosing the best method for separating mixtures

...continued

Applying

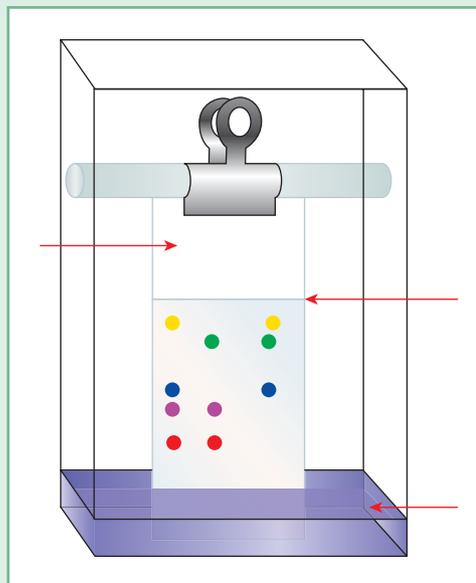
- 4 Explain what happens to particles during the process of evaporation and the process of condensation. Draw pictures of the particles to help in your explanation.

Analysing

- 5 Compare and contrast evaporation and crystallisation.

Evaluating

- 6 a Copy and label the diagram on the right.
 b Explain what is meant by 'mobile phase' and 'stationary phase'.
 c Write the colours in order from least to most soluble in the solvent.
 d Why should the bottom line be done 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.



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.



Review questions

Remembering

1 Give definitions for the following key words:

- a** Insoluble **b** Saturated **c** Soluble.

2 Recall a term used to refer to liquid homogeneous mixtures.

3 What is the name of the piece of paper at the end of a chromatography experiment?

4 Choose from the 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 Choose 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 Make a list of examples in industry that use the following separation techniques.

- a** Distillation **b** Filtration **c** Centrifugation **d** Evaporation

7 What method of separation (1–5) would you use to perform the separations (A–E)?

1 Evaporation

2 Filtration

3 Chromatography

4 Distillation

5 Magnetism

A Separating based on magnetic properties

B Separating based on heating liquid

C Separating based on evaporation and condensation

D Separating based on size

E Separation based on solubility

8 **a** You decide to make toffee by dissolving sugar in water. Which would be faster: using big sugar cubes or using regular sugar crystals?

b What else can you 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 Copy and complete the following table.

Method of separation	Description of how it works	Example from home
Decanting		
Flocculation		
Evaporation		
Filtration		
Crystallisation		



SCORCHER

- 11 Give an example of a mixture you would separate using evaporation. Explain why no other method would work better.
- 12 What is the correct order of the steps needed to obtain salt from a mixture of salt and pepper?
- 13 How can you distinguish between:
- a colloid and a suspension?
 - a suspension and a solution?
- 14 How could the following mixtures be separated into their components?
- How could you get the copper sulfate from copper sulfate solution?
 - How could you get the water from clothes?
 - How could you get the peas out of a mixture of peas and water?
 - How could you get the oil out of a mixture of water and oil?
 - How could you get sand from a mixture of sand and iron filings?
 - 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. Give 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. Suggest a reason for this.
- 16 Match the colloid name (A–E) to the states of matter that make up the colloid (1–5).

Colloid
A Hair gel
B Mist
C Smoke
D Foam
E Emulsion

State
1 A gas in a liquid
2 A liquid in a solid
3 A liquid in a gas
4 A solid in a gas
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 below.

Substance	Amount (in grams) that dissolved in a 100 mL glass of water
Baking powder	15
Salt	45
Sugar	223
Flour	1

- Which substance did Lottie find was most soluble?
 - 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 on the right.
- Which glass contained the saturated solution?
 - Explain how you know this.
- 19 Some liquid antibiotics suggest that you shake the bottle before you use them. Why would you need to do this? Explain using terms you have learned in this chapter.

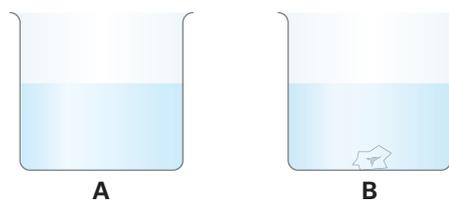


Figure 5.36 The crystal in glass A has disappeared, while the crystal in glass B has grown.

Analysing

20 Copy and complete the following table.

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.
- 22 Soluble nutrients can be absorbed by the roots of plants through microscopic holes, but insoluble nutrients cannot. Explain why.
- 23 Suggest how you could separate:
- a liquid from a liquid
 - solid from a liquid
 - solid from a solid.

24 You have been doing a graphic design course and have created an awesome poster. However, you forgot which ink pen it was that you used to create the main heading. Figure 5.37 shows the results of a chromatography experiment you carried out to identify the ink. Five inks were compared: A, B, C, D and E.

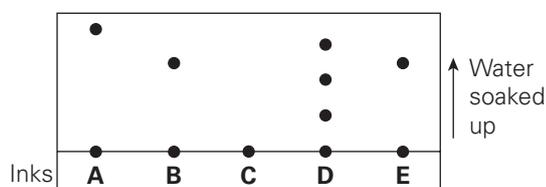


Figure 5.37 Chromatogram of your results

- You know your ink is just one colour. Which ink sample is a mixture of different colours?
 - Which two inks are the same?
 - You know your ink is not soluble in water, so which ink sample is the one you want?
- 25 You are given a green powder that is soluble in water. You would like to make a large crystal of the unknown green powder. What steps would you take to do this?

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

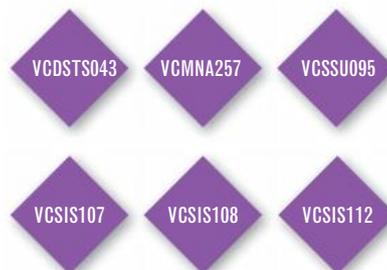
- 27 Draw a flow chart to illustrate the separation processes you would use to separate a mixture of pebbles, sand, salt and water. Clearly show what was separated at each step.
- 28 Design a contraption that could separate polystyrene balls from sand and gravel suspended in muddy water. Include an annotated diagram and a glossary of the separation techniques used.

STEM activity: Cleaning up an oil spill

Background information

Environmental engineers use the principles of engineering, soil science, biology and chemistry to help solve a number of environmental problems. For example, one environmental problem they are called upon to assist with is cleaning up oil spills and other environmental hazards.

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 the 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 (soaking up the oil using sponges and absorbent rope), and dispersing 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 water.

Activity instructions

Following your teacher's instructions, you are going to create your own oil spill and then play the role of an environmental engineer and work together to try different methods to clean the oil from water.

You will collect data on the oil removal and consider the effectiveness and costs of each method. You will not only think about your role as an environmental engineer, but also consider the viewpoint of the oil company. You will write a report for your local government presenting your findings.



Figure 5.38 A dolphin swims next to an oil spill.

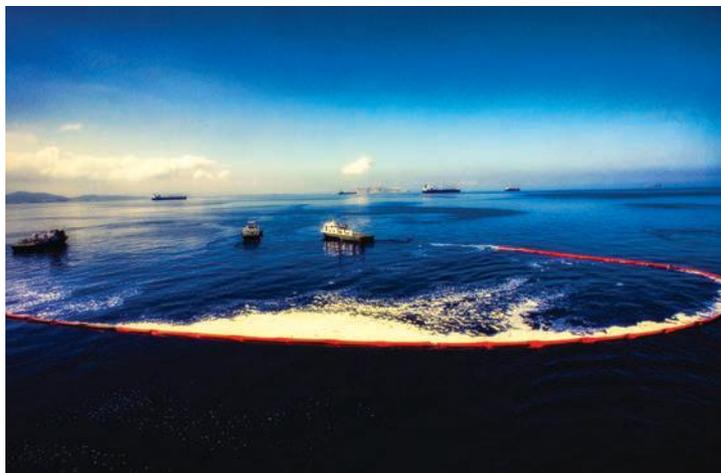


Figure 5.39 Booms and skimmers helping to contain and clean-up the oil spill.

You may like to start by doing the following:

- List all the possible ways of cleaning up an oil spill and what materials you have access to that could do the job (see Suggested materials section). For each material, consider whether they are a skimmer, absorber or dispersant; then record how expensive you think each might be.
- Write a hypothesis or prediction about what you think will be the most effective and cost efficient way to clean-up your oil spill.
- Consider how you will record your data given that you will be comparing the environmental engineers point of view and that of the oil company, in terms of the effectiveness of the different cleaning methods and the cost.

Suggested materials

- small squeeze bottle of 'grease-fighting' dishwashing detergent
- 100 mL vegetable oil
- jugs of water
- gravy powder
- aluminium foil roasting pan
- large stone or rock that can sit in the roasting pan and act as land
- 2 cm length of icy-pole stick to act as a boat
- cotton balls
- plastic spoon
- small sponges
- paper towel

Evaluate and modify

- 1 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).
- 2 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 them from occurring in the future?
- 3 Consider skimming as a clean-up technique. Hypothesise on what would be the impact of the ocean waves on the effectiveness of this technique. Is it cost effective when you need to have boats with specialised equipment for the task?
- 4 Consider an absorber as a clean-up technique. Reflect on how you would dispose absorbers 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.
- 5 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.
- 6 Measure the volume of crude oil spilt into your ocean, and the volume of crude oil removed. What percentage of crude oil was successfully removed from the ocean? Did any technique prove to be more effective? Explain the possible causes of any differences between the two volumes.
- 7 You now have enough information to write your report. Prepare a report for local government that summarises your simulation findings – include the different methods, their effectiveness and their costs, from both the point of view of the environmental engineer and the oil company. Include what method/s you think should be utilised by environmental engineers in the future when analysing an oil spill in a local waterway.

Chapter 6 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 7 days in a week and 365 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.

Curriculum

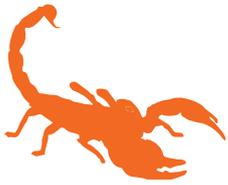
Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the Sun, Earth and the Moon (VCSSU099)

- | | |
|---|--------------------|
| • comparing times for the rotation of Earth, Sun and Moon, and comparing the times for the orbits of Earth and the Moon | 6.1, 6.2, 6.3 |
| • modelling the relative movements of the Earth, Sun and Moon and how natural phenomena such as solar and lunar eclipses and phases of the Moon occur | 6.1, 6.2, 6.3, 6.4 |
| • explaining why different regions of Earth experience different seasonal conditions | 6.2 |

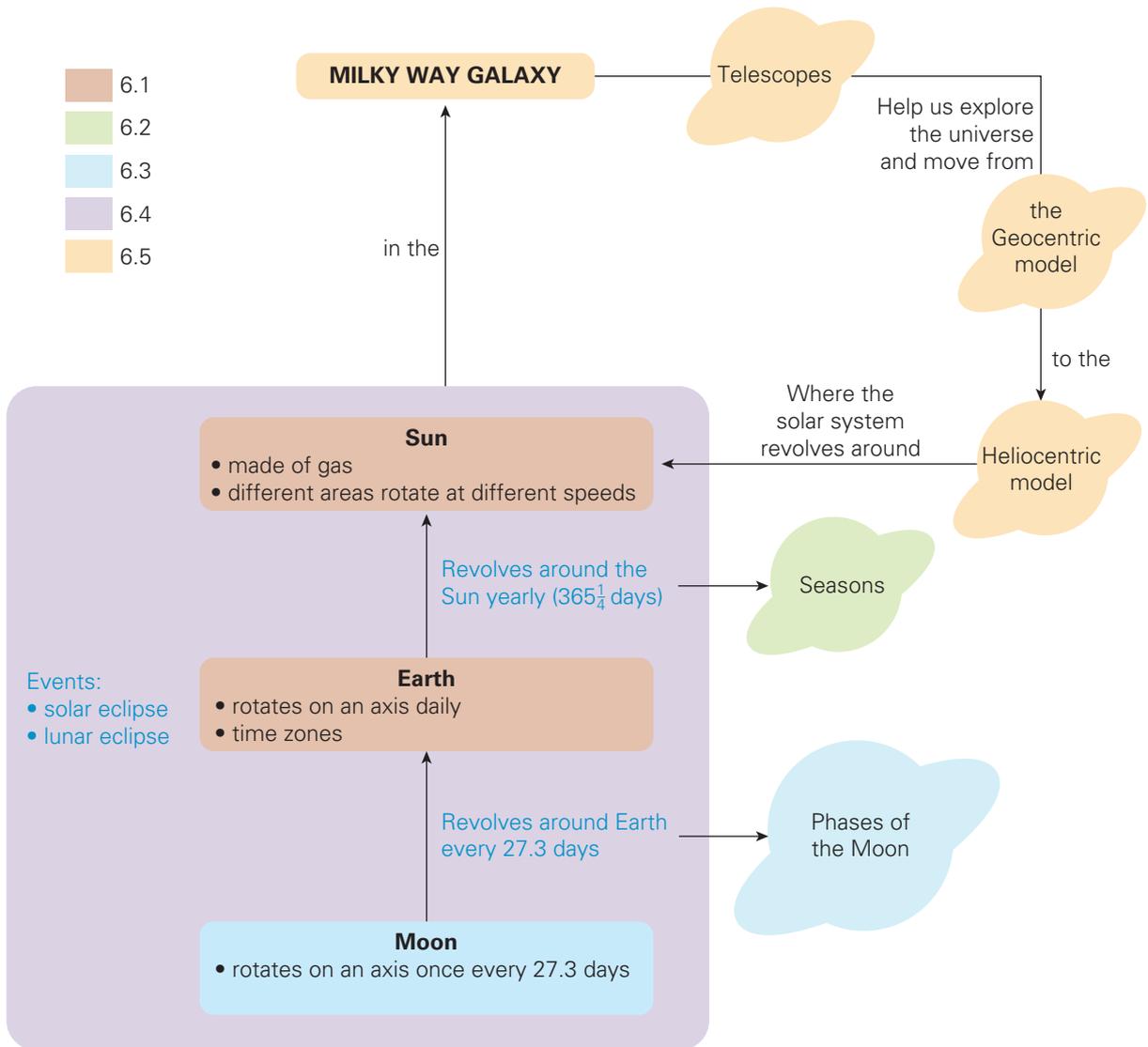
Victorian Curriculum F–10 © VCAA (2016)

Glossary terms

annular eclipse	horizon	Southern Hemisphere
apogee	leap year	sunspot
blood moon	lunar eclipse	syzygy
dawn	mass	telescope
dusk	Northern Hemisphere	time zone
elliptical	orbit	total eclipse
Equator	partial eclipse	umbra
far side	penumbra	waning
geocentric model	perigee	waxing
gravitational field	revolution	
heliocentric model	solar eclipse	



Concept map





6.1 Our rotating Earth

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.

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 and it is cold. 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 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.

Try this 6.1

Some flowers have a daily cycle.

Did you know? 6.1

Daisies close their petals at night and open them again during the day. Arctic poppies and young sunflower buds turn their heads to follow the Sun as it moves across the sky.



Figure 6.2 Daisies have their petals open during the day (left) and close them as the light fades (right).

Finding out why

For this activity you will need a round yellow balloon or ball, a 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, and the smaller balloon/ball to represent Earth, and draw a little map of Australia on the smaller balloon/ball with a small dot to represent your location.

Try this 6.2



Figure 6.1 Melbourne just after sunset. Temperatures generally increase during the day and decrease at night.

Our rotating Earth

Earth is a giant ball in space that is spinning slowly, 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 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.

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 horizon is the point where the sky appears to meet the land or the sea

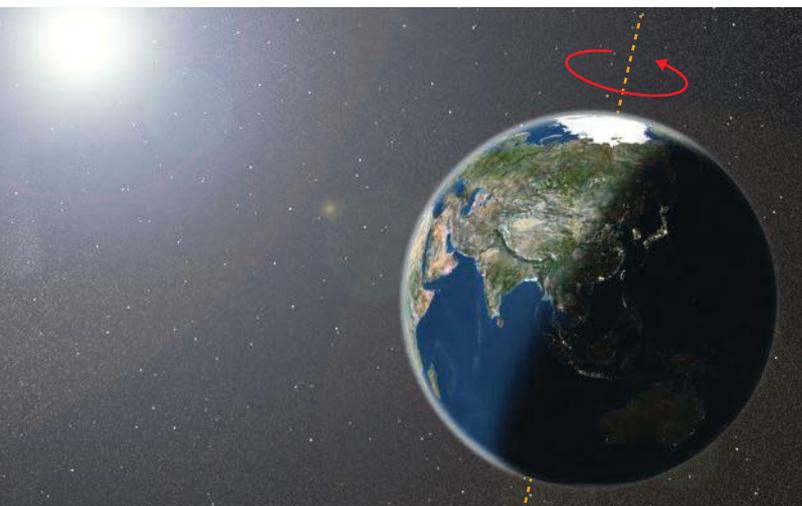


Figure 6.3 It is night-time in Australia as Earth turns on its axis with the Sun in the distance. This picture shows how day and night are caused by Earth's rotation.

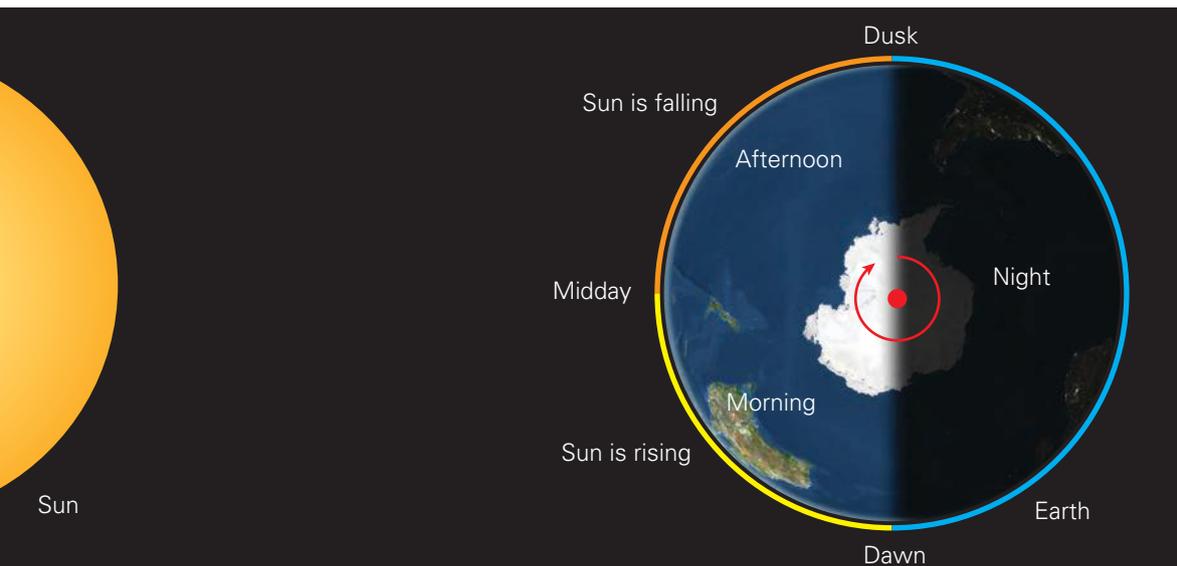


Figure 6.4

The view of Earth from above the South Pole. Earth is rotating clockwise and as it does, different parts of the world experience morning (yellow), afternoon (orange) and night (blue). This image shows morning in Australia.

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? 6.2

Because Earth is rotating, the whole

Did you know? 6.3

state of Victoria is moving to the east at around 360 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 around the Sun at a speed of around 28 kilometres every second. If an aircraft could fly at that speed, it would get to London from Melbourne in about 10 minutes!

Temperature and shadow changes

The temperature changes 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. This means the temperature goes up 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.

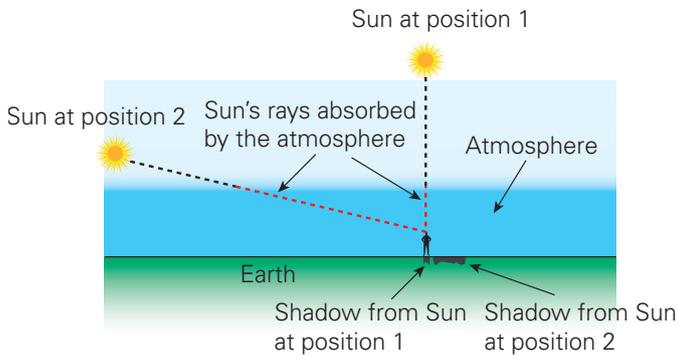


Figure 6.5 The Sun's rays pass through less atmosphere when it is close to being overhead. For this reason, the midday sunlight is more intense and more likely to cause sunburn. The length of your shadow also changes.

Practical 6.1

Recording the movement of the Sun

Aim

To simulate how you see the Sun moving during a day.

Materials

- camera
- yellow balloon

Method

In a group, using a balloon and a camera, try this.

- 1 Appoint someone to be Earth to hold a camera.
- 2 Appoint a second person to be the Sun holding the balloon.
- 3 The person with the camera stands in front of the Sun and rotates slowly while recording a video.

Results

View the video recorded.

Evaluation

- 1 What did you see?
- 2 Did it appear as though the Sun is moving past the camera?
- 3 What was the cause of the movement?

Conclusion

From this activity we can claim that motion of the Sun _____. This is supported through observing _____. This means that _____.

Antipodes

Did you know? 6.4

The place on the exact opposite side of the world to a region is called its antipodes. The antipodes of Melbourne can be found in the middle of the Atlantic Ocean, due west of Portugal. Whatever is happening in Melbourne, the exact opposite is happening at the antipodes. For example, if the Sun is setting in Melbourne, it will be rising at its antipodes. If it is winter in Melbourne, it will be summer at the antipodes.



Figure 6.6 The antipodes of Melbourne is west of Europe in the Atlantic Ocean.

Why do the stars move across the sky at night?

Like the Sun, the stars do not move. Their movement is an illusion caused by Earth's rotation. You can actually measure the movement of the stars at night by using your hand in the same position as in the following picture. As it takes Earth around 24 hours to complete a full rotation, this means the stars appear to move at a speed of 15 degrees per hour. You can check it out at home when the night is clear.

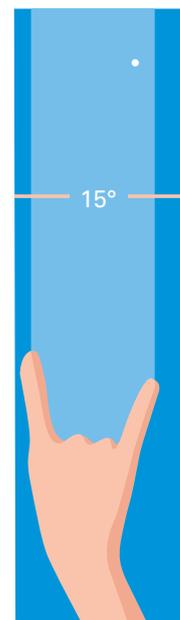


Figure 6.7 You can measure the distance stars travel in an hour by using your hand.



Figure 6.8 The stars in the sky are not moving; it is Earth's rotation that makes them appear to move.



VIDEO
Describe the movement of the stars.

Time zones

It takes around 24 hours for Earth to complete one rotation, which is 360° . This means Earth is rotating at a rate of about 15° per hour. For this reason, Earth is

- 1** Define the following terms in your own words and add them to your glossary: rotation, dawn, dusk.

2 Explain why the Sun and stars appear to move across the sky, when they really are not moving.

3 Explain why it is cold at night and warm 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.

Quick check 6.1

divided vertically into 24 **time zones**, each of which is about 15° or 1 hour apart. At certain times of the year there may be up to 38 time zones because of daylight saving of half or one hour differences.

time zone

Earth is divided into 24 time zones, each about 15° of longitude and each one representing a time difference of 1 hour

It does get complicated! Time zones are measured from Greenwich in the UK and the time in Greenwich is called Greenwich Mean Time or GMT.

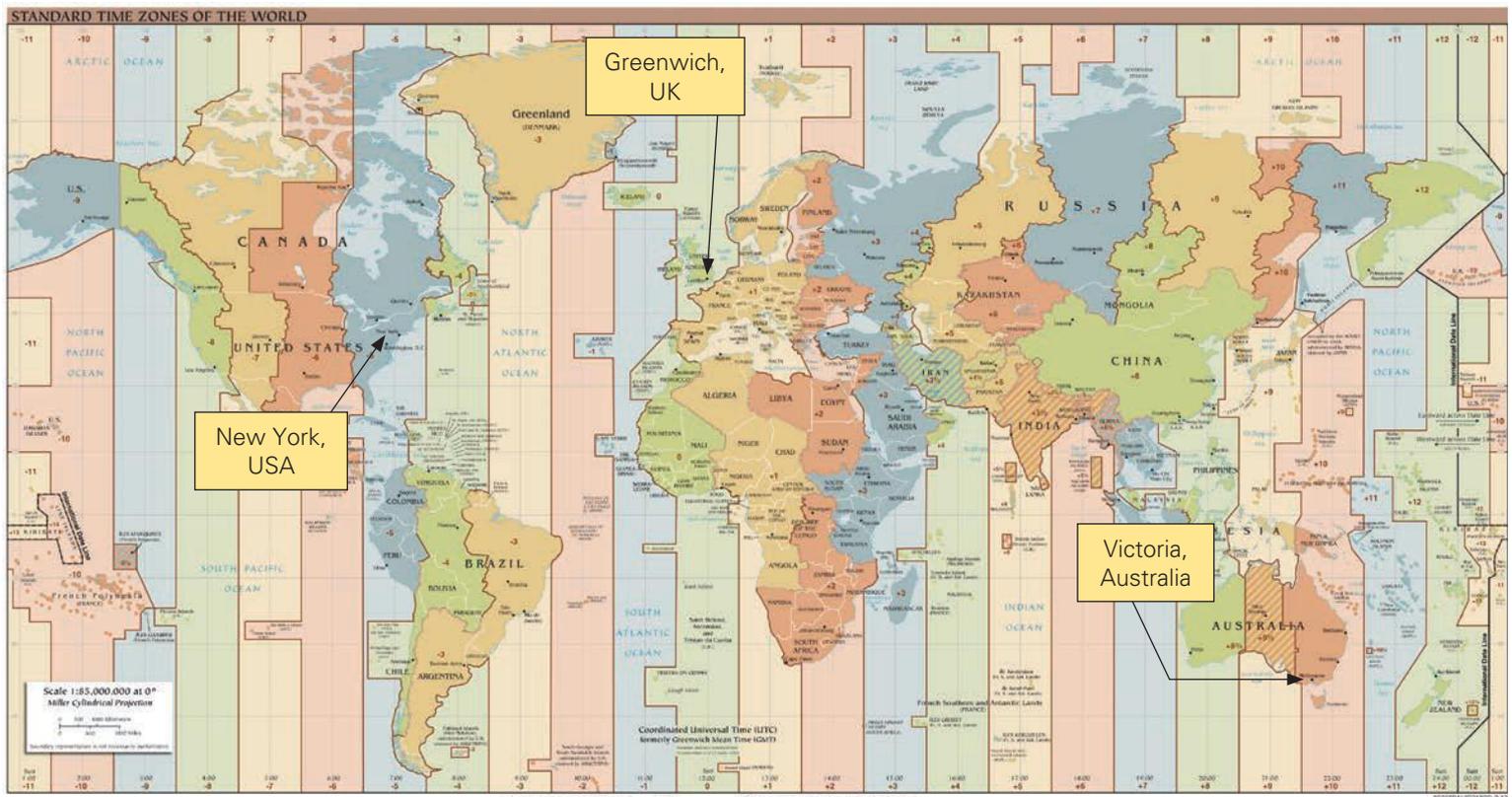


Figure 6.9 The time zones of the world. The state of Victoria is 10 hours ahead of GMT because it is about 150° east of Greenwich, whereas New York is 5 hours behind GMT because it is about 75° west of Greenwich.

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 goes down 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.

Indirect effects of Earth's rotation

Explore! 6.1

There are some amazing things that happen in our world that are linked to our daily cycle but are not directly a consequence of Earth's rotation. Carry out some research on the internet 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 6.10 Why is the sky red at sunset? (The answer is upside down.)

Clouds 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.

Mars has blue sunrises and sunsets!

Did you know? 6.5

The Martian atmosphere is too thin to scatter blue light, but it is full of dust particles that scatter red light. This means that on Mars, the sky is pink during the day and at dawn and dusk the sunrises and sunsets are blue!



Figure 6.11 A beautiful blue sunset on Mars, taken by the NASA Mars Curiosity rover

Quick check 6.2

- 1 State how many degrees Earth rotates in one hour.
- 2 State how many time zones there are.
- 3 Explain why it is necessary to have time zones.
- 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 ball – 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!

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, proving 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.

sunspot

feature on the Sun's surface that moves slowly across the surface



VIDEO

Describe the Sun's surface and contrast it to Earth's

Be careful

NEVER use binoculars or telescopes to look anywhere near the Sun.

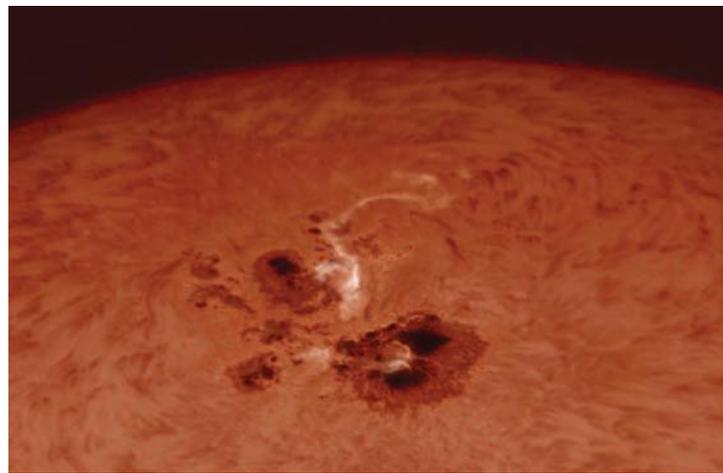


Figure 6.12 Sunspots, such as the one shown, are visible for about 11 days as they cross the face of the Sun.

- 1 State how long one rotation of the Sun takes.
- 2 Explain how it is known that the Sun rotates.

Quick check 6.3



QUIZ

Section 6.1 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 where time zones are measured from.
- 4 Describe how sunsets on Mars are different from those on Earth.

Understanding

- 5 Explain how Earth experiences day and night.
- 6 Suggest 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 At what time of the day is it most important to wear sunscreen and seek shade? Explain your answer.

Analysing

- 10 What would happen if Earth did not have different time zones?
- 11 Outline the consequences of removing 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.



6.2 Earth's yearly cycle



WORKSHEET

Apart from rotating on its axis, which results in the day-night cycle that repeats daily, Earth also orbits around the Sun following an **elliptical** path. It takes $365\frac{1}{4}$ days for Earth to orbit 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. We call that year a **leap year**.

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 a large object where another object can experience its gravity or pull

Why does Earth orbit the Sun?

An object with a large **mass** attracts an object with less mass and causes it to go into orbit if it is in its **gravitational field**. 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

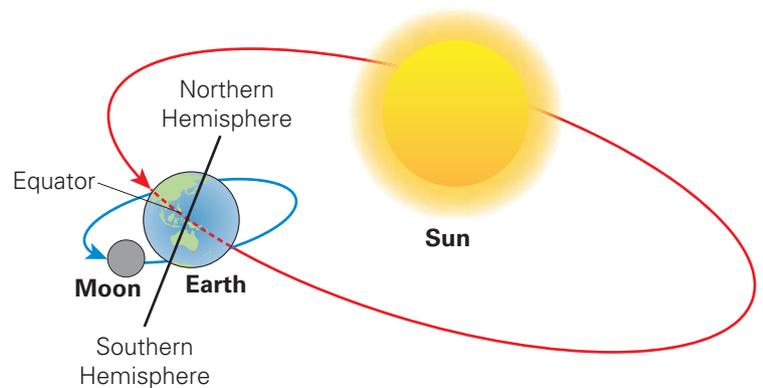


Figure 6.13 The Moon orbits around Earth, and Earth orbits around the Sun. Standing at the North Pole, the rotation appears anticlockwise.

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 the 21 June. The longest day occurs around the 21st day of 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.

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

Figure 6.14 Summer on the Mornington Peninsula



Figure 6.15 Autumn in the Macedon Ranges

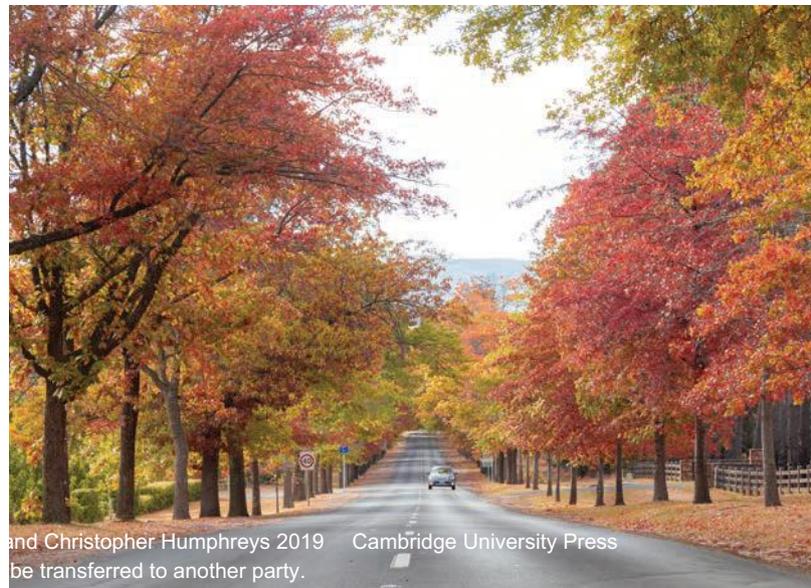




Figure 6.16 Winter on Mount Buller



Figure 6.17 Spring on the way to Geelong

What changes during the year from season to season?

What things do you observe changing throughout the year that are explained by the seasons changing? Discuss with your colleagues and then see how many of the following you came up with.

- The number of hours of daylight. 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 place on the horizon where the Sun rises and sets moves. The Sun always rises 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 Northern and Southern hemispheres always have opposite seasons.

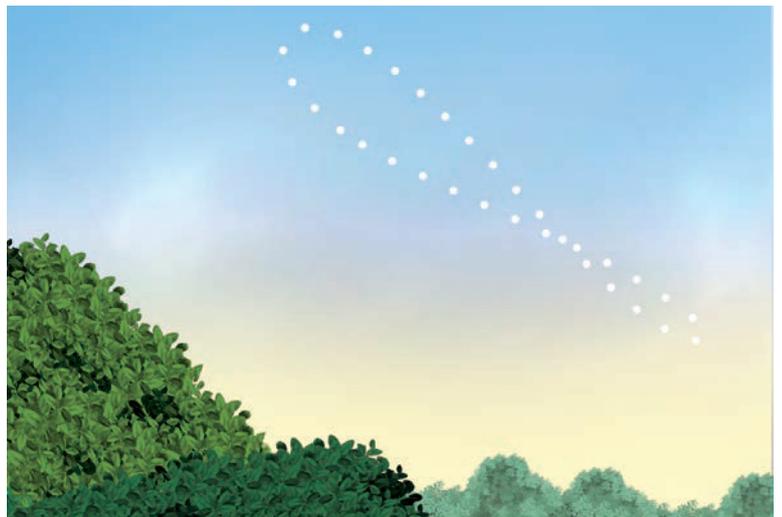


Figure 6.18 This illustrates the position of the Sun at the same time each week for a whole year.

- 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.

Why do seasons occur?

Believe it or not, Earth's tilt can explain of all 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.

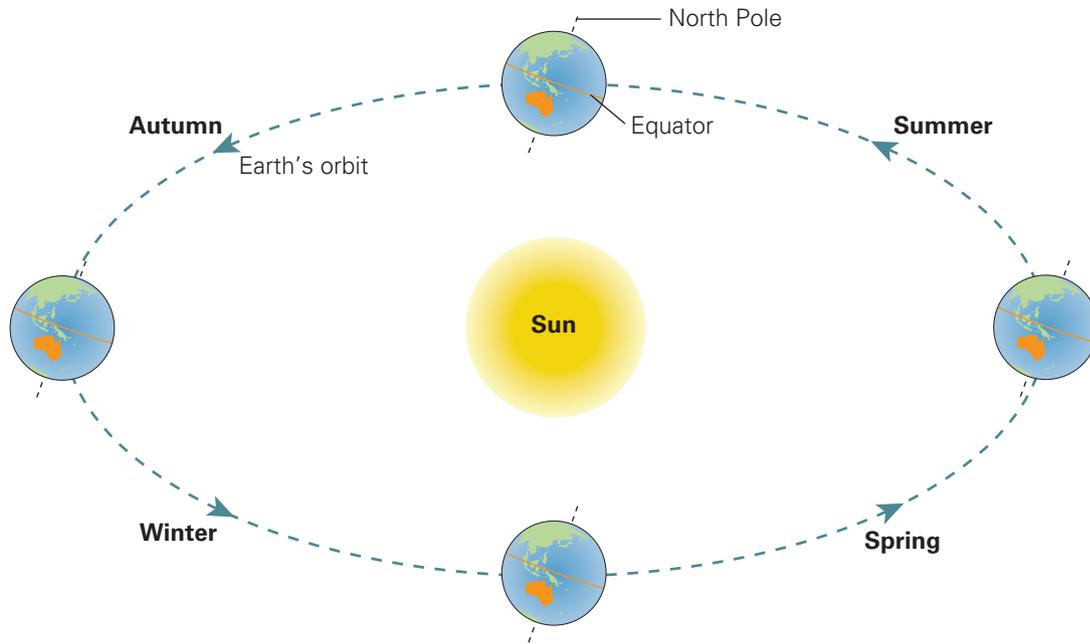


Figure 6.19 Seasonal configuration of Earth and the Sun. The tilt of Earth causes the different seasons during the year. Australia is shown in orange.

- 1 Define the terms 'orbit', 'revolution' and 'elliptical' in your own words and add them to your glossary.
- 2 How long does it take for Earth to orbit the Sun?
- 3 List things that change during the year due to the seasons.

Quick check 6.4

Practical 6.2

Modelling the seasons

Aim

To understand seasons by modelling Earth's path around the Sun.

Materials

- 20 cm or larger polystyrene ball
- lamp
- wooden skewer

Method

- 1 Carefully stick the skewer all the way through the middle of the polystyrene ball. This will create an axis around which Earth can spin.
- 2 Label the North and South Poles and the Equator on your polystyrene ball.

Be careful

Take care when handling light sources after extended use – they may be hot.

continued...

...continued

- 3 Hold the ball at arm's length in one hand and tip it, so that the top of the stick is nearer you than the bottom. This simulates the tilt of Earth.
- 4 Circle the lamp with the model, being sure to keep Earth tilted and facing the same way for the duration of the orbit around the lamp.

Results

Describe which parts of Earth are pointing towards the Sun at each point of its orbit.

Evaluation

- 1 Using a diagram, explain how this model shows how seasons work.
- 2 Why is it essential to ensure that Earth's North Pole always keeps pointing in the same direction?
- 3 How could this model be improved?

Conclusion

From this activity we can claim that seasons are caused by _____. This is supported through observing _____. This means that _____.

How do animals adapt to the seasons?

Explore! 6.2



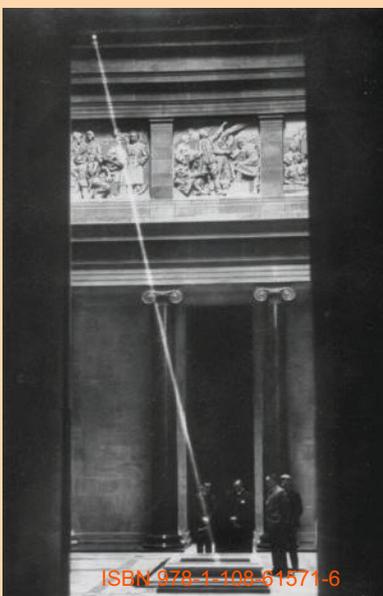
Figure 6.20 Black bear and cub hibernating



Figure 6.21 Greylag geese migrating

The cycle of animal and plant life follows 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.



The Shrine

The Shrine of Remembrance, located on St Kilda Road, Melbourne, was built as a memorial to the men and women of Victoria who served in World War I and is now a memorial to all Australians who have served in war. On Remembrance Day, at the 11th hour on the 11th day of the 11th month each year, a ray of sunlight shines through the roof exactly onto the Stone of Remembrance in the centre of the Sanctuary inside the Shrine.

Figure 6.22 A ray of light illuminates the Stone of Remembrance at the Shrine in Melbourne

Did you know? 6.6



QUIZ

Section 6.2 questions**Remembering**

- 1 State how long a complete cycle of all four seasons takes.
- 2 Based on your research from page 214, name some creatures that are known to migrate with the seasons.
- 3 Describe how plants and animals act differently in summer than in winter.

Understanding

- 4 State the reason for the seasons on Earth.
- 5 Describe how the seasons are different in tropical north Australia.
- 6 Draw a diagram to help explain the progression of the seasons. Label each position with the corresponding season.

Applying

- 7 It is winter in Australia. What month could it be?
- 8 It is winter in China. What month could it be?
- 9 It is spring in Australia. What month could it be?

Analysing

- 10 Describe what the effect would be if the angle of tilt of Earth's axis of rotation was increased by 5°.
- 11 The table shows hours of daylight in Melbourne on 30 April 2018.

Date	Sunrise	Sunset	Hours of daylight
30 April	6:59 a.m.	5:34 p.m.	10 h 35 min.

State whether you expect the number of daylight hours to be more or less than 10 hours 35 minutes on 1 May.

Evaluating

- 12 The Sun only lights up a tunnel containing a statue of Rameses twice a year. Deduce 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.
- 13 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. Deduce in which months these occur in the Southern Hemisphere. Justify your answer.



6.3 Movement of the Moon



WORKSHEET

Recall that Earth orbits around the Sun because the Sun has greater mass. The mass of Earth is 81 times the mass of the Moon and so, for the same reason, the Moon revolves around Earth.

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



WIDGET
Phases of the moon



VIDEO
Moon phases as seen from space

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

other half is in shadow. The amount of the bright side you can see from Earth depends on which phase the Moon is in. Figure 6.23 shows the

names of the phases of the Moon. 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**.

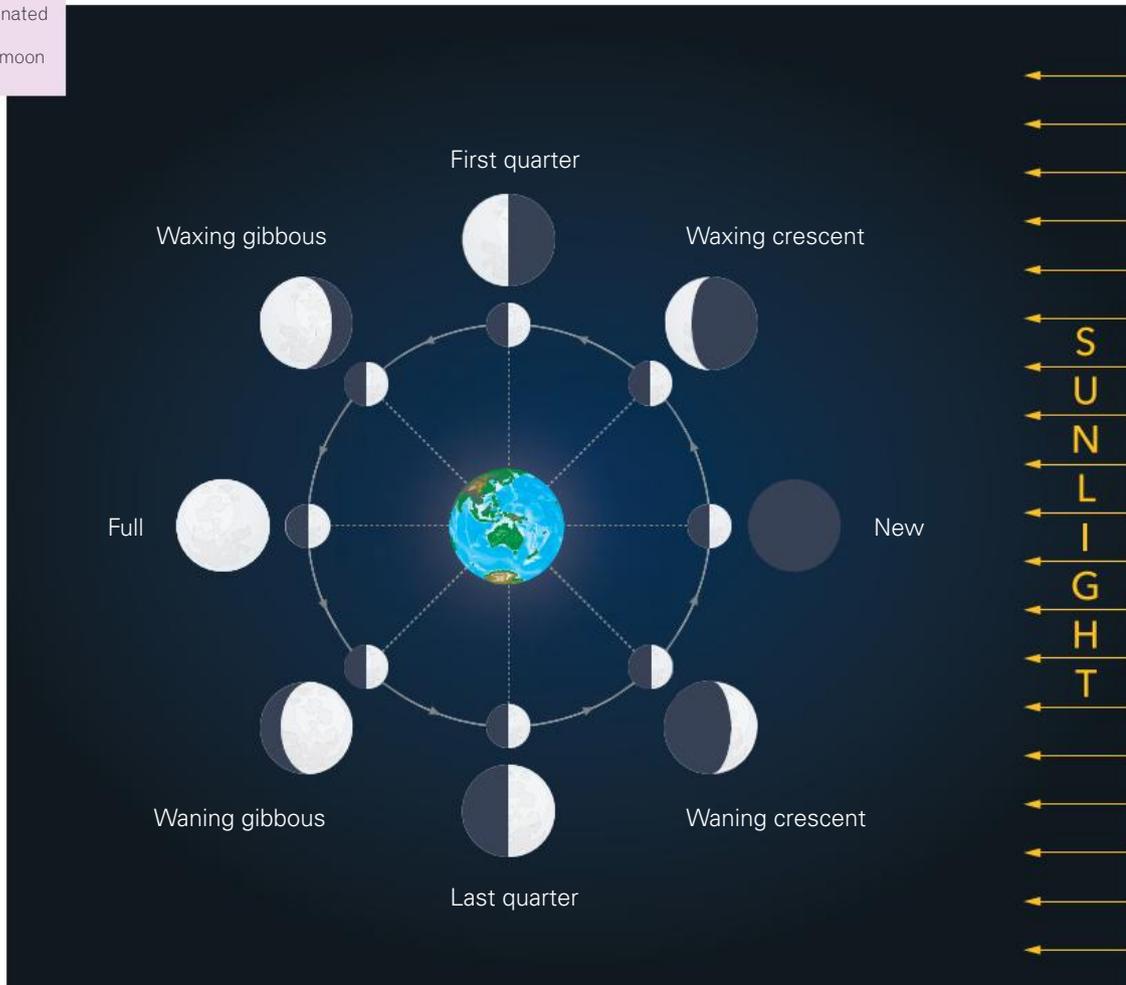


Figure 6.23 The phases of the Moon in the Southern Hemisphere

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 and the time taken to orbit

Earth are the same. The Moon takes about 27.3 days to orbit Earth – the same time it takes to rotate just once.

- 1 Explain how you can see

Quick check 6.5

- 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.

The days are getting longer!

The Moon is moving through space at a speed of one kilometre every second to orbit Earth! It used to move much faster and was much closer. 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, days on Earth were only 18 hours long! The further away the Moon is, the slower Earth rotates. But don't worry, at this rate scientists won't have to recalculate the length of a day for hundreds of millions of years!

Science as a human endeavour 6.1

Figure 6.24 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. 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.

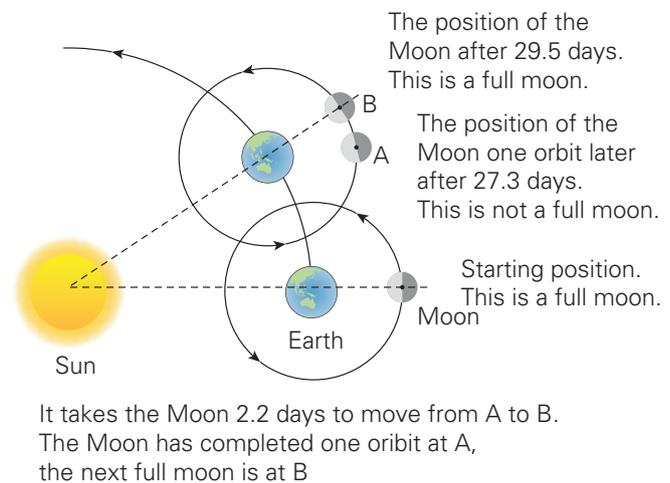
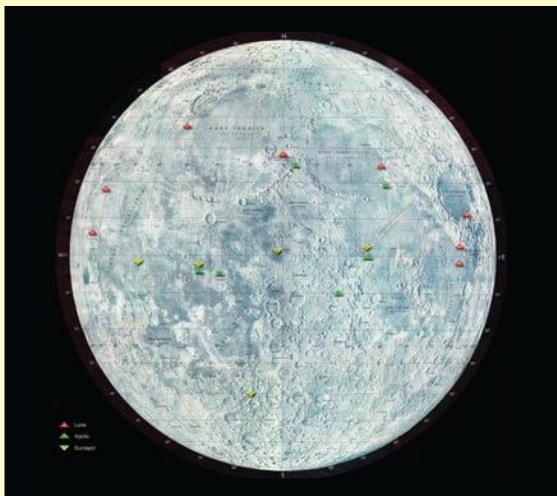


Figure 6.25 The time between full moons and the orbital period of the Moon are different by 2.2 days.

**How many times have astronauts landed on the Moon?****Explore! 6.3**

The lunar map on the left 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 space shuttles.

Figure 6.26 Soviet (red triangles) and USA (green and yellow triangles) lunar landing sites

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.

far side

the face of the Moon that is always turned away from Earth; also called the dark side



Figure 6.27 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 the surface there.

Over the past 50 years, NASA has sent out many probes to explore the solar system and have obtained clearer images of the far side of the Moon.



Figure 6.28 (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.

- 1 Define the terms 'waxing' and 'waning' and add them to your glossary.
- 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?

Quick check 6.6

Practical 6.3

Modelling the phases of the Moon

Aim

To model the phases of the Moon.

Materials

- an electric lamp
- 8 cm polystyrene ball
- pencils

Method

- 1 Stick the pencils 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 the results section.
- 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.

Results

Draw diagrams of your observations at each point in the cycle.

Evaluation

- 1 Describe where the ball was in relation to your head when it was at the following phases.

a New moon	e Waxing crescent
b Full moon	f Waning crescent
c Waxing gibbous	g First quarter
d Waning gibbous	h Third quarter
- 2 How could you improve this simulation?

Conclusion

From this activity we can claim that the phases of the moon are caused by _____.

This is supported through observing _____. This means that _____.

Be careful

Take care when handling light sources after extended use – they may be hot.

Section 6.3 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 Compare the speed of the Moon today to the speed it travelled millions of years ago.
- 5 List the phases of the Moon.

Understanding

- 6 Explain why the time taken for the Moon to orbit Earth is different to the time between full moons.
- 7 Explain why a half-lit Moon is called a quarter moon.
- 8 Explain why the Sun and Moon appear the same size in the sky.

continued...



QUIZ

...continued

Applying

- 9 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.

Use the chart from the Astronomical Society of Victoria in Figure 6.29 showing the phases of the Moon for 2019 to answer questions 10–12.

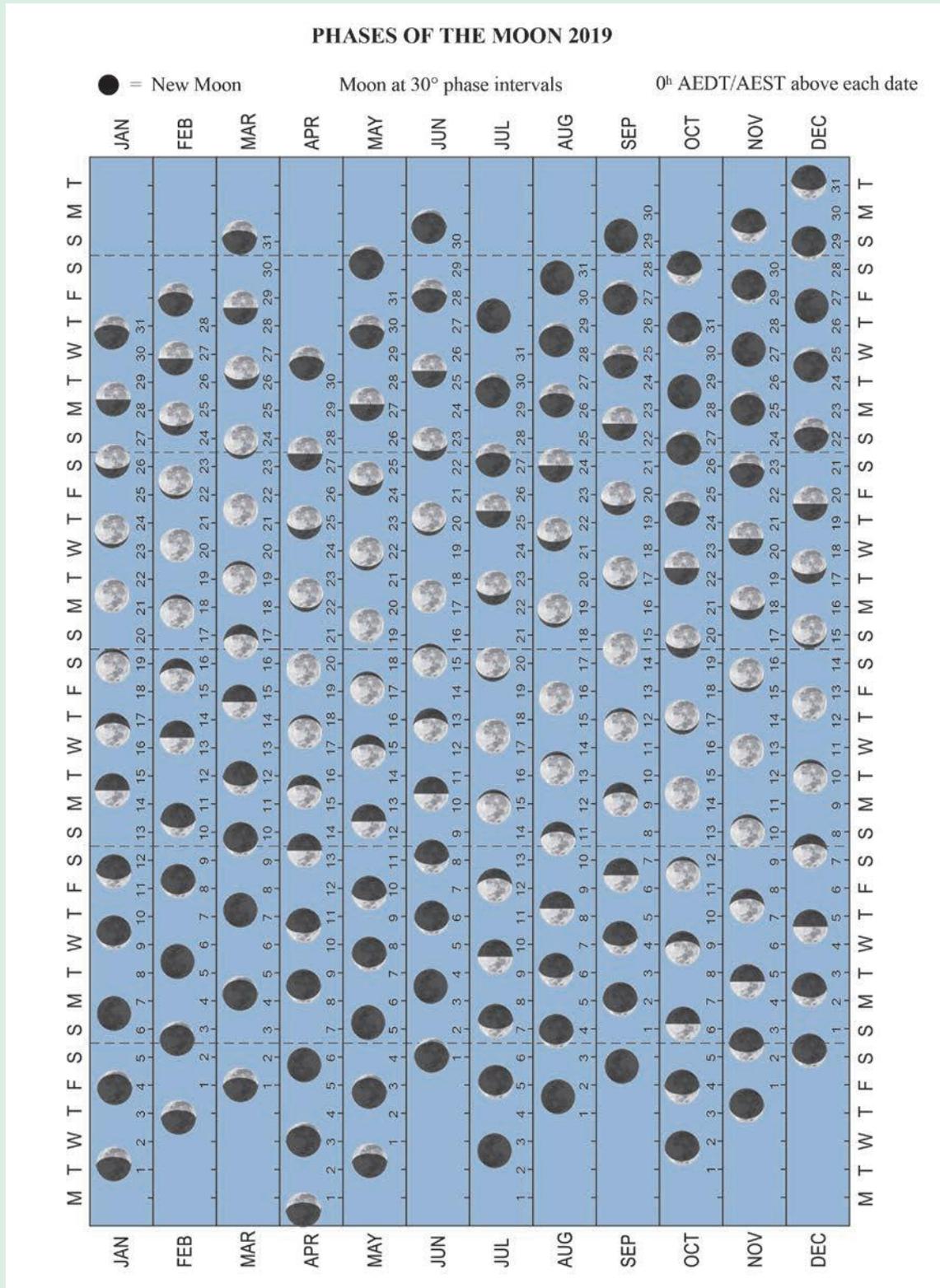


Figure 6.29 The lunar calendar for 2019 showing the dates for each of the phases

continued...

...continued

- 10 Describe the phase of the Moon on 22 December 2019.
- 11 Describe the phase of the Moon on 23 July 2019.
- 12 A blue moon occurs if there are two full moons in a month. Use the chart to find if there are any blue moons in 2019.

Analysing

- 13 Explain how it is possible for the Sun's equator to rotate at a different rate to the Sun's polar regions.
- 14 Approximately how many weeks are there from first quarter phase to last quarter phase of the Moon?

Evaluating

- 15 Suggest how the Moon would look if it did have an atmosphere and experienced weather.



6.4 Eclipses

The motions of Earth around the Sun and the Moon around Earth are complex and require mathematics to describe them precisely; however, they are completely 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 motion around Earth, there is a chance that the Moon may come exactly between Earth and the Sun. If this happens the Sun, Moon and Earth all line up, astronomers call this 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.



WORKSHEET

solar eclipse

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

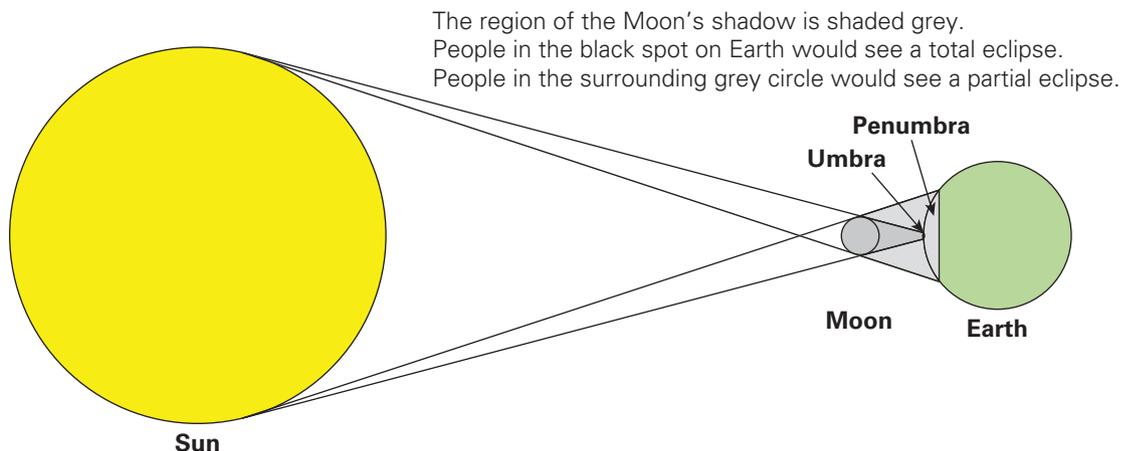


Figure 6.30 A solar eclipse occurs when the Moon comes between Earth and the Sun.

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, it 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 won't see it. The diagram on the previous page is not to scale and the size of the shadow areas is greatly exaggerated.

- total eclipse**
the Sun is completely blocked by the Moon
- umbra**
the region in a shadow where the light is completely blocked
- partial eclipse**
the Sun is partially blocked by the Moon
- penumbra**
the region in a shadow where the light is partially blocked



Figure 6.31 A solar eclipse photographed from the International Space Station. The Moon's shadow only covers a small fraction of Earth's surface.

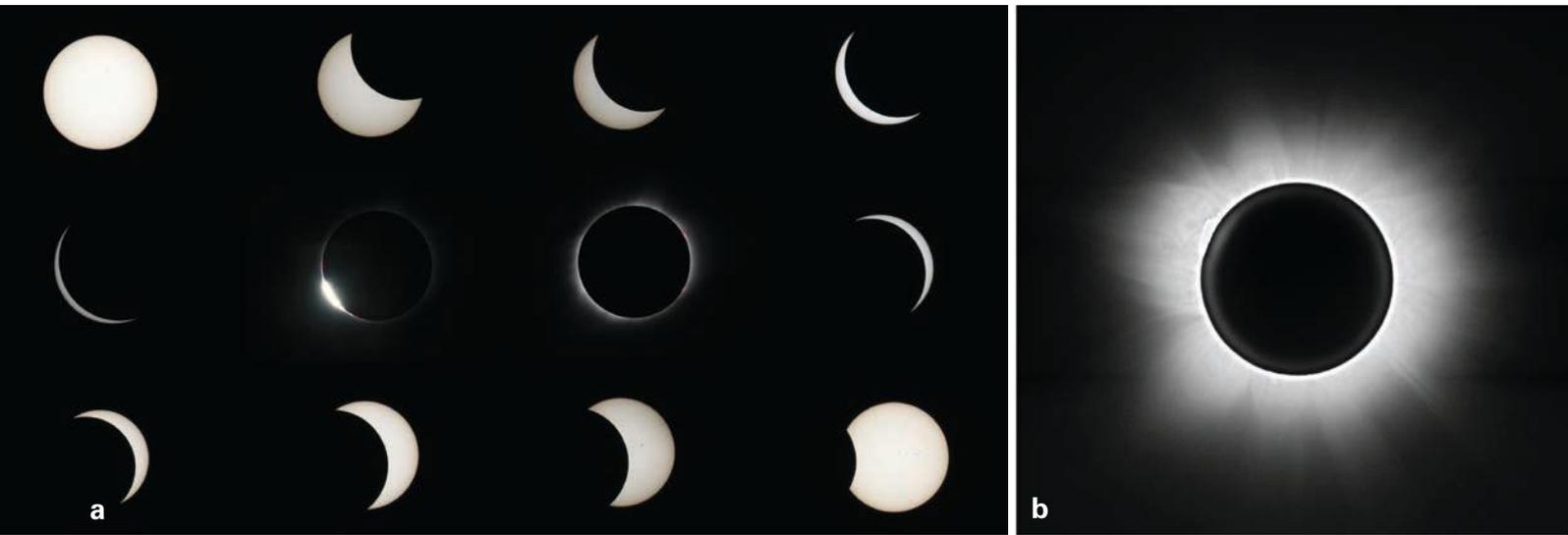


Figure 6.32 This series of images shows (a) the stages of a total solar eclipse, and (b) totality.

How far is it to the Sun?

Try this 6.3



Figure 6.33 Earth and the Moon are drawn here to scale. The Sun is 400 times further away than the Moon.

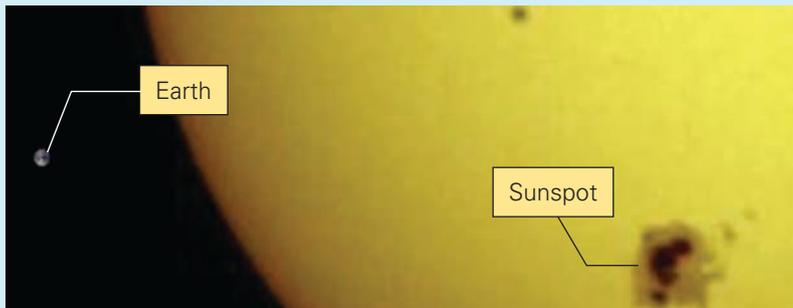


Figure 6.34 It might be tempting to think that the Sun is of a similar size to Earth because it can be blocked by the Moon, but the Sun is much larger than Earth. In this image, Earth is placed next to a portion of the Sun to compare their sizes.

Measure the distance from Earth to the Moon in Figure 6.33. Multiply the distance by 400 to work out how far away the Sun would be if it were also included in the picture.

What is an annular eclipse?

The Sun is about 400 times bigger than the Moon but is also 400 times further away, so the Moon and Sun appear to be about the same size in the sky. This means that the Moon is just big enough to cover 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
when the Moon is closest to Earth

apogee
the point in the Moon's orbit when it is furthest from Earth

annular eclipse
the Moon blocks the Sun but where the Moon is further away and the outer edge of the Sun is still visible

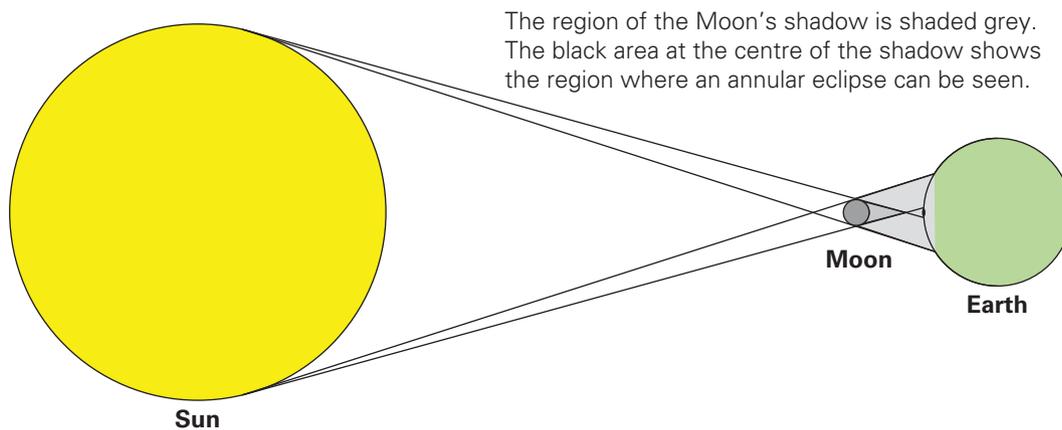


Figure 6.35 If the Moon is not at its closest to Earth at the time of the eclipse, the result is an annular eclipse. The dark area is where an annular eclipse can be seen, the lightly shaded region on Earth surface experiences a partial solar eclipse (not to scale).



Figure 6.36 An annular solar eclipse seen through a cloud

Eclipses

Explore! 6.4

Eclipses are relatively rare, so some people are prepared to travel long distances to witness them. During a total eclipse, the Sun's light is completely blocked from reaching Earth for several minutes, so it is similar to night time and can be confusing for wildlife. The circular shadow of the Moon moves across Earth at about 33 km/min. As it moves, the eclipse becomes visible at different places.

- 1 Summarise how often total and annular solar eclipses occur and can be viewed in Australia.
- 2 Can eclipses be predicted? Find out how and share when the next total solar eclipse and next annular solar eclipse can be viewed in Australia.

- 1 Define the term 'syzygy'.
- 2 Explain why a solar eclipse is only visible from a small part of Earth.
- 3 Explain the difference between a blue moon and a super moon.

Quick check 6.7

Lunar eclipses

What happens when the Moon moves into Earth's shadow?

A lunar eclipse occurs when the Moon moves into Earth's shadow.

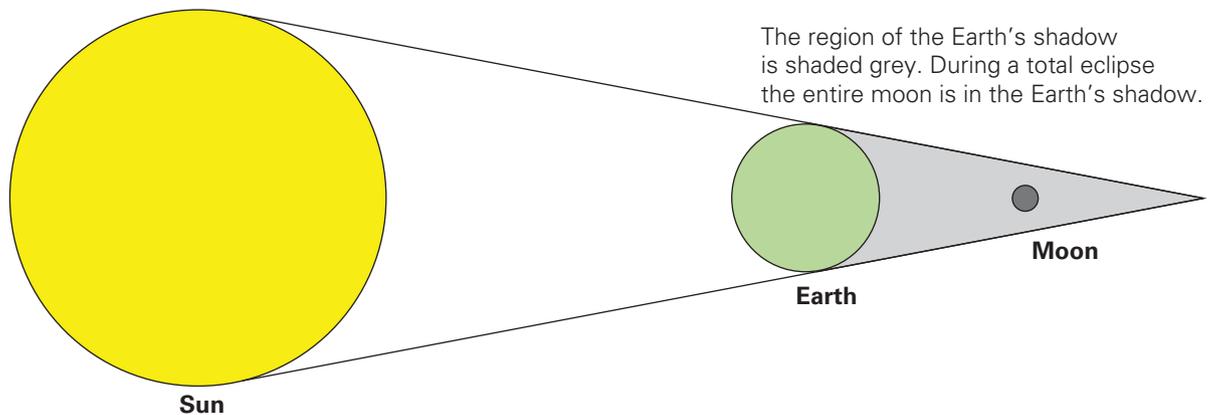


Figure 6.37 Earth is much bigger than the Moon, so Earth's shadow is big enough to cover the whole of the Moon.



Figure 6.38 A total lunar eclipse in progress. The round edge of Earth's shadow is visible.



Figure 6.39 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

Comparison of solar and lunar eclipses

Although the Sun and Moon are involved in both kinds of eclipses, 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 being moved into Earth's shadow.

	Solar eclipse	Lunar eclipse
Duration	A few minutes	A few hours
Who can see it	A small area only	Everyone on Earth
Occurrence	Rare, 2–5 solar eclipses per year	Rare, 2–5 lunar eclipses 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 6.1 Differences between solar and lunar eclipses

Practical 6.4: Self-design**Modelling solar and lunar eclipses****Aim**

To model a solar and a lunar eclipse.

Materials

- high wattage lamp
- globe
- tennis or golf ball
- string

Method

Use the materials provided to model a solar and lunar eclipse.

Be sure to write your method in step-by-step, easy-to-follow instructions.

Results

Record your observations of the shadows created in this model.

Evaluation

- 1 How was a solar eclipse modelled in this practical?
- 2 How was a lunar eclipse modelled in this practical?
- 3 What would happen if you changed the size of the ball?
- 4 How could this model be improved?

Conclusion

From this activity we can claim that eclipses are caused by _____. This is supported through observing _____. This means that _____.

Be careful

Take care when handling light sources after extended use – they may be hot.

Section 6.4 questions**Remembering**

- 1 Recall how solar and lunar eclipses are created.

Understanding

- 2 Suggest 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.

Applying

- 3 Recall the phases of the Moon. Utilise the information to decide in which phase of the Moon a lunar eclipse occurs.
- 4 Recall the phases of the Moon. Utilise it to decide in which phase of the Moon a solar eclipse occurs.

Analysing

- 5 Compare and contrast a partial and a total solar eclipse.

Evaluating

- 6 Suggest why eclipses are so rare.
- 7 Outline the factors that need to be considered when viewing a solar eclipse versus a lunar eclipse.
- 8 Describe how our experiences on Earth would be different if the Moon was larger.



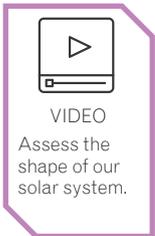
QUIZ



6.5 Exploring the universe



WORKSHEET



VIDEO
Assess the shape of our solar system.

The solar system

Earth is one of the eight planets that orbit the Sun. All the planets except Mercury and Venus have moons. Jupiter, which is the biggest planet, has more than 60 moons. The solar system is the name given to the Sun and all its orbiting planets, including Earth.

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 giant planets, Uranus (1781) and Neptune (1846) were discovered.

telescope

an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

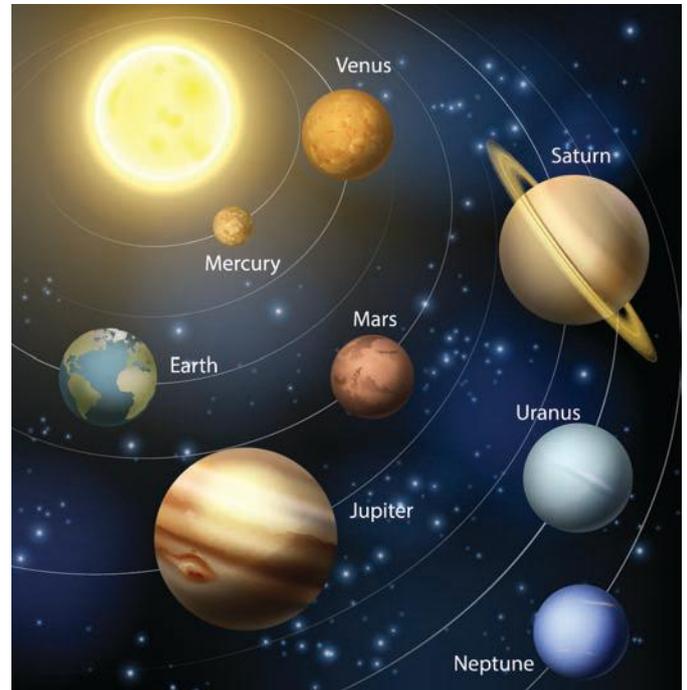


Figure 6.40 The solar system includes Earth. All the planets except Uranus and Neptune can be seen without a telescope.

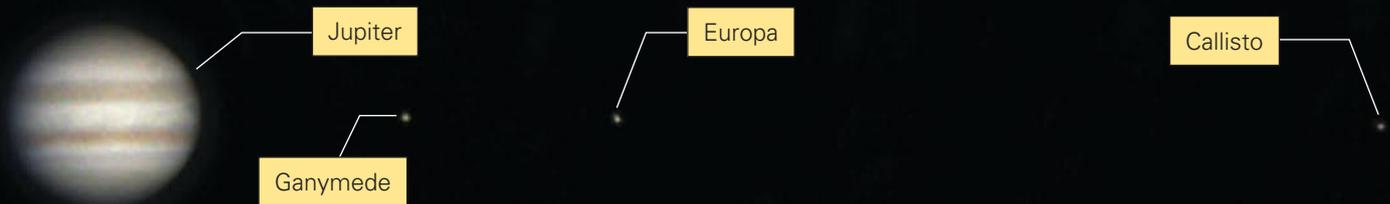


Figure 6.41 Jupiter and three of its moons: Ganymede, Europa and Callisto

Geocentric versus heliocentric models of the solar system

Aristarchus of Samos who lived from around 310 BCE to 230 BCE 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 6.42), an astronomer,

Science as a human endeavour 6.3

heliocentric model

a model where the Sun was the centre of the solar system

geocentric model

a cosmological model where Earth was the centre of the universe

continued...

...continued

geographer and mathematician who lived in 127–145 AD. All astronomers at that time used this model and it was the preferred explanation of how the solar system works for more than a thousand years.

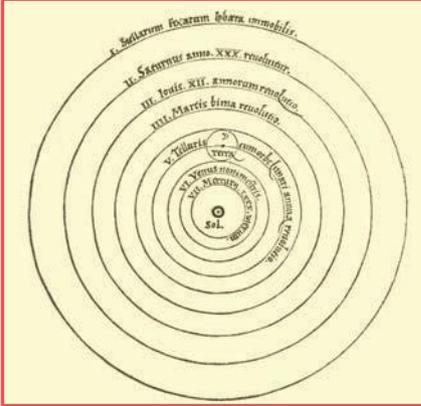


Figure 6.43 The diagram of Copernicus' heliocentric system, in Latin, as it appears in his book *De Revolutionibus orbium coelestium*, *On the revolutions of the heavenly bodies*, in 1543. 'Sol' is the Sun and 'Terra' is Earth.

It was not until the year 1543, approximately 1400 years after Ptolemy (and 1800 years after Aristarchus!) that Nicolaus Copernicus proposed his heliocentric model, borrowing from the work of Aristarchus. The model stated that, in fact, it is Earth that revolves around the Sun (Figure 6.43).

In 1610, Galileo Galilei, an Italian astronomer, first looked at the heavens with a telescope and made observations that confirmed 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.

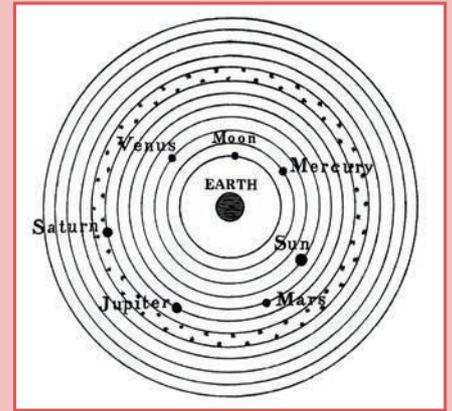


Figure 6.42 Historical artwork of the Earth-centred (geocentric) Ptolemaic cosmological model

Our galaxy

It was outside the solar system that the most exciting discoveries were made. The faint band of light that can be seen on dark

moonless nights was seen 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 6.44 The Milky Way Galaxy as seen from Indonesia

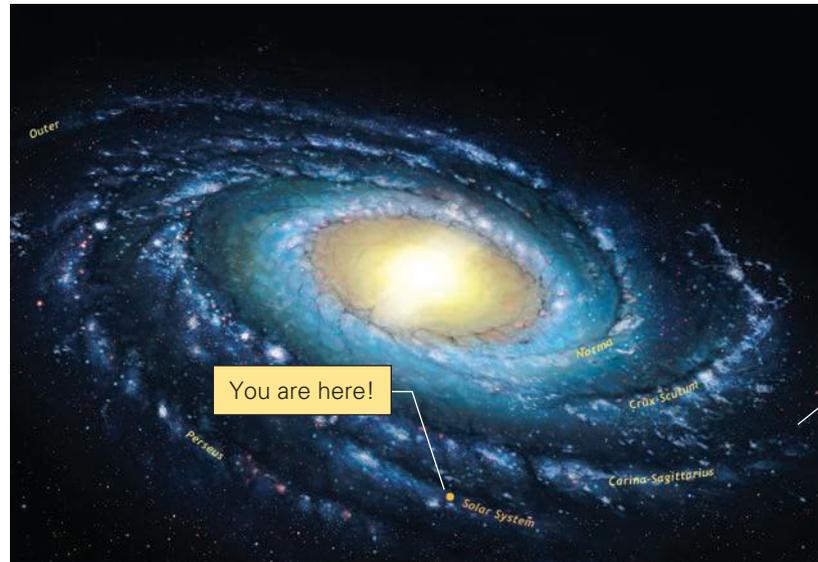


Figure 6.45 The Milky Way Galaxy showing the position of our solar system

Practical 6.5

Making a telescope

Aim

To make a working refracting telescope.

Materials

- 2 cardboard tubes
- convex lens with 30 cm focal length
- convex lens with 5 cm focal length
- piece of card paper
- Blu-Tack
- elastic bands

Method

- 1 Blu-Tack or glue one lens to one end of each of the cardboard tubes, as in the diagram.
- 2 Wrap the piece of card around the tube with the lenses facing out. Secure with elastic bands.
- 3 Look at an object in the distance. Focus the telescope by lengthening or shortening the tube. The length of the tube should be about 35 cm for viewing distant objects.

Be careful

WARNING:
Do not look at
the Sun or any
bright lights
with a telescope.

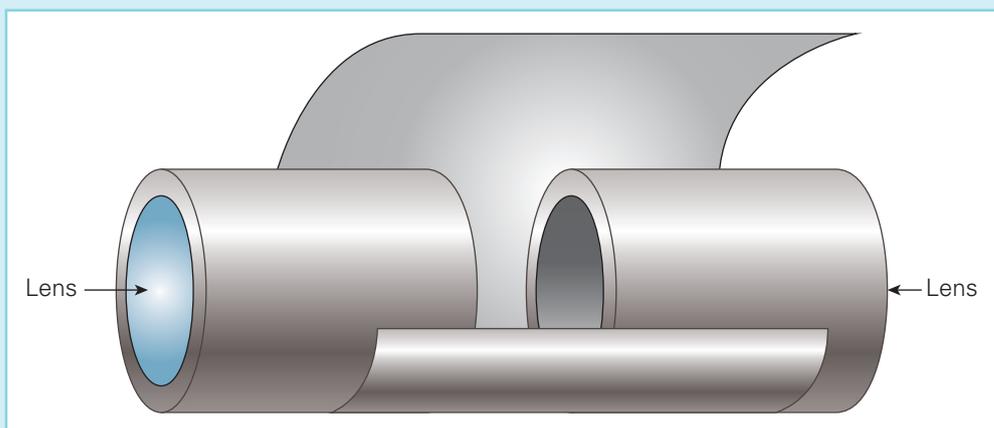


Figure 6.46

Results

Record your observations on how your telescope works.

Evaluation

- 1 Describe how well your telescope worked.
- 2 Explain how simple telescopes like this have helped scientists throughout history.

Conclusion

From this activity we can claim that telescopes work as a result of _____. This is supported through observing _____. Therefore, it can be concluded that _____.

Improvements on the telescope

The telescope has had a profound 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 lenses with mirrors. 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.

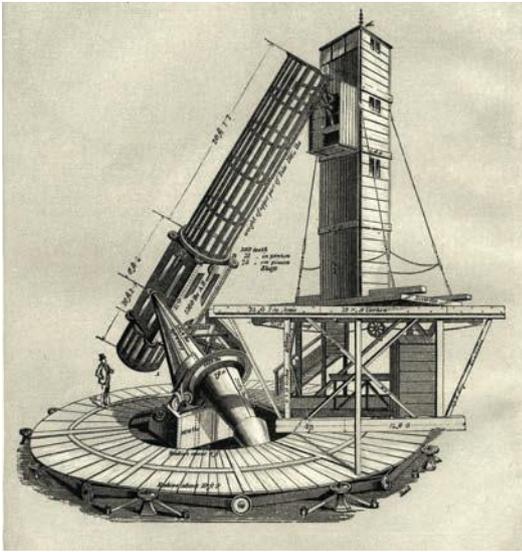


Figure 6.47 The Newtonian telescope, 1870, a type of reflecting telescope that uses two mirrors

It is easy to measure the brightness of a star, but more information can be obtained by attaching a spectrometer to a telescope. 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 forever 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. He was the first to realise that our galaxy, the Milky Way, was just one of billions of galaxies in the universe and furthermore discovered that the galaxies were all moving apart from each other. 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.

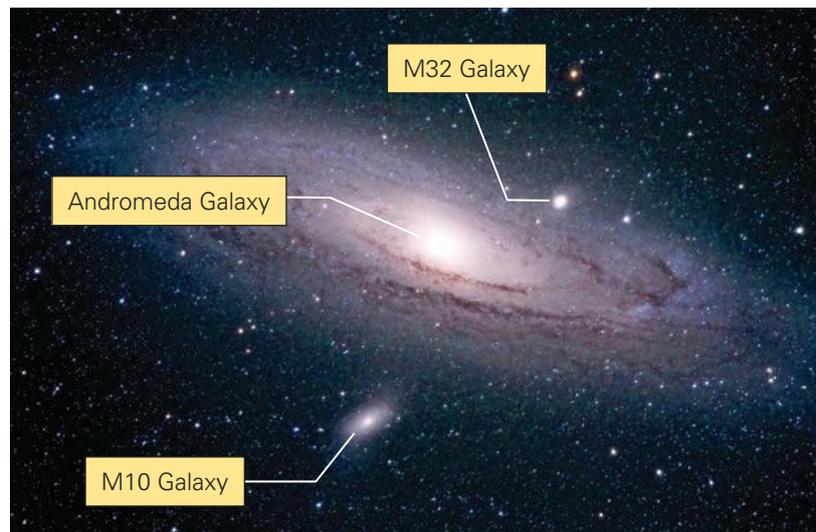


Figure 6.48 The Andromeda Galaxy. This nearby galaxy is similar in structure to the Milky Way. Two other galaxies (M10 and M32) are also visible.

The Hubble Space Telescope

Hubble's contribution was recognised when a telescope built in 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.

Science as a human endeavour 6.4



Figure 6.49 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)** Using the Hubble Space Telescope shows that even the darkest patch of sky is found to be full of galaxies.

Science as a human endeavour 6.5

The LUVOIR

While the Hubble Space Telescope provided a huge leap forward in how much of the universe is visible, it has just about reached the end of its useful life. A new concept for a telescope named LUVOIR, (**L**arge **U**ltra**V**iolet, **O**ptical, and **I**nfra**R**ed) can do much more than Hubble. It will be 16 metres in diameter and be able to collect 40 times the amount of light that Hubble could. This is the newest technology for telescopes today and 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!



Figure 6.50 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 due to the many observations made since

the invention of the telescope. 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.



QUIZ

Section 6.5 questions

Remembering

- 1 What is the solar system made up of?
- 2 What galaxy is Earth in?

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 There are two main types of telescopes: reflecting and refracting. Suggest the difference between the two.

Analysing

- 8 Why is it important to have telescopes that can gather data on light other than visible light?
- 9 Compare and contrast the geocentric and heliocentric models.

Evaluating

- 10 Describe how telescopes have changed our understanding of the universe. How might the understanding of the universe be different if the telescope had not been invented?

Review questions

Remembering

- 1 Approximately how many times does Earth spin in one month?
- 2 Approximately how many complete phase cycles of the Moon are there in one year?
- 3 Why is it difficult to specify the time taken for the Sun to rotate?
- 4 Does the Sun rise first in Sydney, Melbourne or Perth?
- 5 The antipodes of a point is that point projected through Earth to the opposite side. Where is the antipodes of the North Pole?



Understanding

- 6 Explain why an eclipse can never occur during a quarter moon.
- 7 It is dark in Brisbane and daylight in Perth. Is it morning or evening?
- 8 Give two reasons why the average winter temperature is higher in Brisbane than in Melbourne.

Applying

- 9 Do places near the Equator experience seasons? Explain your answer.
- 10 Could there be a solar eclipse and a lunar eclipse in the same month? Explain your answer.
- 11 The Moon is slowly moving away from Earth. Draw a diagram to show why total solar eclipses will become less likely in the future.

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?

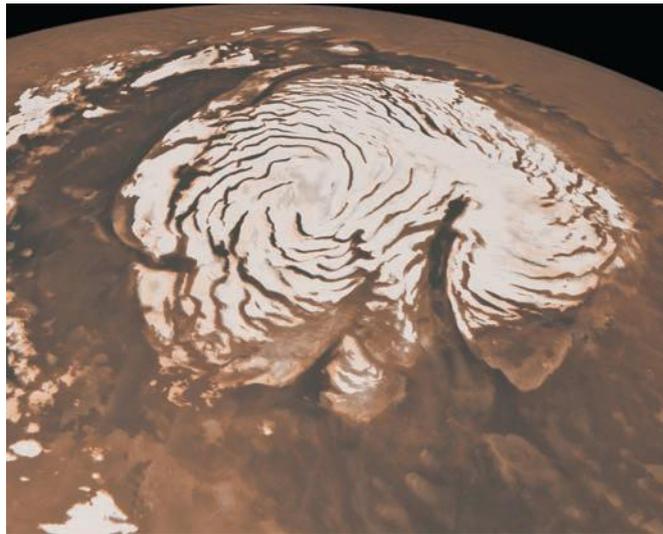


Figure 6.51 A polar ice cap on Mars

- 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 write a brief summary of how the technology has changed.
- 16 Make a list of things discovered about the universe throughout history. Speculate what might be found in the future with developing technology.

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 is, 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 towards it. 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. But 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.

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 Law of Orbital Motion is elegant and straightforward, stating that:

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 6.2 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 6.2 Distance and orbital period data for planets located in the inner 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 6.52), and to gain a visual understanding on how Kepler's Law of Orbital Motion applies to planets orbiting the Sun.

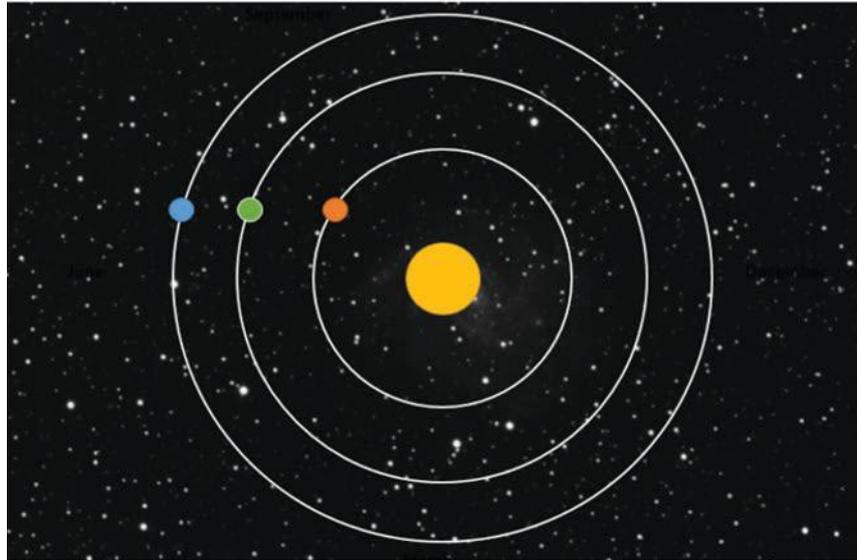


Figure 6.52 Model of the solar system

Suggested materials

- laptop
- Microsoft PowerPoint
- paper and pencil to perform simple calculations

Evaluate and modify

- 1 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 (Mercury) have shorter orbital periods compared to planets located further away (Saturn). Therefore, you should make changes to your simulation to make it behave closely to the real solar system.

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 use change the values (seconds) and make your simulation more realistic.

- 2 Discuss with at least three of your colleagues the challenges you have encountered throughout this project. List the strategies or actions that allowed you to overcome it.

- 3 Reflection is an integral and vital aspect of any project out there in the real world. In your honest opinion, *list* what you would like to have included, removed or modified from this challenge and ways to improve the way we visualise our solar system.
- 4 Planets in the 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 accuracy is due to the distance between the Sun and the planets (i.e. the closer, the faster).

Now, imagine the following scenario: scientists just released some breaking news announcing 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 is 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 law, whether the orbital period of planets would change at all in this new hypothetical scenario.

- 5 Now consider you want to create 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 7 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 for. 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 massively affected by the things we humans do to change our world.

Curriculum

Some of Earth's resources are renewable, but others are non-renewable (VCSSU100)	
• considering what is meant by the term 'renewable' in relation to the Earth's resources	7.1, 7.2
• considering timescales for regeneration of resources	7.1, 7.2
Water is an important resource that cycles through the environment (VCSSU101)	
• considering the water cycle in terms of changes of state of water	7.3
• investigating factors that influence the water cycle in nature	7.3
• exploring how human management of water impacts on the water cycle	7.4

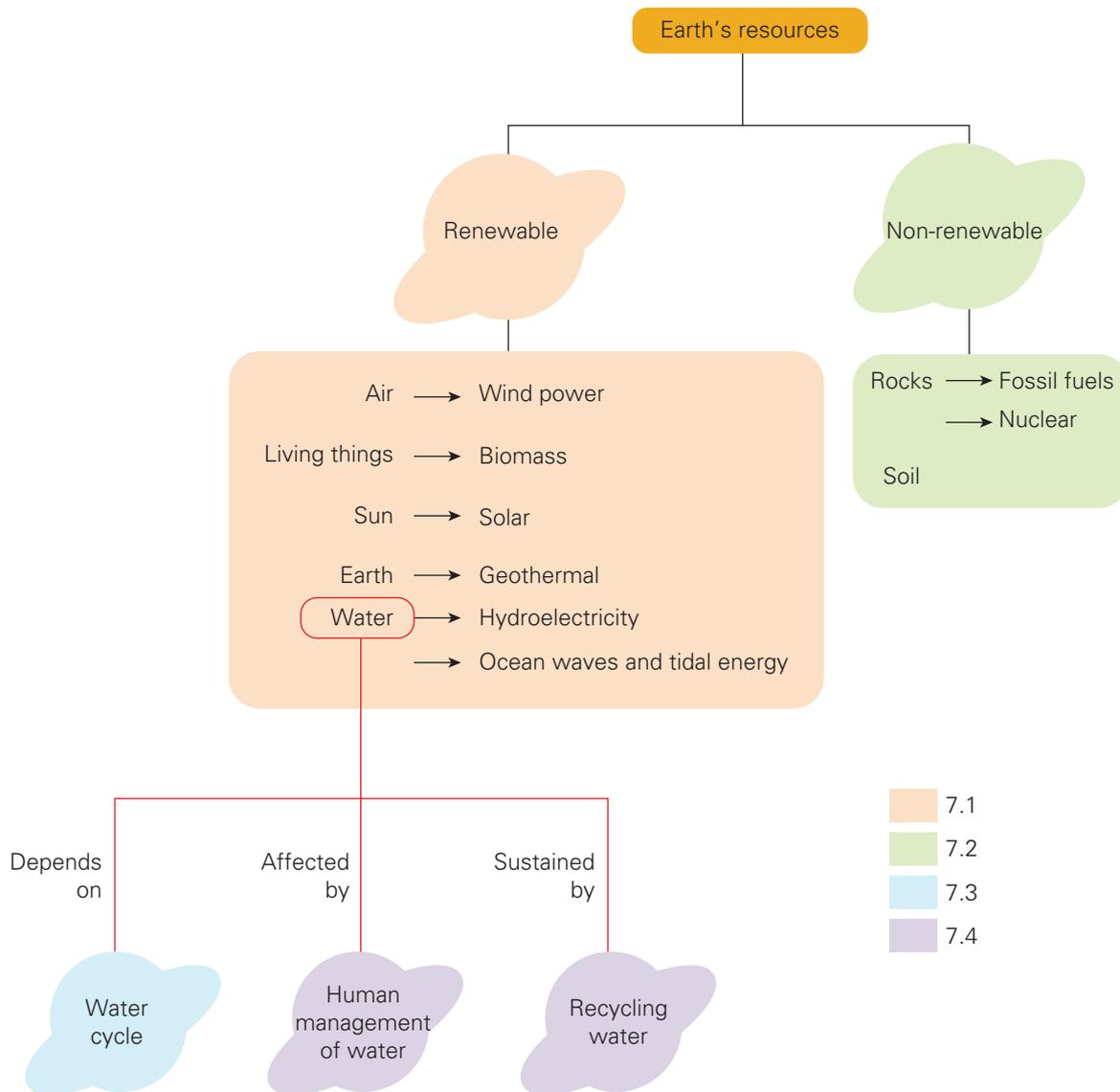
Victorian Curriculum F-10 © VCAA (2016)

Glossary terms

barrage	hydroelectricity	photovoltaic
biomass	impermeable	precipitation
blackwater	infiltration	renewable
condensation	mineral	resource
evaporation	non-renewable	runoff
fossil fuel	nuclear energy	silt
geothermal energy	ocean energy	solar energy
greenhouse gas	percolation	transpiration
greywater	permeable	urban water cycle
groundwater	pervious	water cycle



Concept map



- 7.1
- 7.2
- 7.3
- 7.4



7.1 Renewable resources

Introduction to Earth's resources

Every year, you start school by bringing certain **resources** to your classes – for example, textbooks, laptop/iPad, sports gear and stationery – things that will help 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 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**. Both renewable and non-renewable resources need close monitoring.



resource
natural commodity that is valuable in supporting life

mineral
a useful 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

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 7.1 Can you guess the types of energy sources can you see in the image? Are they renewable or non-renewable? You can discuss this with your classmates.

Left to right, top to bottom: biofuel (renewable), hydropower (renewable), nuclear (non-renewable), wind (renewable), coal or rocks (non-renewable), solar or sun (renewable).

- 1** What are the six major resources provided for us 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 | |

Quick check 7.1

In 2018, Hobart makes the list!

Did you know? 7.1

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 hydropower, followed by wind, solar, biomass and geothermal.

Water

Water is a renewable resource as it can replenish itself many times over within a human lifetime. Fresh water, not just any water, is an extremely important resource that all living things 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 plants, animals, manufacturing, agricultural 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.

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 **hydroelectricity** (water), **geothermal energy** (heat from the earth), energy from the ocean waves and tidal energy (water), wind energy (air), fuel from **biomass** (living things) and **solar energy** (energy from the Sun). These forms of energy are termed 'cleaner' than non-renewable forms, as they usually do not produce as much **greenhouse gas**.



hydroelectricity

producing electricity by the force of fast moving water such as rivers or waterfalls

geothermal energy

using energy from the heat inside Earth

biomass

dead plant and animal material suitable for using as fuel

solar energy

using the energy from the Sun to produce electric power

greenhouse gas

gases that prevent heat from Earth escaping into space

groundwater

water that collects below Earth's surface

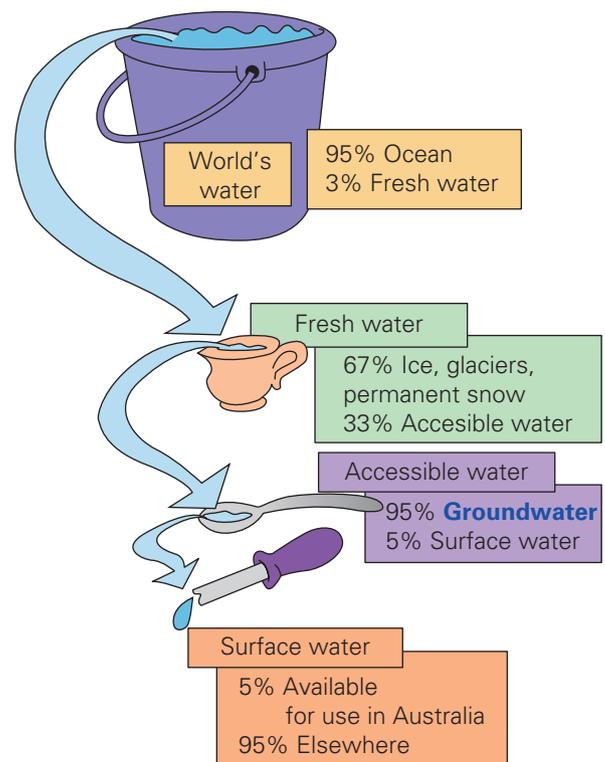
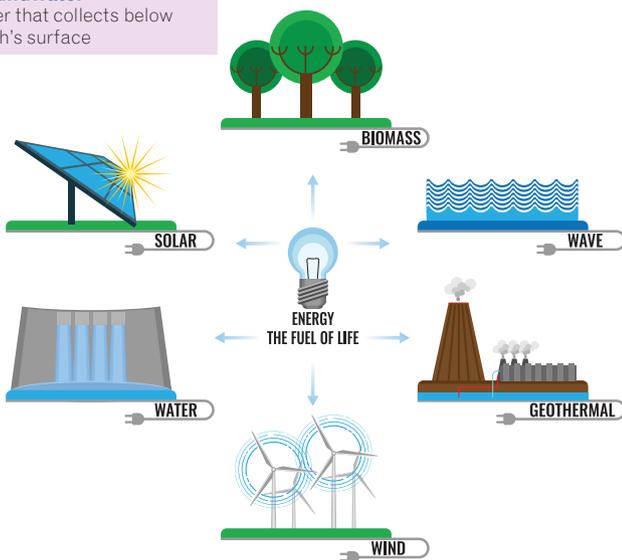


Figure 7.2 There are many different types of renewable energy sources.

Figure 7.3 Only about 1% (33% of 3%) of the world's water is accessible fresh water.

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.

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 7.5 Guthega Dam supplies water to power Guthega power station as part of the Snowy Mountains Hydro-Electric Scheme in New South Wales.

Energy from water: Hydroelectricity

Hydro (water) electricity is a clean source of energy producing no greenhouse gases. First, rivers are dammed to capture huge amounts of water. The dams hold water at a height, increasing the pressure of the water flowing to a lower level because of 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.

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

Australian surfers would agree that there is so much coastline around Australia that 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. One method of doing so 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.

ocean energy

energy harnessed from the ocean such as waves and tides

barrage

a barrier to generate electricity from tidal power

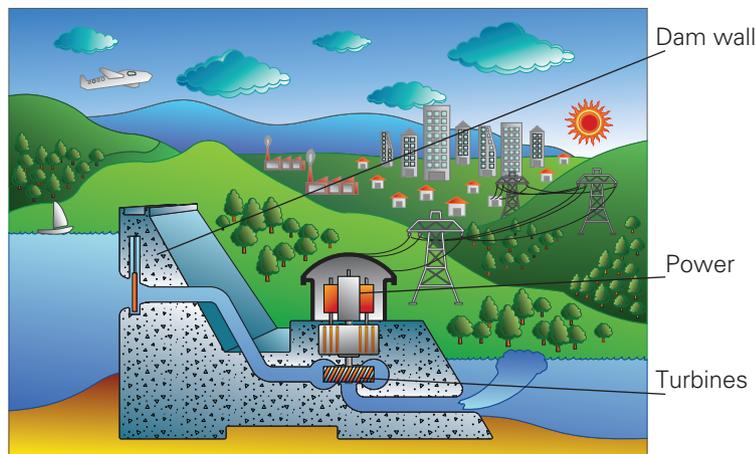


Figure 7.4 Cross-section of a hydroelectric dam

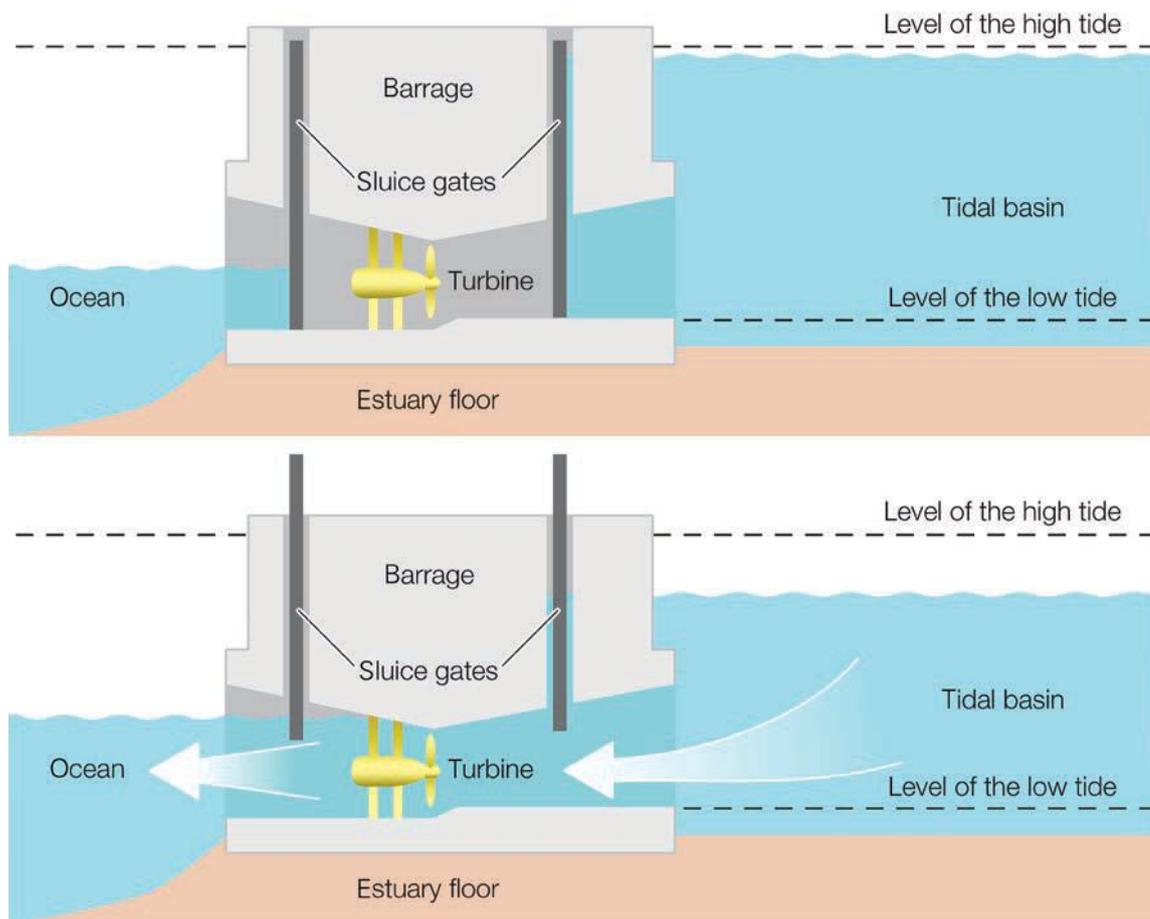


Figure 7.6 A tidal barrage, an artificial barrier, built across a river to generate electricity by tidal power

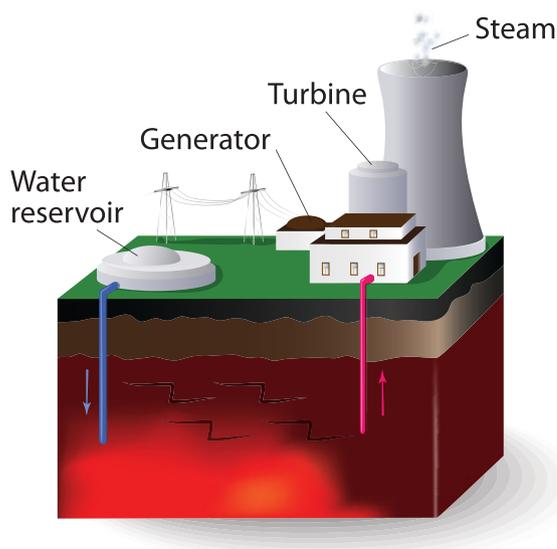


Figure 7.7 In geothermal power stations, heat from Earth's core is used to heat water and this is then used to turn a turbine. The water is cooled and returned to the heat source.

Heat from the earth

Energy from the earth: Geothermal

Geothermal energy is naturally occurring heat from deep within 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 liquids (hydrothermal process), 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 7.8 Geothermal power station



Generating power from the ocean

Science as a human endeavour 7.1

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 buoys capture energy from the ocean waves as they pass by. It requires only a small pipe to carry high-pressure seawater ashore to a turbine to produce electricity with no dangerous emissions. For the last couple of 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 began.



Figure 7.9 The CETO 5 harnessing ocean energy off the coast of Western Australia

- 1 List the reasons 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 wind blowing across the sea.
 - c Wave energy depends on the gravitational pull of the Moon and the Sun, and Earth's rotation.

Quick check 7.2

Air

The air is made up of mostly 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 breathe in, 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. When the blades spin, the shaft holding the blades turns as well. So as the shaft turns, it will also turn inside a generator, and consequently produces 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.

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 material as it takes about 25 years until a tree can be chopped down and used.

Energy from living things: Biomass

Biomass is the name given to any material derived from dead plant and animal matter, as well as their wastes. The reason for this is that plants can store the Sun's energy so that it can be used later, and if animals eat the plants they essentially consume the stored energy. There are several ways in which the energy can be released.

- The breakdown of manure and food scraps produces methane gas that releases energy when burned.
- The 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 7.10 The largest wind farm in Australia is the Macarthur Wind Farm in Victoria. What do you think may be the downside of wind farms?



Figure 7.11 Wood pellets (left) and dry dung (right) are both examples of biomass – fuel developed from organic materials.

Practical 7.1

Which grass produces more biomass?

Aim

To determine which grass produces the most biomass in a set period of time.

Materials

- 25 wheat or rye seeds
- 25 corn seeds
- 25 oat seeds
- potting mix
- 3 milk containers or small seedling pots
- light under which to grow

Be careful

Ensure a dust mask and gloves are worn when using potting mix.

Method

- 1 Write a prediction about which type of grass will produce more biomass over 14 days.
- 2 Plant the seeds in separate containers and ensure they are labelled.
- 3 Keep the seeds moist and grow them under an appropriate lamp.
- 4 Draw up a table for recording plant growth. For example, include:
 - date planted
 - date of first sprout
 - date of tenth sprout
 - height of growth every two days.
- 5 After 14 days, record the height of the sprouts for the final time. Then pull out the plants, wash and dry them before weighing the plants.
- 6 Dry the plants in the sun until they are crispy and then weigh them again.



Figure 7.12 Which grass produces more biomass?

Results

- 1 Record all measurements over the 14 days in a table.
- 2 Record the fresh weight and dry weight of the different grass types.

Evaluation

- 1 How did you determine the biomass of the different grass types?
- 2 Which type of grass is the best converter of light energy into biomass?
- 3 Were there any sources of error in this experiment? How could they be minimised in the future?

Conclusion

From this activity we can claim that the biomass produced by certain grasses _____. This is supported through observing _____. This means that _____.

- 1 What makes air a resource?
- 2 List some advantages and disadvantages of wind farms.
- 3 Explain why biomass is considered renewable.
- 4 List five examples of biomass that could be found at a garbage dump.

Quick check 7.3

The Sun

The Sun is one of more than a billion stars in the Milky Way. Its energy is renewable as it has enough nuclear fuel to keep shining for another 5 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 using 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. Unfortunately, though, you will not see many large photovoltaic power plants around, as photovoltaic systems have been expensive and the Sun does not shine at night!

photovoltaic
able to produce electricity
from light

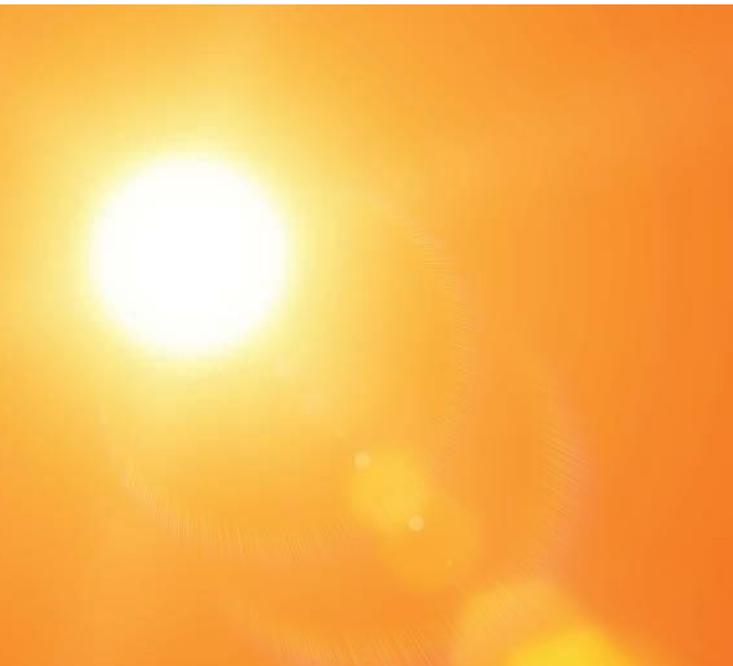


Figure 7.13 The Sun's energy shines down on us and is essential for life on Earth.



Figure 7.14 These photovoltaic solar panels convert the Sun's energy into electricity directly.

- 1 Explain why we call the Sun's energy a resource.
- 2 Is solar power a reliable source of energy?
- 3 How does using solar energy impact on the environment?

Quick check 7.4**Practical 7.2: Self-design****Which solar collector is the best?****Aim**

To determine which of three designs of solar collector absorbs the most heat energy (gets the hottest) after 15 minutes bathed in the Sun's energy.

Materials

- garbage/plastic bags of different colours, i.e. black, green and white, to act as solar collectors
- a range of insulating materials
- aluminium foil
- sticky tape
- 3 thermometers or data logging temperature sensors

Method

Follow these steps to make a solar collector.

- 1 Take a garbage/plastic bag, make a small hole in the side and insert the thermometer. Use sticky tape to seal around the hole.
- 2 Put 1 litre of water into the garbage/plastic bag, squeeze out the air and tie a knot.
- 3 Place the solar collector on the ground in sunlight for 15 minutes, recording the temperature inside the collector at time zero and at 15 minutes.

These are possible experiment ideas.

- Use three different coloured garbage/plastic bags.
- Use three garbage/plastic bags of the same colour and vary whether the solar collector is on the ground or on top of insulating material/s.

Write a prediction about which of your three designs you expect to absorb the most heat energy after 15 minutes in the sun.

Results

Draw up a table summarising the results for your three different designs - the before and after temperature recorded for each design must be included.

Evaluation

- 1 The independent variable in an experiment is the thing you deliberately change or manipulate; everything else needs to stay the same. Identify the independent variable in your experiment.
- 2 The dependent variable in an experiment is the thing you measure and expect to change because of the independent variable. Identify the dependent variable in your experiment.
- 3 What causes the temperature in the solar collector to change?
- 4 Explain the differences you observed between your three different designs.
- 5 Were there any possible sources of error? How could you minimise the effect of errors?

Conclusion

This experiment (supports/does not support) the claim that heat energy _____. We can see this from the results where _____. Therefore, it can be concluded that heat energy _____.

Engineering as a career**Explore! 7.1**

Engineering is a career that helps make people's lives easier and safer. Engineers are scientists, inventors, designers and builders, who can construct tools, create vehicles, run simulations, design chemical compounds and so much 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 7.15 Some of the many roles of renewable energy engineers



QUIZ

Section 7.1 questions**Remembering**

- 1 Read each statement and identify which renewable energy source is being described.
 - a Water wheels are the oldest machines used for capturing this type of renewable energy.
 - b This energy source captures the energy from the air.
 - c By digging deep wells and pumping the heated underground water or steam to the surface, this energy can heat homes.
 - d This type of energy depends on the gravitational pull of the Moon and the Sun.
 - e This energy source can use wood, straw and manure.
 - f This energy source involves building a dam to raise the level of water in the reservoir.
 - g This type of energy comes when pressure acting on the rocks and minerals of the Earth's core generates heat.



Figure 7.16 Solar power discs in the Australian outback

continued...

...continued

- h** This energy source involved forcing waves into a narrow channel to increase their power and size before they spin turbines.

Understanding

- 2** Copy and complete the following table summarising different renewable energy sources by filling in the gaps.

Type of energy	How it works
	Water is often collected behind a dam. When released, this fast-flowing water is used to turn a turbine, 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.

Table 7.1 Renewable resources

Applying

- 3** What prevents hydroelectricity from being used everywhere in Australia?
4 Deduce why solar energy is sometimes called 'green' energy.
5 What are the disadvantages of using solar energy?



Figure 7.17 Gordon Dam in Tasmania

Analysing

- 6** Draw up a table which summarises the advantages and disadvantages of a hydroelectric power station.
7 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.

Evaluating

- 8** Give reasons why some people think forests can be classified as a renewable resource and others consider it to be a non-renewable resource.

7.2 Non-renewable resources



WORKSHEET



VIDEO
Non-renewable resources

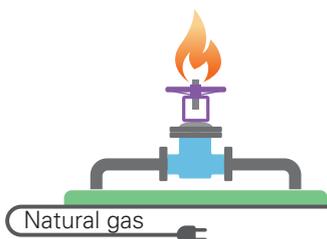
Remember that non-renewable resources cannot be replaced easily and not within a human lifetime. Of Earth's resources, rocks, minerals and soil are all non-renewable resources. These resources also provide non-renewable energy sources like fossil fuels and **nuclear energy**.



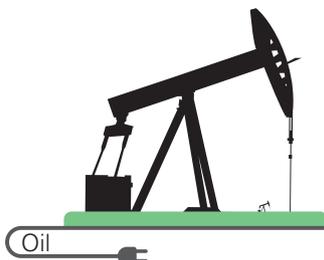
Nuclear



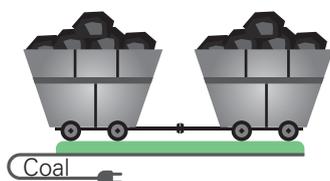
Energy



Natural gas



Oil



Coal

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 have a specific chemical structure that is the same throughout the entire mineral. Rocks, on the other hand, are solid materials found at Earth's crust and are composed of different minerals that vary throughout the structure of the rock.

nuclear energy
the energy obtained from changes within the atomic nucleus from nuclear fission, or fusion

There are three main types of rocks that form over many thousands to millions of years. These rocks and their minerals are not always replaced quickly once they have been mined and used, and consequently they are considered a non-renewable resource.

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 contains aluminium. Table 7.2 summarises the minerals your body uses.

Figure 7.18 There are many different types of non-renewable energy sources.

Mineral	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 from your lungs
Mineral source				

Table 7.2 Some of the different minerals that our bodies need

Energy: Fossil fuels

Rock layers also contain resources that are not minerals, such as coal, oil and natural gas. 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 can change the plant and animal remains into fossil fuels. So, we can say that fossil fuels are made from the remains of fossilised prehistoric living things. 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.



Figure 7.19 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 heat 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.

As with all energy sources, whether renewable or non-renewable, there are



Figure 7.20 A coal-fired power station. The short wide towers you can see are cooling or condensing towers; they are involved in recycling steam and releases water vapour. The tall narrow chimneys release carbon dioxide and ash as it is connected to the furnace.

advantages and disadvantages to the use of coal.

The other fossil fuels, oil and gas, are among the most important raw materials we have. Every day we use many things that are made from oil or gas. Look at the picture following and think about all the things you have used today that rely on oil or gas.



Figure 7.21 We use oil and gas every day in so many ways. Can you list all the different items you use regularly that are made from oil or gas?

- 1 Define the terms 'rocks' and 'minerals'.
- 2 Why are rocks and minerals considered to be non-renewable?
- 3 Name the three resources that collectively are called fossil fuels.
- 4 Outline the steps involved in turning coal into electricity.

Quick check 7.5**Practical 7.3: 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 litres of pond water or water that has been sitting under pot plants
- sand and soil
- 2-litre clear plastic bottle
- 1 large balloon
- gaffer tape
- funnel
- stirring rod

Method

- 1 Using the funnel, put the sand in the bottom of the plastic bottle.
- 2 Then alternate layers between the fish and green leaves and sand, ending with sand on the top about three-quarters of the way up the bottle.
- 3 Gently pour the pond water down the stirring rod 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 window so that it will warm up, and watch the changes over time.
- 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.

continued...

Be careful

Ensure that all materials are disposed of in a well-ventilated area.



Figure 7.22 Experimental set-up

...continued

Evaluation

- 1 What caused the balloon to inflate? What was the source of this? Explain the change you observed.
- 2 How could the results of this experiment be used to suggest alternative uses of garbage dumps? Can you find somewhere in the world where this is already happening?
- 3 With the time it took to run this experiment, why did we not end up creating oil? Explain your answer.
- 4 How could you improve this activity to better model the production of natural gas from organic material?

Conclusion

From this activity we can claim that natural gas _____. This is supported through observing _____. This means that _____.

Practical 7.4

Dewatering sediment

The process of removing the minerals from the ground is called mining. There are two main types of mine – open-cut and underground. In both these types, dewatering and water transfer play important roles. Mine dewatering is an essential part of extracting the resource, as it lowers the groundwater level around the mine to ensure the stability of the mine walls during and after excavation.

Aim

To investigate the process of dewatering and its relationship to oil and gas.

Materials

- plastic tray larger than 30 cm in length and more than 5 cm deep
- sufficient dry sand to make a layer 2.5 cm deep in the tray
- jug of water
- 30 cm ruler
- a student wearing one gumboot

Method

- 1 Place a layer of dry sand in the bottom of the tray to a depth of 2.5 cm (use the ruler to help guide you). Record the depth of the sand.
- 2 Predict what you think will happen to the sand level when you add enough water to make the sand very wet. Record your prediction.
- 3 Add water to the sand until it is very damp (about 1 litre). Record the height of the damp sand.
- 4 Have the student with the gumboot stand firmly on the sand in the tray with that foot for one minute before stepping off.
- 5 Wait one minute and record what has happened to the level of the damp sand.



Figure 7.23 Compressing sand squeezes out the water.

Results

Record your measurements and observations.

continued...

...continued

Evaluation

- 1 Explain any changes (or lack thereof) in the height of the sand after the water had been added at step 2. Was your hypothesis supported by the results?
- 2 Explain your observations of the damp sand level after it has been stood on.
- 3 Dewatering is the name given when water comes out of a substance or sediment. What would happen to the remains of dead things that are in the sediment when it gets compressed?
- 4 Were there any sources of error in this experiment? What changes would you make to this activity if you were to do it again, to make it more successful by minimising the errors?

Conclusion

From this activity we can claim that dewatering _____. This is supported through observing _____. This means that _____.

Energy: 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: these are summarised in Table 7.3.

Nuclear power is not renewable, but it is potentially unlimited. Its main advantage is that it does not produce greenhouse gases, 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.

Figure 7.24 A nuclear power plant



Type	Description	Example
Nuclear fusion energy	Where particles are fused together to form new particles. This fusion causes a large amount of energy to be released.	The Sun
Nuclear fission energy	This type of energy comes from splitting particles, which releases a large amount of energy as a result.	Nuclear power plants heat water and produce high-pressure steam. This high-pressure steam is used to run turbines which generate electricity.

Table 7.3 There are two types of nuclear energy.

Going nuclear

Explore! 7.2

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 and disposal of nuclear waste.
- 2 Explain the arguments for and against building a nuclear power station in Australia.

- Quick check 7.6**
- 1 Describe the two different types of nuclear energy.
 - 2 List the advantages and disadvantages of nuclear energy.

Soil

Soil is made primarily from rocks. Rocks break down and form rock particles, clay, **silt**, sand or gravel. These combine to form soil. Soil production occurs over very long periods of time, sometimes only a centimetre of depth every thousand or so years. Soil also contains

air, water, and often material from decaying plants and animals, and living things (such as worms, bacteria and fungi).

silt
sand or soil that is carried along by flowing water and then dropped usually at a river's opening or bend



Figure 7.25 Rocks are worn back and broken down by the action of elements like wind and rain (weathering). This forms small particles, which are carried away from the source rock in a process called erosion. Here you can see the evidence of erosion – the formation of London Bridge along the Great Ocean Road in Victoria.

Practical 7.5

Properties of soil

Aim

To investigate the properties of soil and suggest ways soil can be used by living things.

Materials

- 1 teaspoon each of three different soil samples: sample A, sample B, sample C

Method

- 1 Take a teaspoon of sample **A** soil and place it in the palm of your hand.
- 2 Ask your partner to add water drop by drop until the soil is wet but with no excess water. Play with the mixture – roll it into a ball, a sausage, flat like a pancake, in a cube. Record your observations of the soil texture in the 'No excess water' columns of the results table below.
- 3 Ask your partner to add two or three more drops of water to your sample. Repeat your explorations and record your observations in the 'Excess water' columns of your table.
- 4 Wash your hands after handling the soil.
- 5 Repeat steps **1–4** with the other soil samples.

Results

Table showing the texture of three different samples of soil in two different conditions

Soil sample	No excess water		Excess water	
	How it behaves	How it feels	How it behaves	How it feels
A				
B				
C				

continued...

...continued

Evaluation

- 1 Consider your findings. Summarise the characteristics of the three different samples.
- 2 How would the different properties of the samples determine what they can be used for? Record what could be some possible uses for the three different samples. Remember, these uses can relate to plants, animals or people.

Conclusion

From this activity we can claim that the properties of soil _____. This is supported through observing _____. This means that _____.

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 sea management strategies. For example, the Gunditjmara people in the Lake Condah region developed processes for farming enough eel to feed up to 10 000 people!

When Europeans arrived, they brought farming practices from their homelands, which were very different environments from 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 done. One example is the use of traditional fire management, which you have read about in Chapter 3.



Figure 7.26 Selecting what areas to burn, when and how often, is part of Aboriginal and Torres Strait Islander peoples' knowledge of the land.

Did you know? 7.2

- 1 What is soil made of?
- 2 Why is soil considered to be a non-renewable resource?
- 3 What is weathering?
- 4 How is erosion different from weathering?

Quick check 7.7

Come up with some strategies that you can use as an individual, family and community to reduce your use of Earth's resources.

Try this 7.1



Figure 7.27 A slogan used to help us remember the impact of our way of life on Earth's resources

Section 7.2 questions

QUIZ

Remembering

- 1 Match up the following words with their definitions in the second column.

Term	Definition
Mineral	Made from broken down rocks and from clay, silt, sand or gravel, which combine in different proportions
Soil	Solid materials found at Earth's crust
Rock	Building blocks that have a specific chemical structure, which is the same throughout the entire substance

- 2 Name a non-renewable energy source that is not a fossil fuel.
 3 For each resource, indicate whether it is renewable or non-renewable.

Resource	Non-renewable	Renewable
Water		
Oil		
Gum trees		
Sheep		
Gas		

Understanding

- 4 If oil and gas resources run out, outline 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 fossil fuels are non-renewable.
 7 Outline 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 Why are nuclear power stations 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.



7.3 The water cycle



WORKSHEET

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, remember that water has three states – solid, liquid and gas. Can you recall how the particles are arranged in solids, liquids and gases?

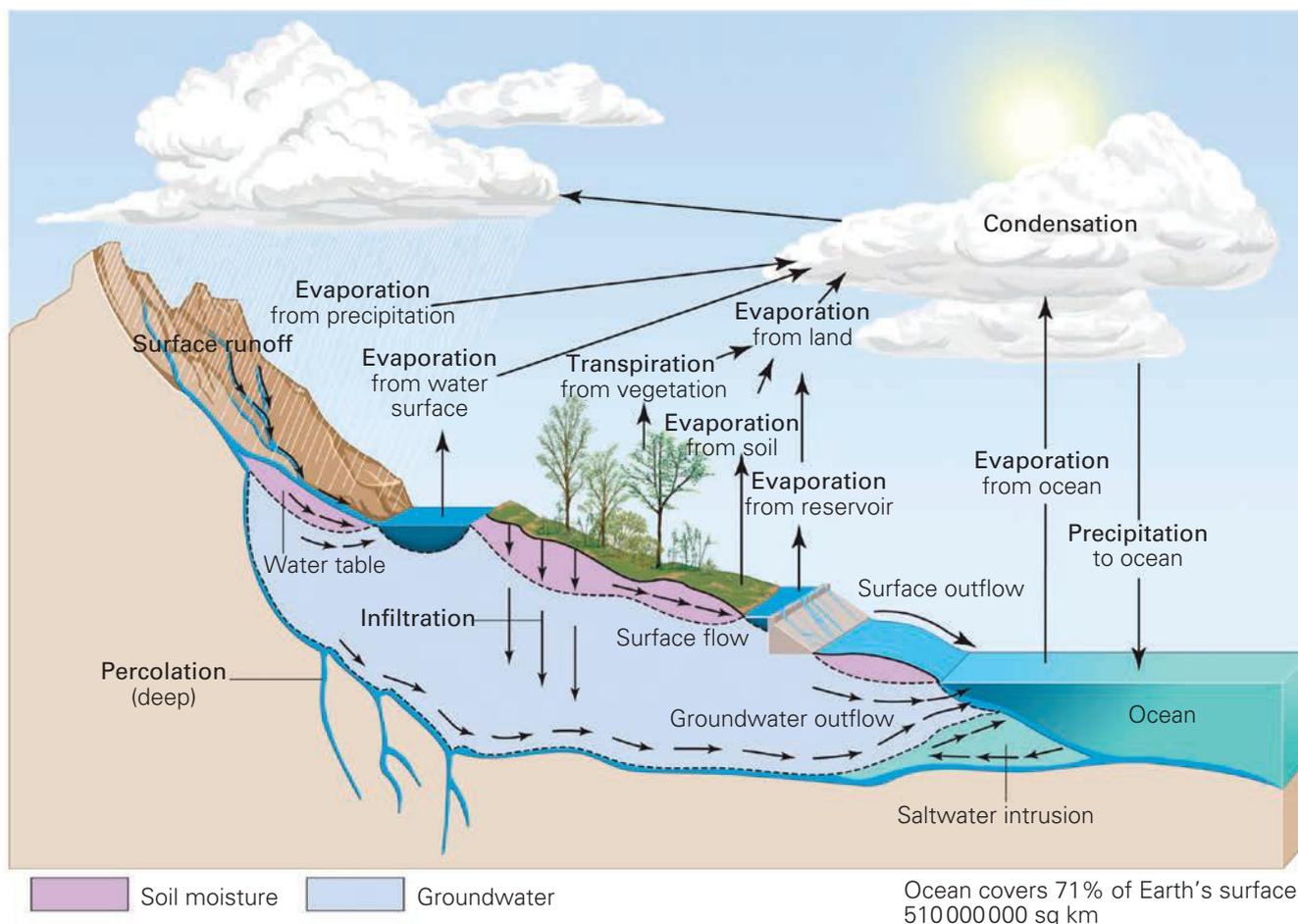
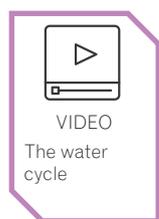


Figure 7.28 A representation of the water cycle demonstrating the processes involved



The water cycle

Uptake from roots

Plants actively take up soil water through their roots, absorbing water and nutrients to grow. Some trees have specialised root structures that allow them to obtain water from sources 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, especially trees, draw water up through their stems and trunks to their leaves. This water is then released to the atmosphere through tiny pores in the leaves. When the temperature is high, these pores may close to reduce water loss.

transpiration
the process of losing water through the surface of a plant

Practical 7.6

Transpiration

Aim

Investigate the movement of water through a plant.

Materials

- 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 on it 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 Mark the water line with the marker.
- 7 Place the test tube rack in a sunny spot.
- 8 Monitor the test tubes (about once a day) until your teacher tells you to stop. Each time you check the test tubes, measure how far the water level has fallen in each test tube.

Results

Graph your results. Put both sets of data on one set of axes.

Evaluation

- 1 Why did you smear petroleum jelly on the leaves?
- 2 Why did you set up two test tubes?
- 3 Describe what happened to the water levels in the test tubes.
- 4 Explain any differences you observed using terms you have learned.
- 5 Were there any sources of error in this experiment? How could they be minimised in the future?

Conclusion

From this activity we can claim that in plants, water _____. This is supported through observing _____. This means that _____.

- Quick check 7.8**
- 1 Recall from Chapter 4 the three states of matter. What are the three states of water?
 - 2 Explain how water taken up into the roots of plants is linked to transpiration.
 - 3 What changes in state occur during transpiration?

Evaporation

You may recall from Chapter 5 that **evaporation** is when water changes from a liquid to a gas (i.e. into water vapour). Heat from the Sun provides enough energy to evaporate liquid water from the sea, lakes and wet land surfaces and turn it into water vapour. Remember, hot air rises and so the water vapour gets carried upward.

evaporation
when heat causes liquid to become gas

Reducing evaporation**Did you know? 7.3**

Aboriginal and Torres Strait Islander peoples used to dig wells to reach groundwater. Before they moved on to another area, they would fill the well with clean sand. This not only meant that animals and birds couldn't bathe in or foul the water, but it also meant that there would be reduced water loss by evaporation. It only takes 90 cm of sand to reduce evaporation to almost zero! This is also why some Aboriginal and Torres Strait Islander peoples would bury themselves in sand to stop sweat loss in extreme heat.



Figure 7.29 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.

Practical 7.7: Self-design**Investigating the rate of evaporation****Aim**

To carry out a fair test to investigate:

- How surface area affects the rate of evaporation

OR

- How temperature affects the rate of evaporation

OR

- How wind affects the rate of evaporation.

Materials

- water
- thermometer
- plastic measuring cylinder
- 4 × 2-litre empty plastic ice-cream containers
- empty, wide plastic container; for example, a margarine container
- empty, narrow plastic bottle; for example, a soft-drink bottle
- fan

Method

- 1 Decide which factor – surface area, temperature or air flow – you would like to investigate.
- 2 With your classmates, design an experiment using the materials in the list to investigate how your factor affects the rate of evaporation. Write this down step by step as a method.

continued...

...continued

- 3 Write a prediction about what you think will happen.
- 4 After you have checked your design with your teacher, set up your experiment.
- 5 You may need to run your experiment over several days as evaporation is a slow process.

Results

- 1 Record your results in a table.
- 2 Graph your results to compare the volume of water in each container over the monitoring period.

Evaluation

- 1 In a fair test, try to keep everything the same in the experiment except the one thing you are investigating – the independent variable. Your independent variable would have been surface area or temperature or air flow. So, what were some of the variables that you had to keep the same?
- 2 Look at your results.
 - a In which container did all the water evaporate most quickly?
 - b In which container did it evaporate most slowly?
- 3 Look at your graph. Describe the shape of the graphs of the water volume versus time for each container.
- 4 Look at what have you discovered.
 - a Which container had the largest surface area of water exposed to the air?
 - b Does the size of the surface area of the water affect the rate of evaporation? If so, how?

OR

- a Which container was exposed to the greatest heat?
- b Does the temperature of the water affect the rate of evaporation? If so, how?

OR

- a Which container was exposed to the strongest wind?
- b Does the exposure to wind affect the rate of evaporation? If so, how?

- 5 How would you improve your method if you were able to carry out your investigation again?

Conclusion

From this activity we can claim that _____. This is supported through observing _____. This means that _____.

Condensation

Water vapour (water that has evaporated) rises up into the atmosphere: 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 clouds to form (recall Chapter 5). A cloud always has parts that are evaporating and

condensing at the same time, causing certain areas to shrink or grow.

condensation
where heat is lost causing a gas to become a liquid

Planes drawing in the sky

Did you know? 7.4

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 7.30 Contrails of a plane

Practical 7.8: Teacher demonstration**Making clouds****Aim**

To investigate how water clouds are formed.

Materials

- a little methylated spirits or ethanol
- hot water
- a 2-litre clear plastic cool-drink bottle with lid
- a match

Method

- 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?

Results

Record what you observed at each stage of the process.

Evaluation

Explain your observations using the following terms: pressure, smoke, condense, water vapour, water drops, cloud.

Conclusion

From this activity we can claim that clouds _____. This is supported through observing _____. This means that _____.



Figure 7.31 What figures can you see or imagine in the clouds?

- 1** Link the processes 'evaporation' and 'condensation' to the formation of clouds. State whether they are heating or cooling processes.
- 2 a** What phase change occurs for the water to form clouds?
- b** Is the water in clouds fresh water or salt water? Why?

Quick check 7.9

Precipitation

Precipitation is condensed water vapour that falls as rain, snow or hail. Because there is still water vapour rising due to evaporation, not all of the condensed water in the clouds falls.

precipitation

water that falls from the clouds towards the ground as rain or snow

Infiltration and percolation

Infiltration is the movement of water into the soil after precipitation has occurred.

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

Percolation is the movement of water within the soil. 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



Figure 7.32 Rain over Mount Oberon at Wilson's Promontory

and fell on the land, must percolate through the land to rejoin the sea. Moving water and the sediment it carries changes the surface of our planet. Erosion contributes as well by changing the shape of mountains and taking sediments into the sea.

But what happens if the precipitation lands on rock, not soil, so infiltration and percolation 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**.

impermeable

not allowing liquid or gas to go through

runoff

water that flows away from high areas to low areas

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).

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



Figure 7.33 Uluru in the rain. Uluru is composed of arkose rock, which is a coarse-grained sandstone, rich in the mineral feldspar (an abundant rock-forming mineral).

- 1 Define these terms: precipitation, infiltration, percolation and surface runoff.
- 2 What stage of the water cycle follows the process of condensation in the atmosphere?
- 3 What term is used to describe the movement of water into Earth's surface?
- 4 Explain the permeability of rock.

Quick check 7.10**Practical 7.9****Modelling the water cycle****Aim**

To investigate how the water cycle can best be modelled to demonstrate all the components.

Materials

- 250 mL beaker
- water
- ice cubes
- Bunsen burner
- heatproof mat
- tripod
- gauze mat
- large watch glass
- matches
- safety glasses

**Method**

- 1 Half fill the beaker with water.
- 2 Heat the water using the Bunsen burner until it is boiling.
- 3 Stop heating and carefully cover the beaker with the watch glass. It needs to act as a lid on the beaker. Observe what happens to the bottom of the watch glass and record your observations.
- 4 Remove the watch glass 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 watch glass and place ice cubes on its top.
- 7 Observe what happens to the space between the water and the watch glass.

Be careful

Be careful when using a Bunsen burner. Wear your safety glasses.

Results

Record your observations at each stage.

Evaluation

- 1 In detail, describe what happened to the bottom of the watch glass the first time you covered the boiling water with the watch glass. 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 and mention which part of the experiment represents each part you talk about.
- 4 Were all the components of the water cycle represented in this experiment? Explain each component and which part of the experiment represents them.
- 5 How could your experiment be improved to better model the water cycle?

continued...

...continued

- 6 Safety is important when carrying out experiments. Looking at the previous picture and considering what you already know about safety in the laboratory, list the safety precautions you need to follow when using a Bunsen burner.

Conclusion

From this activity we can claim that the water cycle _____. This is supported through observing _____. This means that _____.

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 7.4 summarises the 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, 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 little pores 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 of these processes to occur.
Landscape features	Runoff Percolation	When the precipitation lands on a permeable surface, there is a high amount of percolation and very little runoff.
Vegetation	Transpiration	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.
Sunlight	Evaporation	The more sunlight there is, the more evaporation will occur; for example, in the summer when days are longer, more evaporation occurs.

Table 7.4 Summary of the natural factors that affect the water cycle



QUIZ

Section 7.3 questions

Remembering

- 1 What are the everyday terms for the states of water?
- 2 What changes of state are involved in water changing from gas to liquid to solid?
- 3 How is rain formed?

Understanding

- 4 Decide 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 the following diagram and work out what each number represents. Name each of the processes and include a definition.

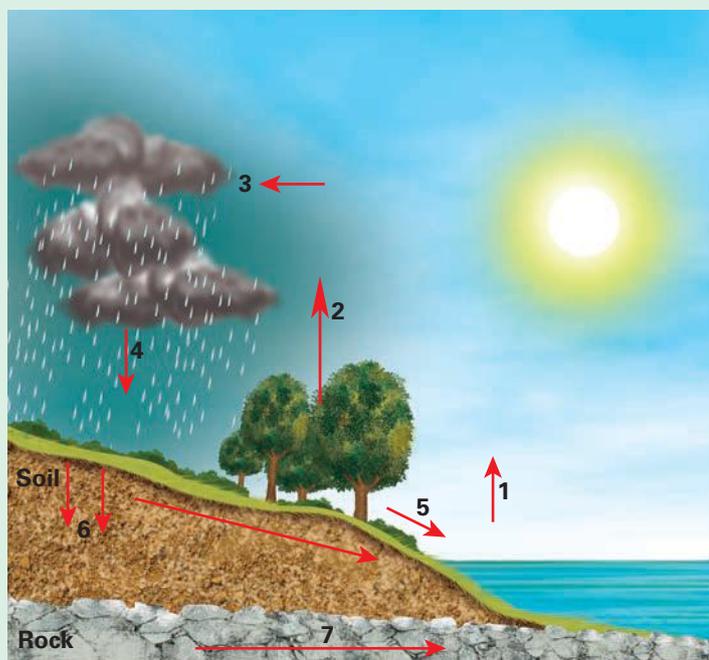


Figure 7.34 The water cycle

Analysing

- 6 Copy and complete the following table summarising the changes (if any) in state that water goes through in each process.

Process	State of water-start	State of water-end	Where?
Evaporation			
Transpiration			
Condensation			
Precipitation			
Runoff			
Infiltration			
Percolation			

continued...



...continued

- 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 Sometimes clouds are full of water vapour and yet never produce precipitation. Explain why this may be the case.
- 9 Summarise, with explanations, the natural factors in the environment that can affect the process of transpiration.

Evaluating

- 10 '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.
- 11 What would happen to Earth if the process of precipitation was not part of the water cycle? Justify your answer.



7.4 Human management of water



WORKSHEET

The natural water cycle is free of any objects made by humans, and is mostly composed of permeable surfaces like soil. Remember, these permeable surfaces encourage the water to move through by infiltration, resulting in higher levels of groundwater. However, humans have changed the landscape and developed ways to store water, move water, pollute water and treat water.

The urban water cycle

The way we humans have urbanised our world has affected the natural water cycle,

urban water cycle
a water cycle that includes the consequences of increased development

consequently it often gets referred to as the **urban water cycle**.

Water catchments to tap

Most of Melbourne's drinking water comes from forests high up in the Yarra Ranges. This area is called a catchment as it is like a giant bucket, waiting to catch rain. The water then flows down the mountain along creeks and into rivers and oceans. When it



Figure 7.35 In this photo, you can see both historical and modern architecture in Melbourne's CBD. In the foreground is Princes Bridge, which was completed in 1888. Imagine how the city has changed since then! Can you explain how these changes would have affected the water cycle?

rains, the runoff eventually flows into the reservoirs and water mains that make up our water supply system (that is, the clean water that we can use in our homes). Is this a natural process?

No, humans have interfered with the water cycle so that we can store water (in these reservoirs)

for when we need it, and then use pumps and pipes to transport the water to our homes.



Figure 7.36 Maroondah Reservoir in the Yarra Valley, Victoria. On the left is the dam wall and the right, the reservoir itself.

Practical 7.10

Gravity and water pumps

Aim

To investigate the effect of gravity on water and 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 (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 BCE. 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 7.37.
- 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 Stand one basin on top of a pile of books. Leave the other on your bench and fill with water.

continued...

...continued

- 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 books. 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 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.

Evaluation

- 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 Where do 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. Would it 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? Explain.

Conclusion

From this activity we can claim that _____. This is supported through observing _____. This means that _____.

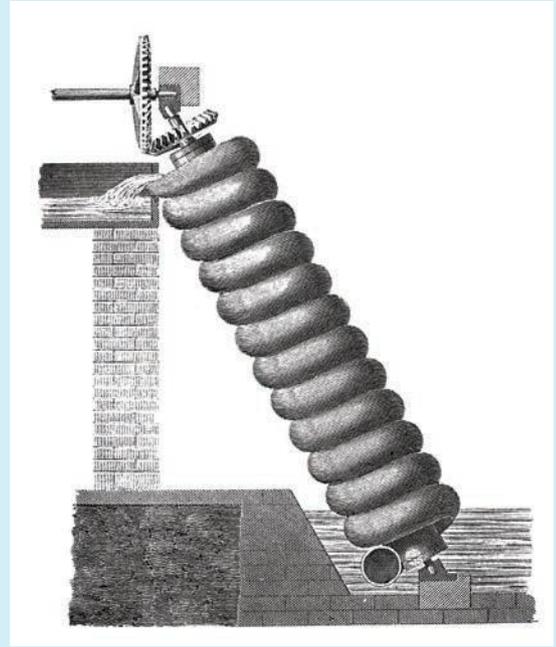


Figure 7.37 19th century engraving of Archimedes' pump, called a screw, used to transport water

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 one of two treatment plants in Melbourne's east and west. These treatment plants remove toxic substances, so the sewage can be safely pumped out to sea and back into the natural water cycle, or recycled and used for irrigation on farms, parks and golf courses.

Stormwater – drains to our bays

Sadly, the natural water cycle cannot function normally in urban areas 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 collects in nearby rivers and creeks, then travels out into our bays, where it re-enters the natural water cycle.



Figure 7.38 Stormwater drains and pipes return water to rivers and the oceans but not always in the condition it should be in.

It is important to keep in mind there are problems with stormwater, which are summarised in Table 7.5.

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	<ul style="list-style-type: none"> • More pollution • Stream banks will erode more quickly • Habitat of aquatic animals will be damaged • Breeding cycles of those aquatic animals will be disrupted
Low soil moisture	<ul style="list-style-type: none"> • Trees develop shallow root systems • Trees become unstable

Table 7.5 Summary of the problems with stormwater

Create a table that compares 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.

Quick check 7.11

- | | |
|---------------|--------------|
| evaporation | runoff |
| transpiration | infiltration |
| condensation | percolation |
| precipitation | |

The Murray–Darling Basin

Explore! 7.3

The Murray–Darling Basin is a large geographical area in the interior of south-eastern Australia, and is Australia's biggest catchment. Its name is derived from its two major rivers, the Murray River and the Darling River. The basin is home to an amazingly rich variety of birds, fish, insects, plants and marsupials. It is so important that the federal government has set up a special authority to manage it.

- 1 Read about the Basin Plan. Define the terms 'upstream' and 'downstream' in a river. What are water access rights?
- 2 What is the controversy about water rights? That is, how is the current situation causing problems for farmers downstream?



Figure 7.39 The Murray–Darling Basin is Australia's biggest catchment, covering four Australian states and territories, connecting 23 different rivers and providing water to produce more than one-third of Australia's food supply.

Recycling water

Two types of wastewater are created in your home: **greywater** and **blackwater**.

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.

greywater

water that has been used before; for example, from washing, which can be stored and used again in toilets and such like

blackwater

waste water from toilets



Figure 7.40 The use of greywater has become popular.

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 5 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.

- 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 Summarise the advantages and disadvantages of reusing your household greywater.

Quick check 7.12

Water treatment

Werribee has one of Melbourne's two water treatment plants. It is a historic plant that treats half of Melbourne's sewage but, 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!

Figure 7.41 The lagoons of the Western Treatment Plant in Werribee





QUIZ

Section 7.4 questions

Remembering

- 1 What might recycling greywater involve?
- 2 List some ways our water in nature can be kept pure.

Understanding

- 3 Explain why water tanks that supply water are built high up in towers.
- 4 Outline how blackwater is different to greywater.

Applying

- 5 Identify one method you could use at home to recycle water, and explain why it is important that water is recycled in nature.
- 6 You want to recycle your greywater and use it to water your vegetable garden. What should you do to ensure your greywater is safe to use on plants?

Analysing

- 7 List the processes in the water cycle that are affected when land is cleared of vegetation to create urban areas (cities and housing).
- 8 Explain the relationship between the temperature of the atmosphere increasing due to global warming, and rain.
- 9 Draw a simple sketch of the urban water cycle.

Evaluating

- 10 Give reasons, 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 drink or not drink recycled water.

Review questions

Remembering

- 1 Copy and complete the following table by naming the missing Earth resources and what their uses are.

Resource	Uses
Water	
	Living things to breathe, burning things, wind for drying clothes, powering windmills
Living things	
Rocks	
	Growing food, building, making things like ceramics
	Hot springs, geothermal energy
Energy from the Sun	

- 2 Define the terms 'urban water cycle' and 'stormwater'.
- 3 Give two examples of fuels made from biomass.



SCORCHER

Understanding

- 4 Explain why hydroelectricity would not be possible if it was not for solar energy.
- 5 Compare a hydroelectric power station and a nuclear power station.
- 6 Outline 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 reuse rather than buy new items. Explain why this is the case.
- 10 Outline 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 Identify where greywater and blackwater come from.
- 15 What process of the water cycle is interfered with when there are concrete surfaces everywhere?

Analysing

- 16 Copy and complete the following table by first classifying each of the resources as renewable or not, and then recording how long it takes it to renew.

Resource	Renewable or non-renewable	Timescale for renewal
Geothermal		
Coal		
Wind		
Tides		
Natural gas		
Biofuel		

- 17 The Sun, wind, water and geothermal are all renewable sources of energy. While there are many advantages to using these sources, discuss what some of the limitations might be.
- 18 Compare hydroelectricity with a giant battery.
- 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.
- 20 Compare pervious rock and impermeable surfaces.
- 21 Evaporation and transpiration appear similar. Distinguish between these two processes.
- 22 Compare natural water flow to stormwater flow in terms of impact on the environment.

Evaluating

- 23 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.
- 24 Imagine you have just got out of the pool and your towel is all wet. Give reasons for the conditions you think will allow your towel to dry the fastest, i.e. cause the most rapid evaporation of water.
- 25 Do you think humans have altered the water cycle? Give reasons for your decision.

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. 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 7.42 Outbreaks of waterborne diseases often occur after severe weather events.



Figure 7.43 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
- 2-litre plastic bottles with the bottoms cut off
- scissors
- paper towel
- squares of mesh, 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

Evaluate and modify

- Describe the important design features of your filtration system.
- List the materials and justify why you used each material for its purpose.
- Tabulate your materials and what pollutants you expect them to remove from the polluted water.
- Demonstrate how to use your 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.
- 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.
- Measure the volume of polluted water poured into your filtration system, and the volume of cleaned water produced. What was the percentage of change? Explain the possible causes of any differences between the two volumes.
- 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?
- Draw your new and improved design.
- What design constraints or limitations might be different for engineers developing real water filtration system?

Chapter 8 Forces

Chapter introduction

When you travel to school you might use a train, car, bus or bicycle, 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 bigger 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.

Curriculum

Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)

- | | |
|---|----------|
| • investigating the effects of applying different forces to familiar objects | 8.1 |
| • investigating common situations where forces are balanced and unbalanced, for example, stationary and falling objects | 8.2, 8.3 |
| • investigating a simple machine such as a lever or a pulley system | 9.1, 9.2 |
| • exploring how gravity affects objects on the surface of Earth | 8.2 |

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Glossary terms

air resistance

alloy

applied force

balanced forces

brittle

buoyancy force

drag

elastic

electromagnet

electrostatic force

field

force

friction

gravity

impact force

magnetic field

magnetic force

mass

mouldable

muscle

net force

pull

push

repel

rotate

static electricity

streamlined

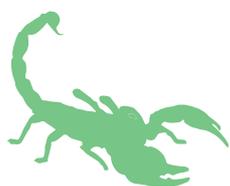
tension

turning force

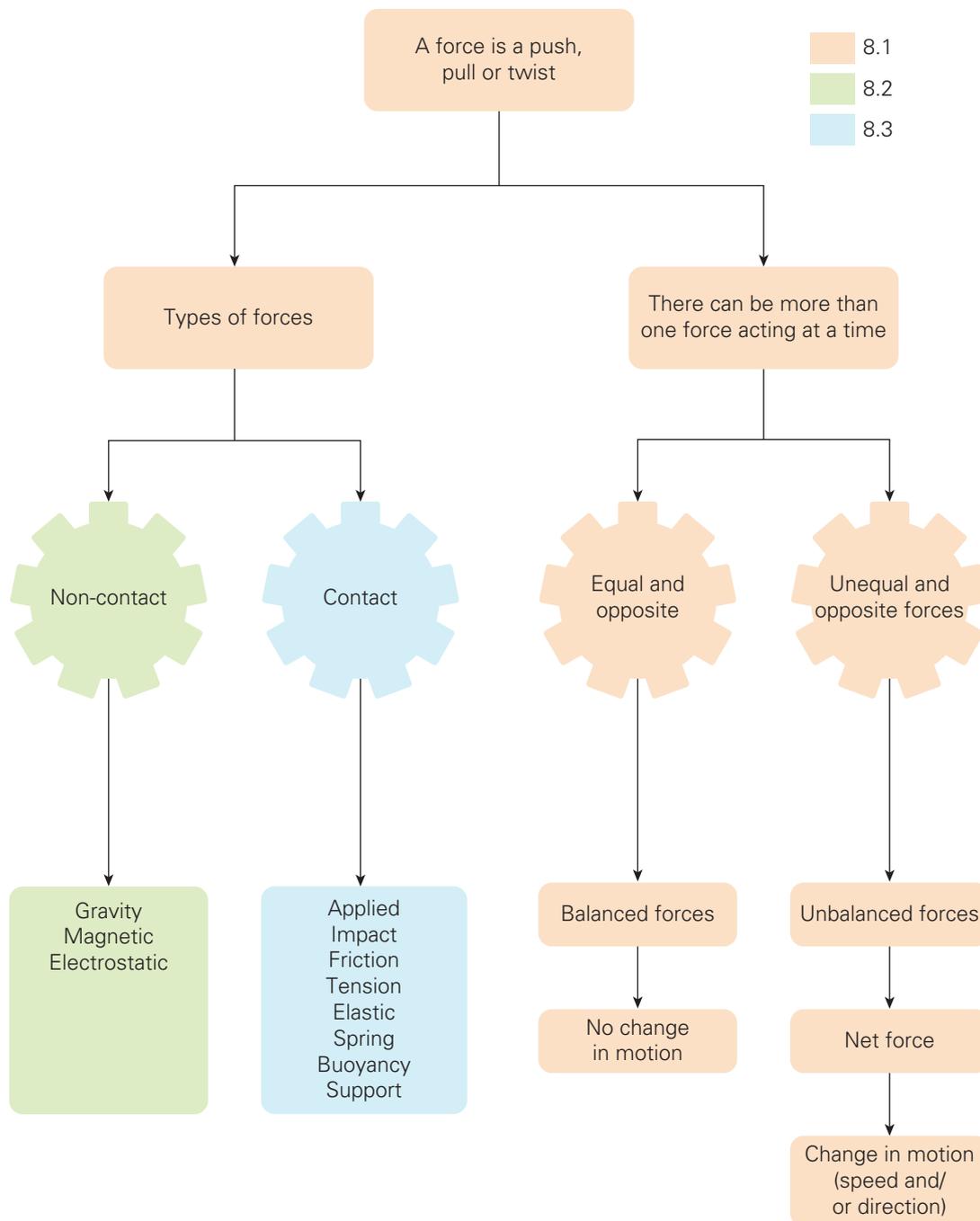
twist

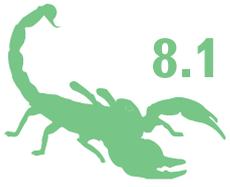
unbalanced forces

weight



Concept map





8.1

Applying forces on objects

A **force** occurs whenever something is given a **push** or a **pull**, or is rotated or twisted.

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

Forces are part of our everyday life and 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, that's a force, or pull on your

socks, strum guitar strings or slam dunk a basketball ... all forces! Forces are found not only in our own lives, but in nature as well. Consider the force on a bird's wing as it soars in the air, the sweep of a whale's tail in the water and the push in a grasshopper's legs as it jumps. In your own body, your **muscles** apply forces when you move.



WORKSHEET

muscle
tissue in the human body capable of exerting a force

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.

Try this 8.1



Figure 8.1 Having fun in the park means lots of forces are in action.

Table 8.1 gives a revision of the forces and associated terms.

Contact or non-contact	Type of force	Description	Example
Contact forces	Pushing force	One object moves or tries to move another that it is touching, away from it.	Pushing a trolley.
	Pulling force	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 force	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 (or tries to make them) slow down relative to each other.	Brake pads rubbing on the wheel of a bike.
Non-contact forces (acting at a distance)	Force of gravity	The force that pulls masses towards the centre of Earth.	The weight of an object.
	Magnetic force	The attraction or repulsion of magnets.	A magnet picking up bits of iron.
	Electrostatic force	The attraction or repulsion of objects that have a static electrical charge	Attraction of a rubbed balloon for pieces of paper.

Table 8.1 Forces revision

How are forces measured?

Forces are measured using a unit called the newton (N). One newton is approximately the force you need to hold a large apple.

Springs are usually used to measure forces because a spring will stretch when a pulling force acts on it and is squashed or compressed when a pushing force acts on it. In your classroom, you may use something called a spring balance, which can measure pulls. 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

mass or, in everyday speech, **weight**. But mass and weight are not the same thing in science, though in daily life the terms are used interchangeably. 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

mass

the amount of substance in an object that never changes, even in space

weight

the force of gravity on an object; it is measured in newtons and changes in space

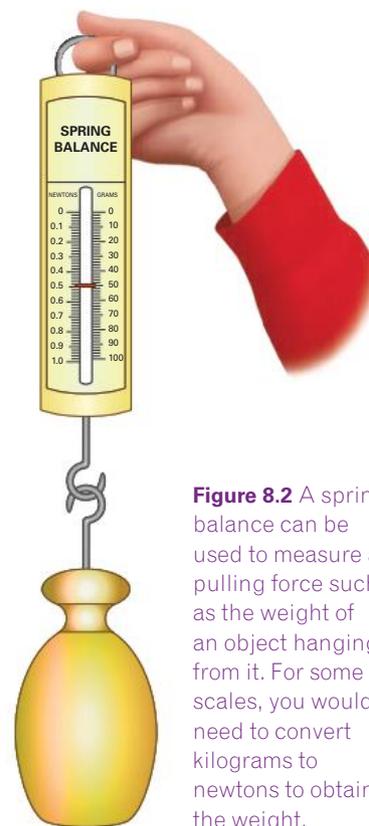


Figure 8.2 A spring balance can be used to measure a pulling force such as the weight of an object hanging from it. For some scales, you would need to convert kilograms to newtons to obtain the weight.

gravity at its location. You often refer to the weight of objects but really you are referring to their mass. The weight of an object is the force with which gravity pulls it towards the centre of 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.

On the surface of Earth an object with a mass of 1 kilogram has a weight of about 9.8 newtons (N). So, if a spring balance is labelled in newtons, it can also be used to measure mass in kilograms (approximately) with a conversion rate of $1 \text{ N} = 0.102 \text{ kg}$. Your kitchen or bathroom scales can measure forces (approximately) if you use a conversion of $1 \text{ kg} = 9.8 \text{ N}$.

Practical 8.1

Investigating forces

Aim

To measure some everyday forces.

Materials

- 10 N, 20 N, 100 N spring balances
- a selection of items from your laboratory

Method

- 1 Copy the results table into your book.
- 2 Collect at least five items from around your laboratory to measure their weights. Record these in your results table.
- 3 Hook each item onto the spring balance and measure the force required to hang (suspend) it against gravity. Record the measurement in your results table.
- 4 Place each item on a bench and attach a spring balance near the base and record the force required to get the object moving.
- 5 Then drag it steadily at constant speed along the laboratory bench. Record the force reading when the item is moving at a steady rate. Write it in your results table.
- 6 Drag each item at roughly the same speed.

Results

Item	Force required to suspend item	Force required to get item moving	Force required to drag item at constant speed

Evaluation

- 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 Sort the items in order from most to least force required to drag them.
- 4 Describe the trend in the data. Propose why some objects required a larger force to drag them.

Conclusion

From this activity we can claim that the force required to move different objects is _____. This is supported through measuring _____. Therefore it can be concluded that _____.

A new device to measure the force of a bird's wings while flying

In 2015, research came out about a new device that is going to help scientists understand the forces birds generate while flying. You know that a bird flaps its wings to fly but determining how a bird generates lift has been the 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 and these forces are recorded to produce a precise measurement for each stroke of the bird's wings.

Science as a human endeavour 8.1



Figure 8.3 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 of the force and the size of the force. For example, look at the image of a hanging plant held by a hook in Figure 8.4. The plant is pulling down due to **gravity**, and the length of the arrow represents the size of the weight force. The weight of the plant pulls on the chain, and a force in the chain, called **tension**, pulls up to keep it hanging. You draw an arrow for the tension going in the opposite direction. The hanging plant is not moving, it is suspended, and therefore the weight and tension forces are equal and opposite, so they are balanced. Their arrows are drawn to the same length.



Figure 8.4 The tension in the chain pulling up (red) balances the pull down (blue) of the plant due to gravity.

In Figure 8.5, there are three plants and you can draw a force of gravity arrow for each one, with length proportional (corresponding) to weight. The weight forces are added to make the total weight, and the tension arrow is equal to the total

weight, so you draw it to a length equal to the total length of the three gravity arrows added together.



Figure 8.5 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

Is there only the one force acting at a time?

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 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 8.6). If the forces are equal, they cancel each other out



Figure 8.6 In a rugby scrum, the forces of the two teams are working against each other.

and there is no movement. Equal and opposite forces are said to be **balanced**.

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.

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



Figure 8.7 Unbalanced forces exist when there are not equal sized forces pulling in opposite directions, so there will be a change in movement.

- 1 Define the following key terms in your own words and add them to your glossary: 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.

Quick check 8.1



WIDGET
Fly a helicopter

continued...

...continued

- 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 8.8 exerts an upward force on her bag when she carries it, while the downward force is gravity.
- a Are these forces acting together or working against each other?



Figure 8.8 A hiker carrying a backpack

- b How could you indicate this by drawing and labelling arrows on the picture?

What are the results of applying a force?

You may have noticed that a force can be applied to make an object move 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:

- 1 A force can balance another force so there is no change in its motion. (The important word here is 'change'.

Balanced forces are acting on a moving object as long as its speed and direction are not changing.)

- 2 A force can change an object's speed to make it go faster or slower.
- 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.

twist
to turn something

rotate
to turn or spin on an axis



VIDEO

How do you know a force is acting on an object?

Practical 8.2

Observing forces

Aim

To investigate the effect of forces on everyday objects.

Materials

- rubber band
- lump of modelling clay

continued...

...continued

- tennis ball
- bar magnet
- paperclip
- inflated balloon
- plastic counter

Method

- 1 Draw the results table in your book.
- 2 Perform each task in the table and record your observations.

Results

Task	Observations	
	Change in motion or shape	Force that caused the change
Stretch the rubber band		
Squash a lump of modelling clay		
Drop a tennis ball and catch it when it bounces		
Bring a bar magnet close to the 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		

Evaluation

- 1 What observations indicate that a force was acting in each task?
- 2 Which objects experienced a change in shape? Was this change permanent?
- 3 When you bounced the tennis ball, did it change shape at any point?
- 4 Propose a task with the rubber band that would involve balanced forces acting on it.

Conclusion

From this activity we can claim that forces can cause _____. This is supported through observing _____. Therefore it can be concluded that _____.

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 or if it is moving it 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 (blue arrow) was bigger than the push up of the shelf (red arrow), 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'.

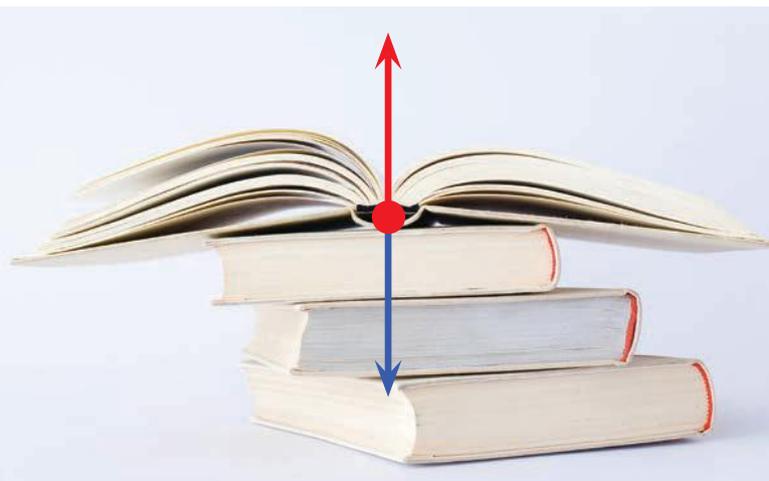


Figure 8.9 The weight of the book (blue) is pulling down towards Earth due to gravity. This is balanced by the support force of the other books pushing back at it (red).

An object floating in water, like the ball in Figure 8.10, 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.

buoyancy force

the force experienced by an object that is partially or fully submerged in a fluid, eg. water



Figure 8.10 The weight of the ball (blue) is balanced by the buoyancy force of the water (red).

These rocks at Stonehenge in England have been exerting forces on each other for 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?

Try this 8.2



Figure 8.11 The weight of the horizontal stone is balanced by the support force from the two vertical stones.

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 five forces that act on it as it moves. The engine pushes it forward, while **air resistance** and a force called **friction** slow it down. 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.

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

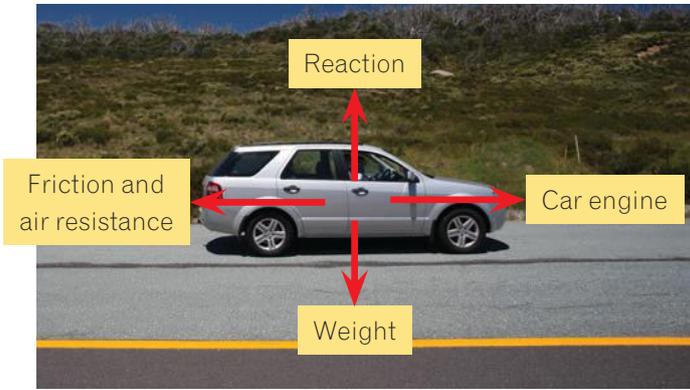


Figure 8.12 The forces on the car are balanced and the car travels at a constant speed.

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 8.13 The force of the wind on the sail of a yacht helps it move steadily through the water.

- 1 A painting is hanging on a wall from a nail. Would the forces on it be 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. Are these two forces balanced?
- 3 A swimmer is racing from one end of the pool to the other at a constant speed. What must be true of the forces on the swimmer?
- 4 Draw a sailing boat like the one in Figure 8.13, 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.

Quick check 8.2

2 A force can change an object's speed.

Sports are great places to look for unbalanced forces, and it is these unbalanced forces that allow a force to change an object's speed by making it go faster or slowing it down. Can you think of some examples 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

impact force
a contact force which sometimes only lasts for a short time; often impact forces change an object's speed

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 bat. Can you think of other examples of where a force makes something speed up?



Figure 8.14 The force of the golf club changes the speed of the golf ball from zero to extremely fast in a matter of milliseconds.

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 (because of friction) and eventually stop.

Practical 8.3: Teacher demonstration

Balanced and unbalanced forces

Aim

To produce a balanced and unbalanced force on an object.

Materials

- retort stand, boss head and clamp
- pulley
- string
- spring balance
- block of wood

Method

- 1 Set up a single pulley system on a retort stand, boss head and clamp. It might look like this.
- 2 Attach the spring balance to one end of the string and the wooden block to the other end.
- 3 Hold the string so the block does not move. Record the force.
- 4 Using a constant speed and force, pull the wooden block up using the pulley system.
- 5 Record the force required to lift the block at a steady pace.
- 6 Produce an unbalanced force by speeding up or slowing down the speed in which you lift the block. Record the force required to do so.

Results

Record the force required to hold the block still, to lift it at a constant speed, to lift it speeding up, and to lift it slowing down.

Evaluation

- 1 How did the required force differ between holding the block in place and pulling the block up at a constant speed?
- 2 How did the force differ between pulling the block at a constant speed and when varying the speed?

Conclusion

From this activity we can claim that unbalanced forces cause _____. This is supported through observing _____. The observations mean that if _____.

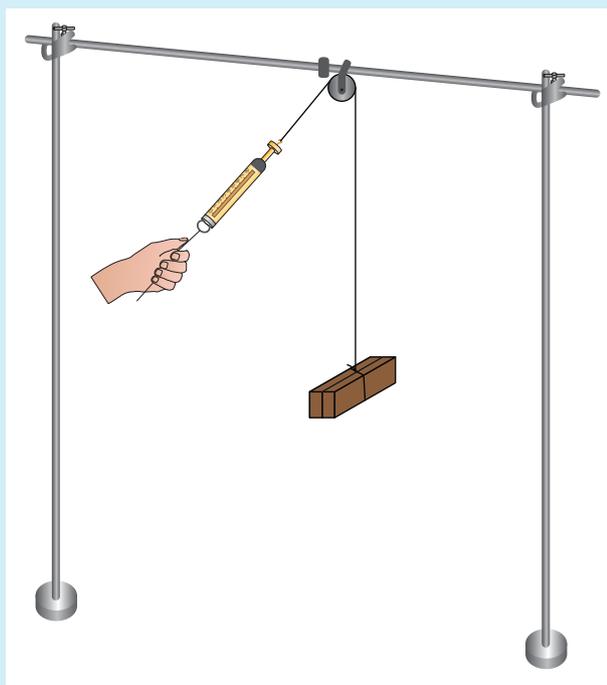


Figure 8.15 Experimental set-up

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 or a steering wheel 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.

turning force
a force that makes an object start or stop rotating



Figure 8.16 In the bathroom, the force of your hand results in the top of the tap rotating.



Figure 8.17 In the workshop, screwdrivers and drills require a force to make them turn.



Figure 8.18 In the kitchen, a food mixer uses turning forces.

What about changing the direction of an object using force? In Figure 8.19, you can see how it is possible for the side cushion of a pool table to exert an impact force that can change the direction of a ball in such a way that its speed stays the same. There are lots of sports where you can see a force change the direction of an object like a ball.

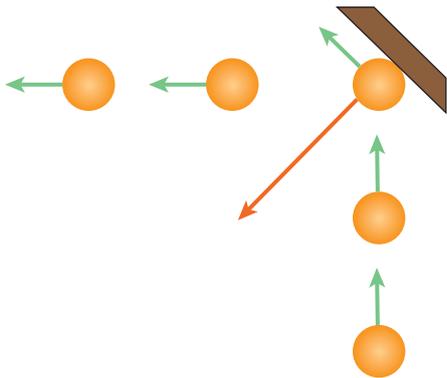


Figure 8.19 When a ball hits a side cushion on a pool table at an angle, the direction of the ball changes after the impact without changing its speed. The red arrow indicates the force of the side on the ball, and the green arrows represent the speed and direction of the ball.

- Quick check 8.3**
- 1 Think of some sports where a force can change the speed of an object or a person.
 - 2 Think of some sports where a force can change the direction of an object or a person.
 - 3 Think of sports where a force can change the rotation (spin) of an object or a person.
 - 4 Is it possible for an object to speed up or change direction without a net force?
 - 5 Are two forces that speed up, slow down, or change the direction of an object 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

mouldable
soft enough to be shaped

new shape. Plasticine and Play-Doh are examples of materials that children enjoy moulding easily. A material that can be moulded easily is called **mouldable**.



Figure 8.20 Dough is moulded by forces into a new shape.



Figure 8.21 Potters use a wheel to spin the clay as they shape it to form a bowl.

brittle
a material that is likely to break or snap when subject to a force

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**, these include glass and pottery which break into pieces if they are subjected to a large enough force.



Figure 8.22 Glass can shatter if a large impact is applied



Figure 8.23 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

elastic
elastic materials bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

force is removed. Elastic materials can also exert a force of their own called an elastic force when their shape is changed.

Figure 8.24 The spring on this park ride will allow the turtle to move around while staying upright.



Practical 8.4**Unbalanced forces****Aim**

To observe the effects of unbalanced forces.

Risk assessment

- Hygiene, spittle. Do not use someone else's straw after it has been used.
- You could use a battery cooling fan for the first part, but not the game.

Materials

- table tennis ball
- drinking straws
- Blu-Tack

Method

- 1 Use the drinking straw to blow the table tennis ball:
 - a when it is moving towards you
 - b when it is moving away from you
 - c when it is moving across in front of you.
- 2 In your results, record your observations of the table tennis ball for each of the situations above.
- 3 Now play a game of blowball. Use the Blu-Tack and straws to set up two sets of goal posts. In groups of four, with two people in each team, see who can score the most goals. Start by one person blowing the ball into the middle of the table. Each time the ball falls off the table, the game must be reset.

Results

Situation	Observations
a	
b	
c	

Evaluation

- 1 Explain how each situation is an example of an unbalanced force in action.
- 2 Are there any forces on the table tennis ball that are in balance? Explain your answer.

Conclusion

From this activity we can claim that unbalanced forces cause _____. This is supported through observing _____. This means that if an object changes _____.

Match each word to its correct description. Add the terms to your glossary in your own words.

Quick check 8.4

Brittle

Can be stretched but always returns to its original shape when the force is removed.

Elastic

Can be made into a new shape.

Mouldable

Breaks into pieces when a force is applied.



QUIZ

Section 8.1 questions

Remembering

- 1 State the name given to two forces that cancel each other'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 Copy and complete the following table with 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 examples of materials that are:
 - a able to be moulded
 - b brittle
 - c elastic.
- 10 Can water exert a force? Explain your answer.
- 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, are you still exerting a force on it if the milk carton is not moving?
- 14 You are sitting on the couch at home after a big day at swimming sports. Sketch yourself and draw arrows to represent the forces acting on you. Are the forces balanced?
- 15 In Figure 8.26, the weight (force of gravity) of the gymnast is balanced by the tension in the ropes. Draw a sketch of the gymnast and include arrows to represent the forces acting on him.

Analysing

- 16 Analyse Figure 8.27 and describe or draw the forces on the cyclist. Assume they are moving at constant speed in a straight line.



Figure 8.25 An Australian Football League game in progress. Kicking the ball is an example of an impact force.



Figure 8.26 A gymnast



Figure 8.27 A cyclist

continued...

...continued

17 You know force is measured in newtons but how could you explain to a friend in a different class how big 30 N is?

Evaluation

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. 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.



8.2 Types of forces: Non-contact

You have already 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 will encounter at school and at home.

Push and pull

In groups, take a few moments to think of as many 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.

Try this 8.3

Non-contact forces are forces that act at a distance, through all states of matter, and outer space. They do not require physical contact for the force to act. Did you have any non-contact forces in your list?

There are three key non-contact forces you will investigate:

- gravity
- magnetic forces
- electrostatic forces.

Gravity

You experience gravity on Earth as the force that pulls you towards the centre of 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 man-made satellites that enable us to communicate and predict the weather in orbit. But can you believe that the force of attraction between you and Earth goes both ways? You also pull Earth towards you, but because Earth is so much bigger, the the effect of your force on the Earth cannot even be noticed.



WORKSHEET



VIDEO

Give examples of non-contact forces.



Figure 8.28 A book falling 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.

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, this force is due to gravity and is called weight. You may also have heard of ‘air resistance’, the force you can feel on your hand when you wave it quickly, but, this force is much smaller than the weight of the book, so

it falls faster and faster (unless you are talking about a book that falls more than a few hundred metres, in this case, the air resistance can be enough to balance the force of gravity).

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.

Drop test

Try this 8.4

- 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?

Force fields

You may not be able to see gravity but it is always there. Earth’s gravity creates a force **field** around it.

- 1 Find a simple definition of ‘force field (science)’. (Make sure it is not the fictional kind of force field in movies and books.)
- 2 Find out and summarise what it means to say that Earth’s gravity creates a force field around it.
- 3 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.

field
a region in space in which an object is affected by a force

Explore! 8.1

Different gravitational pulls

At the beginning of section 8.1, you learned that mass and weight are not the same thing, and on Earth’s surface an object with a mass of 1 kilogram has a

weight of about 9.8 N. Table 8.2 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.

Location	Mass (kilograms)	mass \times gravity = Weight (newtons)
Surface of Earth	1	9.8
Surface of the Sun	1	275
Surface of the Moon	1	1.6
Surface of Mars	1	3.7
Deep Space	1	0
Surface of a neutron star	1	2000000000000

Table 8.2 The table shows how a mass of 1 kg has a different weight at different locations in the universe because of the different strengths of gravity.

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, 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.

Practical 8.5

Mass versus weight

Aim

To investigate the relationship between mass and weight.

Materials

- 10 N spring balance
- 2 sets of slotted 500 g weights
- retort stand, boss head and clamp

Method

- 1 Copy the results table into your book.
- 2 Set up the retort stand, boss head and clamp so the spring balance hangs from the clamp.
- 3 Place a 100 g weight on the spring balance. Record the weight in newtons into your results table. You will need to convert grams to kilograms by dividing the mass in grams by 1000.
- 4 Continue adding 100 g of mass, recording the weight after each addition.

Results

Mass (g)	Mass (kg)	Weight (N)
100		
200		
300		
400		
500		

- 5 Use your results to draw a line graph. Draw a single straight line through the points (this is called a line of best fit and it might not exactly go through all the dots). Extend your line to the edge of the graph. This is called extrapolating the graph.

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Evaluation

- 1 Use the line graph to predict the weight of a 1 kg mass.
- 2 Use the spring balance to measure the weight of the 1 kg mass. How accurate was your graph?

Conclusion

From this activity we can claim that mass and weight are _____. This is supported through the results which indicate _____. This means that if an object has an increased mass, _____.

- 1 Define these key terms: gravity, mass and 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. Is this correct? What would the weight really be, in newtons?
- 4 Use the table showing 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.

Quick check 8.5

Air resistance

The force of gravity on Earth pulls everything downwards. Objects with a greater mass (heavier objects) have a bigger weight and are harder to lift, but do heavier masses fall more quickly than light objects?

If you did not know the answer you would probably guess that they do, if a piece of paper and a golf ball are released from the same height at the same time then you might guess that the golf ball would hit the ground first.

Practical 8.6

Gravity versus air resistance

Aim

To investigate if heavier masses fall quicker than lighter ones.

Materials

- golf ball
- 3 pieces of A4 paper
- stopwatch

Method

- 1 Copy the results table into your book.
- 2 Hold the golf ball at eye level. Drop the golf ball and have your partner time how long it takes to hit the ground. Record your results
- 3 Repeat step 2 with a piece of paper held horizontally.
- 4 Scrunch up a piece of paper into the same size and shape as the golf ball and repeat step 2.
- 5 Roll up a piece of paper into a narrow tube, use a piece of tape to hold it in place. Repeat step 2 with the tube held vertically.

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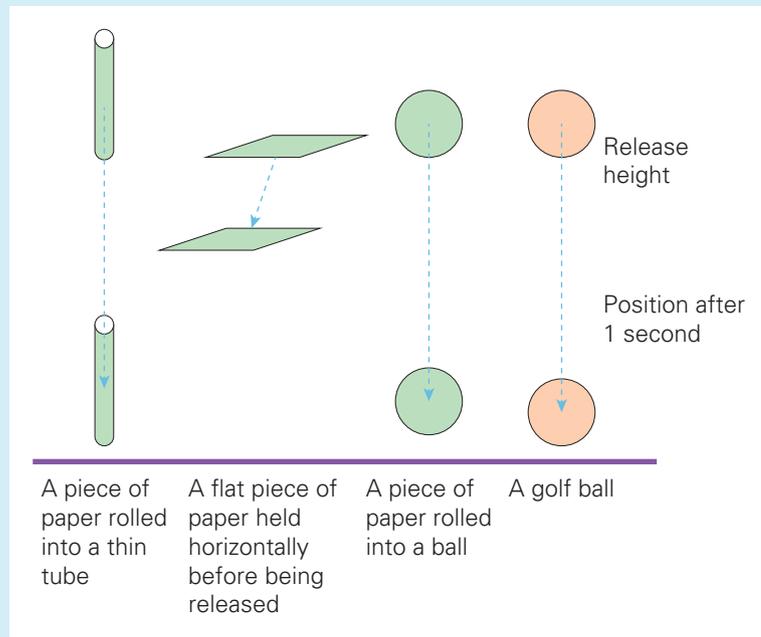


Figure 8.29 An experiment to investigate if heavier masses fall quicker than lighter ones.

Results

	Golf ball	Flat paper	Scrunched paper	Tube of paper
Time to hit ground				

Evaluation

- 1 List the objects from fastest to slowest to hit the ground.
- 2 State what forces are acting on the objects as you drop them.
- 3 Compare and contrast the time it took for the golf ball and the scrunched paper to hit the ground. Can you explain this observation? Think about the fact that aircraft designed to travel fast through the air have smooth surfaces.
- 4 Which piece of paper took the smallest amount of time to hit the ground? Propose a reason as to why. Think about the fact that an object moving through the air has to push air out of the way.

Conclusion

From this activity we can claim that heavier objects _____. This is supported through observing _____. This means that _____.

The experiment 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 tube where a tiny area of the edge of the paper 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 together.

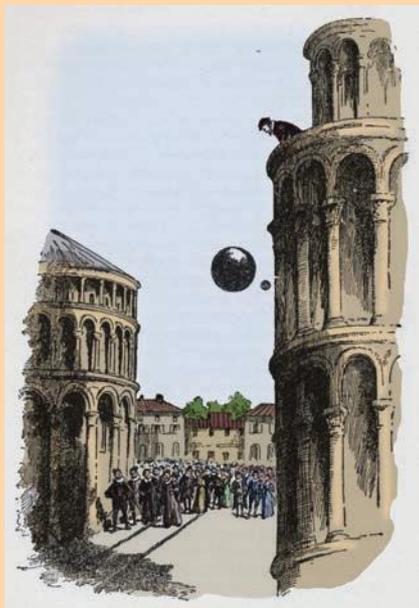


Figure 8.30 Galileo's experiment: dropping two stones of different mass out of a tower to see which landed first.

now been demonstrated many times, most famously on the Moon where David Scott of Apollo 15 performed the experiment on the Moon where there is no atmosphere.

Did you guess how Galileo measured time without a clock? He used his pulse.

Galileo's experiment

Galileo 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, in the absence of air resistance, 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 hit should the ground at the same time. Galileo measured the distance and time for a ball to roll down a ramp, he had a ruler to measure distance, but clocks had not yet been invented, can you guess how he measured time in his experiments?

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 another force, 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

Did you know? 8.1

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 equals your weight,

and so you fall at a constant speed which is relatively slow and safe. The speed at which air resistance equals weight for a falling object is called the terminal velocity.

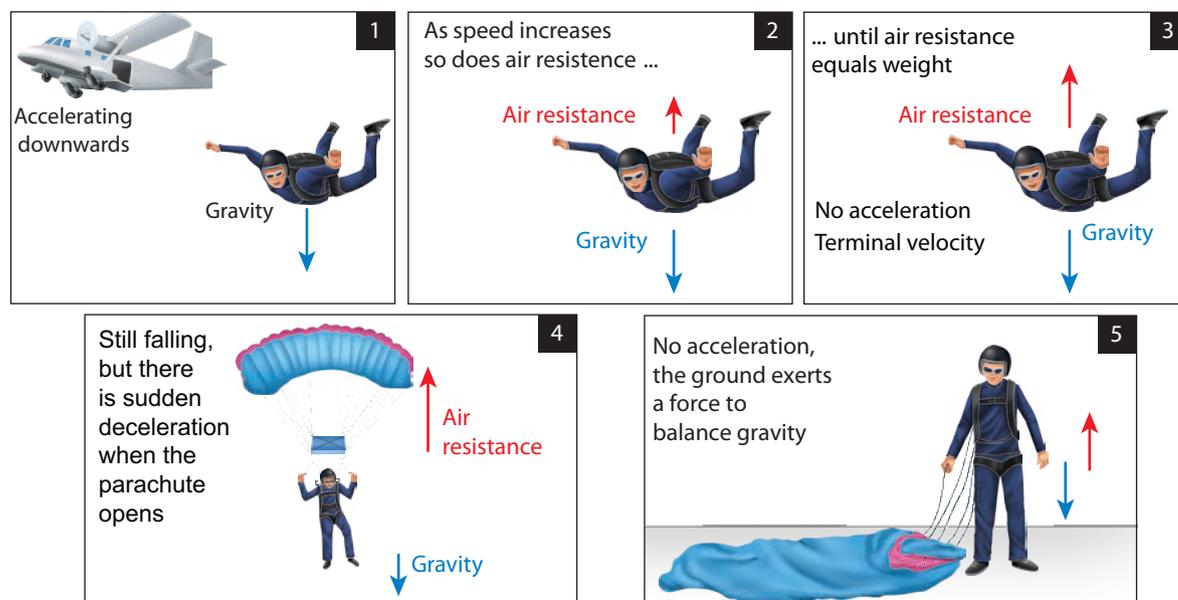


Figure 8.31 The way a parachutist falls depends on the size of the pull of gravity and the air resistance from the parachute.

Practical 8.7: Self-design

Drop time of a parachute

Aim

To investigate what affects the drop time of a parachute.

Materials

- plastic freezer bags
- scissors
- modelling dough
- stopwatch
- cotton or string
- metre ruler

Method

Using the materials provided, design and build a parachute to investigate the effect of one of the following variables on the drop time of a parachute:

- mass of the sky diver
- surface area of the parachute
- shape of the parachute
- length of the connecting string

Results

Draw a suitable table to record your results.

Evaluation

- 1 Write the procedure of the investigation in your book.
- 2 Summarise the results you obtained.
- 3 Provide a possible explanation for your observations.
- 4 List some improvements that could be made to your experiment.

Conclusion

From this activity we can claim that _____. This is supported through observing _____.
The observations mean that if _____.

- 1 Explain the meaning of the terms 'air resistance' and 'terminal velocity' or 'terminal speed'.
- 2 Describe the relationship between the speed an object falls at, the pull of gravity and air resistance.
- 3 Look at Figure 8.32.
 - a What are the names of the two forces acting on the capsule?
 - b Describe how these forces change before and after the parachute is opened.

Quick check 8.6

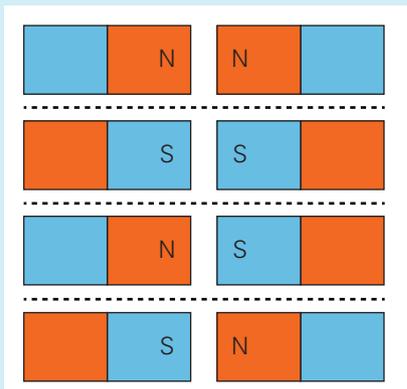


Figure 8.32 When astronauts return to Earth from space, the air resistance of their parachute provides an upwards force equal to the weight of the capsule they are safely enclosed within.

Magnetic forces

- 1 Which of the situations below display interactions between like poles?
- 2 Which situations display interactions between unlike poles?
- 3 What can you conclude about attraction and repulsion forces between magnets and their poles?

Try this 8.5



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.

magnetic force
a non-contact force between a magnet and another magnet or magnetic metal

repel
to force back or apart

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.

You may have found in the 'Try this' activity that north and south poles attract each other, but two like poles **repel**.

Some magnets always retain their ability to be magnetic and so they are called

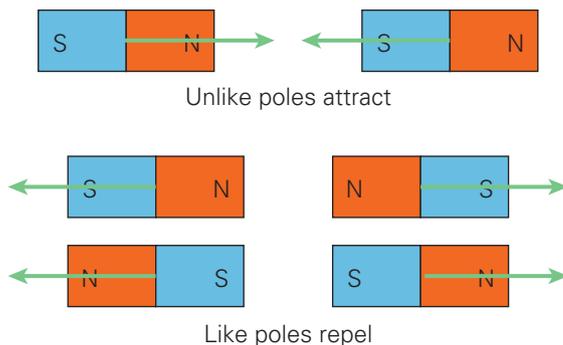


Figure 8.33 Forces between magnets

permanent magnets. An example would be a fridge magnet – they are always magnetic. On the flip side, metals like soft iron become magnets only when they are near a permanent magnet, they have the ability to 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).

alloy
a substance composed of two or more metals

- Collect the following items:
- bar magnet, pencil, pen, paper, plastic straw, coins, paperclips, iron nail, metal spoon, aluminium foil, copper wire.

Try this 8.6

- 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

magnetic field
the space around a magnet where the magnetic force acts



Figure 8.34 Magnetic fields around a magnet form a particular pattern.

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 8.34. You can see the iron filings are strongly attracted to the south pole

of the magnet and amazingly, they are lining up in a certain way. 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 shaped magnets.

Practical 8.8

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**, **2** and **3** with the horseshoe magnet.

Results

Draw a sketch of the pattern formed by the iron filings.

Evaluation

- 1 Can you identify where the magnet's poles are?
- 2 Where does the magnetic field appear to be the strongest?
- 3 Investigate different patterns formed with two or more magnets placed near each other.

Conclusion

From this activity we can claim that magnetic field lines _____. This is supported through observing _____. The observations mean that if _____.

- 1 Why is magnetism considered a non-contact force?
- 2 Complete the following sentence: Opposite poles _____ each other while poles that are the same _____ each other.
- 3 Explain the difference between a permanent and a temporary magnet.
- 4 What is a magnetic field? Draw a picture of the field around a bar magnet and indicate the direction of the magnetic field lines.

Quick check 8.7

A 3D printed magnet?!

It is very difficult for scientists to produce a permanent magnet with a magnetic field of a specific pre-determined shape. Except, in 2016, scientists at Vienna University were able to produce permanent magnets using a 3D printer. This means that the magnets can be produced in complex forms and scientists can customise the shape of the magnetic fields. Due to the cost effective and efficient nature of the process, scientists can now dream about the sorts of things they can do with magnets.

Science as a human endeavour 8.2

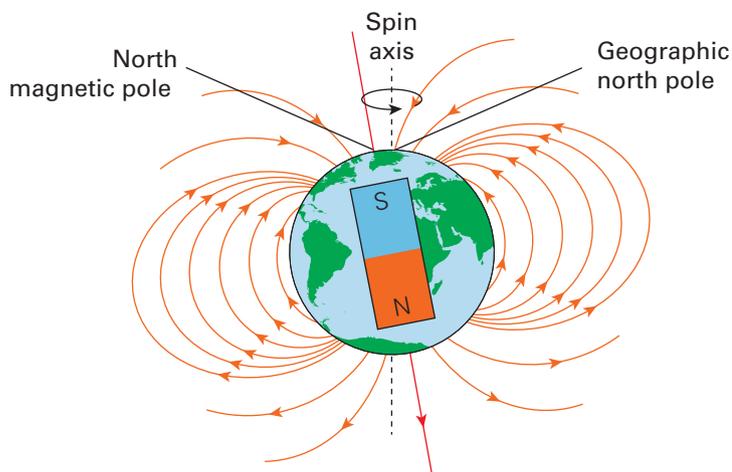


Figure 8.35 The south pole of a magnet resides at the geographic North Magnetic Pole of Earth, which is close to the geographic North Pole. You know this because a compass always points north, and opposites attract, so the north of a compass is attracted to the south pole of a magnet.

Earth is a giant magnet with magnetic poles near the geographic poles. A suspended magnet will turn until its north pole points geographically north, because of its attraction to the south pole of the internal Earth magnet. This is a property of natural magnets or lodestones and has been used by navigators for thousands of years. You should remember though that what is called the North Magnetic Pole by geographers is called the south pole of Earth's magnet by scientists.

Practical 8.9

Making a compass

Aim

To make a functional compass from a steel nail.

Materials

- bucket of water
- steel nail
- a strong magnet
- a piece of cork or polystyrene foam

Method

- 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 around 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 and then place the nail on top.

Results

Record your observations in your book.

Evaluation

- 1 Can an unmagnetized steel nail be turned into a permanent magnet?
- 2 Which end of the nail is the north pole? How did you know this?
- 3 Check the accuracy of the homemade compass with an ordinary compass. How accurate was the homemade compass? Suggest one way in which the accuracy could be improved.

Conclusion

From this activity we can claim that steel nails _____. This is supported through observing _____. The observations mean that if _____.

Sea turtles use Earth's magnetic field to find home

Did you know? 8.2

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 8.36 The sea turtle is guided along the coast by Earth's magnetic field.

Magnetism and electricity are closely related; wires carrying electricity can create a magnetic field around them.

Magnets called **electromagnets** can be made by coiling a wire around a piece of iron. When the battery is connected, the iron becomes a magnet and when the current stops the magnetic force ceases.

electromagnet

a magnet made by passing electricity through a coil of wire



Figure 8.37 How to make a simple electromagnet

Practical 8.10: Teacher demonstration

Making a simple electromagnet

Aim

To make a functioning electromagnet

Materials

- 3 V battery pack consisting of 2 AA batteries
- long nail
- compass
- 2 insulated wires with alligator clips (one short, one long)
- switch
- paperclips

Method

- 1 Copy the results table into your book.
- 2 Use the short wire to connect the powerpack to the switch.
- 3 Carefully wrap the long wire around the nail 10 times, ensuring to only wind in one direction.
- 4 Connect one end of the long wire to the powerpack and the other end to the switch.
- 5 Set the DC power to 6 V and press down the switch.
- 6 Test your electromagnet by seeing how many paperclips it picks up. Record this number in the results table.
- 7 Repeat steps **3–6** increasing the number of coils according to the results table.

Be careful

Make sure you only turn on your electromagnet for a short time. If left on, it will get hot.

continued...

...continued

Results

Number of coils	Number of paperclips
10	
20	
30	
40	
50	

Evaluation

- 1 How did the number of coils affect the strength of the electromagnetic force?
- 2 Does the nail remain magnetic when the power pack is switched off?

Conclusion

From this activity we can claim that the number of coils _____. This is supported through observing _____. The observations mean that if _____.

Uses of magnets

You may not realise 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, EFTPOS 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 object functioning.

Explore! 8.2

- 1 Outline the reasons why they say Earth is like a big magnet.
- 2 Explain how an electromagnet is different to a bar magnet.
- 3 List some examples of electromagnets used every day.
- 4 What are the advantages of an electromagnet over a permanent magnet?

Quick check 8.8**Electrostatic forces**

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?

Try this 8.7

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. It can be used to pick up pieces of paper with a balloon after rubbing it on your hair or clothes.

electrostatic force
a non-contact force between positive and negative charges, opposite charges attract, like charges repel

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.

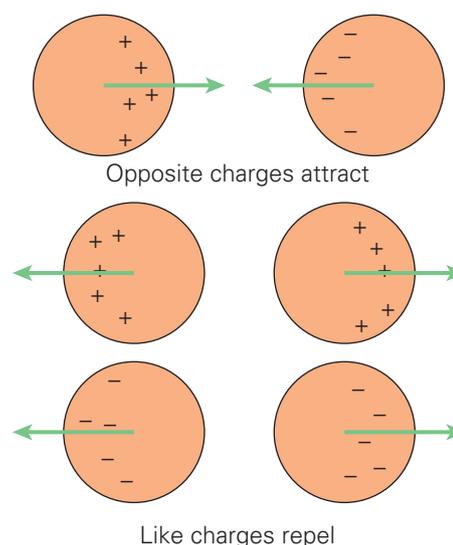


Figure 8.38 Forces between charges

Like gravity and magnetism, objects with an electric charge also create a force field around them. The electrostatic force field is the region where a charged particle will feel the electrostatic force.

Look at Figure 8.39. The machine the girl is touching is called a Van de Graaff generator, and essentially it separates positive and negative charges. The negative charges are the ones that move. They are sent down to the ground and released. Meanwhile, the positive charges 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

static electricity

a build-up of electric charge

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 on to you, if they do not leak away they can jump to the door handle and this is the shock you feel.



Figure 8.39 Electrostatic forces can make your hair stand on end.

Practical 8.11

Investigating static electricity

Aim

To observe the effects of static electricity.

Materials

- 2 balloons
- a metre ruler
- string
- woollen cloth

Method

- 1 Rub the inflated balloon with the woollen cloth and place it against a wall. Record your observations in your book.
- 2 Suspend the balloon from the metre ruler using the string.

continued...

...continued

- 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.

Results

Record your observations.

Evaluation

- 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 this?

Conclusion

From this activity we can claim that charged objects _____. This is supported through observing _____. The observations mean that if _____.

- 1 Define the key terms 'electrostatic force' and 'static electricity'.
- 2 Complete the following sentence: Opposite charges _____ and like charges _____.
- 3 Explain how a Van de Graaff generator works.
- 4 Why do you sometimes get a small electric shock even though you have not touched a supply of electricity?

Quick check 8.9



QUIZ

Section 8.2 questions

Remembering

- 1 List which forces are acting on a dropped book that falls to the floor.
- 2 Name the force which a magnet exerts.
- 3 List some objects which use 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 Does the mass of an object change as it moves around the universe?
- 9 If you travelled to the Moon, would your weight increase, decrease or stay the same?
- 10 What is your weight in deep space?
- 11 State which ball will hit the ground first: a wood 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. What magnetic pole must be near the North Pole?
- 13 Which types of forces have a force field?

Applying

- 14 Calculate the weight of a 5 kg cat on Earth ($g = 9.8 \text{ N/kg}$) and on Mars ($g = 3.7 \text{ N/kg}$)

continued...

...continued

- 15 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 How are charged objects and magnets similar?

Analysing

- 20 Would a hammer and a feather hit the ground together if dropped from the same height at the same time on the planet Mercury where there is no atmosphere? Give reasons for your answer.
- 21 Examine how a compass works. Why is it useful?
- 22 Parachutes have large pieces of material. Explain what the purpose of it 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.



8.3 Types of forces: Contact

Contact forces are pushes, pulls and rotations which require the objects to be in contact with each other. You have already learned about gravity, a non-contact force, which is one of the forces that is a part of everyday life. There is a contact force that is also part of everyday life: 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 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 to see the football

better on the television. Friction always acts in the opposite direction of relative motion and so tries to slow down 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 go around corners. On the positive side playground slides would be really fast and a roundabout, once started, would carry on spinning forever.



WORKSHEET



VIDEO
Give examples of contact forces.

Practical 8.12: Self-design**Investigating friction****Aim**

To investigate the force of friction on rough and smooth surfaces.

Materials

- large block of wood with hook attached
- spring balance
- a variety of different surfaces (see the Methods for ideas)

Method

- 1 Use a spring balance to pull a large block of wood across your desk top. Ensure that you pull the block with a constant speed. The force on the spring balance will be equal to the force of friction. Record this reading in your results table.
- 2 Repeat the measurement two more times to get a more accurate result. Try to make sure that you pull the block at the same constant speed each time. You could do this by dragging it the same distance in the same time. Take the average of your three trials.
- 3 Repeat step 1 on four different surfaces. You may wish to test surfaces such as vinyl floor, carpet, concrete, sandpaper, grass or bitumen.

Results

Surface	Friction force			
	Trial 1	Trial 2	Trial 3	Average
Desk top				

Display your results in a bar graph.

Evaluation

- 1 Why was it necessary to measure the friction of each surface three times and take an average?
- 2 List your surfaces in order of lowest to greatest friction force.
- 3 Explain why some surfaces create more friction than others.
- 4 Design and carry out an experiment that investigates what happens to the force of friction if the mass of the block is increased. You may like to carry out the same experiment as above but with a heavier block. Record your results in a table and generate a bar graph.

Conclusion

From this activity we can claim that friction depends on _____. This is supported through observing _____. This means that _____.

Friction between surfaces

As you would have found 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.

So, 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 create heat. 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, heat is not always welcome because it can represent wasted energy or be dangerous.

Minimising friction between surfaces

One way to reduce friction forces 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 and thus generate less heat. In the following image, clean oil is put into an engine to lower the friction between the moving parts. If the oil in the car is not working the

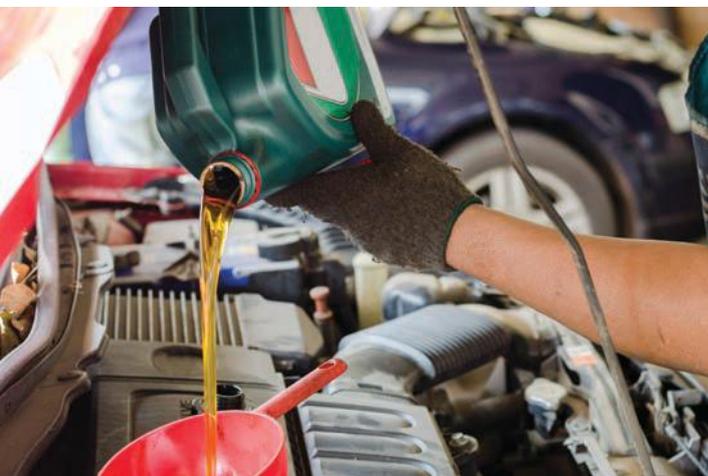


Figure 8.40 Petrol engines need oil to lower the friction inside.

extra frictional forces will destroy the engine as the metal parts heat up and expand.

Another way friction can be reduced, especially when moving heavy loads from one place to another, is to use the wheel and axle. This is one of the earliest and widely used inventions that has ever been made.



Figure 8.41 The wheel and axle allows objects to be moved over a surface with very little friction.

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 being 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, and being long and thin they also tend to run straight where wheels would slide sideways.

Wheels do not work well if the ground is very rough, so trains need tracks and cars work best on roads. Wheels don't 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.



Figure 8.42 Seaplanes use floats to land on water instead of wheels.



Figure 8.43 The friction force on an arrow as it flies through the air is small.

are often treated together as fluid friction.

streamlined
designed to minimise air resistance or drag

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.

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.

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 three trains in the images below; as trains have become faster their design has become more streamlined.

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?

Try this 8.8

Friction in gases and liquids

In this course, 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

Figure 8.44 Trains have become more streamlined as their speed has increased.





Figure 8.45 Metal springs come in many different sizes and strengths.

Elastic and 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 and this is called a spring or **elastic** force.

elastic

elastic materials bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

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.

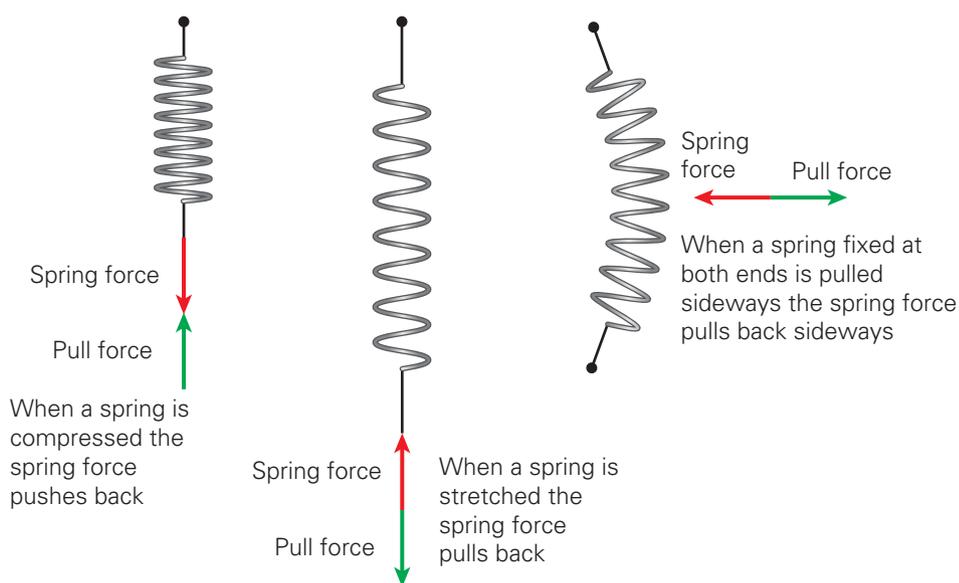


Figure 8.46 Three ways to apply a force to a spring

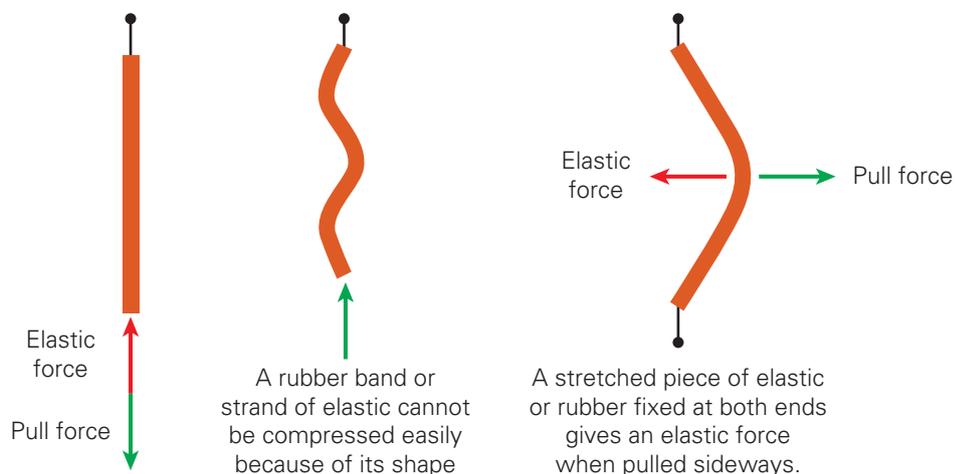


Figure 8.47 Two ways to apply a force to a rubber band

Quick check 8.10

- 1 Explain what friction is and how it works.
- 2 Outline two features of a car that are designed to minimise friction.
- 3 Outline two features of a car that are designed to maximise friction.
- 4 Define the key terms 'air resistance', 'drag' and 'streamlined'.
- 5 Why is a shark's body streamlined, whereas a koala's is not?

Practical 8.13**Stretching springs****Aim**

To investigate the relationship between force and extension for a spring.

Materials

- spring
- retort stand, bosshead and clamp
- set of 500 g 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 Use a ruler placed next to the weight holder to record its initial position.
- 3 Add 100 g masses to the weight holder up until 500 g of slotted weights is reached. Each time a new mass is added, record the new position of the bottom of the weight holder (see the Results table).

Results

Mass (g)	Weight added (N) $g = 10 \text{ N/kg}$	Extension (m)
0 (holder only)	0	0
100	1	
200		
300		
400		
500		

Evaluation

- 1 Draw a graph of force (weight) on the vertical versus extension on the horizontal. Remember to convert grams to kilograms before calculating the weight.
- 2 What trends can you identify 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 _____. The observations mean that _____.

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 have adapted to bend in the wind. If they become rotten and unable to bend they will break in a storm. Elastic forces are used by divers on a springboard to gain extra height when they dive.



Figure 8.48 The diver makes use of the elastic forces in a springboard.

The force exerted by a bow on an arrow is another perfect 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.



Figure 8.49 An archer uses elastic forces in a bow to fire an arrow.

- Quick check 8.11**
- 1 What is a spring force?
 - 2 What is an elastic force, and how does it compare to a spring force? Add the terms to your glossary.
 - 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 placed on or beneath the surface of a liquid. If an object 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 its weight (when it will rise) or equal to its weight (when it will float at a constant height).



Figure 8.50 Buoyancy forces allow heavy container vessels to float.



Figure 8.51 The lemon floats and bubbles of gas rise to the surface due to buoyancy forces.

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 a rubber ball.

Try this 8.9

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?

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 8.52, the buoyancy force (blue) is approximately equal to the force of gravity (orange).

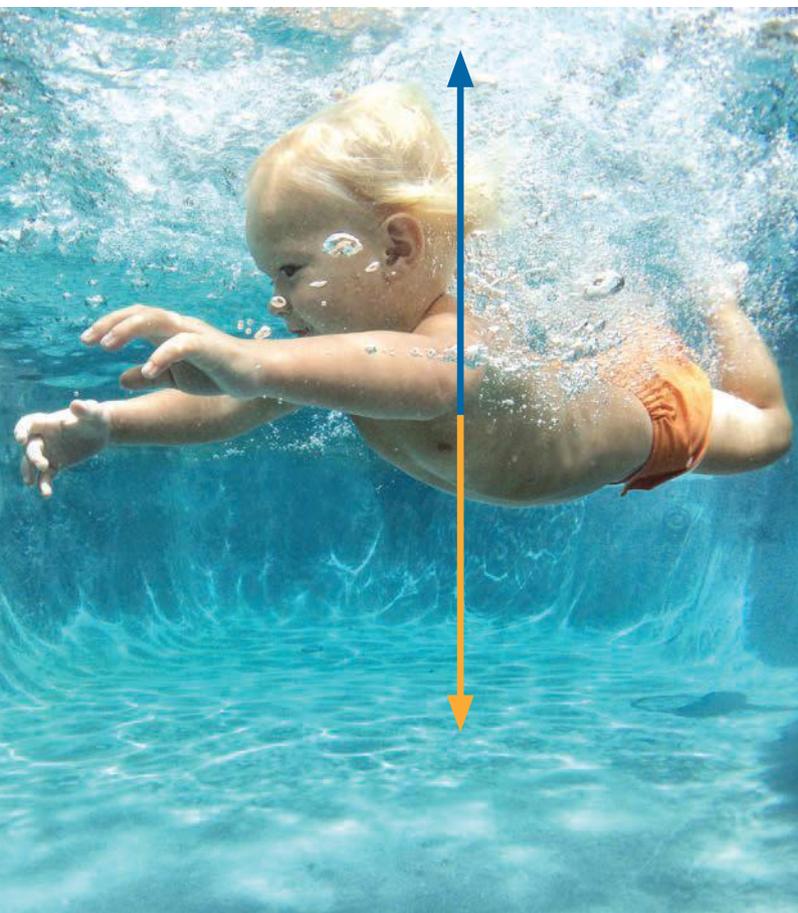


Figure 8.52 The buoyancy force on the baby is approximately equal to the baby's weight.

Buoyancy forces are everywhere!! Did you know? 8.3

Hot magma inside Earth is lighter than cooler magma and buoyancy forces cause giant bubbles of hot magma to move towards Earth's surface.

These create volcanos 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

applied force
force that is applied to an object by another object or person

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? Keep in mind that impact forces can be useful as well as dangerous. A pressure cleaner emits a jet of water at a high speed, when the water hits its target its speed changes quickly causing the water to exert a force on the ground that can be used to clean a surface.

In car accidents, impact forces can cause serious injuries, but these can be reduced by using seat belts, crumple zones and air bags. All of these are designed by people that understand forces. They spread the impact over a larger area and time, so it is less dangerous.

Bike helmets

Australia and particularly the state of Victoria 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, and to spread the force over a larger area and longer time via the thick foam to lessen the effect of the force on the head. Similarly, occupants of cars wear a seatbelt to absorb the forces 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 and so injuries can be prevented if these forces can be lessened by spreading them over a larger area and longer time so the body is protected.

A major study presented in 2016 looked at bike helmet use around the world. Based on more than 64000 cyclists, the study found helmets reduce the risks of a serious head injury by nearly 70%, 51% for head injury, 33% for face injury and 65% for fatal head injury. So, regardless of whether they are compulsory, wearing head protection is highly recommended!

Science as a human endeavour 8.3



Figure 8.53 Luke Bell of Australia wearing a helmet that protects his head and which is designed also to minimise air friction.

- 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 Outline why Victorians are required to wear seat belts in cars and bike helmets when riding, in the context of impact forces.

Quick check 8.12

Section 8.3 questions

Remembering

- 1 Give the names of five main types of contact force.
- 2 Which contact force can be easily used to warm up a small object or surface?
- 3 What is 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. Give 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.

continued...



QUIZ

...continued

Applying

- 6 To carry drinking water in a small backpack when you are going running, would you choose a glass or a plastic bottle? Explain why.
- 7 Compare the two cars in Figure 8.54 and decide which one is designed to go faster. Explain your answer.



Figure 8.54 Which car will go faster?

Analysing

- 8 The foot in Figure 8.55 belongs to a swan. Use your knowledge of forces to analyse the structure of the foot and explain how it is adapted to be used in water.



Figure 8.55 The foot of a swan

Evaluating

- 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 recommend how you would use or modify each material to cope with earthquakes. Give your reasons and examples.
- Brittle
 - Elastic
 - Bendable

Review questions

Remembering

- 1 Define the term 'force'.
- 2 State the units for mass and weight.
- 3 List five contact forces.
- 4 List three non-contact forces.
- 5 Define the term 'net force'.
- 6 What word is used to describe two forces that are equal in size and act in opposite directions?
- 7 Can an object change direction without a force?



Understanding

- 8 Does an object always move when a force acts on it?
- 9 Can an object at rest start spinning without a force?
- 10 Describe what happens if the forces on an object are unbalanced.
- 11 There are many forces between the parts of Sydney Harbour Bridge. Are all the forces between the parts balanced or unbalanced? Explain your answer.



Figure 8.56 The Sydney Harbour Bridge

- 12 Identify the pair of equal and opposite forces on each of the Moroccan tree-climbing goats in Figure 8.57.



Figure 8.57 Moroccan tree-climbing goats only climb argan trees.

- 13 If an object is travelling horizontally in a straight line at a constant speed, does it need a force to keep moving? Explain your answer.

Applying

- 14 Figure 8.58 shows a scientist inspecting seagrass in Queensland. Around his waist he is wearing a heavy belt made of metal. Apply your knowledge of forces to explain the function of this belt.



Figure 8.58 Diver wearing a weight belt

- 15 Metal recycling takes place in most cities, aluminium, copper and steel are the most 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. Identify a way that could be used to easily carry out the second step.

Analysing

- 16 On snow and ice, wheels with tyres are often replaced by skis and tracks on vehicles. Examine and contrast the skis and the tyre below and describe how their shape and friction forces relate to their use.



Figure 8.59 Skis versus tyres

Evaluating

- 17 Use your answer to the question on the previous page and knowledge of forces to explain how a snowmobile works and justify why it is preferred for snow compared to a normal motorcycle.

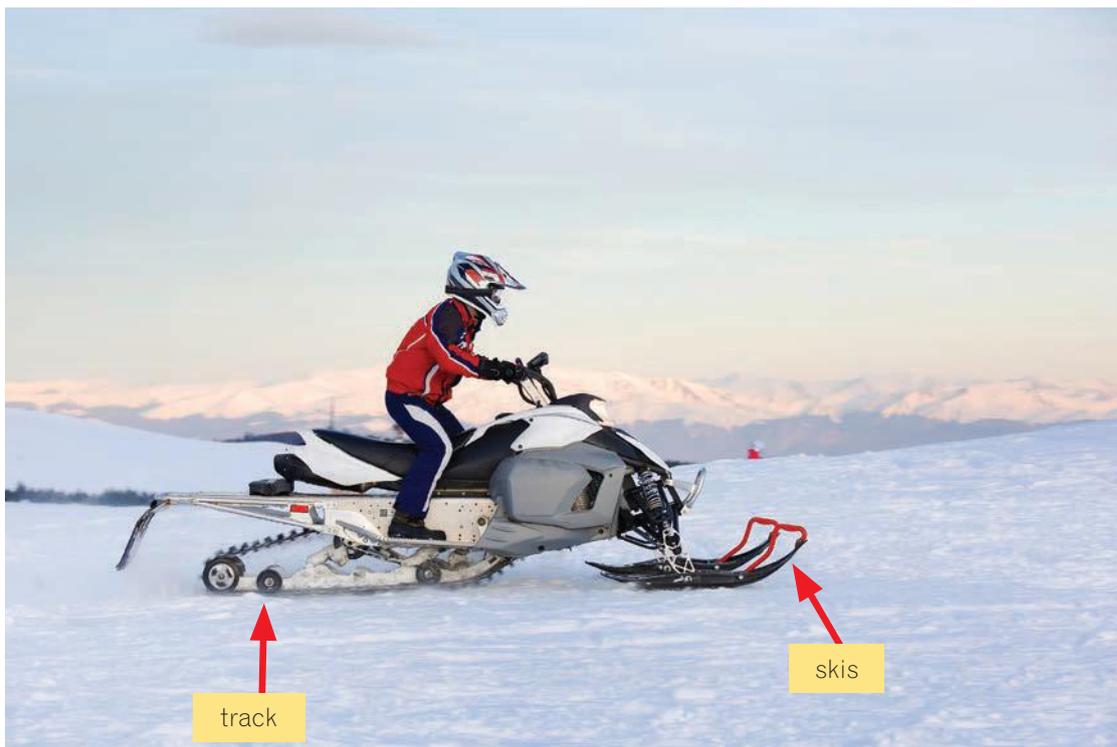


Figure 8.60 Snowmobiles use skis and a track instead of wheels.

STEM activity: Designing and prototyping a ferry

Background information

Ferries are used worldwide to connect two or more points (e.g. Manly Ferry, the *Spirit of Tasmania*). 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. From Practical 4.4 in Chapter 4, you know that 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!

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.

VCSSU133

VCSSU103

VCDSTC048

VCDSCD049

VCDSCD051

VCSIS113

VCSIS082



Figure 8.61 Ferries are part of the public transport system in many places in the world.

Part 1: Investigate the science and technology of boats

Materials

- Plasticine or clay or mouldable modelling material that is denser than water and has some water-resistance; that is, it will not dissolve quickly or fall apart in water
- tank, bucket or bowl of water
- measuring cylinder of the type used in Practical 4.4

Method

- 1 Roll the modelling clay into a ball without any air inside, place in the tank of water and confirm that it sinks in water.

- 2 Using the equation, complete the statement below.

$$\text{Density of the modelling clay} = \frac{\text{mass}}{\text{volume}}$$

Density of water = 1 gram per millilitre

If the modelling clay sinks, then the density of the modelling clay must be _____ than 1 gram per millilitre.

- 3 Take the same piece of modelling clay and mould it into a flat sheet, then form it into a little open boat, with a shape like a cup or an oval bowl. Make the sheet thin enough and the cup deep enough so you can get your modelling clay boat to float on water.
- 4 When you can get the modelling clay to float, think about what has changed. Has the mass, volume or density of the modelling clay changed? Does the 'volume (or density) of the boat' have any meaning, and is its value greater or smaller than the volume and density of the modelling clay itself?
- 5 Think of the displacement method you used to measure the volume of irregular objects in Practical 4.4. When submerged, objects displaced water and the level of water in the measuring cylinder went up. Design an experiment to find out if the level of water in a container goes up when you float your modelling clay boat in it. Find out if the level of water goes up with bigger and heavier plasticine boats. If possible, note where the water level comes up to on the boat, add some small weights to it and see if the water level on the boat changes.
- 6 What can you conclude about the amount of water displaced and the weight of your boat and any load in it?
- 7 What can you conclude about the upwards buoyancy force of the water on your boat and the amount of water it displaces?

Part 2: Investigate the stability of different shapes of boats

Using cardboard, make some simple small cardboard boats with different shapes and proportions; for example, with flat bottoms like a

box, with round bottoms like half a cylinder, or with v-shaped cross-sections. Test them to see which is more stable when you make waves in the water. Does adding small weights in any part of the boat make them more or less stable?

Part 3

Using the knowledge gained in parts 1 and 2, list the characteristics and features that are important for a boat, then draw a design and prototype using cardboard and a number of different materials that will be provided by your teacher. Finally, test your prototype(s) by placing a 100 g object inside your boat, placing it in the water and allowing it to move from point A to point B and back.

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)

Evaluate and modify

- 1 Discuss with at least three of your colleagues, the challenges you have encountered throughout this project. List the strategies or actions that allowed you to overcome it.
- 2 Reflection is an integral and vital aspect of any project in the real world. Create a list of improvements to your design that could be applied to this project to improve or refine its performance.

If you have failed this task do not worry, keep trying! Discuss with your team mates if it would be possible to redesign the payload (for example, breaking it into smaller bits) to suit your unsuccessful design. Discuss how cost effective such changes would be.

- 3 Your design was successful and you managed to move your payload successfully across the river. Now, test your design with two, three, four and five payloads at once.

Chapter 9 Simple machines

Chapter introduction

In the previous chapter, you learned about how forces affect the world around us. Forces are necessary to carry out basically 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.

Curriculum

Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)

- investigating a simple machine such as a lever or a pulley system

9.1, 9.2

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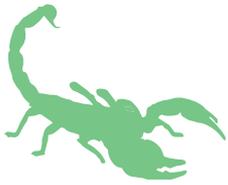


Glossary terms

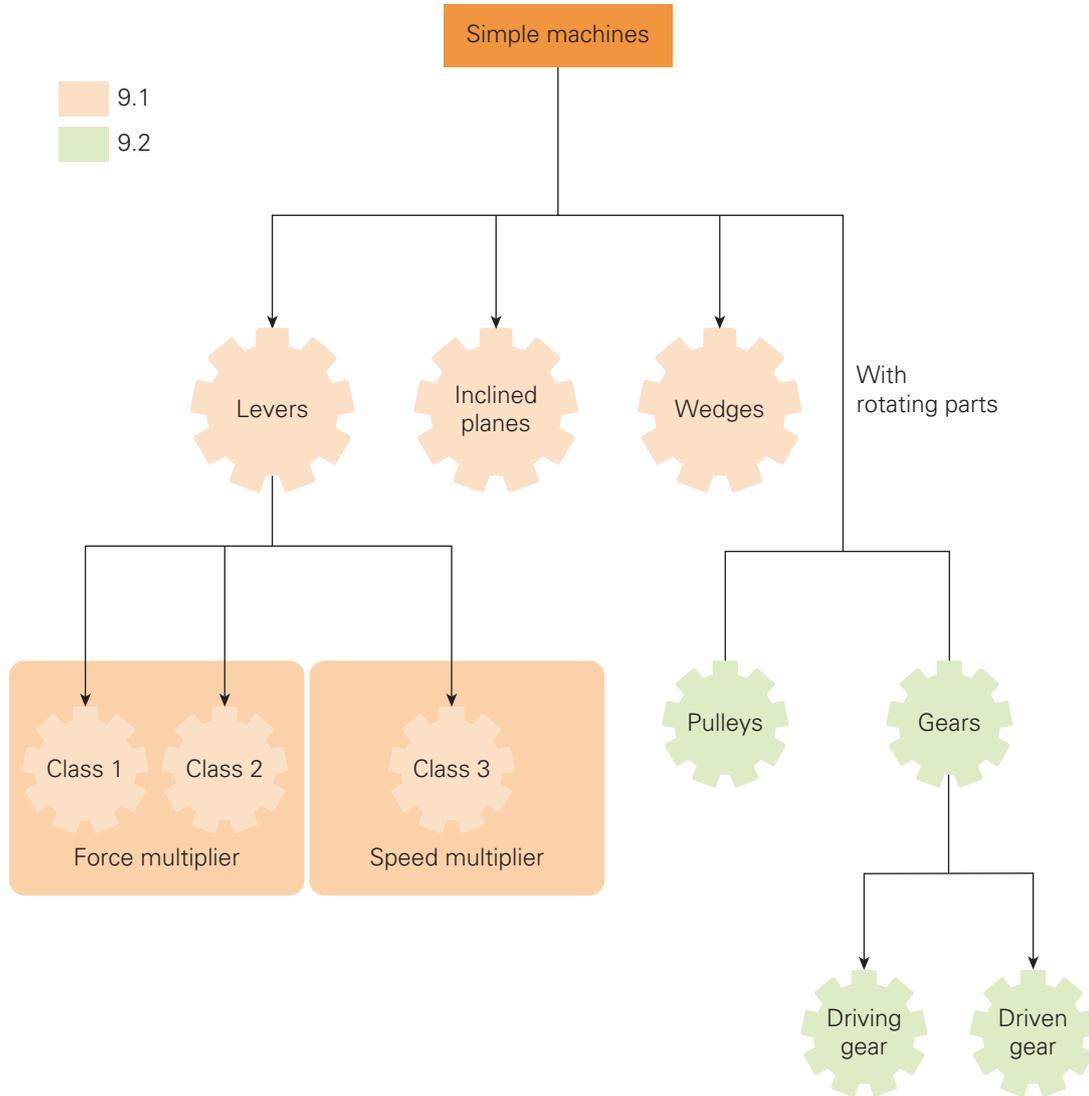
class 1 lever
class 2 lever
class 3 lever
cog
driven gear
driving gear

effort
force multiplier
fulcrum
gear
lever
load

load force
mechanical advantage
pulley
ramp
simple machine
speed multiplier



Concept map





9.1

Investigating simple machines

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 work generally 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 needed to

simple machine

a basic mechanical device for applying a force and changing either its size or direction

lever

a 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

apply to the machine is called the **effort** and the object being moved is called the **load**. The **load force** is the amount of force required to move the load, which the machine applies.

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 then 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!

The effort required to move a given load is given by this formula:

$$\text{effort} = \frac{\text{load force}}{\text{mechanical advantage}}$$

For example, if the load force is 120 N and the mechanical advantage of the machine is 4, then the effort required is:

$$\begin{aligned} \text{effort} &= \frac{120 \text{ N}}{4} \\ &= 30 \text{ N} \end{aligned}$$

Levers

Can you define what a lever is and can you name some common levers? Read on to find the answer to this question.

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.



Figure 9.1 A garlic press is an example of a lever.



WORKSHEET



VIDEO

Name and classify the simple machines you see.

Find a tin of Milo or hot chocolate and try **Try this 9.1** 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?

class 1
a lever in which the fulcrum is between the load and effort

class 2
a lever in which the fulcrum is at one end and the load is between the fulcrum and the effort

class 3
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

A lever consists of a rigid arm, which may be bent or straight, 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**.
- 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 9.2, levers can be used to move objects that would otherwise be impossible to do with our bare hands!

Figure 9.2 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.



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 larger than your load moves.

A diagram of a class 1 lever is in Figure 9.3. Note that the blue and red arrows in the diagrams that follow show 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, you are not using the arrows to show the weight of the load (which would be opposite to the load force), nor to show speed or distance moved.

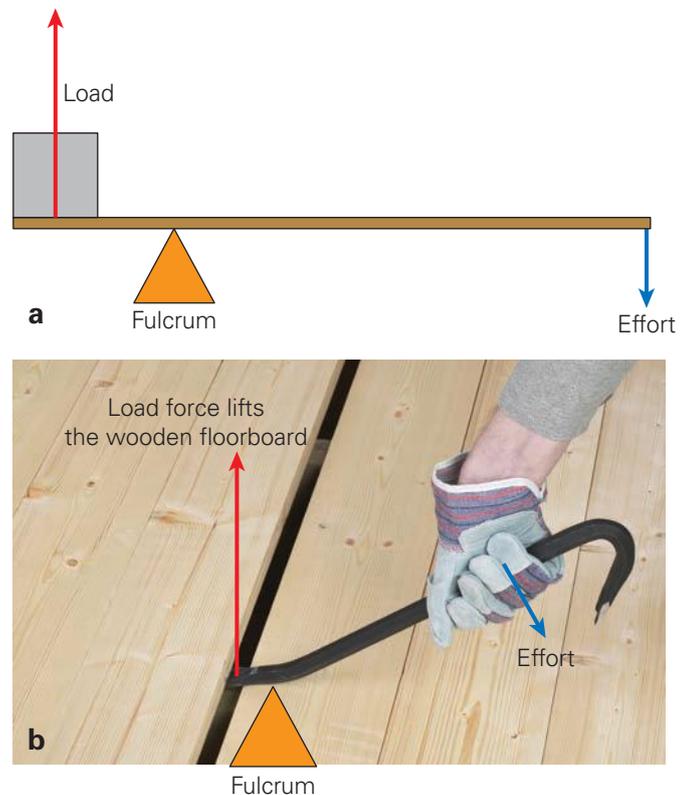


Figure 9.3 (a) A class 1 lever: the fulcrum is between the load and the effort. **(b)** A class 1 lever being used to lift a wooden floor. The effort force is shown in blue. In this case, the load force in red is used to lift the wooden floor. The lever would need to be pushed down quite far to lift the wood a small amount.

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.

A diagram of a class 2 lever is shown in Figure 9.4.

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.

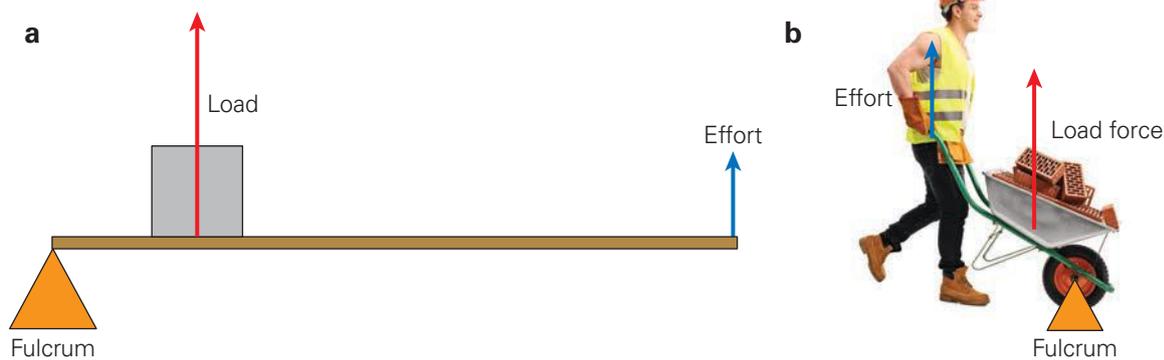


Figure 9.4 (a) A class 2 lever. The fulcrum is at one end and the load is between the fulcrum and the effort. **(b)** A wheelbarrow is an example of a class 2 lever. The workman does not have to apply as much effort force to lift the load. Without this simple machine, it would be nearly impossible to lift that amount of bricks!

Practical 9.1

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

- metre ruler
- rubber stopper
- 200 g mass

Method

- 1 Place the rubber stopper under the metre ruler at the 20 cm mark. The rubber stopper is acting as a fulcrum.
- 2 Place the 200 g mass on top of the ruler at the 0 cm mark.
- 3 Using your hand, push down on the other end of the ruler to lift the 200 g mass.
- 4 In your results table, draw a simple diagram of the setup, labelled with positions of fulcrum, effort and load, and distance between effort and fulcrum. Record how easy or hard it was to lift the mass and approximately the distance moved by the effort.
- 5 Move the rubber stopper to the 40, 60 and 80 cm mark, repeating steps 3 and 4.

Results

Position of stopper (fulcrum)	Diagram of set-up, with measurement detail	Description of effort required to lift the load	Approximate distance moved by the effort
20 cm			
40 cm			
60 cm			
80 cm			

continued...

...continued

Evaluation

- 1 State which class of lever was used in this experiment.
- 2 Explain how the effort force changed as the distance between the fulcrum and effort changed.
- 3 As the distance between the fulcrum and effort changed, was there any change in the distance you had to push down on the lever?

Conclusion

From this activity we can claim that the distance between the effort force and fulcrum _____. This is supported through observations that _____. This means that _____.

Class 3 levers

Class 3 levers are different to class 1 and 2 levers. The effort force 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 are force multipliers. They 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. 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!

speed multiplier
something that increases the speed of an object

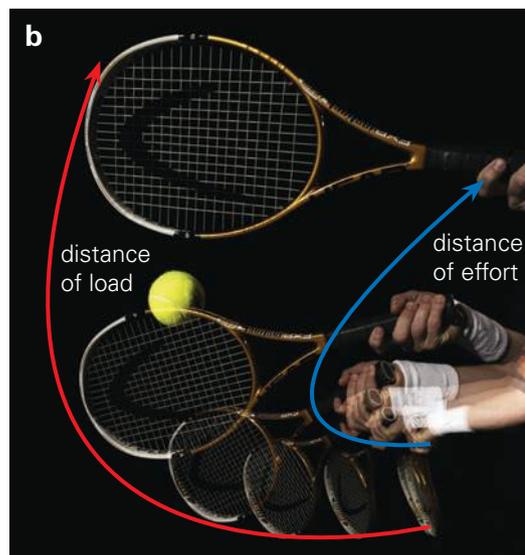
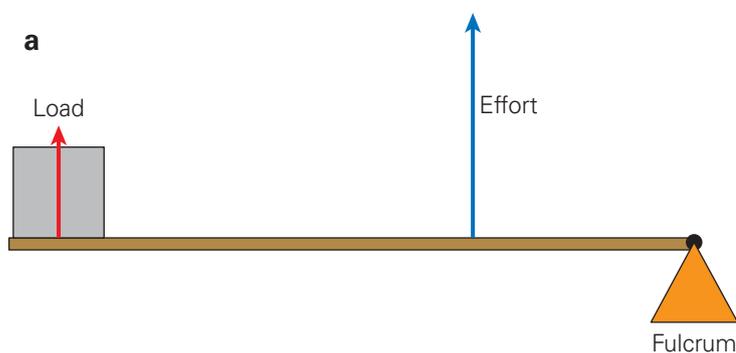


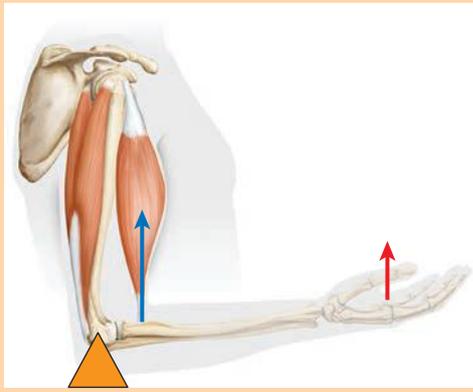
Figure 9.5 (a) In a class 3 lever the fulcrum is at one end and the effort force is between the load and the fulcrum. **(b)** In a tennis racquet, the wrist acts as the fulcrum and the effort is applied by the hand to the handle. The load is in the middle of the racquet head. The head of the racquet moves a larger distance than the hand, multiplying its speed (note that the blue and red arrows are force arrows, not speed or distance arrows).

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.

Try this 9.2

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 things that can be identified in nature as levers are birds' beaks and crabs' claws.

Did you know? 9.1



Fulcrum

Figure 9.6 The arm is a class 3 lever.

Extension

The mechanical advantage is related to the distances of the load and effort forces 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 $\text{mechanical advantage} = \frac{\text{load force}}{\text{effort}}$,

which gives us:

$$\begin{aligned} \text{mechanical advantage} &= \frac{\text{load force}}{\text{effort}} \\ &= \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}} \end{aligned}$$

Notice that load force is divided by effort in the case of forces, but it is the other way around in the case of the distance to the fulcrum.

Figure 9.8 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.

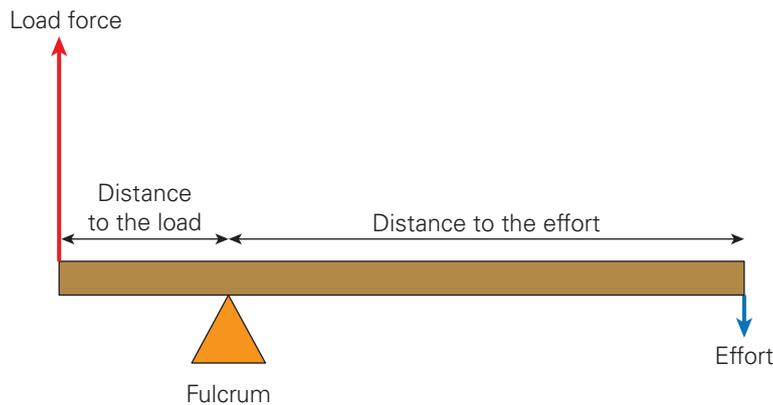


Figure 9.7 How to measure the distances to the fulcrum

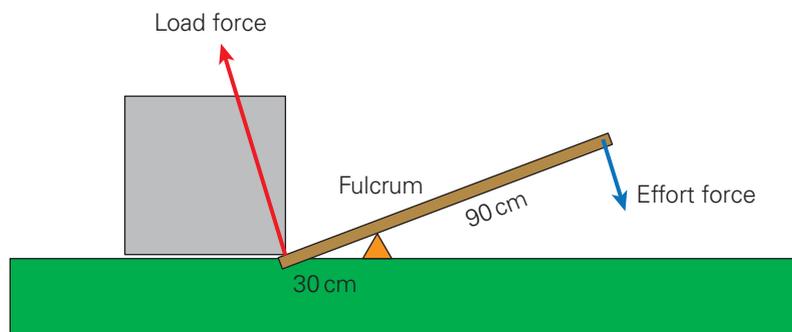


Figure 9.8 This short lever has a mechanical advantage of 3 (90/30).

Figure 9.9 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.

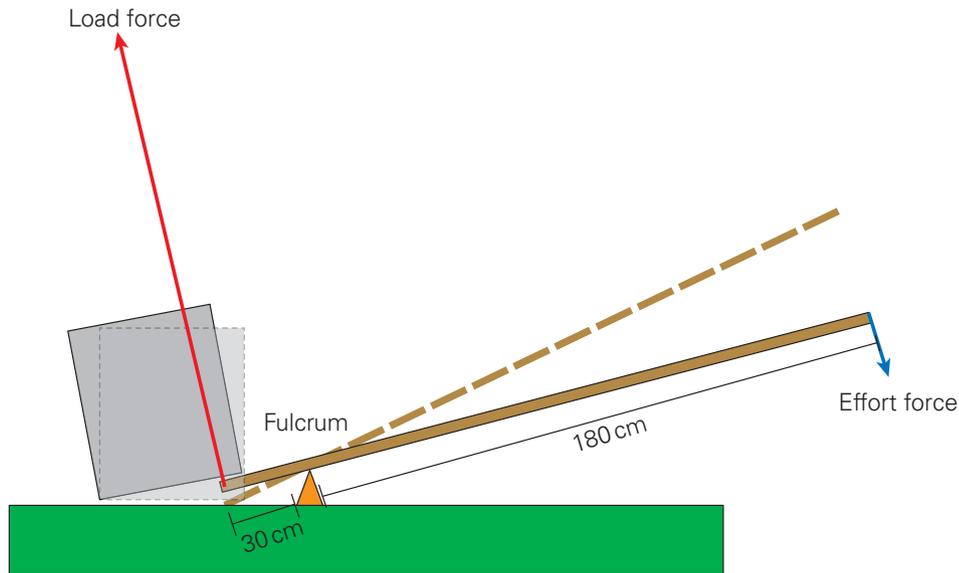


Figure 9.9 If the distance between the effort and the fulcrum is increased to 180 cm using a longer lever, the mechanical advantage increases to 6 ($180/30$). Notice that, as shown by the dotted line, the effort force moves through a much greater distance than the load force.

Levers making life easier

You may not have realised it, but every time you eat a bowl of ice cream, you are using a third-class lever. That's right! A spoon is a type of lever even though you do not use it for its lever-related property of multiplying speed. Using our understanding of forces and simple machines, we are now able to create modified eating utensils that may help people who have trouble using cutlery.

Parkinson's disease is a disorder of the nervous system, where the parts of the brain that control muscles are damaged. People with Parkinson's disease have trouble making smooth movements with their arms and legs. This results in a characteristic shake or tremor and makes it hard for sufferers to control and coordinate their movement. Simple things that we take for granted, such as feeding ourselves, can become very hard for people affected by Parkinson's disease.

A company called Verily offers Liftware, a selection of stabilising and leveling handles and attachments designed to help people with hand tremor or limited hand and arm mobility retain dignity, confidence and independence.

Liftware Steady is designed to help people with hand tremor, which may be related to Parkinson's disease or essential tremor, eat more easily. The stabilising handle contains motion sensors that detect hand motion, and a small onboard computer that distinguishes unwanted hand tremor from the intended movement of the hand. To counteract hand tremor and stabilise the utensil, the onboard computer directs two motors in the handle to move the utensil attachment in the opposite direction of any detected tremor.

Liftware Level controls the angle of a utensil, such as a spoon, for people with unintended muscular movements that make it difficult to enjoy a meal. The Level handle contains sensors that detect hand motion, and a small onboard computer that distinguishes motions that would tip or tilt the utensil too much. To counteract any unintended motion, the onboard computer directs two motors in the handle to keep the utensil at the optimal angle for eating.



Figure 9.10 Special motion sensors and levers in this cutlery help those who have limited movement.

Science as a human endeavour 9.1

- 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, how much effort would be required to lift the load?

Quick check 9.1

$$\left(\text{effort} = \frac{\text{load force}}{\text{mechanical advantage}} \right)$$

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 can't go up inclines of more than about 20° so mountain roads on land that rises at a greater angle are designed

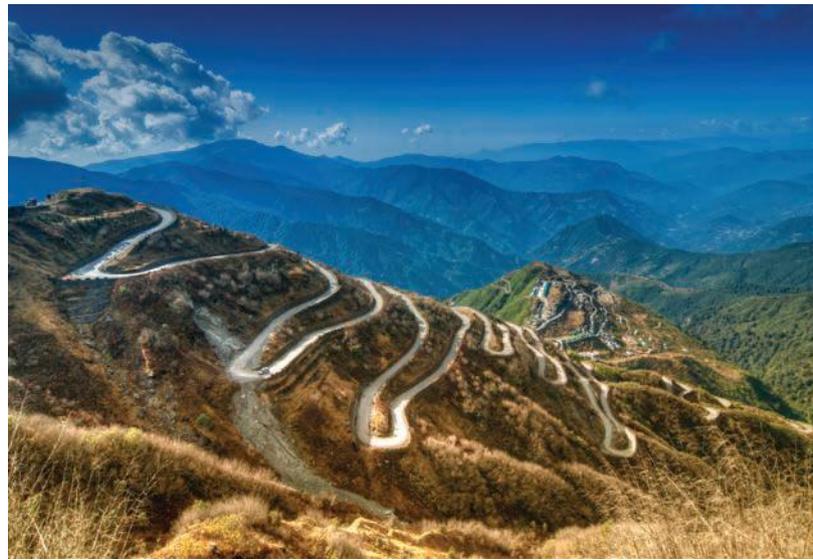


Figure 9.12 Mountain roads have hairpin bends to reduce the incline for vehicles.

Figure 9.11 Ramps are used to lift heavy objects.



Figure 9.13 The ramp makes it easier for the car to pull the boat out of the water.



Figure 9.14 A removalist using a ramp to unload objects from a truck

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.

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.

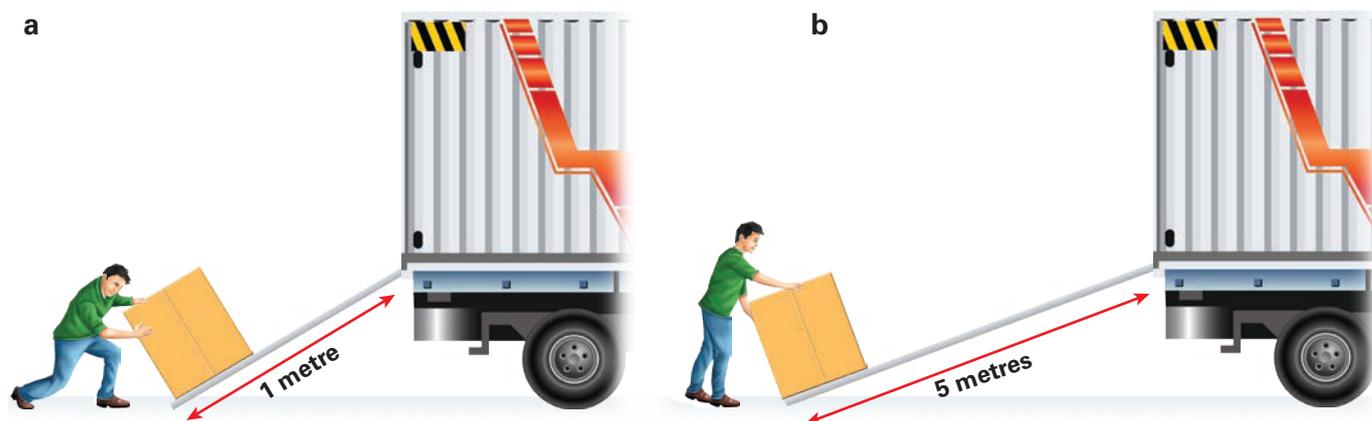


Figure 9.15 (a) Using a ramp decreases the amount of effort needed to lift the object into the truck. **(b)** A less steep ramp gives a greater mechanical advantage but you have to push the object further.

Practical 9.2: Self-design

Calculating the effort force

Aim

To design and carry out an experiment to test the effect of increasing ramp height on the effort force required to pull a mass up a ramp.

Materials

- books or wooden blocks
- spring balance
- 500 g weight holder
- long wooden plank

continued...

...continued

Method

Using the materials provided, design an experiment to test the effect of the height of a ramp on the effort force needed to pull a 500 g mass up the ramp.

Results

Draw a suitable table to record your results.

Evaluation

- 1 Discuss how increasing the height of the ramp affected the force required to pull a mass up a ramp.
- 2 Describe how the experimental design ensured the experiment was a fair and reliable test.
- 3 How could you improve your experiment?

Conclusion

From this activity we can claim that the height of a ramp affects _____. This is supported through observations that _____. This means that _____.

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.

Did you know? 9.2

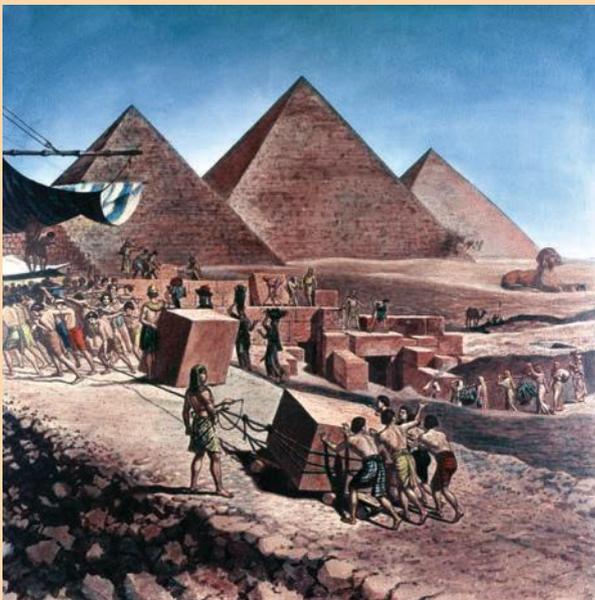


Figure 9.16 Egyptian slaves moving large stones up a ramp

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, and 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 9.17 Screws and bolts are a special type of inclined plane.



Archimedes' screw was invented by the Ancient Greek scientist, Archimedes. Essentially a giant screw, the machine was used for irrigation in the Nile Delta and for pumping out water and 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.

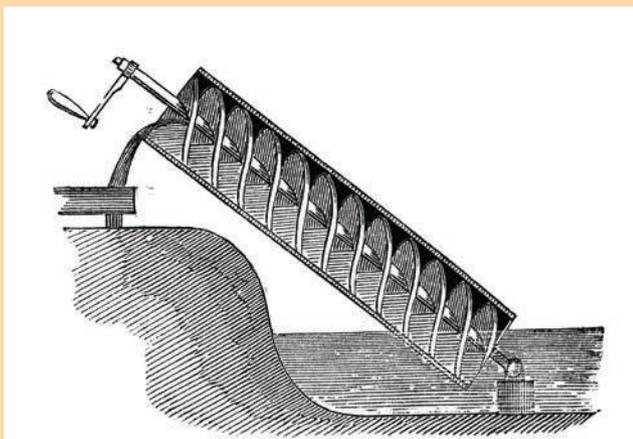


Figure 9.18 Archimedes' screw is used for lifting water.

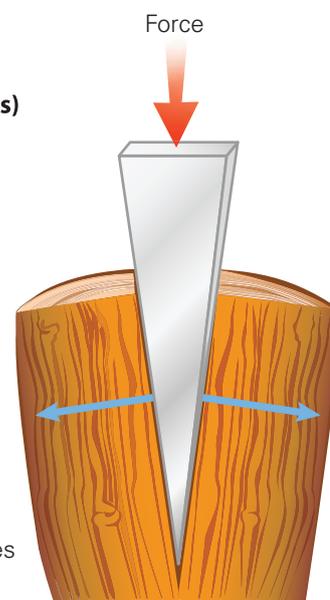
Did you know? 9.3

Wedges

A wedge is a simple machine with two inclined planes, which changes the direction of force and also multiplies it. In the diagram the vertical force applied to the wedge by the 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 wedges 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.

WEDGE (one of the six simple machines)



A downward force produces forces perpendicular to its inclined surfaces

Figure 9.19 A wedge used to split a block of wood. It has been 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.

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.

Quick check 9.2

- 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.



QUIZ

Section 9.1 questions

Remembering

- 1 To calculate mechanical advantage, you must divide _____ by _____.
- 2 If the mechanical advantage is 3, what is the maximum load if the effort is 25 N?
- 3 If the mechanical advantage is 4, what is 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 Would you consider the lower beaks of the birds to be levers? Examine the picture of the parrot skull 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.

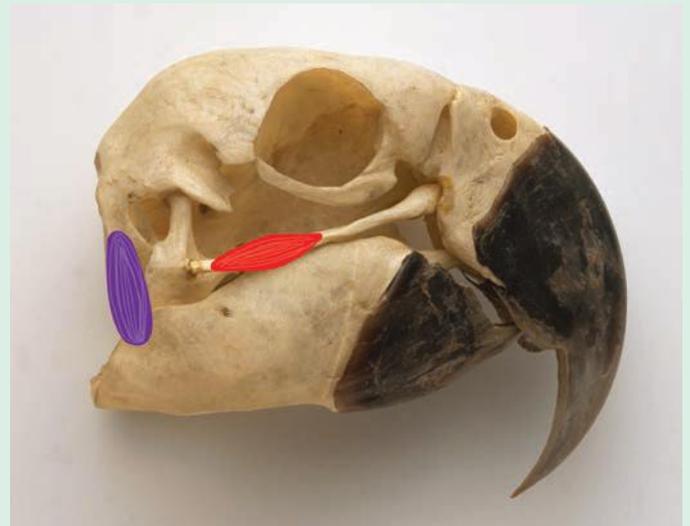
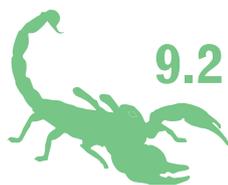


Figure 9.20 The lower beak is pulled up (beak closed) by the contraction of muscles shown in red. It is moved down (beak opened) by the muscles shown in purple.



9.2

Simple machines with rotating parts



Pulleys

Pulleys can be used to lift heavy objects. The most common pulley system you might see in everyday life 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 some blinds that cover windows.



Figure 9.21 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.

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.

Practical 9.3: Teacher demonstration

Investigating the effect on effort force of more pulleys

Aim

To investigate the effects on the effort force after adding more pulleys to a pulley system.

Materials

- a number of different pulleys
- string
- 500 g mass
- ruler
- spring balance

Method

- 1 Set up the 1, 2, 4 and 6 pulley systems as shown below.

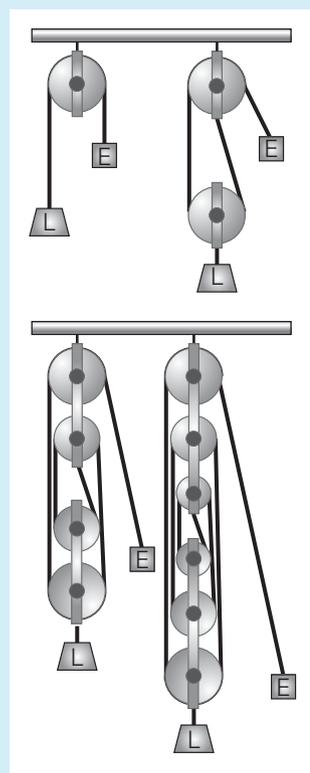


Figure 9.22 L represents the load force (the weight of the mass attached) and E represents the effort force required to lift the mass.

continued...

...continued

- Hook the 500 g mass onto each of the pulley systems and observe the difference in effort needed to lift the 500 g weight by pulling on the string.
- Using the spring balance, record the effort force needed to lift the mass, and the length of rope pulled to lift the load 5 cm for each of the pulley systems.

Results

	Single pulley	2 pulleys	4 pulleys	6 pulleys
Load	5000 N	5000 N	5000 N	5000 N
Effort force				
Distance required to lift the load 5 cm				

Evaluation

- Describe the difference that was measured between the different pulley systems when lifting the 500 g mass. If you do not have the chance to try the pulley systems, your teacher will describe the difference measured.
- Referring to your results, how did the effort force change as the number of pulleys increased?
- How did the distance required to lift the load 5 cm change as the number of pulleys increased?
- How can these results be explained?

Conclusion

From this activity we can claim that the number of pulleys affects _____. This is supported through observations that _____. This means that _____.

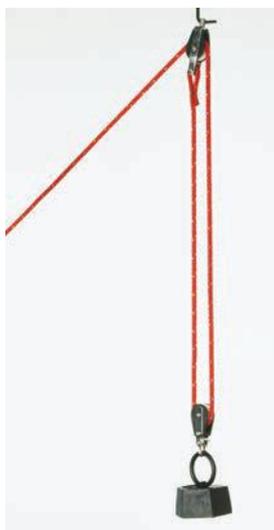


Figure 9.23 A two-pulley system

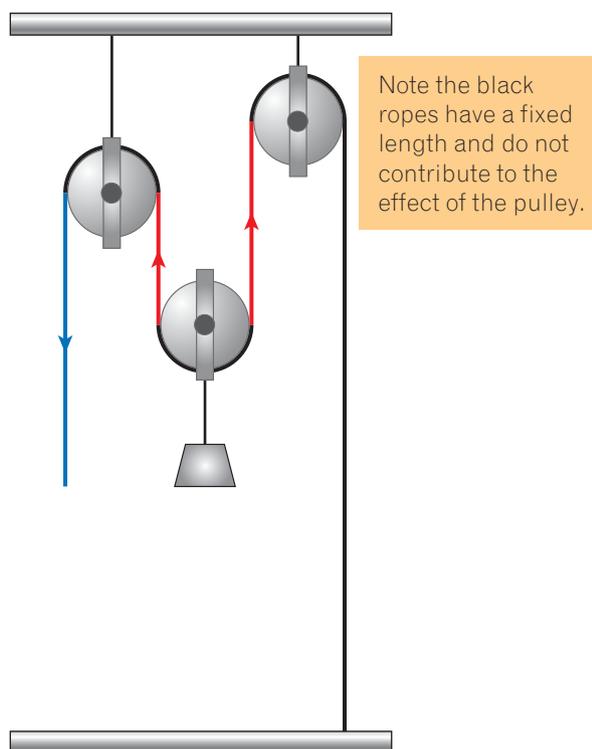
Pulleys are often found on sail boats, where heavy objects need to be lifted and held high up in the air. Imagine trying to lift and hold a sail up all by yourself! With pulleys, you simply need to pull on the rope.

Extension

Let's investigate mechanical advantage further.

Mechanical advantage = number of strings supporting the load.

In Figure 9.24, 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.



Note the black ropes have a fixed length and do not contribute to the effect of the pulley.

Figure 9.24 A pulley system with a mechanical advantage of 2

In Figure 9.25, 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.

Note the black ropes have a fixed length and do not contribute to the effect of the pulley.

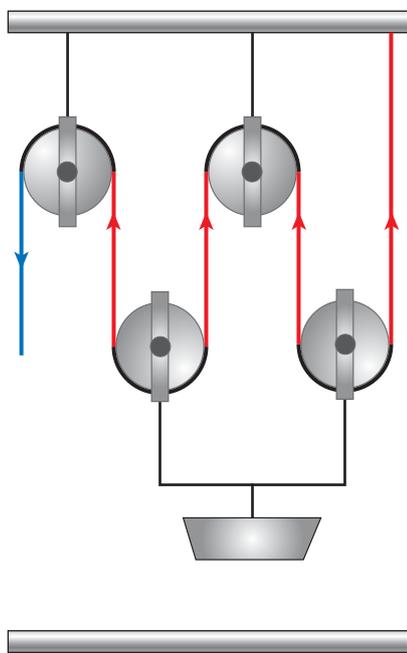


Figure 9.25 A pulley system with a mechanical advantage of 4

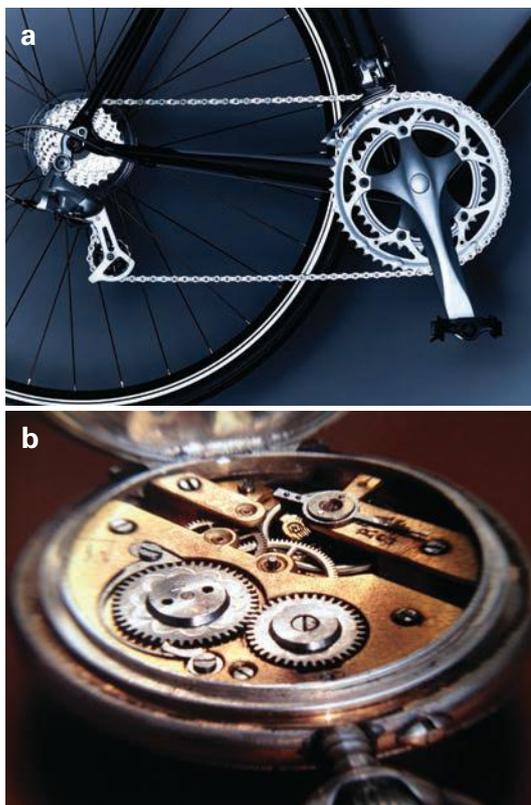


Figure 9.26 (a) Chained gears in a bicycle (b) Meshed gears in a pocketwatch

- 1 What is the mechanical advantage of the pulley system shown?

Quick check 9.3

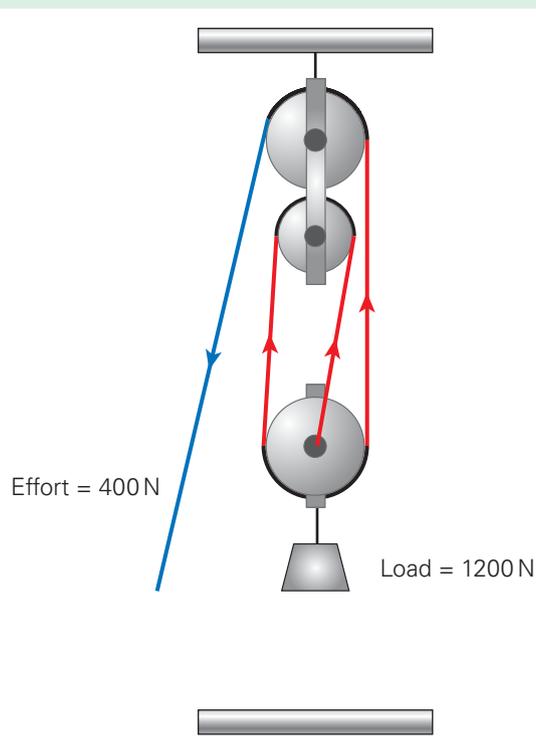


Figure 9.27 A pulley system

- 2 Use the formula

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

to calculate the maximum load that could be lifted if an effort force of 40 N was applied.

- 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. You may recognise gears in bikes or clocks. In a bike, the gears are connected by a chain, whereas in a clock the gears are called ‘meshed’ gears because the teeth fit into each other.

gear
a device consisting of connecting sets of wheels with teeth

cog
one of the tooth-like parts around the edge of a wheel

When gears of different sizes can be used, they can be either speed or force multipliers. In a gear system, the **driving gear** (the gear the effort force is applied to) 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 many more times. A motor can be attached to the gear to produce a turning force. An old-fashioned egg beater is an example of

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



Figure 9.28 Every time the larger driving gear turns once, the smaller driven gear turns multiple times, spinning faster.



Figure 9.29 A hand beater. The handle turns the large gear, which in turn spins smaller gears that cause the beaters to spin fast.

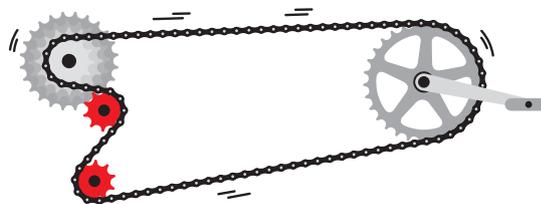


Figure 9.30 Force is applied to the larger gear by turning the pedal with your foot. This turns the smaller rear gear many times, allowing you to ride your bike with speed!

this sort of gear system in use! In this case, you turn the larger gear using the handle and the beaters spin faster than you are turning the handle. A bike and a hand beater work 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 also found on bikes, especially mountain bikes.

You will need either a hand beater or a hand drill.

Try this 9.3

- 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 setup to show how the machine works. Be sure to label the driving gear and driven gear.
- 4 For every turn 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?



VIDEO

How is a bicycle a complex machine?



WIDGET

Gear ratios



Section 9.2 questions

Remembering

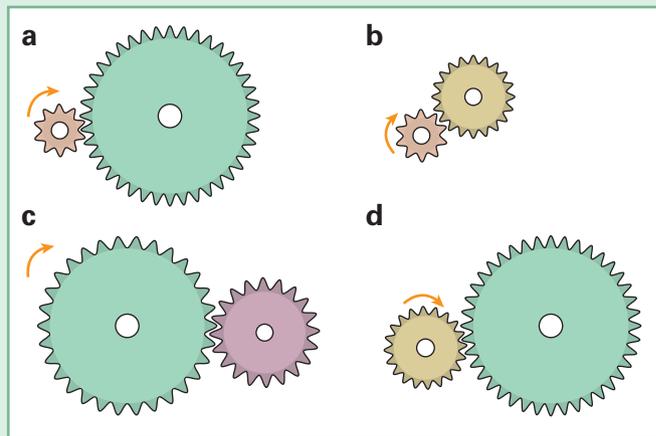
- 1 List some everyday objects that use gears.
- 2 Draw a diagram of the gear set-up most commonly used in bikes.

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

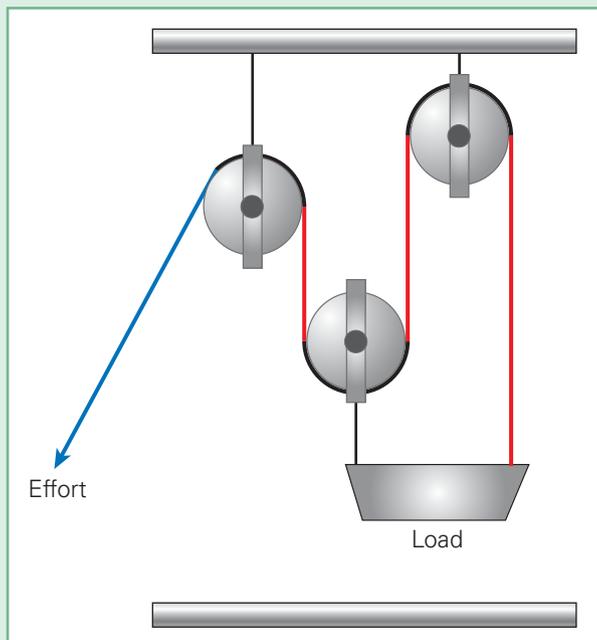
- 5 State whether the following gears are speed or force multipliers. The arrows indicate the driving gear.



Analysing

- 6 An experiment was done with the pulley system shown in Figure 9.31 and the results are shown in the table. 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 9.31 A load system

continued...

...continued

- 7 Analyse the bike gear system in Figure 9.32. Explain why a bike might have a number of different-sized driven gears.



Figure 9.32 Bike gear system

Evaluating

- 8 A gear system has a driving gear with 30 teeth and a driven gear with 25 teeth. Is it a force multiplier or a speed multiplier? How could it be made more effective; that is, how could it be made to multiply speed or force more?





Review questions

Remembering

- 1 How many different classes of lever are there?
- 2 What are the two different types of gears called?

Understanding

- 3 Figure 9.33 shows tongs used for a barbecue. Would you class them as a lever and if so, what class of lever are they?



Figure 9.33 Barbecue tongs

Analysing

- 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, would the maximum load that could be lifted be less than 320 N or more than 320 N? Explain your answer.

- 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 9.34 and calculate the maximum load that can be moved with this lever.

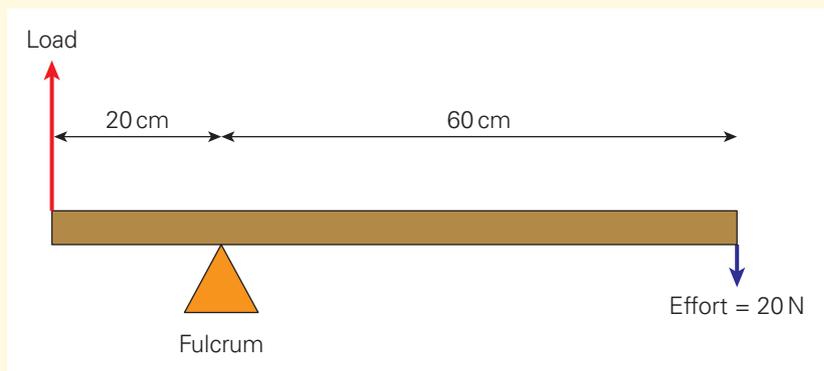


Figure 9.34

- 6 Extension: Analyse the pulley system in Figure 9.35 and state the mechanical advantage. Use your result to calculate the maximum load that can be lifted by an effort force of 80 N.

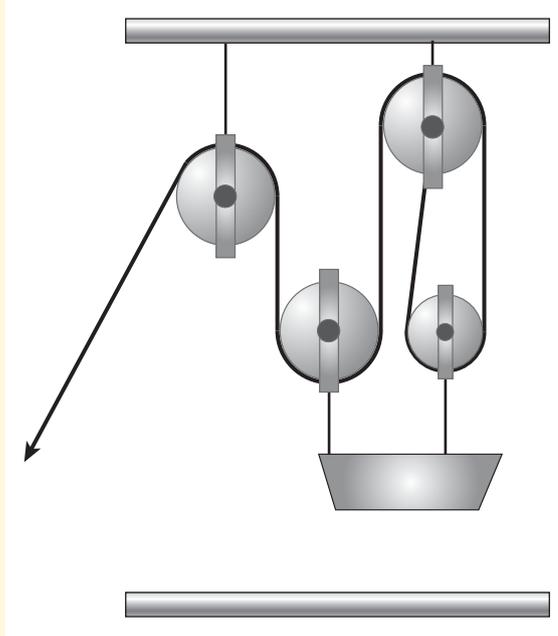


Figure 9.35

Evaluating

- 7 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. What are the advantages and disadvantages of each situation?



STEM activity: Designing and prototyping a mechanical arm

Background information

A machine is an apparatus that uses power to apply 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!

VCSU103

VCDSTC048

VCDSCD049

VCDSCD051

VCSIS113

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 9.36 Cranes use pulleys, and may also use levers. It 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 loads – 50 g, 100 g, 250 g, 500 g
- pulleys
- ruler and tape measure

- scissors
- cardboard
- string
- straws
- icy-pole sticks
- string
- sticky tape
- wire

Evaluate and modify

- 1 Elaborate on which simple machines are involved in your design and how they contribute to the motion of the arm.
- 2 Discuss with your team the challenges that have been encountered throughout this activity. List the strategies or actions that enabled you to overcome it.
- 3 List the problems that you encountered. Propose ways that your prototype could be improved if you had more time and resources available.
- 4 Predict what would happen if the prototype was used on a heavier load.
- 5 If you successfully moved the first load, test your prototype again with a heavier load until it fails. Note at which load it failed and suggest a couple of modifications that would enable it to move the heavier load.

Glossary

Chapter 1

analyse to interpret data gathered during an experiment in order to detect trends and patterns, and draw conclusions

concave a surface that curves inwards

convex a surface that curves outwards

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

experiment a controlled situation where data is gathered to answer a question

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

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 notice something significant

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 specific numerical measurement

variable a component of an experiment that changes or can be changed

Chapter 2

anther the part of a flower that produces and releases pollen

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 species of organism

botanist a scientist who studies plants

carpel the female part in a flower, made of the ovary, stigma and style

characteristic a feature or quality something possesses

class the taxonomic ranking below phylum and above order

classification the grouping of similar objects or organisms together

dichotomous key a tool that allows a scientist to identify an organism from a series of two option choices

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

domain the highest taxonomic rank

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

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

non-vascular not containing veins or specialised fluid vessels

order the taxonomic ranking below class and above family

organism a living creature

ovary the container of the ovules

ovule the container of female reproductive cells or 'egg', inside the ovary that will form a seed.

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 specific numerical measurement

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

sepal one of the leaf-like parts forming the outer part of a flower, which surrounds the petals and are usually small and green

sessile an organism that does not move

species the most specific taxonomic ranking below genus

stamen the male part of a flower, consisting of a thin stem that holds an anther

stigma part of the flower that receives pollen

style an extension of the ovary supporting the stigma.

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

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 practise 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 to be used

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

ecosystem the living and non-living components of a specific area

energy the ability to do work producing heat or motion

environment the air, water and land conditions in which an organism lives

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

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 type 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

sympiotic a relationship between two types of living things that help at least one of them survive

tertiary consumer an animal that eats secondary consumers

Chapter 4

boiling a special case of evaporation

Brownian motion the random movement of particles in fluids

chemical property the behaviour of a substance when it reacts with another substance

compress squeeze to make smaller

condensation where heat is lost causing a gas to become a liquid

contraction when substances occupy a smaller volume

density how compact a substance is

deposition where a reduction in heat causes a gas to become a solid

diffusion when substances spread out to occupy a larger area

evaporation when heat causes liquid to become gas

expansion when substances get larger

freezing where heat is lost and liquid becomes solid

gas a substance that expands freely to fill space

Kevlar fibres that have five times the strength for the same weight of steel and are used in a variety of clothing, accessories and equipment (Dupont™ Kevlar®)

liquid a substance that flows freely but has constant volume

mass the amount of substance in an object that never changes, even in space

matter anything that has a mass and volume

melting when heat causes a solid to become a liquid

melting point the temperature at which a specific solid melts

particle model all matter is made of particles that behave differently depending on whether they are solid, liquid or gas

physical property the way a substance looks and acts

pressure putting force (push or pull) onto a substance

radiation energy from heat or light that you cannot see, different from nuclear radiation

solid a substance that is firm and stable

state one of the distinct forms matter can exist in

sublimation where heat causes a solid to become gas

vibrate periodic motion of particles

volume the space an object occupies

Chapter 5

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 lot 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 little of the solute

dissolve cause to become mixed in a substance so that it cannot be seen

distillation a technique to separate substances in a liquid using evaporation through boiling and condensation

emulsion a colloid of two or more liquids

evaporation when heat causes liquid to become gas

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

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

mixture material made up of two or more different pure substances

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 6

annular eclipse the moon blocks the Sun but where 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

far side the face of the Moon that is always turned away from Earth; also called the dark side

geocentric model a cosmological model where Earth was the centre of the universe

gravitational field the region around a large object where another object can experience its gravity or pull

heliocentric model a model where the Sun was the centre of the solar system

horizon the horizon is 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 the Sun is partially blocked by the Moon

penumbra the region in a shadow where the light is partially blocked

perigee when the Moon is closest to Earth

revolution one complete orbit

solar eclipse 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 slowly across the surface

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° of longitude and each one representing a time difference of 1 hour

total eclipse 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 7

barrage a barrier to generate electricity from tidal power

biomass dead plant and animal material suitable for using as fuel

blackwater waste water from toilets

condensation where heat is lost causing a gas to become a liquid

evaporation when heat causes liquid to become gas

fossil fuel fuels, such as gas, coal, and oil, that were formed underground from plant and animal remains millions of years ago

geothermal energy using energy from the heat inside Earth

greenhouse gas gases that prevent heat from Earth escaping into space

greywater water that has been used before; for example, from washing, which can be stored and used again in toilets and such like

groundwater water that collects below Earth's surface

hydroelectricity producing electricity by the force of fast moving water such as rivers or waterfalls

impermeable not allowing liquid or gas to go through

infiltration to move slowly into a substance

mineral a useful 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 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 natural commodity that is valuable in supporting life

runoff water that flows away from high areas to low areas

silt sand or soil that is carried along by flowing water and then dropped usually at a river's opening or bend

solar energy using the energy from the Sun to produce electric power

transpiration the process of losing water through the surface of a plant

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

Chapter 8

air resistance the frictional force of the air

alloy a substance composed of two or more metals

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 force

buoyancy force the force experienced by an object that is partially or fully submerged in a fluid, eg. water

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 objects 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

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 9

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 driven 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 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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