SCIENCE

OXFORD SCIENCE 9

HELEN SILVESTER

SECOND EDITION

VICTORIAN CURRICULUM

OXFORD

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OXFORD SCIENCE 9

HELEN SILVESTER

2ND EDITION

VICTORIAN CURRICULUM

obook pro

OXFORD

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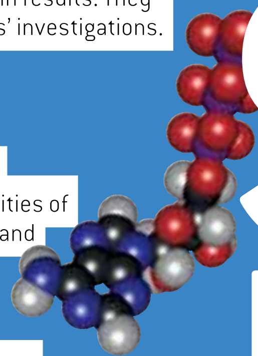
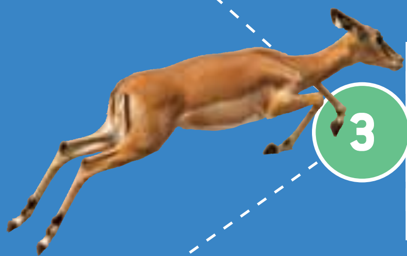
OXFORD SCIENCE 9

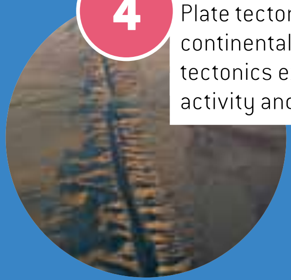
1 Science toolkit
Scientists work collaboratively and individually to design experiments. They control variables and use accurate measurement techniques to collect data. They consider ethics and safety. They analyse data, identify trends and relationships, and reveal inconsistencies in results. They analyse and evaluate their own and others' investigations.



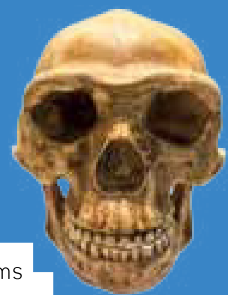
2 Ecosystems
All living things are dependent on each other and the environment around them. Ecosystems are communities of organisms and their non-living surroundings. Matter and energy flow through ecosystems.



3 Control and regulation
Multicellular organisms, such as humans, have systems that respond to changes in their environments. Receptors detect these changes and pass the information to other parts of the organism.

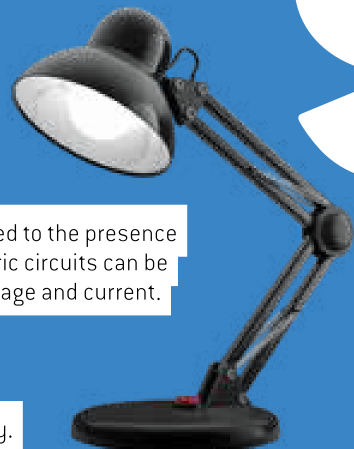


4 Tectonic plates
Plate tectonics is a combination of two theories: continental drift and sea-floor spreading. Plate tectonics explains global patterns of geological activity and the movement of the continents.



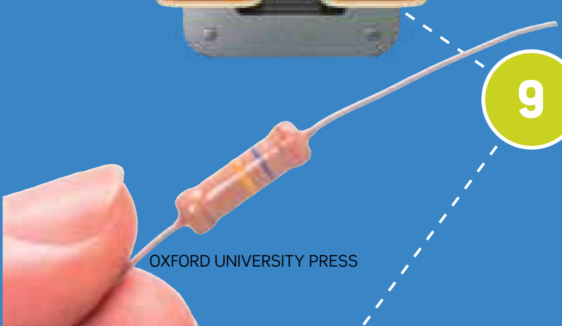
5 Matter
Matter is made of atoms. Atoms are systems of protons, neutrons and electrons. Radioactivity occurs when the nucleus of an unstable atom decays.

6 Chemical reactions
Chemical reactions, including combustion and acid reactions, are the rearrangement of atoms to form a new substance. Through this process, mass is not created or destroyed.



7 Electricity
Electricity is a general term related to the presence and flow of electric charge. Electric circuits can be explained by the concepts of voltage and current.

8 Electromagnetism
Magnetic fields and movement are used to generate electricity.



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OXFORD UNIVERSITY PRESS

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INTRODUCING *OXFORD SCIENCE 7–10 VICTORIAN CURRICULUM*

Oxford Science Victorian Curriculum has been developed to meet the requirements of the *Victorian Curriculum: Science* across Years 7–10. Taking a concept development approach, each double-page spread of Oxford Science represents **one concept**, **one topic** and **one lesson**. This new edition ensures students build science skills and cross-curriculum capabilities, paving a pathway for science success at VCE.

The series offers a completely integrated suite of print and digital resources to meet your needs, including:

> Student Book
> Student obook pro
> Teacher obook pro.

Key features of this Student Book

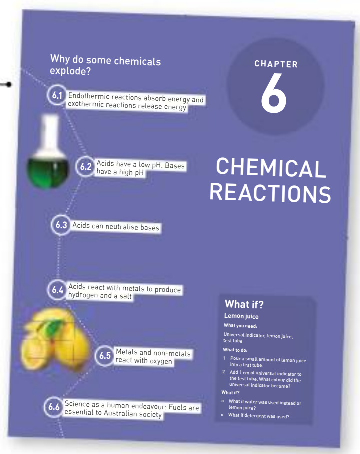
> This Student Book combines complete curriculum coverage with clear and engaging design.

> Each print Student Book comes with complete access to all the digital resources available on Student obook pro.

Focus on concept development

Chapter openers

- Every chapter begins with a clear learning pathway for students.

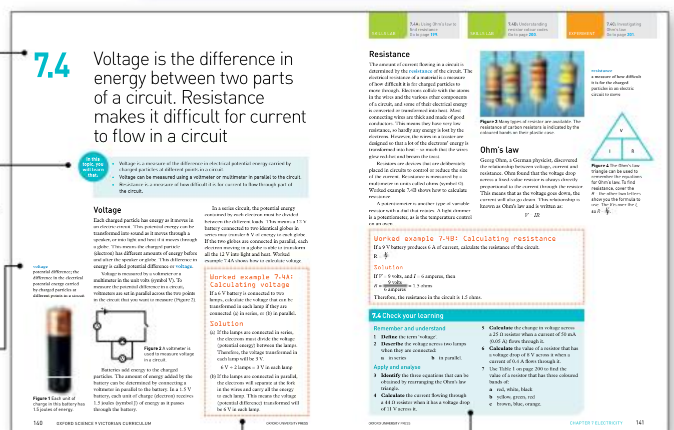


Reflect

- Students are encouraged to self-assess their learning against a set of success criteria in the Reflect tables at the end of each chapter. If students do not feel confident about their learning, they are directed back to the relevant topic.

Concept statements

- Every topic begins with a concept statement that summarises the key concept of the topic in one sentence.



Key ideas

- Key ideas are summarised for each topic in succinct dot points.

Margin glossary terms

- Key terms are bolded in the body in blue text, with a glossary definition provided in the margin.

Worked examples

- Students are provided with step-by-step worked examples for mathematical problems and scientific concepts.

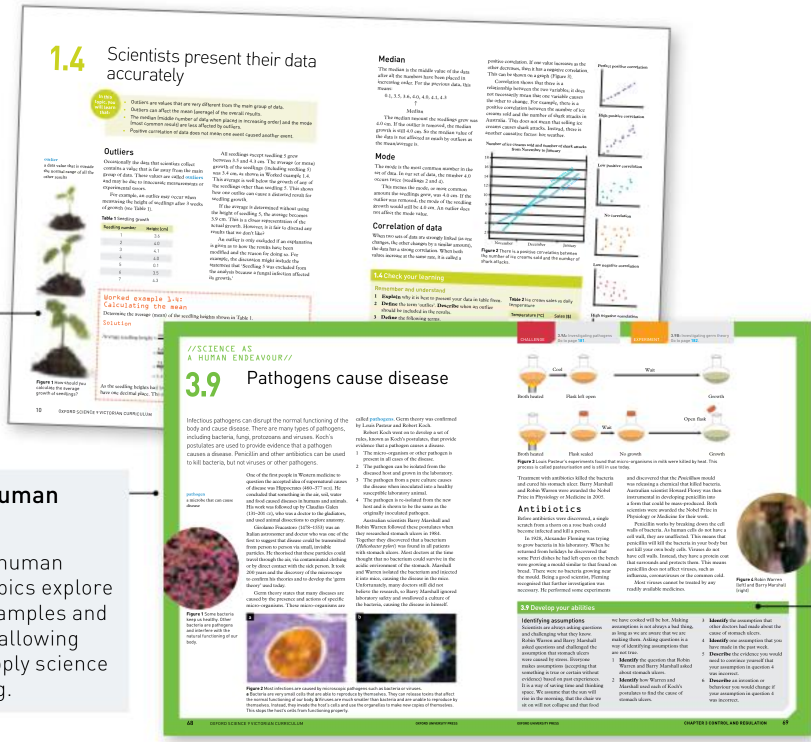
Check your learning

- Each topic finishes with a set of 'check your learning' questions that are aligned to Bloom's taxonomy. Questions are phrased using bolded task words (also called command verbs), which state what is expected of a student and prepares them for studying VCAA science subjects.

Focus on science inquiry skills and capabilities

Science toolkit

- The Science toolkit is a standalone chapter that explicitly teaches important Science inquiry skills and capabilities.



Science as a human endeavour

- 'Science as a human endeavour' topics explore real-world examples and case studies, allowing students to apply science understanding.

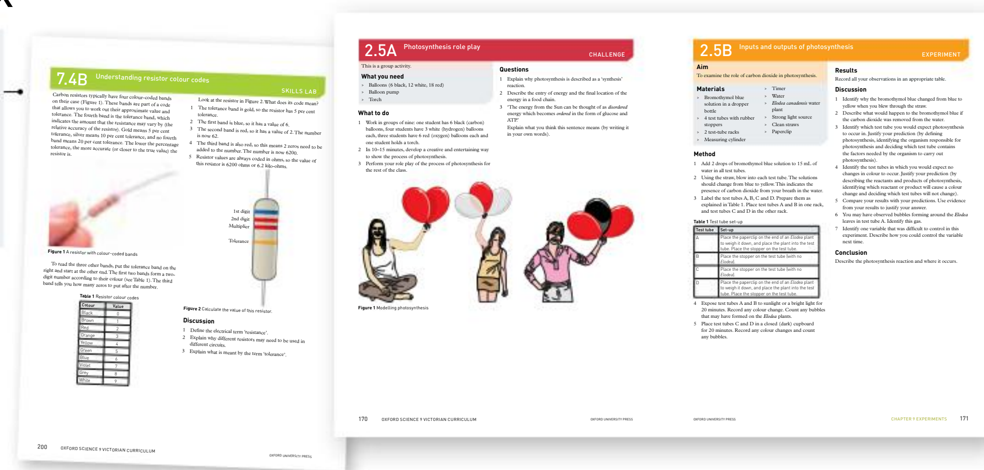
Develop your abilities

- 'Develop your abilities' provide scaffolded opportunities for students to apply their science understanding while developing skills and capabilities.

Focus on practical work

Practical work appears at the back of the book

- All practical activities are organised in a chapter at the end of the book and signposted at the point of learning throughout each chapter.



Challenges, Skills labs and Experiments

- These activities provide students with opportunities to use problem-solving and critical thinking, and apply science inquiry skills.

Focus on STEAM

Integrated STEAM projects

- Take the hard work out of cross-curricular learning with engaging STEAM projects. Two fully integrated projects are included at the end of each book in the series, and are scaffolded and mapped to the Science, Maths and Humanities curricula. The same projects also feature in the corresponding Oxford Humanities and Oxford Maths series to assist cross-curricular learning.

Problem solving through design thinking

- Each STEAM project investigates a real-world problem that students are encouraged to problem solve using design thinking.

Full digital support

- Each STEAM project is supported by a wealth of digital resources, including student booklets (to scaffold students through the design-thinking process of each project), videos to support key concepts and skills, and implementation and assessment advice for teachers.

Key features of Student obook pro

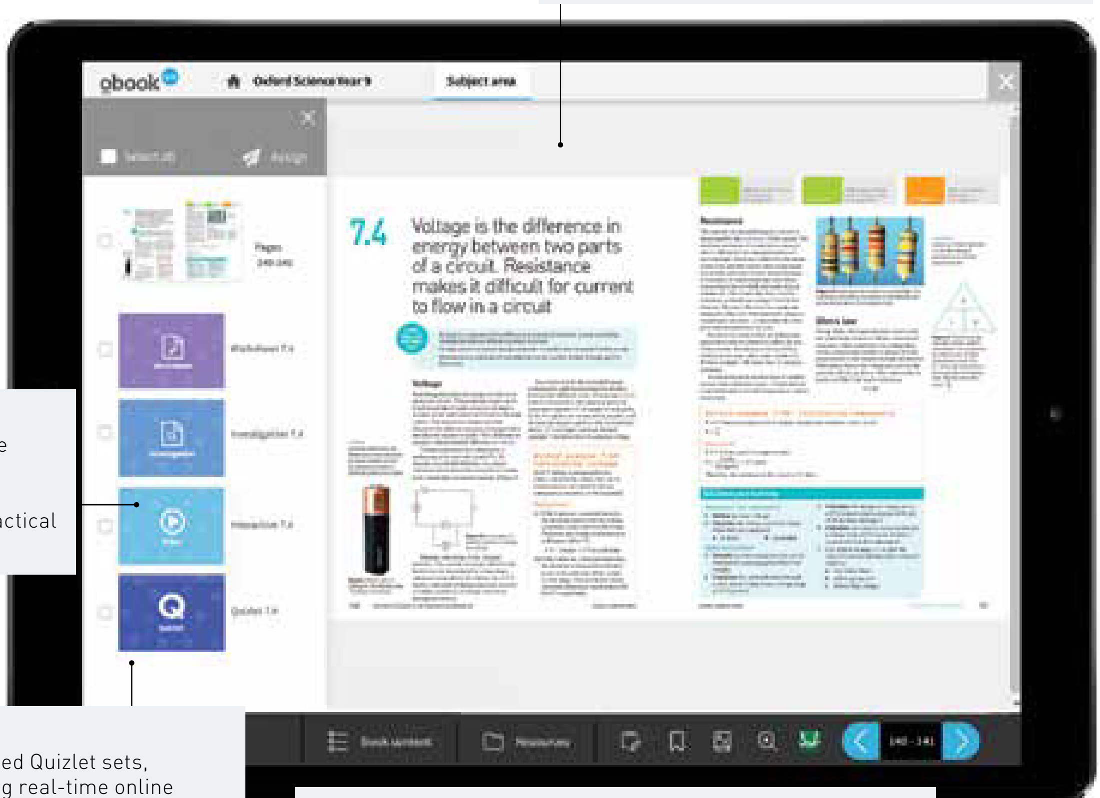
obook pro

- Student obook pro is a completely digital product delivered via Oxford's online learning platform, **Oxford Digital**.
- It offers a complete digital version of the Student Book with interactive note-taking, highlighting and bookmarking functionality, allowing students to revisit points of learning.
- A complete ePDF of the Student Book is also available for download for offline use and read-aloud functionality.

Focus on eLearning

Complete digital version of the Student Book

- This digital version of the Student Book is true to the print version, making it easy to navigate and transition between print and digital.



Videos

- Videos are available online to support understanding of concepts or key practical activities.

Quizlet

- Integrated Quizlet sets, including real-time online quizzes with live leaderboards, motivate students by providing interactive games that can be played solo or as a class. Quizlet can be used for revision or as a topic is introduced to keep students engaged.

Interactive quizzes

- Each topic in the Student Book is accompanied by an interactive assessment that can be used to consolidate concepts and skills.
- These interactive quizzes are autocorrecting, with students receiving instant feedback on achievement and progress. Students can also access all their online assessment results to track their own progress and reflect on their learning.

Benefits for students

- integrated Australian Concise Oxford Dictionary look up feature
- targeted instructional videos for key concepts, practicals and worked examples
- interactive assessments to consolidate understanding
- integrated Quizlet sets, including real-time online quizzes with live leaderboards
- access to their online assessment results to track their own progress.

Key features of Teacher obook pro

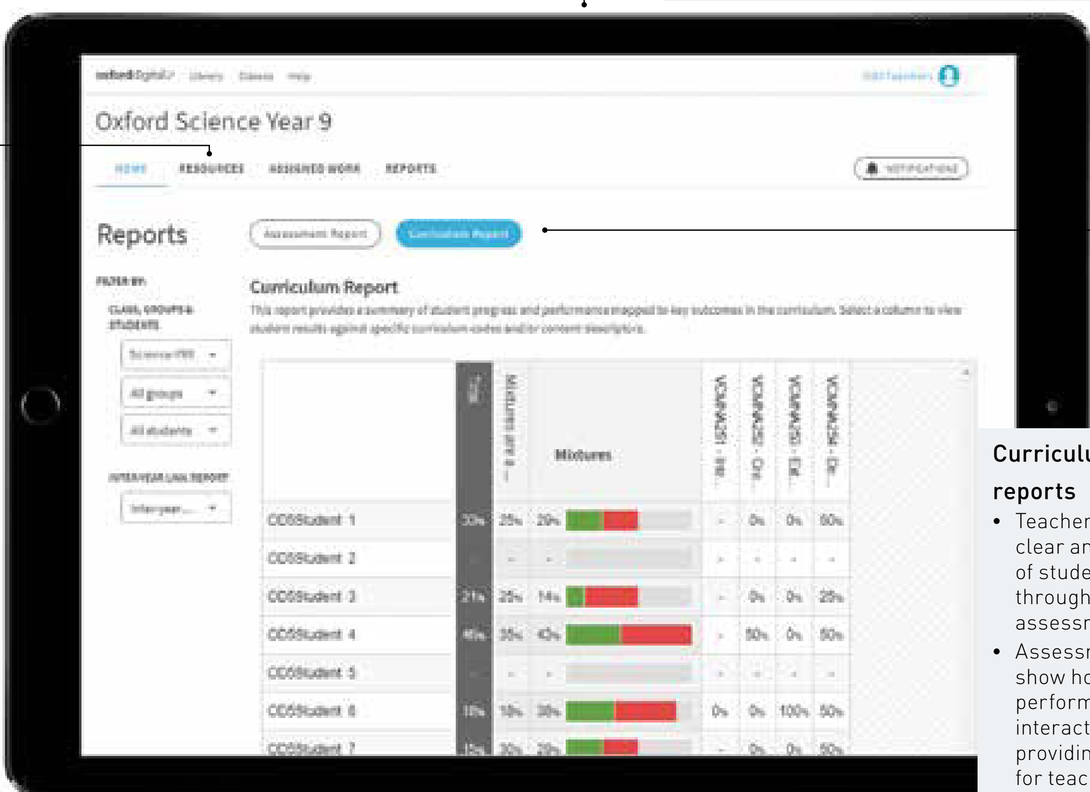
obook pro

- Teacher obook pro is a completely digital product delivered via **Oxford Digital**.
- Each chapter and topic of the Student Book is accompanied by full teaching support. Teaching programs are provided that clearly direct learning pathways throughout each chapter, including ideas for differentiation and practical activities.
- Teachers can use their Teacher obook pro to share notes and easily assign resources or assessments to students, including due dates and email notifications.

Focus on assessment and reporting

Complete teaching support

- Teaching support includes full lesson and assessment planning, ensuring there is more time to focus on students.



Curriculum and assessment reports

- Teachers are provided with clear and tangible evidence of student learning progress through curriculum and assessment reports.
- Assessment reports directly show how students are performing in each online interactive assessment, providing instant feedback for teachers about areas of understanding.
- Curriculum reports summarise student performance against specific curriculum content descriptors and curriculum codes.

Additional resources

- Each chapter of the Student Book is accompanied by additional worksheets and learning resources to help students progress.

Benefits for teachers

- In addition to online assessment, teachers have access to editable class tests that are provided at the conclusion of each chapter. These tests can be used as formative or summative assessment and can be edited to suit the class's learning outcomes.
- Teachers are provided with laboratory support through experiment answer guidance, laboratory technician notes and risk assessments to ensure safe learning experiences.

VICTORIAN CURRICULUM: SCIENCE 9 SCOPE AND SEQUENCE

LEVELS 9 AND 10 DESCRIPTION

In Levels 9 and 10, the curriculum focus is on explaining phenomena involving science and its applications. Students consider both classic and contemporary science contexts to explain the operation of systems at a range of scales. At a microscopic scale, they consider the atom as a system of protons, electrons and neutrons, and understand how this system can change through nuclear decay. They learn that matter can be rearranged through chemical change and that these changes play an important role in many systems. At a macroscopic scale, they explore ways in which the human body as a system responds to its external environment, and investigate the interdependencies between biotic and abiotic components of ecosystems. They develop a more sophisticated view of energy transfer by applying the concept of the conservation of matter in a variety of contexts. They apply their understanding of energy and forces to global systems including continental movement. Students explore the biological, chemical, geological and physical evidence for different theories, including the theories of natural selection and the Big Bang theory. Atomic theory is used to understand relationships within the periodic table of elements. Students understand that motion and forces are related by applying physical laws. Relationships between aspects of the living, physical and chemical world are applied to systems on a local and global scale enabling students to predict how changes will affect equilibrium within these systems.

LEVELS 9 AND 10 CONTENT DESCRIPTIONS	
Science as a human endeavour	
Chapter 3 Chapter 4 Chapter 5 Year 10	Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community (VCSSU114)
Chapter 3 Chapter 4 Chapter 8 Year 10	Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (VCSSU115)
Chapter 1 Chapter 6 Year 10	The values and needs of contemporary society can influence the focus of scientific research (VCSSU116)
Biological sciences	
Chapter 3	Multicellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (VCSSU117)
Chapter 3	An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by synapses (VCSSU118)
Year 10	The transmission of heritable characteristics from one generation to the next involves DNA and genes (VCSSU119)
Year 10	The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (VCSSU120)
Chapter 2	Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (VCSSU121)

LEVELS 9 AND 10 CONTENT DESCRIPTIONS	
Chemical sciences	
Chapter 5	All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (VCSSU122)
Year 10	The atomic structure and properties of elements are used to organise them in the periodic table (VCSSU123)
Chapter 6	Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed (VCSSU124)
Chapter 6 Year 10	Different types of chemical reactions are used to produce a range of products and can occur at different rates; chemical reactions may be represented by balanced chemical equations (VCSSU125)
Chapter 6 Year 10	Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (VCSSU126)
Earth and space sciences	
Chapter 4	The theory of plate tectonics explains global patterns of geological activity and continental movement (VCSSU127)
Year 10	Global systems, including the carbon cycle, rely on interactions involving the atmosphere, biosphere, hydrosphere and lithosphere (VCSSU128)
Year 10	The Universe contains features including galaxies, stars and solar systems; the Big Bang theory can be used to explain the origin of the Universe (VCSSU129)
Physical sciences	
Chapter 7	Electric circuits can be designed for diverse purposes using different components; the operation of circuits can be explained by the concepts of voltage and current (VCSSU130)
Chapter 8	The interaction of magnets can be explained by a field model; magnets are used in the generation of electricity and the operation of motors (VCSSU131)
Year 10	Energy flow in Earth's atmosphere can be explained by the processes of heat transfer (VCSSU132)
Year 10	The description and explanation of the motion of objects involves the interaction of forces and the exchange of energy and can be described and predicted using the laws of physics (VCSSU133)
SCIENCE INQUIRY SKILLS	
Questioning and predicting	
Chapter 1 Chapter 9 Year 10	Formulate questions or hypotheses that can be investigated scientifically, including identification of independent, dependent and controlled variables (VCSIS134)
Planning and conducting	
Chapter 1 Chapter 9 Year 10	Independently plan, select and use appropriate investigation types, including fieldwork and laboratory experimentation, to collect reliable data, assess risk and address ethical issues associated with these investigation types (VCSIS135)
Chapter 1 Chapter 9 Year 10	Select and use appropriate equipment and technologies to systematically collect and record accurate and reliable data, and use repeat trials to improve accuracy, precision and reliability (VCSIS136)
Recording and processing	
Chapter 1 Chapter 9 Year 10	Construct and use a range of representations, including graphs, keys, models and formulas, to record and summarise data from students' own investigations and secondary sources, to represent qualitative and quantitative patterns or relationships, and distinguish between discrete and continuous data (VCSIS137)
Analysing and evaluating	
Chapter 1 Chapter 9 Year 10	Analyse patterns and trends in data, including describing relationships between variables, identifying inconsistencies in data and sources of uncertainty, and drawing conclusions that are consistent with evidence (VCSIS138)

ACKNOWLEDGEMENTS

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CHAPTER

1

SCIENCE TOOLKIT

How do scientists test claims?

1.1 Scientists can test manufacturers' claims

1.2 Scientists must be aware of experimental errors

1.3 Scientists prepare Safety Data Sheets

1.4 Scientists present their data accurately

1.5 Science as a human endeavour: Scientists investigate consumer products

What if?

Staples

What you need:

Ten sheets of A4 paper, a stapler with staples

What to do:

1. Fold an A4 sheet of paper in two.
2. Staple the two halves of paper together with the stapler.
3. Add another sheet of paper to the folded paper so that there are now three sheets over the top of each other.
4. Staple all the sheets together with the stapler.
5. Repeat steps 3 and 4 until the stapler is unable to penetrate all the sheets of paper effectively.

What if?

- » What if another stapler was used?
- » What if another brand of staples was used?
- » What if different paper was used?

1.1 Scientists can test manufacturers' claims

In this topic, you will learn that:

- The scientific method involves forming a hypothesis, planning an experiment that controls the variables, gathering data, analysing results, drawing a conclusion and communicating the results.
- Consumer science is a branch of science that involves applying the scientific method to the claims made by manufacturers.

Figure 1 Ribena was found to contain less vitamin C than its competition, despite the manufacturer's claims.

Figure 2 Anna Devathasan and Jenny Suo

No matter what you buy – toilet paper, a smartphone or a bottle of water – you are being a consumer. As a consumer you make choices and you expect certain things from the products you buy.

Consumer science case study

In 2004, two New Zealand science students, Jenny Suo and Anna Devathasan, exposed a startling fact about the fruit juice drink Ribena while conducting research for their school's science fair. Jenny and Anna decided to compare the vitamin C content of different fruit juice drinks to see if the manufacturer's claims on the labels were correct. The label on Ribena, which contains blackcurrant juice, implied that it had a much higher vitamin C content than the other fruit juice drinks they tested. It said: 'The blackcurrants in Ribena contain four times the vitamin C of oranges'. The students therefore predicted that Ribena would have four times the vitamin C content of orange fruit juice drinks.

Jenny and Anna then analysed the vitamin C content of Ribena and several other fruit juice drinks, using the scientific method. They ensured that their tests were fair and objective. The only difference between the drinks during their tests was the brands. Jenny and Anna did three trials to ensure the accuracy of their results. After each trial, they re-examined their data.

The students were surprised to find that the vitamin C content of Ribena was far lower than most other brands. But because they had followed the scientific method, they were confident that their results were reliable. For this reason, they contacted the manufacturer about the misleading labelling and advertising. When no response was received, they brought their case to a national consumer affairs program.

After their case was broadcast, and after further testing of Ribena, the New Zealand Commerce Commission brought 15 charges against the manufacturer under the Fair Trading Act 1986 (NZ).

The scientific method at work

Jenny and Anna were sure of their results because they followed the scientific method.

Hypothesis

The scientific method involves developing a plan to test a hypothesis that can come from a 'what if' question. For Jenny and Anna, this question was:

'*What if* the vitamin C content of Ribena was compared with other fruit juice drinks?'

This then became a prediction using the words 'if' and 'then':

'*If* the vitamin C content of Ribena is compared with other fruit juice drinks, *then* Ribena will have more vitamin C per millilitre.'

A hypothesis should also include the idea or theory on which the prediction is based. This is done through the use of 'because':

'*If* the vitamin C content of Ribena is compared with other fruit juice drinks, *then* Ribena will have more vitamin C per millilitre *because* blackcurrants have a greater vitamin C content than other fruits.'

A hypothesis should be based on some underlying suspicion, prediction or idea that is based on previous observations. It must be very specific (operational) so that it can be tested.

EXPERIMENT

1.1: What if the absorbency of different paper towels was compared?
Go to page **163**.

Variables

A hypothesis should be tested in an objective way. For example, for a fair comparison of the fruit juice drinks, Jenny and Anna needed to design an experiment that identified all the **variables** that would be operating. The variables in an experiment are the factors that will affect the results in some way. These could include the volume of the fruit juice drinks tested, the age and temperature of the fruit juice drinks, and the quality of the chemicals used in the testing.

To test the hypothesis, all the variables should be controlled except for the one being tested. This is known as the **independent variable** and in Jenny and Anna's case it was the brand of the fruit juice drink being tested. The variable being measured at the end of the experiment is the **dependent variable**, such as the amount of vitamin C in a fruit juice drink.

Method

In this section, a scientist describes the materials and equipment they used, including the concentrations and brands they tested. Diagrams are also useful to illustrate the steps taken. Remember to label all equipment in the diagram and to give the diagram a title.

The number of times you repeat an entire experiment is referred to as repetition. The more times an experiment is repeated and the results are averaged, the more likely it is that the results are reliable.

The **sample size** refers to the number of subjects being tested or used in the experiment. The greater the sample size, the more reliable the results will be and the stronger the evidence available to support the conclusion.

Results

The observations you make, or the data you collect, during your experiment are written down as the results. All observations should be what you *actually* see and not what you *expect* to see. Data can be organised into a table format and a graph to make it easier to understand.

Discussion

Once all the results have been gathered, they need to be analysed for any patterns that show if the independent variable and the dependent variable changed in a similar way. If they did, this means the results are **correlated**.

Conclusion

A conclusion answers the initial question asked about the experiment. It provides evidence that supports or refutes the hypothesis. Any further investigations that may need to be done are outlined in this section.

variable
something that can affect the outcome or results of an experiment

independent variable
a variable (factor) that is changed in an experiment

dependent variable
a variable in an experiment that may change as a result of changes to the independent variable

sample size
the number of subjects being tested or used in an experiment

correlated
when results in an experiment show that independent and dependent variables are related

1.1 Check your learning

Remember and understand

1 **Define** the term 'hypothesis'.
2 **Explain** why an experiment should have a clear and detailed method.
3 **Describe** how a hypothesis that is shown to be wrong can still be useful. **Justify** your answer (by providing an example that matches your description).

Apply and analyse

4 **Consider** the following statement:
'If participants in Group A use Brand A toothpaste for six weeks, then they will have whiter teeth than participants in Group B, who used Brand B toothpaste for six weeks.'
  a **Identify** what is missing from this statement to make it a hypothesis.
  b **Identify** the independent and dependent variables being tested.
  c **Identify** one controlled variable in the experiment. **Explain** why it is important for this variable to be controlled.

Evaluate and create

5 **Evaluate** the claim that 'an increased sample size makes an experiment more reliable'. **Justify** your answer by:
- defining the terms 'sample size' and 'reliable'
- explaining the effect of increasing the sample size in an experiment
- deciding whether increasing the sample size makes an experiment more reliable.

6 Often scientists have to present their findings to the public in order to get action taken. Sometimes this is difficult, so they need to be sure that their findings are reliable. **Explain** how the scientific method ensures that the findings are reliable (by describing all the steps in the scientific method and identifying which steps improve the reliability of the results).

1.2 Scientists must be aware of experimental errors

In this topic, you will learn that:

- In scientific investigations, measurements can only show that a hypothesis is correct if the measurements are accurate.
- To achieve maximum accuracy, the measurement must be taken carefully, using the most suitable measuring device.
- Each scientific device must have a scale appropriate to the accuracy that you require.

accuracy
how carefully, correctly and consistently data has been measured or processed; in science, how close a measured value is to the true value

reading error
an error that occurs when markings on a scale are not read correctly

Choosing the right device

Choosing the right instrument is the first step in making sure the measurements are close to the expected true value (**accurate**). For example, if you needed to accurately measure the volume of a liquid, then you would use a burette or a measuring cylinder, but not a beaker. A burette has a more accurate scale than a measuring cylinder. Both are carefully checked during the manufacturing process; however, a burette has smaller units that can be controlled by the scientist. A beaker often has no scale.

Errors and accuracy

Choosing the right instrument is only part of a scientist's job. It is very important to take care with your measurements. The most common errors in measurement are reading errors, parallax errors and zero errors.

A **reading error** can result when guesswork is involved when taking a reading. For example, when a reading lies between the divisions on a scale, a guess of the actual reading can result in a reading error (Figure 2).

Figure 1 A burette is a laboratory instrument used to accurately measure the volumes of liquids.

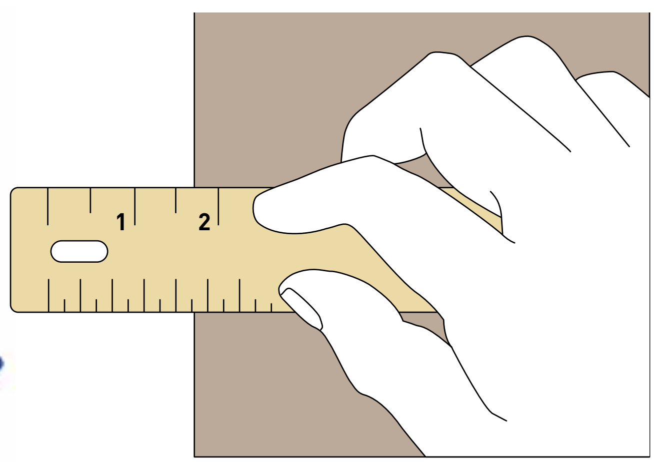


Figure 2 Guessing the reading between units of measurement (for example, between 1.5 and 2) can produce a reading error.

CHALLENGE

1.2: Avoiding errors and improving accuracy
Go to page **164**.

A **parallax error** occurs when the eye is not directly opposite the scale when the reading is being taken. You can avoid parallax errors by making sure that your eye is in the correct position when taking the reading. For example, when reading the level of a liquid in a measuring cylinder, place the cylinder on the bench and line up your eye with the bottom of the meniscus (Figure 3).

A **zero error** happens when an instrument has not been correctly adjusted to zero or the reading has not taken into account the weight of the empty container. For example, scales must be set to zero correctly before making a weight measurement of substances.

To check the accuracy of scales, scientists use a special mass that is known to be exact. When this is placed on the scale, the weight shown by the scale is compared to the known true mass. If they are the same, then the scale is accurate.

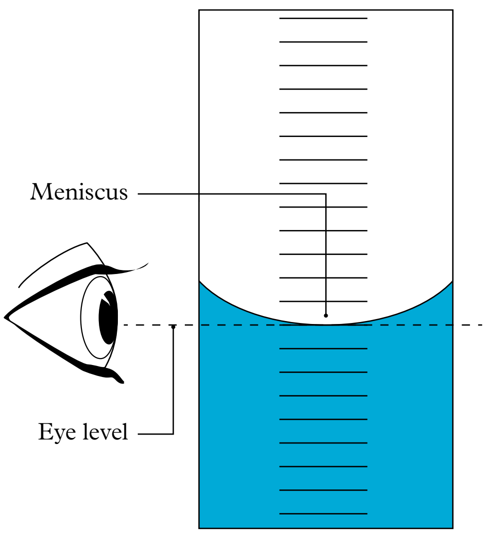


Figure 3 To avoid parallax error, make sure your eye is correctly lined up with the bottom of the meniscus.

Figure 4 Scales must be zeroed correctly before using them.

Mathematical accuracy

When conducting a scientific investigation, mathematical accuracy is very important. To avoid errors, not only must your equipment be appropriate and precise, but your calculations must also be correct. When taking a reading, you should quote the maximum allowed number of **significant figures** (the number of digits). This can represent the accuracy of a measurement or reading.

When recording results, it is important to know the number of significant figures the instrument allows. When adding or subtracting numbers, the final answer will be based on the least number of decimal places. When multiplying or dividing numbers, the final answer can only be quoted correct to the number of significant figures in the least accurate result. For example, if one measuring device measures 10.22 (four significant figures and two decimal places) and a second device measures 20.345 (five significant figures and three decimal places), averaging these results means adding the values. This means the final answer should only have two figures after the decimal point. This might require a **rounding off** procedure. Worked example 1.2 (on page 6) shows how to calculate significant figures.

parallax error
an error, or inaccurate reading, that occurs as a result of reading a scale from an angle

zero error
an error that occurs when an instrument has not been adjusted to zero before the measurement is taken

significant figures
the number of digits that contribute to the overall value of a number

rounding off
reducing the number of significant figures by increasing or decreasing to the nearest significant figure; for example, 7.6 cm is rounded up to 8 cm, 7.2 cm is rounded down to 7 cm

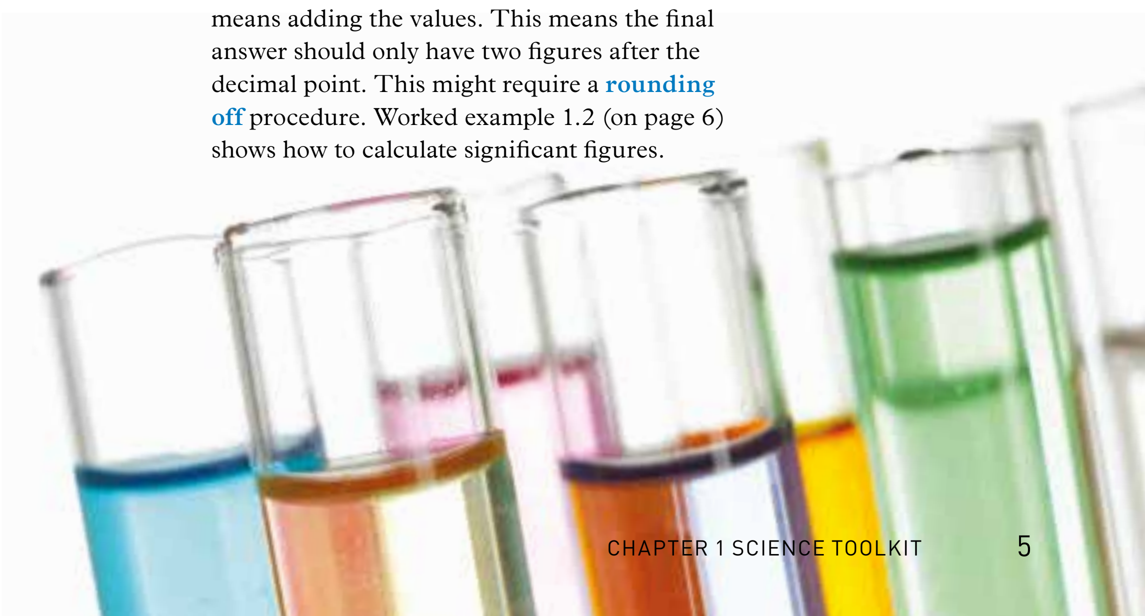


Figure 5 The meniscus is the curved surface of a liquid, as you can see in these test tubes.

Worked example 1.2: Significant figures

A student used two sets of scales to measure 0.44 g of sand and 0.696 g of water. Calculate the final mass when the sand was mixed with the water. Give your answer to an appropriate number of significant figures.

Solution

Add the mass of the sand and water together.

$$0.44 + 0.696\,g = 1.136\,g$$

As one number has only two decimal places, the final answer must have two decimal places. The number (1.136) is closer to 1.14 than to 1.13, so 1.14 is more accurate.

Final mass of sand and water = 1.14 g

Figure 6 Mixing sand and water

Measurements and units

Scientists measure fundamental quantities, such as mass, time and length, in a standard unit that has been agreed upon by scientists around the world. The international system of units, known as the **SI system** of units, is based on the metric system. Table 1 shows some SI units. Other measurements, such as volume, are calculated from those basic units and are called **derived units**.

SI system
an international system of measurement based on the metric system, with units such as kilogram, metre, kilometre

derived units
units of measurement that are calculated using a combination of SI (international system) base units, e.g. cm^3 for volume (base unit is cm), m^2 for area (base unit is m)

Table 1 SI units

Physical quantity	SI unit	Abbreviation or symbol
Length	metre	m
Volume	litre	L
Mass	kilogram	kg
Time	second	s
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A

Although the SI unit for mass is the kilogram, this is not always the most suitable unit to use. Some objects are too heavy or too light for this to be the most convenient unit. The measurement would have too many zeros in it. For example, a mass of 0.000 000 007 43 kg or 850 000 000 kg is very inconvenient to write. Scientists and mathematicians choose a unit that requires as few zeros as possible. They use a system of prefixes before the basic measurement unit, shown in Table 2.

Figure 7 Scales are used to measure quantities of materials used in experiments.

Table 2 Standard prefixes and meanings

Prefix	Symbol	Value	Meaning
peta	P	10^{15}	One quadrillion (one thousand million million)
tera	T	10^{12}	One trillion
giga	G	10^{9}	One billion
mega	M	10^{6}	One million
kilo	k	10^{3}	One thousand
centi	c	10^{-2}	One-hundredth
milli	m	10^{-3}	One-thousandth
micro	μ	10^{-6}	One-millionth
nano	n	10^{-9}	One-billionth
pico	p	10^{-12}	One-millionth of one million

Notice that when the number is larger than the basic measurement, the symbol for the prefix is a capital letter. When it is only a fraction of the basic measurement, the symbol for the prefix is a small letter (i.e. lower case). For example, a megalitre, which is a million litres, is written as ML, while a millilitre, which is one-thousandth of a litre, is written as mL. 'Kilo' is an exception to this general rule. A kilogram is 1000 grams and its symbol is kg.

Figure 8 These dumb-bells weigh 3 kg each.

1.2 Check your learning

Remember and understand

1 **Identify** three kinds of errors that can occur during an experiment.

2 **Describe** how these errors can be reduced to improve accuracy.

3 **Explain** why scientists often repeat experiments and then take an average of the results.

4 **Identify** the symbol for:

- **a** millionths of a gram
- **b** billions of litres
- **c** thousandths of an ampere
- **d** thousands of metres.

Apply and analyse

5 **Identify** the number of significant figures in each of the following measurements.

- **a** 45.22 mL
- **b** 9.0 s
- **c** 8000 L
- **d** 3.005 m

6 A student took the following measurements during an experiment:

5.6 volts, 2.97 amperes, 3000 seconds.

If these three numbers were used in a calculation, **identify** how many significant figures should be stated in the final answer. **Justify** your answer (by explaining how you made your decision).

1.3 Scientists prepare Safety Data Sheets

In this topic, you will learn that:

- A Safety Data Sheet (SDS) contains information about a chemical, such as its various names, the dangers involved in its use and the precautions that should be taken when handling the chemical.
- SDSs should be prepared for all the reactants used and the products produced during science experiments.

SAFETY DATA SHEET
Sodium Chloride: Hazardous chemical

Section 1 - Chemical Product and Company Identification	
MSDS name:	Sodium Chloride
Synonyms:	Common salt; Halite; Rock salt; Saline; Salt; Sea salt; Table salt.
Company identification:	Chemical company
Section 2 - Hazards Identification	
Eye and skin:	May cause eye irritation.
Ingestion:	Ingestion of large amounts may cause gastrointestinal irritation. Ingestion of large amounts may cause nausea and vomiting, rigidity or convulsions.
Inhalation:	May cause respiratory tract irritation.
Section 3 - Handling and Storage	
Handling:	Use with adequate ventilation. Minimise dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Store in a cool, dry, well-ventilated area away from incompatible substances. Store protected from moisture.
Section 4 - Exposure Controls, Personal Protection	
Engineering controls:	Good general ventilation should be used.
Personal protective equipment	
Eyes:	Wear safety glasses with side shields.
Skin:	Wear appropriate gloves to prevent skin exposure.
Clothing:	Wear appropriate protective clothing to minimise contact with skin.
Section 5 - First Aid Measures	
Eyes:	Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin:	Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.
Ingestion:	If victim is conscious and alert, give 2-4 cupsful water. Get medical aid. Wash mouth out with water.
Inhalation:	Remove from exposure to fresh air immediately. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Section 6 - Physical and Chemical Properties	
Physical state:	Solid
Appearance:	Colourless or white
Odour:	Odourless
Boiling point:	1413 deg C
Freezing/melting point:	801 deg C
Solubility:	Soluble
Specific gravity/density:	2.165
Molecular formula:	NaCl
Molecular weight:	58
Section 7 - Accidental Release Measures	
Spills/leaks:	Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.
Section 8 - Fire Fighting Measures	
General information:	Water runoff can cause environmental damage. Collect water used to fight fire. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products. Substance is noncombustible.

Figure 1 Example of an SDS from a manufacturer or certified provider

Anticipate, recognise and eliminate

Scientists work with many hazardous materials when completing experiments. As a result, they need to be aware of anything that might affect their health or safety in the laboratory. The laboratory is a safe place, provided hazards are:

> anticipated
> recognised
> eliminated or controlled.

A Safety Data Sheet (SDS) provides scientists and emergency personnel with information on how to use a particular substance. An SDS also helps scientists understand more about how the chemical should be used during the experiment.

Figure 2 Emergency workers in sealed positive-pressure protective suits communicating with each other

Safety Data Sheets

The information on a Safety Data Sheet includes the following:

> **The various names of the chemical**
  This includes its chemical name and its common generic name, its concentration and structure. For example, DL-threo-2-(methylamino)-1-phenylpropan-1-ol is also called pseudoephedrine.

> **The contact details of the manufacturer**

> **The hazard level of the chemical**
  All chemicals should contain labels relating to their particular dangers. This may include their flammability, corrosive ability, toxicity and ability to cause long-term damage, such as cancers. The risks can be shown using descriptions or the symbols shown in Figure 4.

> **Usage instructions and restrictions**
  Some chemicals may form a dust that can explode. For example, workers in flour mills need to be especially aware of flour dust. This section provides information about how to safely handle and store the substance to minimise the risks.

- **Protective measures**
  The SDS should contain information on the eye and face protection needed, the type of gloves or skin protection required and the possible need for masks.
- **The physical and chemical properties of the substance**
  Everyone in a laboratory should be able to easily identify the chemical. The SDS should include the colour, smell, pH, flammability, solubility, melting and boiling points of the chemical.
- **What to do in the case of a spill (in the laboratory or the environment)**
  This includes first aid measures, any antidotes, symptoms that might result from exposure and if personal protective equipment (PPE) is recommended for first aiders. Advice may be needed on how to cover drains to prevent the chemical making its way into ground water.
- **Fire-fighting measures**
  Some chemicals produce toxic fumes or are highly flammable. Other chemicals become more dangerous if they are exposed to water. Firefighters may need special equipment.
- **How to dispose of the chemical safely**
  This section should include what disposal containers should be used, the effects of sewage disposal and the special precautions that may be needed to ensure the safety of individuals and the environment.
- **How to transport the chemical**
  Information should include any special precautions for transporting this chemical. This may include the Hazchem code (the code provided by the government for each class of chemical).
- **An Australian telephone number of the Office of Chemical Safety**
- **The date the SDS was last reviewed**

Figure 3 The hazards identified in the SDSs are displayed by many industries, including the mining industry.

Figure 4 Pictograms such as these are often seen on the labels of chemicals, to communicate specific hazards.

1.3 Check your learning

Remember and understand

1. **Identify** the meaning of the term 'SDS'.
2. **Explain** why it is important to prepare an SDS before starting an experiment.
3. **Explain** why it is important to have all the different names of the chemical on the SDS.
4. **Describe** the types of personal protective equipment (PPE) you have in your laboratory.
5. **Identify** the phone number of the Office of Chemical Safety in Victoria.

1.4 Scientists present their data accurately

In this topic, you will learn that:

- Outliers are values that are very different from the main group of data.
- Outliers can affect the mean (average) of the overall results.
- The median (middle number of data when placed in increasing order) and the mode (most common result) are less affected by outliers.
- Positive correlation of data does not mean one event caused another event.

Outliers

outlier
a data value that is outside the normal range of all the other results

Figure 1 How should you calculate the average growth of seedlings?

Occasionally the data that scientists collect contains a value that is far away from the main group of data. These values are called **outliers** and may be due to inaccurate measurements or experimental errors.

For example, an outlier may occur when measuring the height of seedlings after 3 weeks of growth (see Table 1).

Table 1 Seedling growth

Seedling number	Height (cm)
1	3.6
2	4.0
3	4.1
4	4.0
5	0.1
6	3.5
7	4.3

All seedlings except seedling 5 grew between 3.5 and 4.3 cm. The average (or mean) growth of the seedlings (including seedling 5) was 3.4 cm, as shown in Worked example 1.4. This average is well below the growth of any of the seedlings other than seedling 5. This shows how one outlier can cause a distorted result for seedling growth.

If the average is determined without using the height of seedling 5, the average becomes 3.9 cm. This is a closer representation of the actual growth. However, is it fair to discard any results that we don't like?

An outlier is only excluded if an explanation is given as to how the results have been modified and the reason for doing so. For example, the discussion might include the statement that 'Seedling 5 was excluded from the analysis because a fungal infection affected its growth.'

Worked example 1.4: Calculating the mean

Determine the average (mean) of the seedling heights shown in Table 1.

Solution

$$\text{Average seedling height} = \frac{\text{sum of all seedling heights}}{\text{number of seedlings}}$$

$$= \frac{3.6 + 4.0 + 4.1 + 4.0 + 0.1 + 3.5 + 4.3}{7}$$

$$= \frac{23.6}{7}$$

$$= 3.371$$

As the seedling heights had two significant figures and one decimal place, the final answer must have one decimal place. The average seedling height is 3.4 cm (3.371 is closer to 3.4 than to 3.3).

Median

The median is the middle value of the data after all the numbers have been placed in increasing order. For the previous data, this means:

0.1, 3.5, 3.6, 4.0, 4.0, 4.1, 4.3
↑
Median

The median amount the seedlings grew was 4.0 cm. If the outlier is removed, the median growth is still 4.0 cm. So the median value of the data is not affected as much by outliers as the mean/average is.

Mode

The mode is the most common number in the set of data. In our set of data, the number 4.0 occurs twice (seedlings 2 and 4).

This means the mode, or most common amount the seedlings grew, was 4.0 cm. If the outlier was removed, the mode of the seedling growth would still be 4.0 cm. An outlier does not affect the mode value.

Correlation of data

When two sets of data are strongly linked (as one changes, the other changes by a similar amount), the data has a strong correlation. When both values increase at the same rate, it is called a positive correlation. If one value increases as the other decreases, then it has a negative correlation. This can be shown on a graph (Figure 3).

Correlation shows that there is a relationship between the two variables; it does not necessarily mean that one variable causes the other to change. For example, there is a positive correlation between the number of ice creams sold and the number of shark attacks in Australia. This does not mean that selling ice creams causes shark attacks. Instead, there is another causative factor: hot weather.

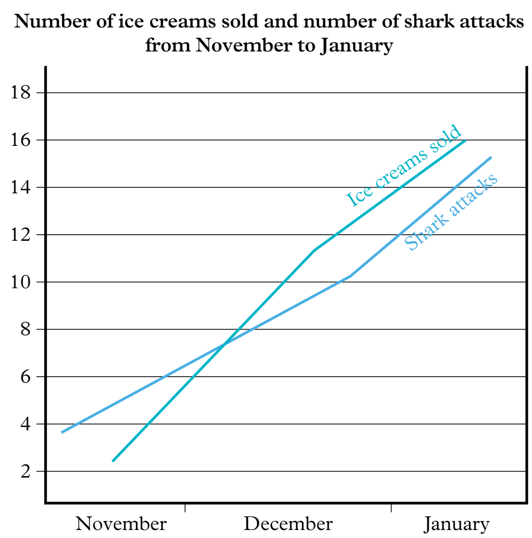


Figure 2 There is a positive correlation between the number of ice creams sold and the number of shark attacks.

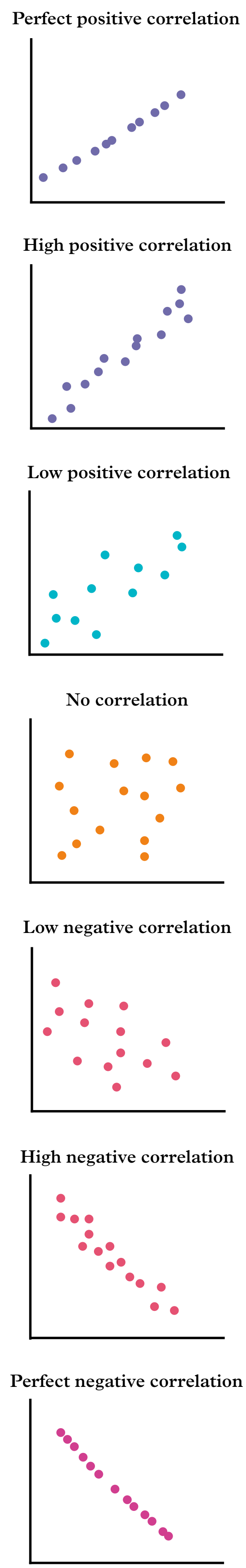


Figure 3 Correlation of data

1.4 Check your learning

Remember and understand

1 **Explain** why it is best to present your data in table form.

2 **Define** the term 'outlier'. **Describe** when an outlier should be included in the results.

3 **Define** the following terms.

  a mean

  b median

  c mode

Apply and analyse

4 Draw an appropriate graph for the data in Table 2.

  a **Describe** any correlation between the daily temperature and ice cream sales.

  b **Explain** the effect the daily temperature has on the number of ice creams sold that day.

  c **Explain** what you would expect to happen to ice cream sales if the daily temperature increased to 40°C.

Table 2 Ice cream sales vs daily temperature

Temperature (°C)	Sales ($)
14.2	215
16.4	325
11.9	185
15.2	332
18.5	406
22.1	522
19.4	412
25.1	614
23.4	544
18.1	421
22.6	445
17.2	408

//SCIENCE AS
A HUMAN ENDEAVOUR//

1.5 Scientists investigate consumer products

Working in groups of two or three, design an experiment to investigate an everyday consumer product. Your aim is to practise using the scientific method. You will need to ensure that you follow the scientific method.

Use the 'Develop your abilities' questions on the next page to design an experiment that investigates consumer products.

Figure 1 Investigating a consumer product: nail polish

Figure 2 More consumer products to investigate: bottled water and bubblegum

Figure 3 Scientists can identify the similiarites and differences between products or substances.

1.5 Develop your abilities

Investigating a product

Choose a consumer product to investigate and discuss what you already know about the product. Identify any claims or slogans that may be tested. Then design a reproducible experiment to investigate these claims or slogans, following the scientific method.

You will need to research the product thoroughly. This may mean visiting a supermarket and comparing the prices and packaging of different brands, as well as searching the internet, journals, books and encyclopedias to identify the science behind your product.

Ideas

Here are some ideas for your investigation.

- Do all brands of bubblegum make the same-sized bubble?
- Do all washing detergents produce the same amount of bubbles and clean the same number of dishes?
- How permanent are permanent markers? What solvents (for example, water, alcohol, vinegar, detergent solution) will remove the ink? Do different brands or types of markers produce the same result?
- Do consumers prefer bleached white paper products or unbleached paper products? Why?
- Is laundry detergent as effective if you use less than the recommended amount? What if you use more than the recommended amount?
- Is bottled water purer than tap water? How does distilled water compare with drinking water?
- How does the pH of juice change with time? How does temperature affect the rate of this chemical change?
- Do all hairsprays hold equally well? And equally long? Does the type of hair affect the results?
- Do all nail polishes dry at the same rate?
- Do some lipsticks stay on longer?
- How absorbent are nappies?
- Do all batteries have the same battery life?
- How long can the life of cut flowers be prolonged?

Evaluate

As a class, discuss each experiment design by answering the following questions.

- Will the experiment produce data that answers the question?
- Is the method repeatable? (Will the same process produce the same results if it is repeated?)
- Could someone else reproduce the experiment? (Are there any steps that require more scientific information to be supplied?)
- Have all the safety considerations been taken into account?
- What changes could be made to improve the design?

Planning for errors

Before you carry out your consumer science investigation, you will need to think about reducing errors and improving accuracy.

- What variables will you need to control, to ensure a fair test?
- How will you make sure your data is accurate and free of errors?
- What type of equipment will you be using? Is this the most appropriate equipment?
- How will you reduce parallax, reading and zero errors in your data measurements?
- What other factors could introduce errors into your investigation? How will you minimise these?

Presenting your results

Once you have completed your consumer science investigation, you will need to analyse your data appropriately.

- Are there any outliers? Can you explain these?
- What methods of data presentation will you use and why?
- What method will you use to describe your results: mean, median or mode?
- Are there any correlations between the sets of data in your results? Do they imply causation?

You will also need to complete a presentation about your investigation. This could be done as a webpage, a slide presentation, an advertisement, a video, or an article for *Choice* magazine, comparing your findings with the manufacturers' claims. Present your findings to the class.

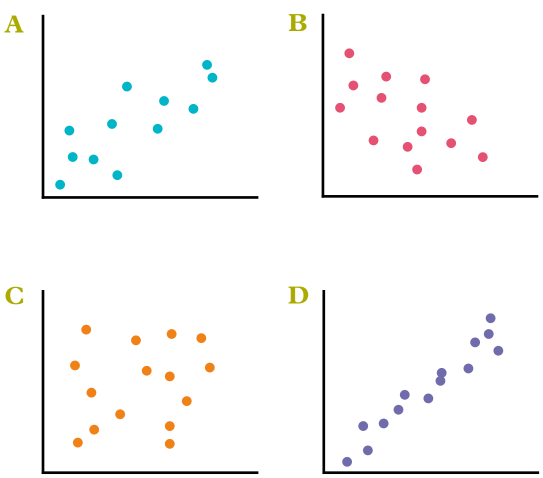
REVIEW 1

Multiple choice questions

1 **Identify** the most appropriate definition of 'independent variable'.
- A the variable that is measured
- B the variable that is controlled
- C the variable that is deliberately changed by the scientist
- D the variable that is measured at the end of the experiment

2 **Identify** which of the following statements is correct.
- A Correlation means causation.
- B Data is described in the method section of a scientific report.
- C Data is analysed in the results section of a scientific report.
- D A Safety Data Sheet should include the PPE to be used for a chemical.

3 **Identify** the graph that indicates no correlation between the variables.



Short answer questions

Remember and understand

4 **Identify** the main steps used when conducting an experimental investigation by the scientific method.

5 **Define** the term 'variable'.

6 **Identify** why consumer scientists are interested in what can be observed and tested, rather than in the slogans and claims of manufacturers.

7 **Describe** how scientists find out about the safety risks involved in an experiment they are planning.

8 Suppose you are conducting a fair experiment in which you have identified six variables. **Explain** how you can be sure of the effect of one particular variable.

9 **Explain** why beakers are not used to measure volumes.

10 **Compare** (the similarities and differences between) zero error and parallax error, by describing each type of error.

11 **Define** the term 'SI unit'.

12 **Identify** the SI unit for the following:
- a time
- b mass
- c length.

13 **Identify** the meaning of the following prefixes for a quantity:
- a mega
- b micro
- c kilo.

14 **Explain** why scientists have developed an internationally agreed system of units.

Apply and analyse

15 A consumer scientist wanted to test the effect of a lotion for treating acne. They first tested the lotion on a group of 20 teenagers, all aged 15, but then they decided to conduct more tests. So they then tested 100 teenagers, all aged 15.
- a **Identify** whether this is an example of experimental repetition or increasing the sample size.
- b **Identify** which result (using 20 teenagers or 120 teenagers) is likely to lead to the most reliable conclusion. **Justify** your answer (by **comparing** the reliability of the test with 20 teenagers to that of 120 teenagers and **deciding** which is more reliable).

16 A scientist was commissioned by a jeans manufacturer to test various denims. The manufacturer wanted a more durable fabric than the one they were currently using. **Describe** how the scientist might test a fabric for durability in a fair and objective way. **Explain** why this is important.

Figure 1 How might a scientist test the durability of different denims?

17 **Identify** the number of significant figures in each of the following measurements:

- a 65.301 g
- b 0.006 420 kg
- c 40 L.

18 **Calculate** the mean, median and mode of the following set of data:

15, 13, 18, 16, 14, 17, 12, 14, 19

19 A lipstick manufacturer claims that their brand of high-gloss lipstick will stay on for at least 6 hours, even during eating and drinking. Design an experiment based on the scientific method to test this claim. First **state** your hypothesis, and then **identify** the variables you will be considering. **Describe** the measurements you will take and how you will ensure that they are accurate.

20 For the experiment you designed in question 19, **describe** the results you would expect to obtain if your stated hypothesis was correct.

Figure 2 What results would be expected for the hypothesis from question 19?

Evaluate

21 For the experiment you designed in question 19, **evaluate** the accuracy of the results that you may measure and suggest what further investigation you could undertake to improve the reliability of your conclusions.

22 For the experiment you designed in question 19, assuming you found that the manufacturer's claim was correct, **create** a scientifically accurate slogan or advertisement for the lipstick based on your findings.

Social and ethical thinking

23 Two phrases commonly used in advertising are 'Scientists have proved …' and 'Recommended by scientists'. These are often accompanied by pictures of named scientists who are paid to appear in the advertisement. **Discuss** the ethical implications of using these phrases or pictures of scientists, by completing the following:

- a **Describe** why the company may choose to use the phrases or a picture of a scientist.
- b **Describe** how a person viewing the advertisement might be affected by the use of the phrases or pictures.
- c **Describe** how a person would be affected if the phrases/pictures were not used.
- d **Evaluate** whether using the phrases/pictures disadvantages the person viewing the advertisement.
- e **Decide** whether the phrases/pictures of scientists should be allowed in advertising.

Critical and creative thinking

24 One source of information for consumers is *Choice* magazine. The magazine reports the results of testing a variety of brands of consumer products.

- a If a consumer scientist was reading a report on the safety of children's pyjamas, **describe** the evidence they might look for to see if the report was fair and objective.
- b If the scientist concludes that the report is reliable, **describe** how the public might be convinced to read such reports before purchasing children's pyjamas.

Research

25 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your findings in a format of your choosing.

» Bottled water

Many people in Australia spend a lot of money on bottled drinking water. Are they doing this because of the way the water is marketed, or are there scientifically supported health benefits in drinking bottled water rather than tap water? Is tap water unsafe to drink? Have there been any cases where water bottlers have been fraudulent in their claims about the water they are selling? Investigate this issue. Find out what dentists and medical experts say about bottled water. Describe the scientific tests that are performed to check that the claims are correct and that the results that have been obtained are valid. After researching and comparing a range of evidence, evaluate whether we should drink bottled water in Australia or use tap water. Describe any limitations of your conclusions (e.g. does it depend on where you live?).

Figure 3 Why do people drink bottled water?

» Mobile phone safety

Research is continuing into the safety of mobile phones, although most people in the Western world have one or use one. You are an advisor to the Minister of Communications and Technology. Produce a report, of at least 10 points, detailing any research that has taken place into mobile phone safety. Make sure you include the outcomes or conclusions reached in these studies.

» Artificial colourings and flavourings in foods

Some people claim that certain artificial colourings and flavourings in foods can cause problems, such as hyperactivity in children. Use the internet and other resources to investigate this issue. Define the term ‘opposing evidence’. Identify whether the warnings are based on anecdotal evidence or scientific evidence. Discuss whether anecdotal evidence can be of value to scientists.

Figure 4 Are artificial colourings and flavourings in foods bad for us?

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 1 ‘Science toolkit’. Once you’ve completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Explain the differences between variables, independent variable and dependent variable in terms of what is controlled, changed or measured. Relate reliability of results to sample size and repetition of the test. Write a scientific report with all relevant sections.	☐	☐ Go back to Topic 1.1 ‘Scientists can test manufacturers’ claims’ Page 2
Define reading error, parallax error, zero error, significant figures, rounding off, SI system and derived units. Explain the importance of minimising experimental error.	☐	☐ Go back to Topic 1.2 ‘Scientists must be aware of experimental errors’ Page 4
Describe the purpose of Safety Data Sheets and provide examples of some of the types of information included on them.	☐	☐ Go back to Topic 1.3 ‘Scientists prepare Safety Data Sheets’ Page 8
Describe the differences between positive and negative correlation, and high, low and no correlation. Explain how to deal with outliers in data. Calculate the mean and mode of data.	☐	☐ Go back to Topic 1.4 ‘Scientists present their data accurately’ Page 10
Describe the factors involved in designing a valid experiment and explain how to increase the reliability of results. Provide examples of common errors that should be minimised or avoided. Present data in an appropriate manner.	☐	☐ Go back to Topic 1.5 ‘Science as a human endeavour: Scientists investigate consumer products’ Page 12

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Test your understanding of this chapter with one of three chapter quizzes.

CHAPTER 2

ECOSYSTEMS

How do we balance our needs with those of the environment?

What if?

Yeast cultures

What you need:

Spatula, dried yeast, warm water, sugar, test tube, ruler, thermometer, timer

What to do:

1 Add 1 spatula of dried yeast to warm water in the test tube and leave for 10–15 minutes before adding 1 spatula of sugar.

2 Measure the temperature of the water at the point of adding the sugar.

3 Measure the height of the yeast culture (an indication of the number of yeast cells) from the base of the test tube. This is the measurement at $t = 0$ minutes.

4 Measure the height of the culture every minute for 15 minutes.

5 Draw a graph of your results.

What if?

» What if hot water was added to the culture? (Would the number of yeast cells increase faster?)

» What if ice-cold water was added to the culture?

» What if twice as much sugar was added?

• What if no sugar was added?

2.1 All living things are dependent on each other and the environment around them

In this topic, you will learn that:

- An ecosystem is a community of living organisms (biotic) and their non-living surroundings (abiotic).
- Ecology is the study of the interrelationships of organisms with other organisms and with their non-living environment.

Video 2.1 What is an ecosystem?

biosphere
a layer around the Earth's surface that supports life; consists of the atmosphere, hydrosphere and lithosphere

ecosystem
a community of living organisms (biotic) and non-living (abiotic) factors

biotic
relating to the living organisms in an ecosystem

abiotic
all the non-living components of an ecosystem; for example, light, temperature, water

habitat
the place where a population of organisms live

population
a group of individuals of the same species living in the same place at the same time

community
different populations living in the same place at the same time

The biosphere – a home for our ecosystems

The **biosphere** is the living world. It is where all the plants, insects and animals live. The biosphere includes any place on Earth where life of any kind can exist. The biosphere can be thought of as the intersection between the atmosphere (gases), the hydrosphere (water) and the lithosphere (land). Because the biosphere is large, and its relationships are complex, we normally study smaller components of the biosphere, called **ecosystems**.

Ecosystems

Ecosystems vary in size. They can be as small as a puddle or as large as the Earth itself. Any group of **biotic** (living) and **abiotic** (non-living) things interacting with each other in a self-sustaining way is an ecosystem. Ecosystems are made up of **habitats**. A habitat is the place where a population of organisms live. Habitats vary in size depending on the amount of food, water and shelter they provide. A **population** is a group of living organisms that are the same species, living in the same place at the same time. When different populations interact with each other, they are called a **community**. For example, a population of humans can live in a town together. When all the plants in their gardens and their pets are included, then it becomes a community.

The habitat must supply all the needs of the organisms, such as food, water, warm temperatures, oxygen and minerals. These make up the non-living, abiotic conditions of the habitat. If the abiotic conditions are not appropriate for a population, then the individuals in that population will move to a more suitable habitat or will die out.

Figure 1 Wetlands such as those in Kakadu National Park in the Northern Territory are an example of an ecosystem.

Benefits of an ecosystem

Humans depend on ecosystems for survival. The variety of organisms that are in the community is important. If an ecosystem has a large biodiversity (many different types of organisms) then it is more likely to survive a major disruption, such as a natural or a human-caused event. If the biodiversity is low, the removal or extinction of a single population can affect all the other organisms that depend on that population for survival. For example, the removal of flies might mean the spiders starve, which would cause a decrease in their population as well as the birds that eat both spiders and flies. The fly larvae (maggots) would also decrease, slowing the breakdown of faeces and other waste, preventing plants from obtaining the important nutrients they need.

Biodiverse ecosystems provide these and a number of other benefits to ensure our continued existence.

CHALLENGE
2.1A: Making a biosphere
Go to page **165**.

EXPERIMENT
2.1B: Purification of water
Go to page **166**.

Figure 2 Dolphins come to the surface of the water to breathe in air and release carbon dioxide through an air hole.

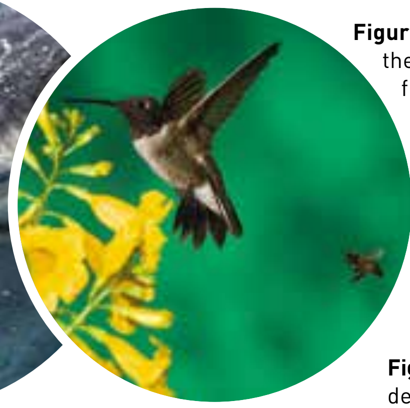

Figure 3 Pollination involves the transfer of pollen from the male parts of flowers to the female parts of other flowers of the same species. Animal pollinators, such as bees, small mammals or birds, visit the flowers for food such as nectar, and transfer pollen when they visit other flowers. Pollen may also be carried by wind or water.

Plants and animals work together to help maintain the balance of gases in the air

Plants and animals continuously cycle gases among themselves, the soil and the air. For example, during the day, plants take in carbon dioxide from the air and release oxygen into the air in a process called photosynthesis. All living things, including humans, use the oxygen in cellular respiration and release carbon dioxide into the air.

Insects, birds and bats help pollinate plants

Plants and animals interact in their search for food. Bees and other insects, as well as some birds and bats, transfer pollen from plant to plant. Pollination (Figure 3) not only helps wild plants, but is also important for crops. Over 70 per cent of plant species worldwide, including fruits and vegetables, are pollinated by animals, insects or birds.

Some organisms decompose organic matter

Some living organisms, called **decomposers**, get the food they need by feeding on the dead. Decomposers (such as maggots) not only prevent dead organisms from piling up, but they also take the nutrients from the dead body to use when building their own bodies. The nutrients are then passed on to other organisms that eat the decomposer organisms. Also, the nutrients that pass through the decomposers as waste end up in the soil in simpler forms that plants can absorb into their roots.

Wetlands and forests clean water

If you poured dirty water through a filter, you would expect cleaner water to come out. A similar thing happens in nature when water passes through a forest or wetland ecosystem. By slowing the flow of water, the plants and animals in the ecosystem trap some of the pollutants and sediments, leaving the water clean.

Figure 4 Fungi are important decomposers. These fungi are feeding on a rotting log.

decomposer
an organism that gains nutrients by breaking down dead organisms into simpler nutrients

Figure 5 The forested water catchment areas around Melbourne are vital for keeping its water supply clean.

2.1 Check your learning

Remember and understand

1 **Identify** three systems that interact to form a biosphere.

2 **Identify** the scientific word for the non-living components of an ecosystem. **Describe** three examples of these components.

3 **Contrast** (the differences between) a population and a community.

4 **Describe** two examples of the benefits that ecosystems provide.

Apply and analyse

5 **Explain** why Melbourne has such good drinking water. Figure 5 may help you to answer this.

Evaluate and create

6 Imagine that someone came to you and asked, ‘Why is the biodiversity of an environment so important?’ Draft a reply, taking into account the key concepts covered in this topic.

7 **Evaluate** the importance of bees to our food supply, by:
- describing the role of bees in food production
- describing the effect on food production if the bee population were to collapse or disappear
- identifying three factors that could cause the bee population to collapse
- deciding whether action is needed to maintain the bee population.

2.2 Relationships between organisms may be beneficial or detrimental

In this topic, you will learn that:

- In a mutual relationship, both organisms benefit.
- In a commensal relationship, one organism benefits and the other organism is unaffected.
- In a parasitic relationship, one organism benefits and the other (host) organism is harmed.

collaboration
a relationship between organisms of the same species working together to ensure their survival

mating
the pairing of a male and female of a species to produce offspring (babies)

competition
a type of relationship between organisms using the same limited resources in an ecosystem

symbiosis
a close physical relationship between two organisms of different species

mutualism
a type of relationship between two organisms of different species in which both organisms benefit

commensalism
a type of relationship between two organisms of different species, in which one organism benefits and the other is not affected

parasitism
a relationship in which one organism (parasite) lives in or on the body of the other organism (host) and benefits while the host is harmed

disease vector
a living organism that can transmit infectious disease between humans, or from animals to humans

In a community, all organisms interact with each other. Individuals in a population may need to collaborate and mate to ensure the species survives. This may also cause competition for food or shelter. Although some organisms do not affect other organisms in an ecosystem, most organisms are part of a large network of living things. These relationships may be beneficial or detrimental. Relationships may be between organisms of the same or different species. Sometimes two organisms from different species form a close relationship. This type of relationship is called symbiosis. Symbiotic relationships include mutualism, commensalism and parasitism.

Relationships within a species

There are three types of relationships between organisms of the same species.

> **Collaboration** occurs when organisms cooperate with each other to ensure their survival. For example, ants leave a trail of scent when they look for food, so that other ants can find the food too.

> **Mating** between members of the same species produces offspring, thus ensuring the survival of the species.

> **Competition** occurs when organisms use the same limited resource. For example, seedlings from the same species compete with each other for light and space as they grow.

Relationships between different species

Symbiosis

Symbiosis is a close physical and long-term relationship between two organisms of different species. Mutualism, commensalism and parasitism are all examples of symbiosis.

Mutualism is a relationship between two organisms in which both organisms benefit.

Commensalism is a relationship in which one organism benefits and the other organism is not affected. Commensalism is relatively rare in the natural world because it is unlikely that an organism will not be affected in some way by a relationship with another organism.

Parasitism is a relationship in which one organism (the parasite) lives in or on the body of another (the host). The parasite benefits but the host is harmed.

Some parasites have difficulty travelling between hosts. For example, malaria is a single-celled organism (*Plasmodium*) that uses mosquitoes to travel between humans. The mosquito acts as a **disease vector** – a living organism that can transmit infectious diseases between humans, or from animals to humans. When the mosquito sucks blood from the host, it also ingests some of the parasite. The next time the mosquito feeds, it releases the pathogen into a new host. This is how diseases such as malaria, Zika virus and dengue fever are spread.

EXPERIMENT
2.2: What if more seeds were planted in a pot? Go to page **167**.

Figure 1 Mutualism A lichen is made up of an alga and a fungus, although you cannot see the two organisms separately (except under a microscope). The alga produces energy for both through photosynthesis, and the fungus provides support and other nutrients.

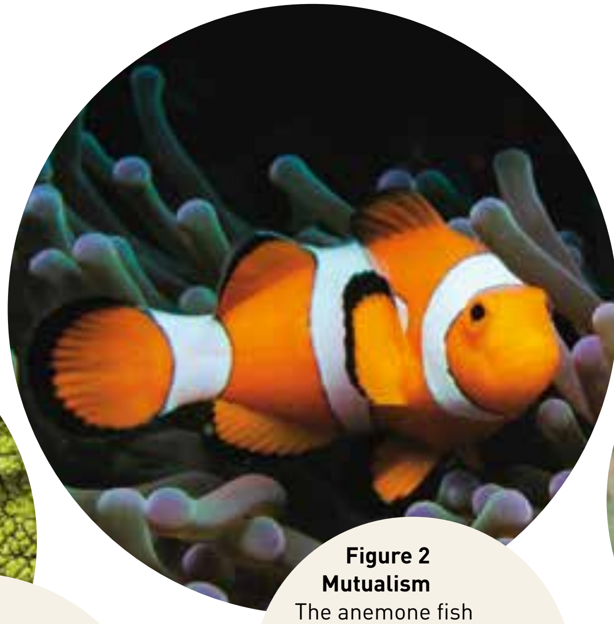

Figure 2 Mutualism The anemone fish hides within the tentacles of the sea anemone, where it is camouflaged from its predators. The sea anemone is cleaned of algae by the fish.

Figure 3 Commensalism Sometimes herbivorous animals such as cattle and water buffalo flush insects out of the grass as they wander through. Birds such as cattle egrets feed on the insects.

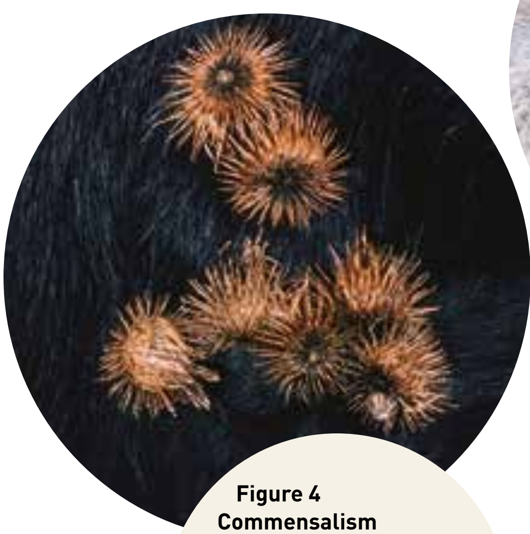

Figure 4 Commensalism Certain plants rely on passing animals to disperse their seeds. The seeds have tiny hooks that attach to animal fur and will usually fall some distance from the parent plant.

Figure 5 Parasitism Ticks attach to the skin of animals and slowly drink their blood. Bacteria from the digestive system of the tick can infect the animal.

Figure 6 Parasitism Hookworms attach to the inner lining of a human or animal intestine, feeding on passing nutrients. If the host doesn't eat enough, the worm has been known to burrow out of the intestines and travel to other organs, where significant damage can be done.

Non-symbiotic relationships

predator
an animal that hunts and feeds on another (prey) for food

prey
an animal that is hunted and killed by another (predator) for food

Two non-symbiotic relationships are predator–prey relationships and competition.

In a predator–prey relationship, one organism (the **predator**) eats another (the **prey**). Therefore, one benefits and the other is harmed. It is not symbiotic, because the relationship between the organisms is not long term and it only happens when a predator is hungry. Predator species and their prey species have a balanced relationship. If all the prey are eaten, then the predators will starve. A graph of predator–prey numbers (Figure 7) shows a typical pattern.

Competition may also exist between members of different species that share a resource such as food (Figure 8).

Inhibition is a particular type of competition that occurs when one organism produces a chemical that directly inhibits or blocks the growth and development of another (Figures 9 and 10).

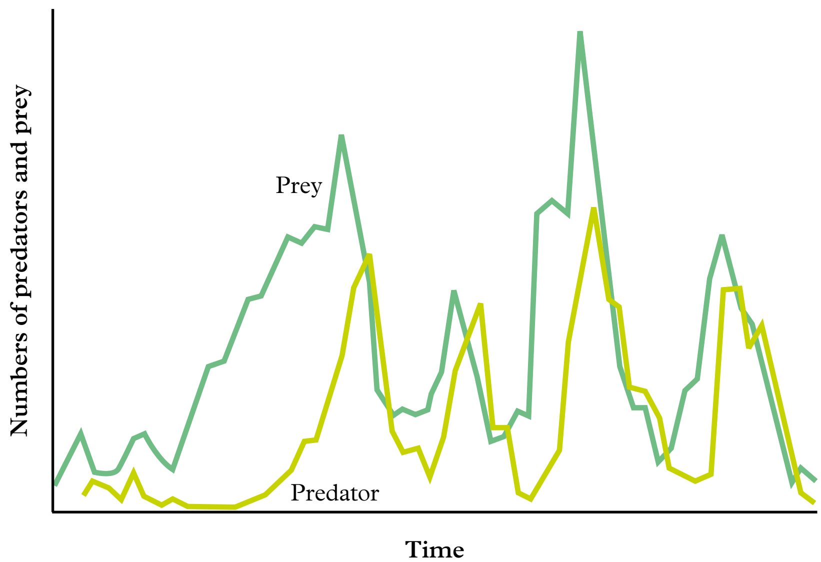

Figure 7 A predator–prey graph. The scales aren't shown but the prey numbers are mostly greater than those of the predators. Notice that the increase and decrease in prey numbers usually comes before the increase and decrease in predator numbers.

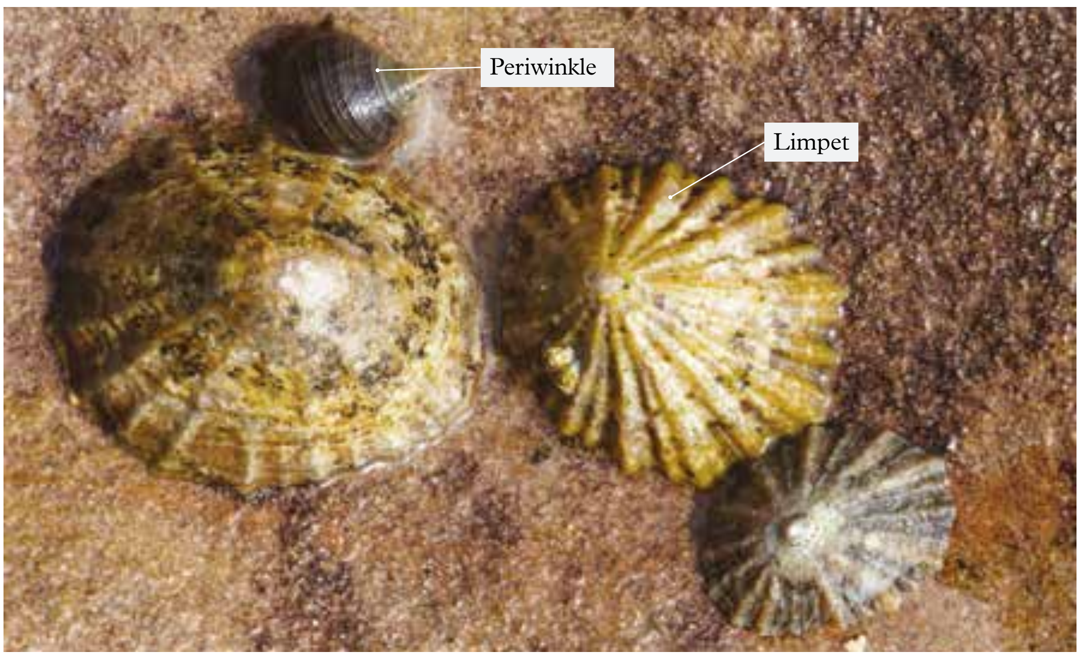

Figure 8 A black periwinkle (*Nerita*) competes for food with the limpet (*Cellana*) on a rock platform – both species feed on algae growing on the rocks. The periwinkle moves faster but does not eat all the algae in its path, so both can survive because the periwinkles usually leave some algae behind for the limpets. However, when the periwinkles are removed, the limpet population increases.

Figure 9 *Penicillium* fungus mould (seen here growing on an orange) produces an antibiotic called penicillin that inhibits the growth of many species of bacteria.

Figure 10 The *Lantana* plant was introduced into Australia and has become a weed. It releases a chemical into the soil that inhibits the growth of native plant species.

2.2 Check your learning

Remember and understand

1 **Define** symbiosis.

2 **Explain** why a large plant that produces a lot of shade prevents smaller plants from growing.

Apply and analyse

3 **Describe** an example of the following relationships.
   - **a** predator–prey
   - **b** mutualism
   - **c** commensalism
   - **d** parasite–host

4 **Contrast** (the similarities and differences between) a predator–prey relationship and parasitism.

5 Some eucalyptus trees have mistletoe plants living on them. Mistletoe has very similar leaves to eucalyptus leaves. Mistletoe can make its own food, but the stems send suckers into the eucalypt to obtain water and minerals. If too much water and minerals are removed, the eucalypt can die. **Identify** the type of relationship that exists between the eucalypt and the mistletoe. **Justify** your answer (by defining the relationship and matching it to this example).

6 Epiphytes are plants, such as ferns and some orchids, that grow high in the branches of other trees, especially rainforest trees. The epiphytes obtain sufficient light to make their own food, collect water from the moist air and obtain minerals from the decaying leaf litter that they catch at their leaf bases. The tree is not affected by these plants. **Identify** the type of relationship that is described. **Justify** your answer.

2.3 Population size depends on abiotic and biotic factors

In this topic, you will learn that:

- All populations in an ecosystem are in dynamic equilibrium.
- Populations can decrease due to deaths, emigration and natural disasters.
- Populations can increase due to births and immigration.

Video 2.3
Fieldwork

emigration
when an organism leaves an ecosystem

migration
the movement of a single organism or a population from one ecosystem to another

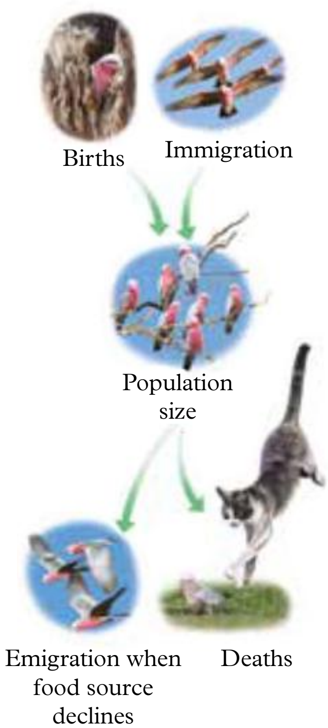

Figure 1 The size of a galah population in a particular area depends on the food available and the number of births and deaths.

The number of organisms in a population can be affected by many factors. Competition for food within a species and between different species can make it difficult for an organism to survive. An increase in the number of predators will cause a population to decrease. A drought or a bushfire can also have long-term effects on a population.

A dynamic balance

All organisms live in a complex web of interrelationships – with each other and with their environment. In an ecosystem, balance needs to be maintained so that all species can exist at their optimum population size.

At its simplest, gains due to reproduction and immigration must balance the losses due to death and **emigration** (leaving; Figure 1).

Consider the food web for an ecosystem shown in Figure 2. If the number of frogs decreased in this ecosystem, consequences could include:

> an increase in grasshopper numbers, which will cause a decrease in grass
> an initial increase in praying mantis numbers because of more grasshoppers
> a decrease in lizard numbers
> birds eating praying mantises instead of frogs and lizards
> a consequent decrease in praying mantis numbers
> a further increase in grasshopper numbers and even more loss of grass. If this was severe enough, the ecosystem would be at risk, as it depends on a good supply of grass.

The most likely outcome is that the bird population would decrease, so all species would return to balance with reduced population sizes. A positive effect is that decreased bird numbers might enable the frog population to recover.

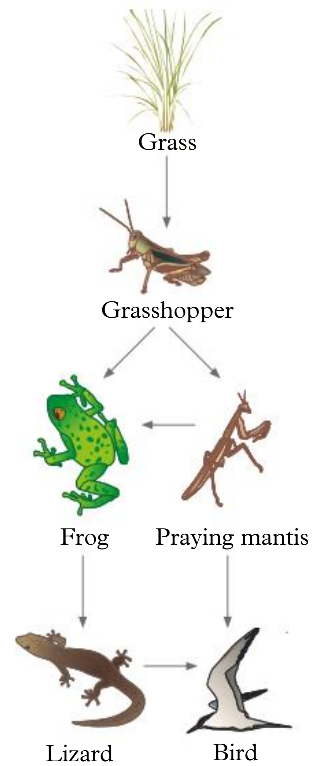

Figure 2 A food web for an ecosystem

Ecosystem balance is a type of dynamic equilibrium. Although change may upset the equilibrium, another equilibrium becomes established. Often, it is not greatly different from the original. Changes in ecosystems occur naturally but they may be intensified by external factors such as floods and bushfires. Reproduction, death, **migration**, natural events (such as seasonal changes), disasters (floods, droughts, earthquakes) and human intervention occur regularly.

Population dynamics

Population dynamics is the study of changes in population numbers within ecosystems. If scientists have an approximate idea of how

CHALLENGE

2.3: Bead and candy counting
Go to page **168**.

many of each species are in a certain location, they can make predictions and take certain precautions to conserve species.

Regular sampling provides information about increases and decreases in population numbers, and causes can be identified.

Counting organisms

There are a number of ways to determine the size of a population. The simplest way would be to count all the organisms, but in practice this is rarely possible. It is easier to estimate the total population by counting a sample from a helicopter, or by using quadrats or capture–recapture methods. For human populations, a census is the usual method.

For plants and stationary animals, **quadrats** (randomly selected square plots) are marked in an ecosystem (Figure 3). The organisms in each plot are counted, an average is obtained and then (knowing the total area of the ecosystem) the estimated number of organisms in the ecosystem is calculated. This method works well if a large number of quadrats are used and the organisms are evenly spread throughout the ecosystem.

For animals that are moving, **capture–recapture** is a popular method. Animals are captured in traps and marked with tags, correction fluid or permanent marker on their tails.

The number counted on the first capture is N_1. The animals are then released and it is assumed that they disperse evenly throughout the population. Another capture (recapture) is made one or two days (or nights) later.

The number of animals in this second capture that are marked are counted (M_2), as well as the total number caught in the second sample (N_2). An estimate of the population is then obtained using the following formula:

$$\text{Total number of animals} = N_1 \times N_2 \div M_2$$

Worked example 2.3 shows how to use the formula to calculate population size.

Capture–recapture is a suitable technique for estimating the population size of small Australian mammals, such as the marsupial *Antechinus* (the common bush rat). Because most native Australian mammals are nocturnal, the traps may be set at night and checked the next morning.

Figure 3 Using a quadrat

quadrat
a randomly selected square plot used to estimate the number of organisms

capture–recapture
a method of estimating the number of organisms in an ecosystem by capturing, marking and releasing a sample of the organisms

Worked example 2.3: Calculating population size

Scientists wanted to determine the size of a bilby population in a small reserve. They used the capture–recapture method to estimate the size of the population.

They captured and marked 9 bilbies on the first night and 8 bilbies (4 marked) one week later.

Calculate the size of the bilby population.

Solution

$N_1 = 9$ $\quad N_2 = 8$ $\quad M_2 = 4$

$$\begin{aligned}\text{Estimated number of bilbies} &= N_1 \times N_2 \div M_2 \\ &= 9 \times 8 \div 4 \\ &= 18\end{aligned}$$

2.3 Check your learning

Remember and understand

1 **Describe** suitable methods for estimating the size of populations of:
  a plants and stationary animals
  b other animals.

2 **Describe** the advantages and disadvantages of each of the methods you described in question 1.

Apply and analyse

3 Students on a field trip with a national park ranger set traps for a small nocturnal marsupial, *Antechinus stuartii*, in a heathland ecosystem. They captured 8 animals on the first night and marked white dots on their tails. Then they released them. On the second night they captured 10 animals, 4 of which were marked.
  a **Calculate** the estimated population size of *A. stuartii* in this ecosystem.
  b **Describe** one way the students could increase the accuracy of this experiment.

Evaluate and create

4 **Evaluate** whether growth in population size is always desirable (by discussing the advantages and disadvantages of continuous growth, and deciding whether the advantages are more important than the disadvantages).

2.4 Introducing a new species may disrupt the balance in an ecosystem

In this topic, you will learn that:

- An organism introduced into an ecosystem can consume the resources of other native organisms.
- An ecosystem needs to establish a new equilibrium after the introduction of a new species.
- Biological control involves the deliberate introduction of an organism that will control or decrease the population of a non-native plant or animal.

All ecosystems are in a precise balance that ensures enough food and resources to support the community of organisms. Introducing or removing a species from an environment can disrupt this balance and have devastating effects on other populations in the ecosystem.

Introducing rabbits

European rabbits were brought to Australia on the First Fleet in 1788. The 250-day journey ensured that the rabbits were well domesticated by the time they arrived here. The rabbit population around Sydney did not grow very quickly. However, when the rabbits were introduced into Tasmania, populations of thousands quickly became established.

Rabbits breed very quickly. A single female rabbit can have up to 14 babies in each litter. If the average female rabbit produces one litter a month, and these new babies are able to breed within six months, the population can grow rapidly (see Figure 2).

Rabbits for hunting

In 1859, farmer Thomas Austin received 24 wild rabbits from England, along with partridges, hares and sparrows, for hunting. These were released near Geelong. This time the rabbits were better equipped to survive. In England, the winters were very cold and these abiotic (non-living) conditions slowed the growth of rabbit populations there.

Figure 1 Rabbits have had a devastating effect on ecosystems in Australia.

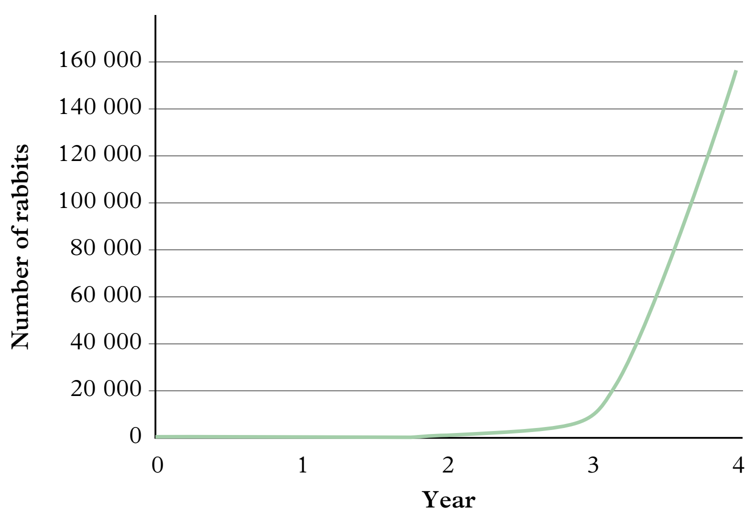

Figure 2 The potential growth of a rabbit population over four years from a single female rabbit (assuming unlimited food and no predators).

CHALLENGE
2.4: Rabbit and fox chasey
Go to page **169**.

In Australia, the winters were much warmer and the clearing of the scrubland created large areas of farmed grasses for food. There were also few predators of rabbits. Over the next 40 years, the rabbits spread as far as Queensland, Western Australia and the Northern Territory.

Controlling the rabbit population

By 1887, rabbits were causing so much damage to the environment that the New South Wales government offered a reward for any new method to decrease the population. Rewards were offered for each rabbit killed, and a rabbit-proof fence across large sections of Western Australia was trialled (Figure 3).

The increase in the rabbit population had a large impact on the local ecosystems. The rabbits competed with the local marsupials for food and destroyed large sections of the habitat with their burrows (Figure 4). Predators of the rabbits (such as dingoes and eagles) grew in numbers due to the increase in food. Unfortunately, these increased numbers of predators also ate the local marsupials, causing those populations to decline. All these factors contributed to the permanent loss of several species of native plants and animals.

Figure 3 Completed in 1907, a rabbit-proof fence was built between Cape Keraudren and Esperance in Western Australia.

Macquarie Island rabbits

In 1985, scientists on Macquarie Island (halfway between Australia and Antarctica) devised a plan to eradicate the cats that had been introduced to the island since the early nineteenth century. It was thought that this would increase the native burrowing bird

Figure 4 Rabbits bite tusks of grasses very close to the ground. Combined with digging extensive burrows, this makes the soil more prone to erosion.

populations on the island. However, when the cats were killed, the island rabbit population increased dramatically, destroying native plants and affecting many other organisms that were native to the island. Scientists needed to find a way to control the rabbits.

Figure 5 a Before: This slope on Macquarie Island had vegetation as recently as 2007. **b** After: The same slope a few years later – it has been ravaged by rabbits since cats were eradicated.

biological control
a method of controlling a population by releasing a living organism (a parasite or consumer) into an ecosystem

disease
a disorder or condition that interrupts the normal functioning of an organism

immune
able to fight an infection as a result of prior exposure

Biological control

All efforts to control the rabbit population by physical means were unsuccessful. In 1938, CSIRO scientists studied a way to control the disease using a living organism (**biological control**). They tested a virus called *Myxoma* for its ability to cause **disease** in rabbits. This virus causes a disease with symptoms including fever and swelling around the head of the rabbit. Death occurs within 14 days. *Myxoma* was eventually released in the wild and quickly killed almost all the rabbits that caught the infection. This increased Australia's wool and meat production within two years. However, a small percentage of rabbits were unaffected by the disease. These rabbits survived and bred a new population of rabbits that were **immune** to the disease. New viruses, such as the rabbit calicivirus, have been tried, with similar results.

Before a species is introduced as part of biological control of pests, scientists must model the possible effects on populations that compete for the same food source or the predators that may prey on them. Scientists must effectively map the food web of the ecosystem and how the balance between all organisms in the community will be affected by the introduction of the biological control organism.

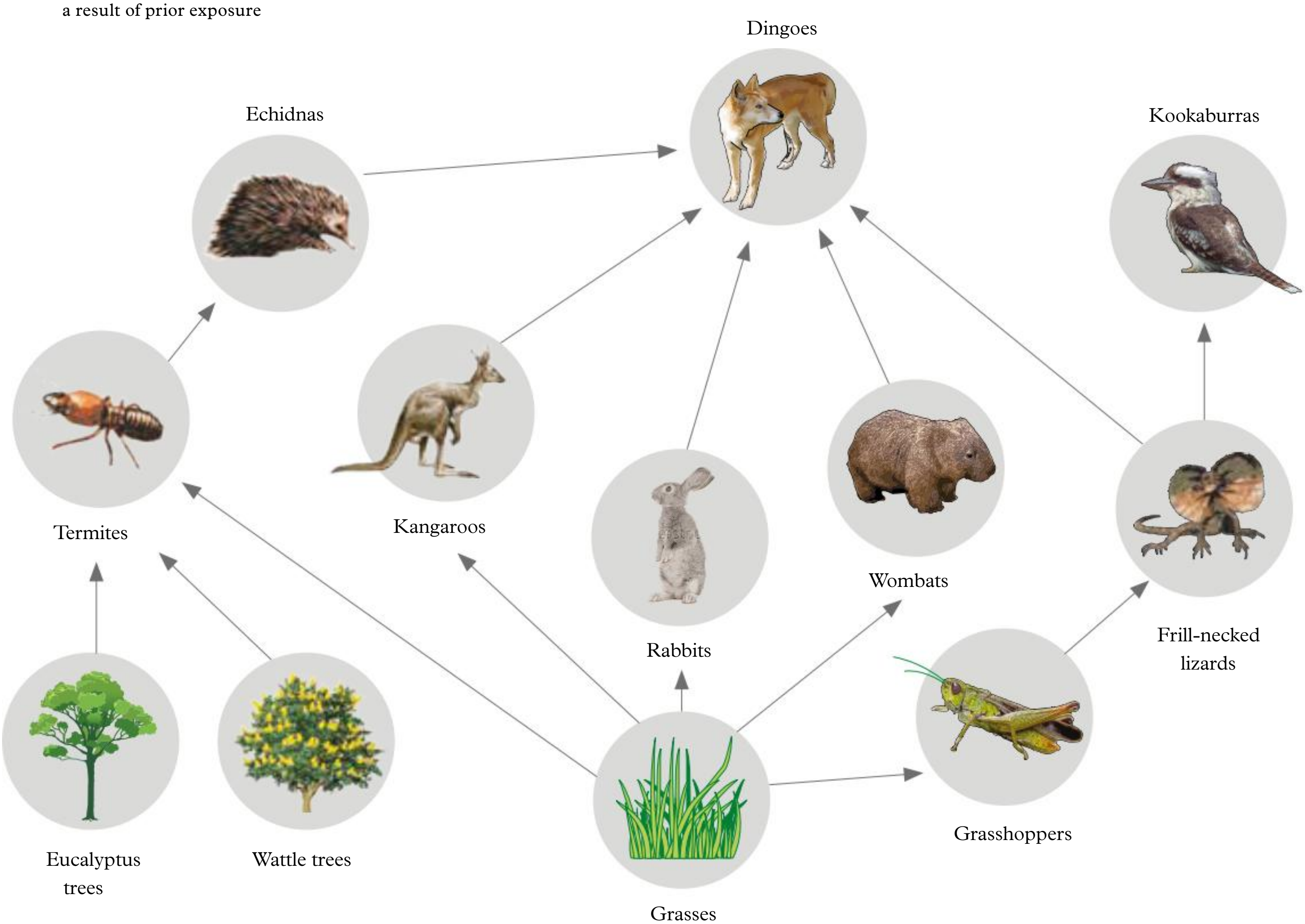

Figure 6 Rabbits compete with grasshoppers, wombats, kangaroos and termites for grass.

2.4 Check your learning

Remember and understand

1 **Explain** why rabbits are referred to as an introduced animal in Australia.

2 **Identify** two reasons why the rabbit population was able to increase so quickly when introduced to Australia.

3 **Define** the term 'biological control'.

Apply and analyse

4 Use the food web in Figure 6 to **identify** two populations that would increase as a result of the introduction of rabbits.

5 **Explain** the effect a large rabbit population would have on the ecosystem in Figure 6.

6 **Explain** why *Myxoma* is no longer effective in controlling rabbit populations.

Evaluate and create

7 **Evaluate** the ethics of using biological control of rabbits, by:
- describing how *Myxoma* infection affects the health of a rabbit
- describing the effect a large rabbit population has on a native environment, including the native plants and animals
- describing how a large rabbit population affects our ability to grow food
- deciding whether the life (and *Myxoma*-related death) of a rabbit is more or less important than the effects you described above. (Does the end justify the means?)

Figure 7 Plants are an important part of an ecoystem.

CHALLENGE

2.5A: Photosynthesis role play
Go to page 170.

2.5 Energy enters the ecosystem through photosynthesis

In this topic, you will learn that:

- Photosynthesis and chemosynthesis are the original source of energy in an ecosystem.
- Photosynthesis is the transfer of light energy from the Sun into chemical energy in glucose.
- Carbon dioxide and water react in the presence of light energy to produce oxygen and glucose.
- Excess glucose is stored as starch.

Video 2.5A
Photosynthesis

Video 2.5B
What is photosynthesis?

Figure 1
Photosynthesis occurs inside chloroplasts. The image shows a cross-section of two chloroplasts, seen through an electron microscope.

photosynthesis
a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

Ecosystems rely on the transfer of energy from one part to another. The first source of energy in most ecosystems is solar energy via photosynthesis. Animals cannot directly use energy from the Sun. Even in caves and other places where there is no light, the energy may be from dead plants and animals, which originally obtained their energy from the Sun. An exception is chemosynthetic bacteria on the ocean floor and in the craters of volcanoes – these bacteria trap the energy from chemicals and chemical reactions occurring under the Earth's crust.

What is photosynthesis?

Living things need energy to grow and repair, to defend themselves, and to move around. The energy in an ecosystem usually originates from the Sun. Plants, some algae and some bacteria are able to transform this light energy into chemical energy through a process called **photosynthesis**. In this process, water and carbon dioxide are converted into glucose (a sugar), oxygen and energy. The overall equation for photosynthesis is:

carbon dioxide + water → glucose + oxygen + water

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

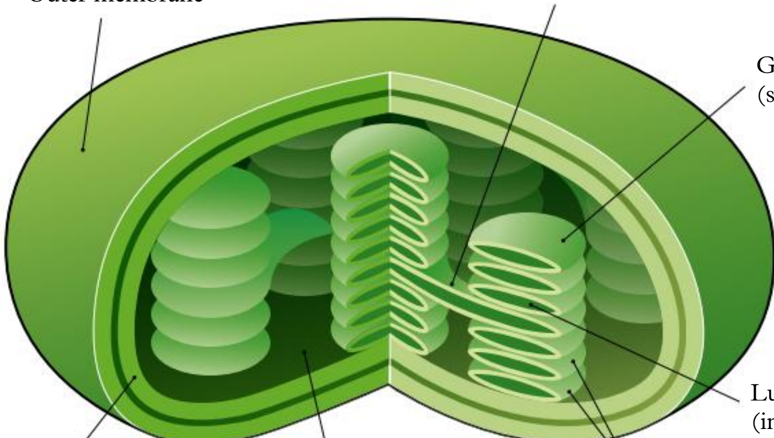

Figure 2 The structure of a chloroplast

EXPERIMENT

2.5B: Inputs and outputs of photosynthesis
Go to page 171.

EXPERIMENT

2.5C: Effect of carbon dioxide on starch production
Go to page 172.

Where does photosynthesis happen?

On average, a plant leaf has tens of thousands of cells. A single cell contains 40–50 chloroplasts, which contain the green pigment **chlorophyll**. Chlorophyll captures the Sun's light energy and uses it in the formation of glucose.

Plants do not breathe the same way we do. Instead, they take in the carbon dioxide needed for photosynthesis through microscopic pores called **stomata** (singular 'stoma') in the leaves (Figure 3). The water needed for photosynthesis enters through the roots and travels to the leaves, where the glucose is made in the chloroplasts.

Factors that affect photosynthesis

Many factors can affect the rate of photosynthesis. If there is not enough light, photosynthesis cannot occur. This can be a problem for young plants trying to grow on the floor of a rainforest. The taller plants compete with them for light. Water is also needed for photosynthesis. In the desert, the lack of rain can restrict the amount of photosynthesis, and therefore the amount of glucose produced.

What happens to the glucose?

Plants are sugar factories, making millions of glucose molecules during daylight hours. Plants require a constant supply of glucose for energy to grow and to repair damage. In daylight, more glucose is made than can be used directly by the plant, so excess glucose is stored in the form of **starch** and other carbohydrates in the roots, stems or leaves of the plant. Some plants store starch in underground storage organs, such as roots and tubers (for example, potatoes, carrots and parsnips all store starch in this way).

Figure 5 Plants use energy from the Sun to grow and repair.

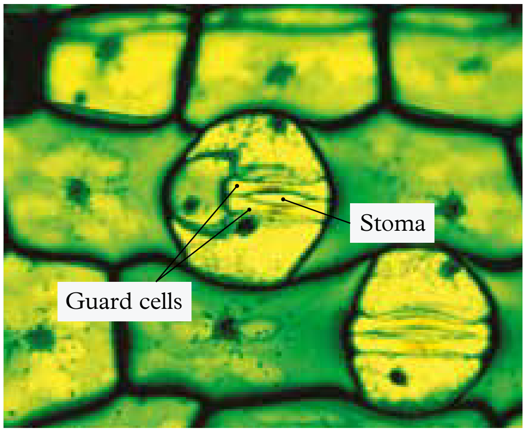

Figure 3 Guard cells open and close the stomata of a plant.

chlorophyll
a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

stomata
small holes in a plant leaf surrounded by guard cells that control their opening and closing; singular 'stoma'

starch
a complex form of sugar that is found in certain foods (e.g. bread, potato and rice)

Figure 4 Starch can be stored in roots and tubers of plants. During the night there is no sunlight for photosynthesis, but plants still need energy to stay alive. Plants break down starch into glucose so that they can survive at night.

2.5 Check your learning

Remember and understand

1 **Identify** where the process of photosynthesis occurs in a plant.
2 **Identify** the chemicals that are used in the photosynthesis reaction.
3 **Describe** how the chemicals needed for photosynthesis enter a plant.

Apply and analyse

4 Draw a flow diagram **summarising** the inputs and outputs of photosynthesis.
5 **Identify** two plant foods that we eat because they are sources of starch.

Evaluate and create

6 'Photosynthesis is the most important metabolic process on Earth.' **Evaluate** the above statement by:
- describing why photosynthesis is important in an ecosystem
- describing what would happen if photosynthesis was not able to occur
- deciding whether the statement is correct.

2.6 Energy flows through an ecosystem

In this topic, you will learn that:

- The energy in glucose is used for movement, growth and repair of an organism.
- The energy in glucose molecules must be converted to ATP in a process called cellular respiration.
- Only 10 per cent of the energy is passed on to the next level in a food chain.
- Waste energy in the form of heat is produced.

Video 2.6A Ecosystem energy transfer

Video 2.6B Cellular respiration equation

Living systems continuously take in energy from the Sun. When one organism eats another, it takes the energy that was stored in the food's cells and tissues. Of this stored energy, 90 per cent is transformed into movement, or the growth and repair of the animal's own cells. This transformation of energy produces a by-product: heat energy. Of all the stored energy that is consumed, only 10 per cent is available to eventually be passed from one organism to the next in a food chain (Figure 1). This means the energy in an ecosystem needs to be constantly replaced (by plants capturing sunlight), as most of it is released as unusable heat energy. Worked example 2.6 shows how to calculate energy in an ecosystem.

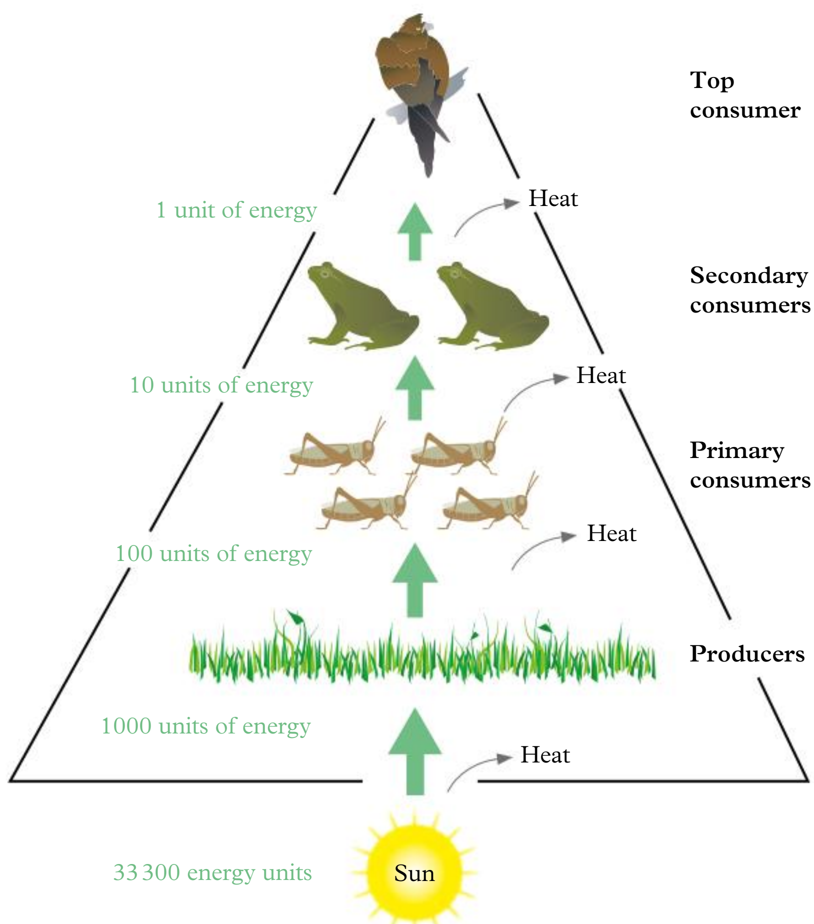

Figure 1 The movement of energy along a food chain can be represented by an energy pyramid. The size of each trophic level represents the amount of energy being passed on to the next level in the food chain.

CHALLENGE

2.6: Food for thought
Go to page **173**.

Energy for work

Energy transformations are an essential part of the metabolic processes (chemical reactions that keep cells working) that keep an organism alive. We can describe these processes as the 'work' of living organisms. Some of the types of 'work' performed by living organisms are shown in Table 1.

Table 1 The 'work' of living organisms

Type of work	Examples
Building compounds	All organisms use energy to build and replicate molecules so they can manage metabolic processes, grow and pass information on to offspring.
Communication inside an organism	Energy is needed for communication within and between cells. Electrical energy and chemical energy are used when nerves transmit information throughout the body.
Physical movement	Energy is supplied for physical movement, such as movement of leg or arm muscles, and involuntary movement, such as contraction of the heart. In plants, energy is used for movement towards sunlight.
Transport	Energy is required to move nutrients and wastes throughout an organism's body. Electrical potential energy is needed to transport materials into and out of cells.

Figure 2 Energy transformations are vital to keep plants growing.

Worked example 2.6: Calculating energy in an ecosystem

If 2000 energy units (joules) were eaten by the grasshopper in Figure 1:

a **calculate** the number of joules available to be used by a frog that ate the grasshopper

b **identify** how the remaining energy was used.

Solution

a Only 10% of the energy in an organism is passed on to the next level of the food chain.

Energy passed on to the frog = 10% of 2000 joules

$$= \frac{10}{100} \times 2000$$

$$= 200 \text{ joules}$$

The frog would receive 200 joules of the 2000 joules eaten by the grasshopper.

b The remaining 1800 joules would have been used by the grasshopper for moving, growing and repairing damage to its body. The chemical reactions in these processes produce the heat energy that is released into the environment.

What is cellular respiration?

Whenever we burn a fuel, such as wood or oil, we release the energy that has been chemically stored in the molecules. This energy in the fuel molecules is organised, or ordered, because it is tied to the molecule. Burning requires oxygen and is a rapid process, releasing the energy as heat energy. Carbon dioxide and water are also produced.

Cellular respiration is similar to burning. Glucose is the molecule that our body uses for fuel. Each cell uses oxygen to 'burn' glucose and convert the energy into ATP (adenosine triphosphate). ATP is much easier for our bodies to use for energy. Fats and proteins can also be converted into ATP in cellular respiration.

Oxygen is used during cellular respiration, and carbon dioxide and water are waste products. Because oxygen is needed for this process, it is often called **aerobic respiration**. The process occurs in the **mitochondria** of all plant and animal cells.

aerobic respiration
the second step in the breakdown of glucose to carbon dioxide and water; occurs in the mitochondria when oxygen is present and produces 34 ATP molecules

mitochondrion
an organelle of a cell, where energy is produced (plural: mitochondria)

glycolysis
the first part of cell respiration in which glucose is broken down to produce energy

Figure 3 An ATP (adenosine triphosphate) molecule. ATP is the energy currency of organisms.

Figure 4 The fermentation of yeast produces carbon dioxide, which makes bread rise.

A closer look at cellular respiration

The energy stored in the chemical bonds of glucose ($C_6H_{12}O_6$) is transferred into ATP during cellular respiration. The general equation for cellular respiration is:

Reactants	Products
glucose + oxygen →	carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36ATP$$

The breakdown of glucose to carbon dioxide and water occurs in two major steps.

1. **Glycolysis** occurs in the cytoplasm and produces 2 ATP molecules and pyruvate.
2. Aerobic respiration occurs in the mitochondria in aerobic conditions (when oxygen is present). It produces 34 ATP molecules.

When we exercise, our muscle cells can run out of oxygen for aerobic respiration. The cells switch to producing energy anaerobically (without oxygen) and lactic acid is produced as a waste product. This does not produce as much ATP energy as aerobic respiration, which is why our muscles feel weaker. In yeast cells, anaerobic respiration (known as fermentation) produces alcohol and carbon dioxide.

Figure 5 When we exercise, cells produce energy without oxygen, which is why our muscles feel weaker.

Photosynthesis and respiration

Photosynthesis and respiration are effectively the opposite of each other. Photosynthesis traps light energy from the Sun, converting it into the chemical energy of glucose. Respiration moves the energy out of glucose and into ATP, which can then be used by cells. Many of the molecules in the two reactions are the same, but they are part of different pathways. Glucose is a product of photosynthesis, whereas it is a reactant in respiration.

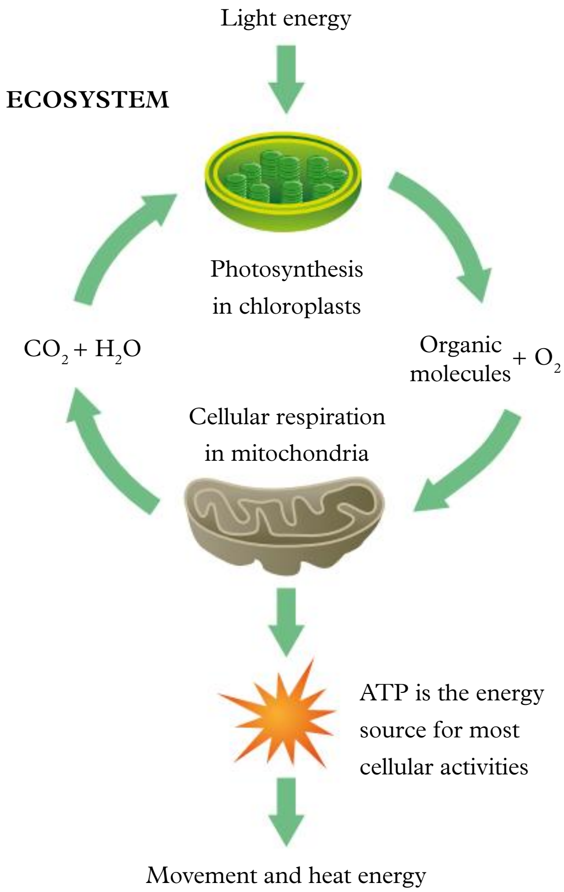

Figure 6 Unlike matter, which is recycled in an ecosystem, energy flows in one direction only, entering as sunlight and leaving as movement and heat.

2.6 Check your learning

Remember and understand

1. **Explain** why plants undergo aerobic respiration.
2. **Explain** why cellular respiration is constantly occurring in cells (by identifying the key product of the reaction and what the organism uses this molecule for).
3. **Identify** the two main steps of respiration.
4. **Identify** the location of cellular respiration in cells.

Apply and analyse

5. **Compare** (the similarities and differences between) cellular respiration and photosynthesis.
6. If a plant converts 50 joules of energy in photosynthesis, **calculate** the amount of energy a herbivore will obtain when it eats the plant.

2.7 Matter is recycled in ecosystems

In this topic, you will learn that:

- Matter cannot be created or destroyed, which means it must be recycled.
- The carbon cycle describes how carbon atoms cycle through an ecosystem.

Figure 1 Logging of rainforests can affect precipitation.

Cycles of matter

Matter (made up of atoms) cannot be created or destroyed. This means matter must be recycled. The cycling of matter from the atmosphere or the Earth's crust and back again is called a biogeochemical cycle (*bio* means 'living'; *geo* means 'earth'). Plants absorb simple molecules such as carbon dioxide, water and minerals, and convert them into sugars by photosynthesis. Animals eating the plants use the sugars and other molecules. When plants and animals die, the molecules in the matter are rearranged by decomposers to obtain energy. Decomposers are essential to the cycles of matter – they break down the molecules in dead organisms and convert them into simple molecules that can be reused by plants.

Scientists will often follow particular molecules or atoms as they cycle through the environment, to establish the health of the ecosystem.

Water cycle

The global water cycle is driven by heat from the Sun. Three major processes driven by solar heat are **precipitation** (rain, snow, sleet), **evaporation** and **transpiration** from plants. These processes continuously move water between land, oceans and the atmosphere. On land, the amount of precipitation is greater than the amount of evaporation/transpiration, and the excess water feeds lakes, rivers and groundwater, all of which flow back into the sea.

Humans can alter the water cycle. For example, cutting down rainforests changes the amount of water vapour in the air (due to transpiration), which alters precipitation.

matter
anything that has space and volume; matter is made up of atoms

precipitation
the process in which water vapour in the upper atmosphere becomes liquid water in the form of rain, snow or sleet and falls to the ground

evaporation
a change in state from liquid to gas; also a technique used to separate dissolved solids from water

transpiration
the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

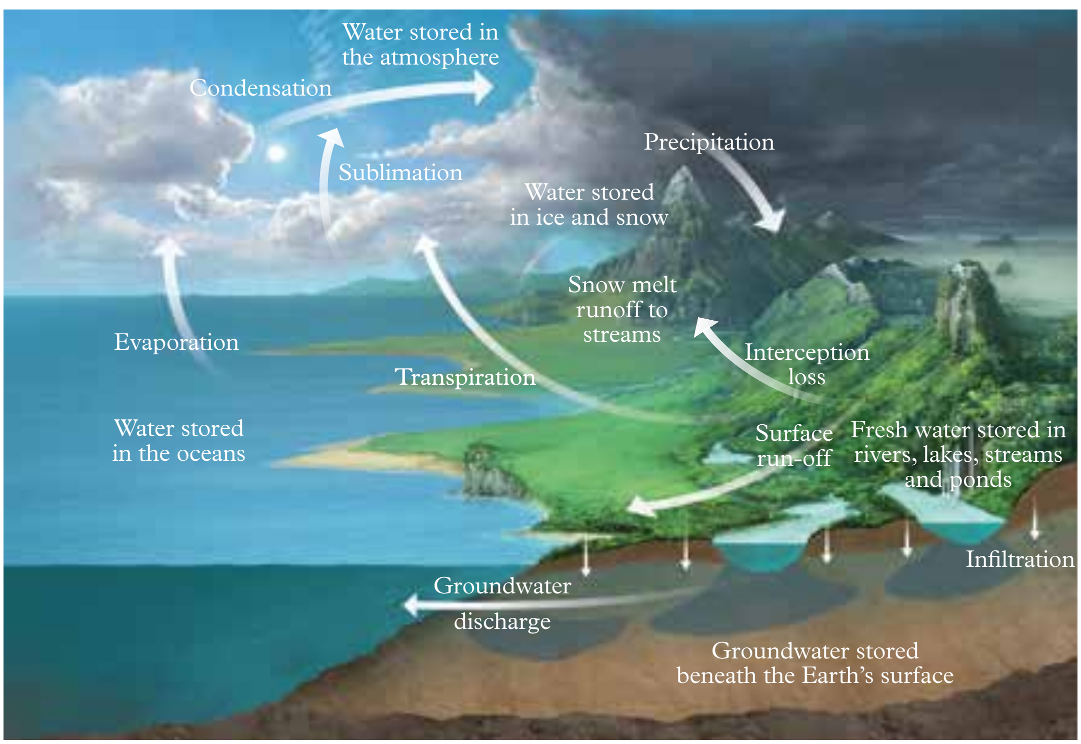

Figure 2 The water cycle

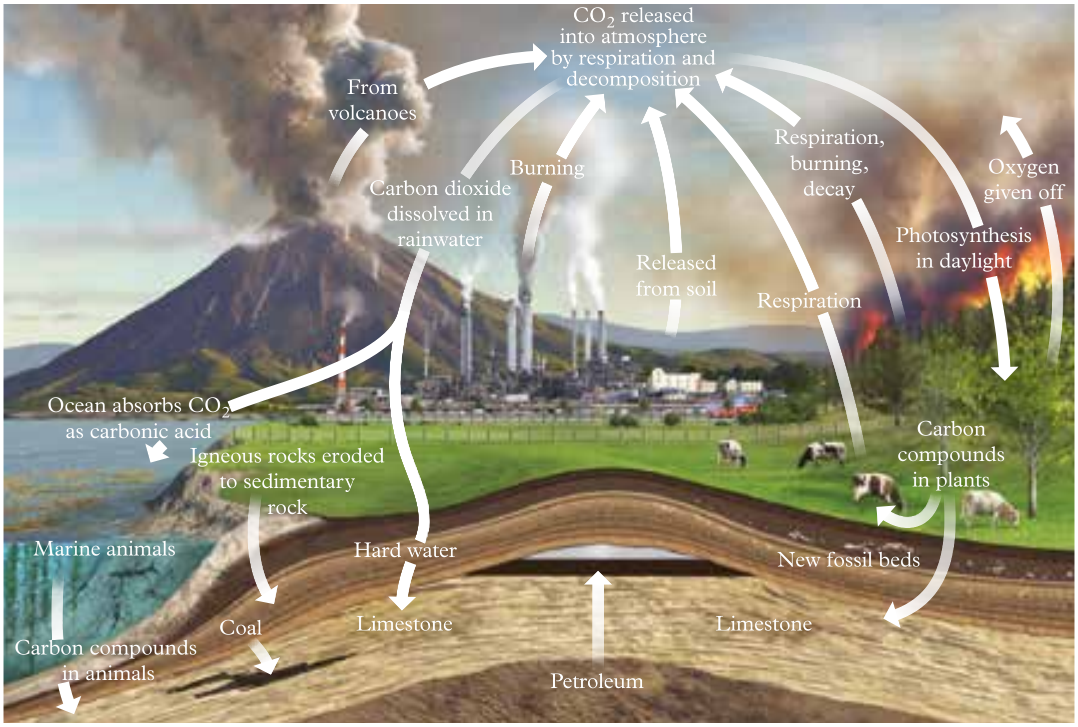

Figure 3 The carbon cycle

Figure 4 A termite mound in the savannah of northern Australia

Water is not available equally in all ecosystems. Water that has evaporated from an ocean may later fall as rain on a forest thousands of kilometres away. Australia is an example of this situation: some areas may be in drought and others may have floods, and organisms in ecosystems in both areas may be affected by disruption of the water cycle.

Carbon cycle

Carbon atoms are found as carbon dioxide in the air and in compounds such as sugars, proteins and lipids (such as fats) in the bodies of living organisms. Globally, the return of carbon dioxide to the air by respiration is balanced by its removal in photosynthesis. Other ways of returning carbon dioxide to the air include the burning of fossil fuels, bushfires and the decomposition of dead matter. The natural balance of this cycle is disturbed by excess burning, which contributes to the **enhanced greenhouse effect** (see Topic 2.9).

Termites recycle carbon

Plant cell walls are made of cellulose, a complex molecule that is insoluble in water and does not break down easily. Fungi are able to break down cellulose and play a major role in the decomposition of wood, but they require a moist environment, such as can be found in a rainforest. In drier areas of Australia, such as forests and woodlands in tropical and subtropical areas, as well as savannah grasslands, termites have a major role in the decomposition and recycling of carbon.

Termites are social insects and live in nests. You may have seen termite mounds in drier parts of Australia (Figure 4). Micro-organisms in the guts of termites break down the cellulose of plant material such as grasses, plants and wood. Scientists have estimated that termites recycle up to 20 per cent of the carbon in ecosystems such as savannah grasslands.

enhanced greenhouse effect
an increase in carbon dioxide and other heat-capturing gases in the atmosphere, resulting in increased warming of the Earth

2.7 Check your learning

Remember and understand

1 **Define** the chemical term ‘matter’.

2 **Describe** how matter moves through an ecosystem.

3 **Explain** what is meant by the term ‘carbon cycle’.

4 **Describe** three ways carbon dioxide can be released into the environment.

5 **Describe** two ways carbon dioxide can be removed from the atmosphere.

Apply and analyse

6 ‘You are eating the same atoms that were in dinosaur poo!’ **Evaluate** the accuracy of this statement (by describing how matter moves through an ecosystem, describing how the atoms in dinosaur poo will change over time and deciding whether the statement is correct).

7 **Contrast** (the differences between) the flow of energy in an ecosystem and the flow of matter in an ecosystem.

2.8 Natural events can disrupt an ecosystem

In this topic, you will learn that:

- The size of a population will increase and decrease as a result of many natural events.
- The limitation of resources, presence of predators, migration and emigration will all affect population numbers.
- Natural disasters such as drought, floods and bushfires will cause changes throughout the ecosystem.
- Some plants and animals have adapted to cope with bushfire.

carrying capacity the maximum number of organisms in a population that can be sustained by an ecosystem

Limiting resources

As the size of a population reaches its maximum **carrying capacity** (ability of the environment to support it), some of its resources, such as food, space and shelter, will become limited. This means some organisms will not have access to these resources and will either die or emigrate (leave). When this occurs, the population will stabilise (reach its maximum size). Once the population decreases, there will be enough resources for those remaining. The population will remain in balance, or equilibrium.

Seasonal changes

When the weather becomes colder, many animals migrate to warmer areas. As a result, their populations decrease in one environment and increase in another. During the breeding season, usually spring, the numbers of animals increases. Flowering plants are pollinated and form seeds that spread throughout the environment, and later germinate. As the population increases, so does competition for resources. Some of these resources can become limiting factors (factors that can affect the survival of an organism). As a result of this competition, some members of the population survive and others die, allowing the population to maintain its balance.

Figure 1 Short-tailed shearwaters leave their burrows on Montague Island on the southern coast of New South Wales and fly to feeding grounds in the area of the Bering Sea (between Russia and Alaska) during the northern hemisphere summer. They return to breed in late September.

Natural disasters

Australia has a widely fluctuating environment. Years of drought have been mixed with torrential rains and flooding. When extreme natural change affects humans, we call these changes natural disasters.

Impacts of floods and droughts

Floods are an overflow of water onto dry land, which has an immediate effect on the growth of plants and the germination of seeds. This is particularly noticeable after a drought, during which plants have managed to survive and seeds have remained dormant. Marine ecosystems do not benefit from floods on land. Run-off brings sediment, pesticides and fertilisers into the marine ecosystem, causing some algal species to dominate the environment.

Floods can be a hazard for some animal life. Small mammals often escape to higher ground. Snakes are flushed out of their cover, as witnessed in the 2011 Queensland floods, and can be a potential danger to humans. Aquatic animals benefit enormously from floods. Fish can breed in water bodies such as lakes. Water birds then have an abundance of fish, insects and waterweeds as sources of food, and they can breed in great numbers, temporarily changing the balance in populations.

Droughts pose an even greater challenge than floods. During a drought, animals migrate elsewhere and manage to survive until conditions have improved. Some populations ‘hang on’ during drought, but other ecosystems are severely affected. For example, extremely dry topsoil was blown from central Australia

CHALLENGE

2.8: Natural disasters in Australia
Go to page **174**.

Figure 2 Flooding in Queensland in 2011

Figure 3 Drought poses a great threat to life.

Figure 4 The bushfires across Australia in 2020 devastated entire communities and put wildlife at risk.

Figure 5 Lack of foliage means a lack of food and shelter for animals.

to Melbourne and Sydney in recent years. This erosion removed essential nutrients for many plants, animals and agricultural ecosystems.

Impacts of bushfires on ecosystems

Bushfires destroy both plant and animal life. Many native Australian plants are adapted for fire resistance and tolerance, and may actually rely on fires to complete their life cycles. For example, wattle seeds will only open when exposed to heat and moisture. These adaptations include:

> thick bark that insulates and protects the growing and transporting tissue inside the trunk (stem; see Figure 6)
> epicormic buds beneath the bark that can regenerate the branches when the fire has passed (Figure 7)
> lignotubers within the roots that can grow into new shoots after fire (Figure 8).

Most *Eucalyptus* species have epicormic buds and lignotubers. While some plants are well adapted, other species of plants do not survive. This can result in the permanent loss (extinction) of the species.

Like plants, some animal populations in fire-prone areas are tolerant of fire. These species can sense fire and escape to other areas or into underground burrows. The most vulnerable are small invertebrates and insects at the larval stage. Even if they survive the fire, many animals will need to migrate away from the environment. The change in the vegetation and the soil conditions alters their food supply and sheltering options. The loss of shelter increases the risk of predation in some cases. Animals may not return to the area for a long time.

epicormic bud
a small growth beneath the bark of a plant that allows regeneration after a fire

lignotuber
a small growth in the root of a plant that allows regeneration after a fire

Figure 6 Native Australian trees have thick bark to protect them from fire.

Figure 7 Epicormic buds beneath bark can regenerate branches after fire.

Figure 8 Lignotubers within roots grow into new shoots after fire.

2.8 Check your learning

Remember and understand

1 **Define** the term 'carrying capacity'.
2 **Identify** two animals (not birds) that migrate due to changing seasons.
3 **Describe** one way an animal might survive a bushfire.
4 **Describe** two ways a plant may have adapted to surviving a bushfire.

Apply and analyse

5 **Identify** one long-term effect on plants of a:
  a drought
  b bushfire
  c flood.
6 In relation to resources in an ecosystem, **describe** what the term 'limiting' means. **Contrast** (the differences between) 'limiting' and 'limited'.

2.9 Human activity can disrupt an ecosystem

In this topic, you will learn that:

- Humans compete with other organisms for resources.
- Water is an essential resource for all organisms.
- Human-generated pollution can affect the survival of other organisms.
- Humans are responsible for the enhanced greenhouse effect.

Video 2.9
Ask a scientist – Dr Dewi Kirono (climate scientist)

Figure 1 Numbers of Murray cod, and other native fish, have decreased significantly due to irrigation. Some fish have now been declared rare or endangered.

Figure 2 Since James Cook sailed into Botany Bay near Sydney in 1770, this ecosystem has become urban because of the many infrastructure changes that have taken place.

Humans can have a significant short-term or long-term impact on the well-being and survival of other species. We compete with plants and animals for resources. We change the ecosystem by removing vegetation, increasing erosion of topsoil and causing global warming.

Competition for resources

In 2021 the world's human population was approximately 7.8 billion and it is predicted to rise to about 9.9 billion by 2050. This will cause an increased demand for food, which means more pressure on the natural resources of the land and sea. These resources may be needed by other species. For example, when water is used to irrigate farms that produce food in the Murray River Basin, this means there is less water for the ecosystems downstream. As a result, the river red gum forests that surround the Murray are placed under extreme stress during droughts.

The lack of water flow has also resulted in the build-up of dirt and silt along the banks of the waterways, preventing further flow of fresh water that is needed by plants and animals downstream.

Humans are also responsible for the permanent removal of trees and plants from bushland. Before European settlement, fallen trees were used as food or shelter by local animals. Removal of these trees makes these animals vulnerable to predators and the extremes of weather. It also removes important matter from the ecosystem, limiting the recycling of matter, which is important to the health of the environment.

Pollution

Human activity has introduced many unwanted chemicals into ecosystems. Some chemicals can cause sickness and/or death of certain species and, in some cases, can result in the collapse of entire food webs. Many industries now have much more restrictive rules about the chemicals that can be released into the environment.

Figure 3 Phosphates in detergents and fertilisers used on agricultural land wash into oceans, lakes, river and other water bodies. This leads to eutrophication – an increase in organisms that reduce oxygen levels in the water, harming other organisms.

Enhanced greenhouse effect

The Earth is surrounded by a thick layer of gases called the atmosphere. When the Sun shines on the Earth, the ground heats up, which in turn heats the gases in the atmosphere. This heat keeps the Earth warm, just like a glass greenhouse keeps plants warm even in the depths of winter. Some gas molecules (carbon dioxide, water and methane) are especially effective at trapping the heat in this process, which is called the greenhouse effect.

Increasing numbers of humans, increasing wealth and more sophisticated technology have resulted in large quantities of fossil fuels being used for transport, industry, agriculture and electricity. When fossil fuels are burnt, they produce large amounts of carbon dioxide,

CHALLENGE

2.9: Field trip
Go to page **175**.

increasing the amount of heat that is trapped in the atmosphere. This enhanced greenhouse effect is causing global temperatures to increase.

Ecological effects of climate change

Although many humans welcome the thought of warmer weather, small increases in average temperatures can have devastating effects on climate systems (the average temperature, wind, sunshine, humidity and rain that occurs in an area – see Table 1). In mountainous areas, plants and animals that need cooler moist environments to survive are losing their habitats as the snowline retreats higher up the slopes. One such animal is the mountain pygmy possum (Figure 4), which needs a snow depth of at least 1 m to provide enough insulation for **hibernation**. Less snow means the cycle of hibernation and breeding is disrupted. This will make it difficult for the possum to breed, and could result in it becoming extinct.

Figure 4 The mountain pygmy possum is listed as an endangered species.

Table 1 Some of the main effects of climate change on ecosystems

Change	Effect
Changes in distribution and abundance of species – migration of species north or south, to higher levels or more suitable locations, due to increasing temperatures	Extinction of some organisms if they cannot adapt to new climatic conditions
Changes in the number of different types of organisms in ecosystems (e.g. due to species competition for resources or invasion of weeds/pests)	Increased weeds and other invasive species (i.e. pests)
Changes in metabolic processes (e.g. cellular respiration, photosynthesis, growth and tissue composition)	Changes in life-cycle events (e.g. breeding, migration)
Ocean acidification due to carbon dioxide being converted to carbonic acid in the ocean	Increased coral bleaching and destruction of and/or changes to coral reefs
Changes in river flows, sediment formation and nutrient cycles	A lack of water, causing extinction and increased toxic algal blooms due to floods
Drying of ecosystems	Decrease in coastal mountain rainforests

hibernation
a state of inactivity of an organism, usually as a result of low environmental temperature

Figure 5 Increased carbon dioxide levels in the atmosphere cause the ocean to become acidic. As a result, the polyps in the coral die, causing bleaching.

2.9 Check your learning

Remember and understand

1 **Describe** two ways humans compete with plants and animals for resources.

2 **Describe** the greenhouse effect.

Apply and analyse

3 **Contrast** (the differences between) the greenhouse effect and the enhanced greenhouse effect.

4 **Describe** two ways your local ecosystem will be affected by the enhanced greenhouse effect.

5 The green sea turtle lays its eggs in the warm sands of northern Australia. If the sand is at 29°C, half the turtles will develop into males and the other half will be females. Below 27°C, most of the turtles will be male. Above 31°C, most of the turtles will be female. **Describe** the effect that global warming will have on the green sea turtle population.

Evaluate and create

6 Currawongs are native birds that thrive in towns and cities because they can eat human food scraps and any bird seeds left out by humans. They also hunt smaller birds and drive them out of an area. **Evaluate** the impact of humans on the bird population in cities (by describing how the currawongs are affected by human populations, and how other birds are affected by human populations, and deciding whether the overall human impact on all birds is positive or negative).

//SCIENCE AS A HUMAN ENDEAVOUR//

2.10 Human management of ecosystems continues to change

Different communities have different views on how to manage their local ecosystems. The ability to see an ecosystem from another's perspective can be useful.

Historical use of ecosystems

Aboriginal and Torres Strait Islander peoples have over 60 000 years of connection and understanding of their diverse landscapes. They believe they have been on this continent from the Dreaming (day one) and time immemorial. The 'out of Africa' model is always changing, especially with new archaeological discoveries and genetics updating their arrival to Australia and their movement through South-East Asia, before arriving in northern Australia.

Aboriginal and Torres Strait Islander peoples used (and still use) fire as a tool to shape the landscape while altering plant life cycles and animal adaptations to manage resources. They are farmers who respect the land because it provides them with the resources for life – food, water, shelter and medicine.

As the original inhabitants of the land, Aboriginal and Torres Strait Islander peoples were aware of the seasonal nature and life cycles of plants and animals in the ecosystems around them. They were prepared to move to areas where plant and animal foods were available at a particular time or season, or when resources were drying up. Instead of considering the land to be owned by a person or group of people, to be cleared and used according to their needs, Aboriginal and Torres Strait Islander peoples consider land management to be based on shared ownership and custodianship with a deep respect for the land. As Indigenous Person of the Year 1999, Bob Randall said, 'We do not own the land. The land owns us'.

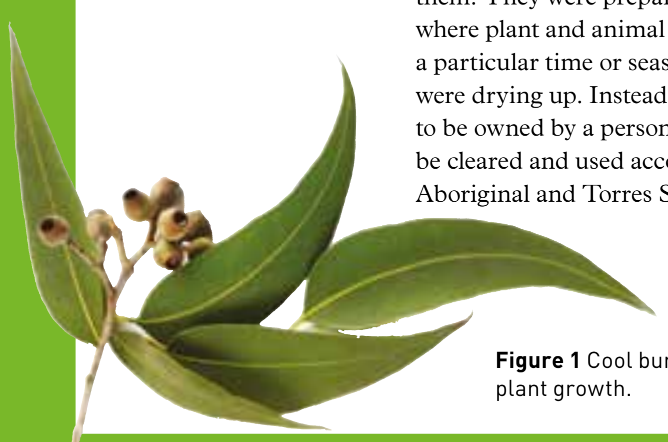

Figure 1 Cool burning promotes new plant growth.

Cool burning, firestick and cultural burning

There is increasing recognition and interest in the Aboriginal and Torres Strait Islander peoples' use of 'cool burning' to control fuel loads and suppress out-of-control bushfires while reducing the emission of greenhouse gases. This is important, with Australia predicted to become hotter and drier under climate change and the increase of catastrophic bushfires, as this knowledge can play a part in managing the landscape. The advancement of knowledge and teachings by Aboriginal and Torres Strait Islander fire practitioners has the idea that the right fire can only have effect through reading *country*. The Aboriginal and Torres Strait Islander ancestors never burnt every ecosystem, otherwise this would decrease ecosystem biodiversity and resources while releasing carbon into the atmosphere.

Early in spring and sometimes at night, with low wind, the grasses are not as dry. Any fires burn slowly and are put out by the heavy night-time dew. This means small fires can be lit to reduce the grasses that form the undergrowth under treetops or canopies. If small patches of undergrowth are burnt, the nutrient matter is recycled back into the soil without destroying all the food available.

This cool burning process has been used by Aboriginal and Torres Strait Islander peoples for thousands of years, and many plants, such as the grass tree (*Xanthorrhoea sp.*), have evolved to flower only when the base of the tree has been burnt by fire.

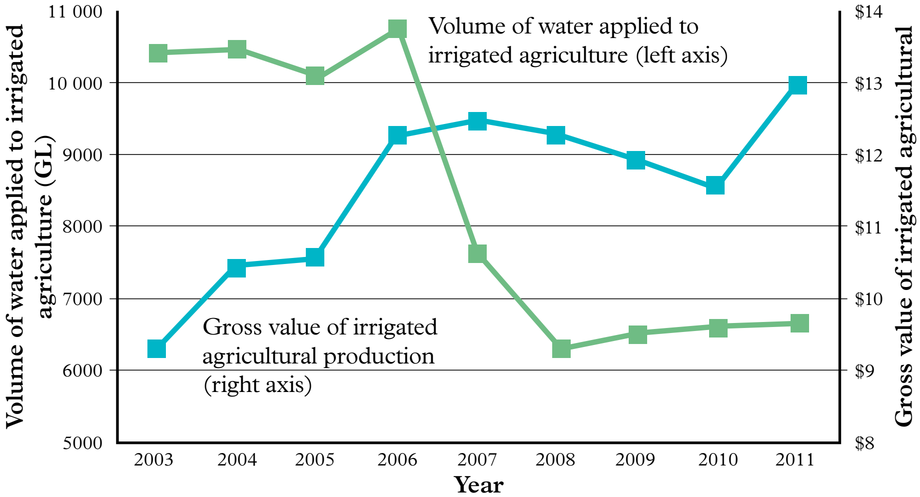

Figure 2 Modern farming involves using water more wisely.

If cool burning is repeated each year, the slow limited burning reduces the release of greenhouse gases (especially methane and nitrous oxide) and the carbon remains trapped in the unburnt large trees and bushes.

Modern needs

As the population of Australia has increased, so too has the need for food. This need must be balanced with maintaining the biodiversity of the unique Australian ecosystem.

In Australia, we currently have plenty of food, thanks to a strong agricultural community. Irrigation of large areas ensures that the crops are able to survive. As shown in Figure 2, Australian farmers have become more effective in their use of water, protecting this important resource for future generations.

In 2018, tropical Cyclone Debbie hit the coast of Queensland, causing major property damage, power outages and millions of dollars of damage to Australia's sugar-cane industry. Global warming is expected to cause storms of this magnitude to become more frequent and spread over larger areas. Some scientists predict that droughts may also become increasingly frequent in all areas of Australia. This will have an impact on the types of crops that can grow in many areas.

In 2010, Australia's chief scientist made some recommendations to enable us to maintain the food production needed to feed Australia and the rest of the world while minimising the effect on the ecosystem.

> Coordinate programs that maintain current food production levels.
> Research methods and crops that would be able to cope with drought conditions.
> Develop methods that allow more efficient use of water and nutrients in agricultural areas.
> Encourage more scientists and engineers to work in agriculture.

This means that agriculture is looking to science and technology to help maintain a balance between food production and biodiversity of the environment.

a

b

Figure 3 Scientists are developing ways to use water more efficiently. **a** Traditional irrigation **b** Modern micro-irrigation system

2.10 Develop your abilities

Evaluating farming practices

Aboriginal and Torres Strait Islander peoples use the seasons for specific purposes. These observations include when flowers are blooming, which pollinating insects are active and when animals are mating. They match these to the positions of the stars and constellations so that they can predict the events of the following year.

1 **Identify** the name of the local Aboriginal and Torres Strait Islander peoples in your area. Research the diverse farming practices used by these peoples, including burning, tilling, planting, irrigating, cropping, storing and trading.

2 'Aboriginal and Torres Strait Islander peoples manipulate the environment to their advantage without changing it significantly.'

Evaluate this statement by:

- describing how the Aboriginal and Torres Strait Islander peoples manipulate the local environment
- describing the long-term effect of these manipulations on the local environment
- deciding whether these long-term effects are significant.

REVIEW 2

Multiple choice questions

1 A relationship between two organisms that benefits both is called:
  - A mutualism
  - B parasitism
  - C abiotic
  - D communalism.

2 Dr Jaxa wants to investigate the number of plants in an ecosystem. What would be the best method of doing this?
  - A Dr Jaxa could count each individual plant type in the whole ecosystem.
  - B Dr Jaxa could set up a capture–recapture.
  - C Dr Jaxa could use a quadrat.
  - D It is not possible.

3 The water cycle involves the processes of:
  - A decomposition and precipitation
  - B precipitation, evaporation and transpiration
  - C aerobic respiration and transpiration
  - D evaporation and photosynthesis.

Short answer questions

Remember and understand

4 **Identify** two ways to define 'ecosystem'.

5 **Compare** (the similarities and differences between) mutualism, parasitism and commensalism.

6 **Describe** the process of photosynthesis.

7 **Identify** the products of photosynthesis that are essential for cellular respiration.

8 **Explain**, using examples, how competition can occur between members of the same species and members of different species.

9 If only 10 per cent of the energy is transferred along a food chain (like the one in Figure 1 on page 32), **describe** what happens to the rest of the energy.

10 Cellular respiration in your cells provides the energy for all your metabolic processes. **Identify** four cellular processes that require energy from respiration.

11 **Describe** one example of how humans, especially since European settlement, have changed ecosystems because of an introduced species in Australia.

12 **Describe** the abiotic conditions in Australian ecosystems that limit populations of living organisms.

13 **Describe** two adaptations that enable Australian plants to survive fire.

14 The floods in north-western Victoria in 2011 caused enormous destruction and some deaths. **Explain** two ways these floods affected the local ecosystems.

Apply and analyse

15 **Analyse** the marine Antarctic food web in Figure 1.
  - a **Describe** the relationship between:
    - i orca whales and fur seals
    - ii Emperor penguins and fur seals.
  - b If overfishing rapidly decreases deep-sea fish numbers, **identify** the pressures this could place on the:
    - i fur seal population
    - ii humpback whale population.

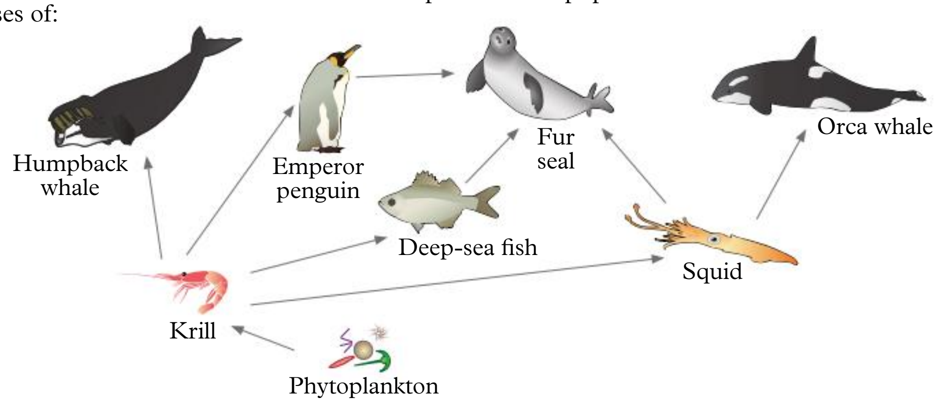

Figure 1 A marine Antarctic food web

16 Seed banks are an important way of preserving plant species that are at risk of decreasing populations or extinction. It involves storing collections of seeds from all areas of the world. **Explain** how a seed bank could contribute to sustainable ecosystems and to biodiversity.

17 Limpets graze on algae on a rock platform. The large limpet, *Lottia,* is found in a territory containing micro-algae; the smaller species, *Acmea,* is found on the edge of this territory (Figure 2).
  - a **Identify** one possible hypothesis (reason) for this situation.
  - b **Describe** an experiment you might set up to test whether your hypothesis is correct.

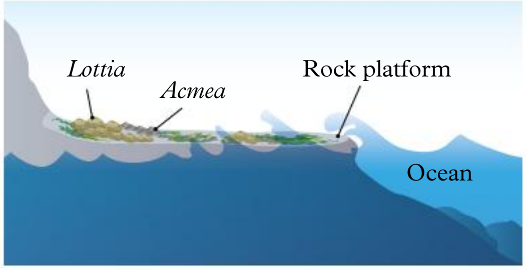

Figure 2 *Lottia* and *Acmea* on a rock platform

18 Observe your school ground or your home garden for one week. Keep a journal, listing any examples of interrelationships between organisms. **Describe** the biodiversity of your environment.

Evaluate

19 **Create** a food web using the organisms that you identified in Question 18.
- a **Identify** one population that affects multiple other species.
- b **Describe** one abiotic factor that could cause this population to decrease.
- c **Describe** what would happen to the other species if the initial population was decreased.

20 The Australian population was fairly stable until European colonisation in 1788. In the past century, it has increased almost fivefold. **Evaluate** the effect of population increase on your local ecosystem (by describing the diversity of plants and animals in the local ecosystem before European settlement, describing the diversity in the local ecosystem now, and deciding whether this change is positive or negative for the biodiversity of organisms).

21 **Identify** the conditions that cause an animal or plant species to be classified as endangered. **Describe** two examples of endangered species in Australia. **Evaluate** whether measures to protect them are adequate (by describing the measures being taken to protect the species, describing the effect these measures are having on the environment, and deciding whether the measures are adequate).

Social and ethical thinking

22 a **Compare** the following research characteristics of the Mary River turtle and the northern quoll:
- i the amount of information on the Wikipedia page of each animal
- ii the number of resources listed at the end of the Wikipedia pages
- iii the attractiveness or cuteness of each animal.

b **Identify** which animal you would be most likely to donate money towards, to protect its environment. **Justify** your decision (by describing which factors you considered when you made your decision).

Figure 3 Mary River turtle

Figure 4 Northern quoll

Critical and creative thinking

23 Draw a concept map showing how photosynthesis and respiration are connected. Include the following terms (plus any others you think are appropriate): glucose, energy, oxygen, carbon dioxide, ATP, water.

24 Imagine it is your job to find out whether soil is 'consumed' as plants grow. Design an investigation to test this idea. **Describe** how you will determine whether the plant(s) have actually 'consumed' the soil. **Identify** the evidence that you will need to collect. **Identify** three variables that you will need to control and **describe** how you will control these variables.

25 Scientific understanding of the relationship between plants and animals in an ecosystem is an important area of scientific research. Ecologists are scientists who specialise in this area of research. Find out what an ecologist does. Write a paragraph that **describes** the highlights of working as an ecologist and some of the disadvantages.

Research

26 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

» Biological control

Australian native plants and animals have adapted to life on an isolated continent over millions of years. Since European settlement, native animals have had to compete with a range of introduced animals for food, habitat and shelter. Rapid changes in land usage, such as increased crop-growing areas, have also affected our soils and waterways. Research the meaning of the term 'biological control'. Find some more Australian examples of successful and not-so-successful examples of biological control.

» Frozen Ark Project

In the Bible story of the floods, Noah protected and conserved animals by building an ark. The Frozen Ark Project is a modern-day project named after this story. What is the Frozen Ark Project? What are its goals? How is it working towards achieving these goals?

» Carbon capture and storage

One measure that has been proposed to decrease the amount of carbon dioxide being added to the atmosphere is to capture and store carbon dioxide. What does carbon capture and storage mean? How will it work? Explain some of the options being considered for storing carbon dioxide.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 2 'Ecosystems'. Once you've completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this	I cannot do this yet.
Define biosphere, ecosystem, biotic, abiotic, habitat, population and community. Describe an ecosystem as the interaction between the abiotic conditions and the biotic community.	☐	☐ Go back to Topic 2.1 'All living things are dependent on each other and the environment around them' Page 18
Define collaboration, mating, competition, symbiosis, mutualism, commensalism and parasitism. Explain the relationship between predator and prey numbers over time.	☐	☐ Go back to Topic 2.2 'Relationships between organisms may be beneficial or detrimental' Page 20
Identify the main factors that increase and decrease population size. Identify suitable species to use quadrat and capture–recapture sampling methods with.	☐	☐ Go back to Topic 2.3 'Population size depends on abiotic and biotic factors' Page 24
Define biological control, disease and immune. Describe the effects rabbits have on Australian ecosystems.	☐	☐ Go back to Topic 2.4 'Introducing a new species may disrupt the balance in an ecosystem' Page 26
Explain the processes involved in photosynthesis. Relate the structure of the chloroplast to its function.	☐	☐ Go back to Topic 2.5 'Energy enters the ecosystem through photosynthesis' Page 30
Explain that energy is passed through ecosystems through food chains in the form of glucose. Relate photosynthesis and respiration in terms of reactants and products, but recognise that they are not reversible versions of each other.	☐	☐ Go back to Topic 2.6 'Energy flows through an ecosystem' Page 32
Explain the main processes involved in the water and carbon cycles. Relate the water and carbon cycle to the cycling of matter through ecosystems.	☐	☐ Go back to Topic 2.7 'Matter is recycled in ecosystems' Page 36
Describe some of the adaptations some Australian plants have to fire. Provide examples of natural events that can disrupt an ecosystem.	☐	☐ Go back to Topic 2.8 'Natural events can disrupt an ecosystem' Page 38
Describe the enhanced greenhouse effect and its causes. Provide examples of human activity that disrupts ecosystems.	☐	☐ Go back to Topic 2.9 'Human activity can disrupt an ecosystem' Page 40
Compare the historical uses of ecosystems with modern practices.	☐	☐ Go back to Topic 2.10 'Science as a human endeavour: Human management of ecosystems continues to change' Page 42

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Compete in teams to test your knowledge.

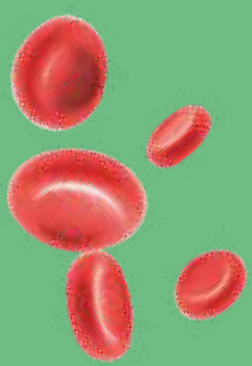
Chapter quiz

Test your understanding of this chapter with one of three chapter quizzes.

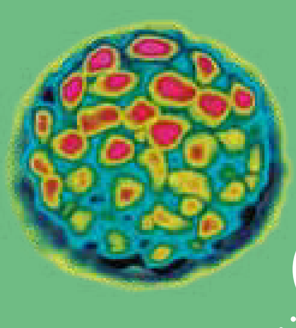
CHAPTER 3

CONTROL AND REGULATION

How does your body respond to change?



- 3.1 Receptors detect stimuli
- 3.2 Nerve cells are called neurons
- 3.3 The nervous system controls reflexes
- 3.4 The central nervous system controls our body
- 3.5 Things can go wrong with the nervous system
- 3.6 The endocrine system causes long-lasting effects
- 3.7 Homeostasis regulates through negative feedback
- 3.8 Science as a human endeavour: Hormones are used in sport
- 3.9 Science as a human endeavour: Pathogens cause disease
- 3.10 The immune system protects our body in an organised way
- 3.11 Things can go wrong with the immune system



What if?

Exploring your senses

What you need:

Blindfolds

What to do:

1. With a partner, explore how the senses of touch, hearing and smell can be used to navigate around a room without the use of sight.
2. Ensure all small or potentially hazardous obstacles are removed from around the room. Decide with your partner the path that the blindfolded student is required to take around the room.
3. Take turns being blindfolded and navigating the room, with your partner walking with you to ensure your safe navigation and providing assistance if needed.

What if?

» What if you wore earmuffs as well as the blindfold?

» What if you blocked your nose?

» What if you were barefoot?

3.1 Receptors detect stimuli

In this topic, you will learn that:

- Your body has receptors that detect changes (stimuli) in the environment.
- The five main types of external receptors detect light, sound, chemicals in the air and in your mouth, and touch.

Video 3.1
How taste works

Interactive 3.1
The human ear

Your body responds to changes in its environment. Receptors detect these changes and pass the information to other parts of the body. A stimulus is any information that your body receives that might cause it to respond.

Responding to change

Within our bodies, we regularly respond to changes without being aware of a **stimulus** and response. What makes you aware that you're hungry or thirsty? Something in your body is communicating with your brain to tell you to find food or water. A similar process occurs when you feel tired or have a headache. What is the source of these stimuli?

Other examples of stimuli are less obvious. We are surrounded by bacteria, viruses and fungi. Although many of them are too small to see, our bodies are constantly monitoring their numbers and fighting off harmful micro-organisms.

Your body is an amazing combination of cells, tissues, organs and systems, all working together. Each plays a part in detecting stimuli and passing on the information to other parts of the body. The structures that receive stimuli are called **receptors**.

stimulus
any information that the body receives that causes it to respond

receptor
a structure that detects a stimulus or change in the normal functioning of the body

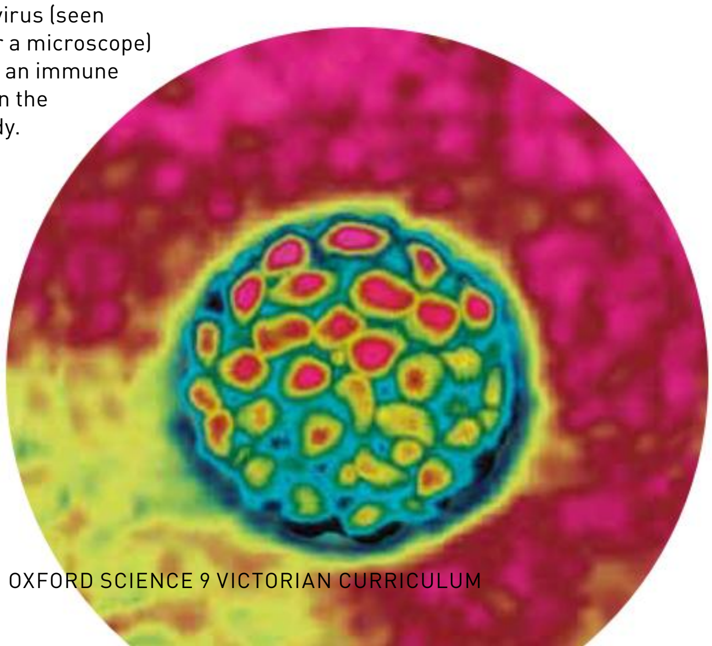


Figure 1 The human papillomavirus (seen here under a microscope) stimulates an immune response in the human body.

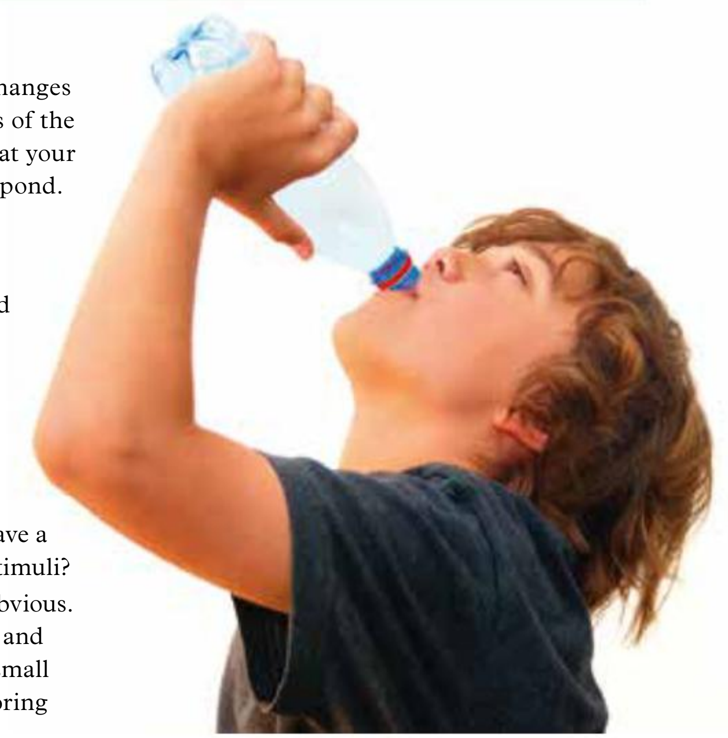


Figure 2 We often respond to hot weather by drinking more.

The sense organs

Our body can detect five main signals: light (sight), sound (hearing), chemicals in the air (smell) and in our mouth (taste), and touch. These are external senses because they tell us about the world outside our body. The sense organs – the eyes, ears, tongue, nose and skin – are highly specialised to receive stimuli from the environment.

Sight

Sight tells us more about the world than any other sense. The pupils change size to control how much light enters the eye. The different types of photoreceptor cells at the back of the eye transform the light into nerve signals for the brain. It is not only your eyes that allow you to

CHALLENGE

3.1: Testing your senses
Go to page 176.

Figure 3 A crocodile's eye has an elliptical (oval-shaped) pupil, which helps to protect its sensitive retina from the bright light of day.

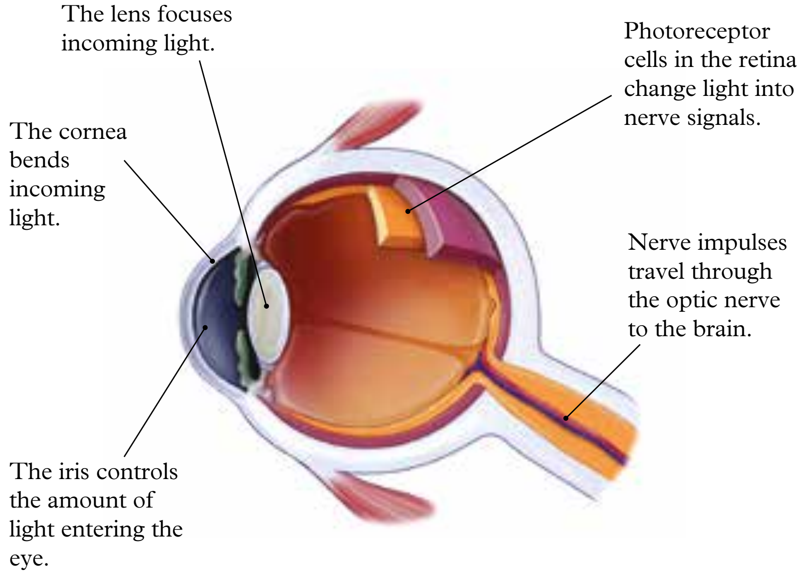


Figure 4 Photoreceptors in the human eye transform light into nerve signals.

see, but also your brain! The information from your eyes is transferred to your brain, which then tells you what you are seeing.

Hearing

The strumming of a guitar causes the particles in the air to vibrate. This in turn causes your eardrum to vibrate. The vibrations are transferred along the bones of the middle ear – the smallest bones in your body – and converted into nerve impulses. The brain then interprets the information, telling you what you are hearing.

Figure 5 The large ears of some bats help them use sound waves to locate their prey.

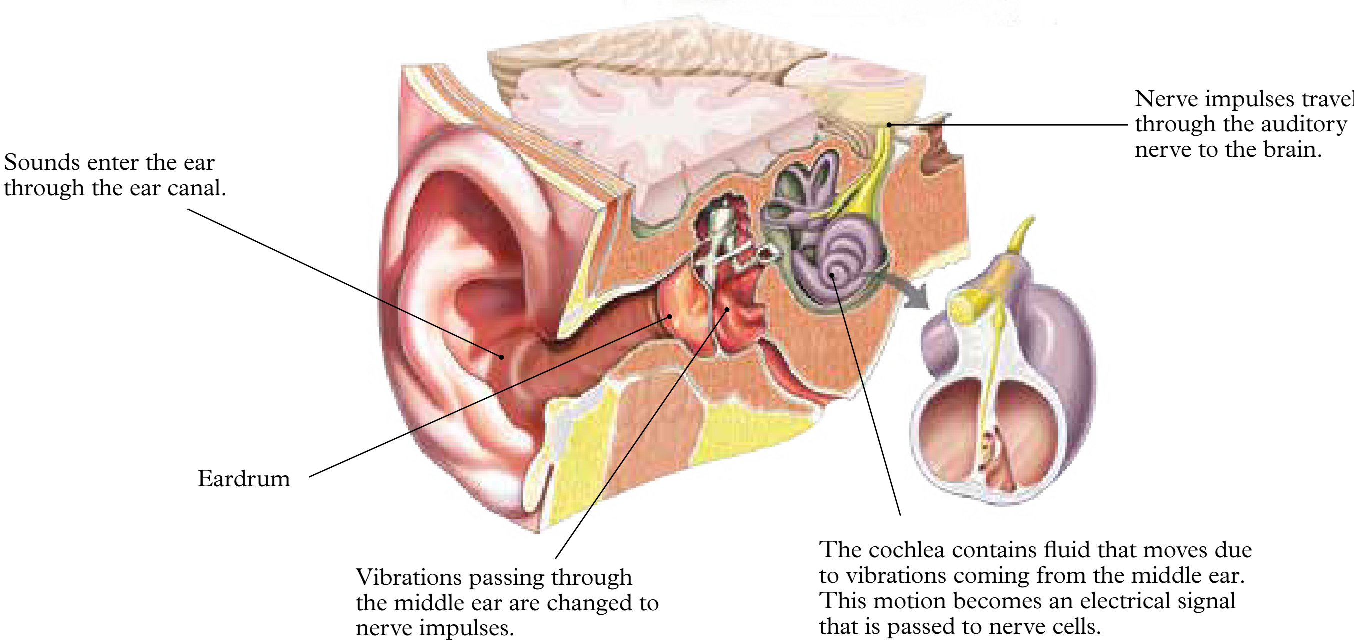


Figure 6 The human ear transfers vibrations to the middle ear. These vibrations become nerve impulses.

Figure 7 A dog uses its tongue for many things, including taste and temperature control. Panting moves cool air over the tongue and lungs, allowing moisture to evaporate and thus cooling the body.

Taste

Your tongue is covered in thousands of tiny taste buds. You can see this in a mirror. Taste buds contain special receptor cells that react to chemicals in foods. These chemical receptors can recognise basic kinds of taste molecules, such as sweet, salty, sour, bitter and umami (savoury). When you eat or drink, the information from the taste receptor cells is sent to your brain through nerves. It is the mix of chemical molecules that your brain detects as the flavours you are tasting.

Smell

Like taste, our perception of smell depends on chemical receptors. The receptors in our nostrils detect chemicals in the air and then send messages to the brain, which interprets the messages and tells us what we are smelling. Smell is closely linked to taste. If this seems strange, think about the last time you had a bad cold and a blocked nose. Did it affect your ability to taste? A lot of what people think is taste is actually smell.

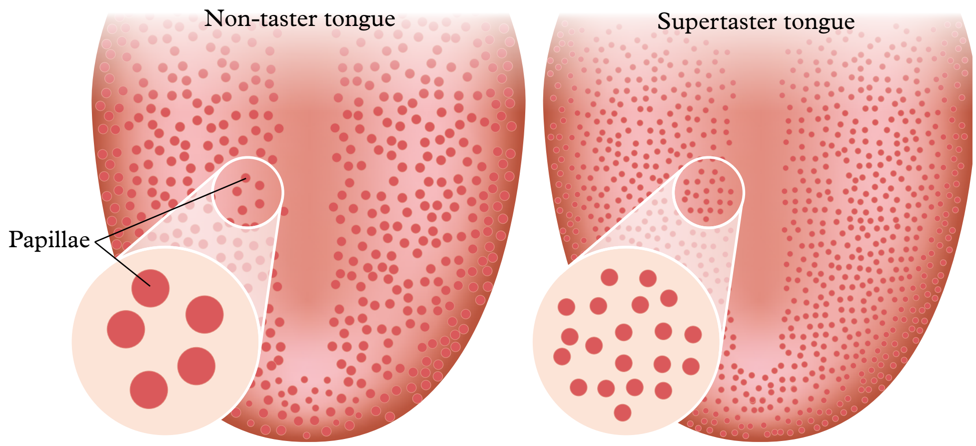


Figure 8 The tongue is covered in bumps, called papillae, which contain tastebuds that enable us to taste. A supertaster has many more papillae than average, and a non-taster has fewer.

Figure 9 Elephants use their trunks for a wide range of smelling tasks, such as sensing danger.

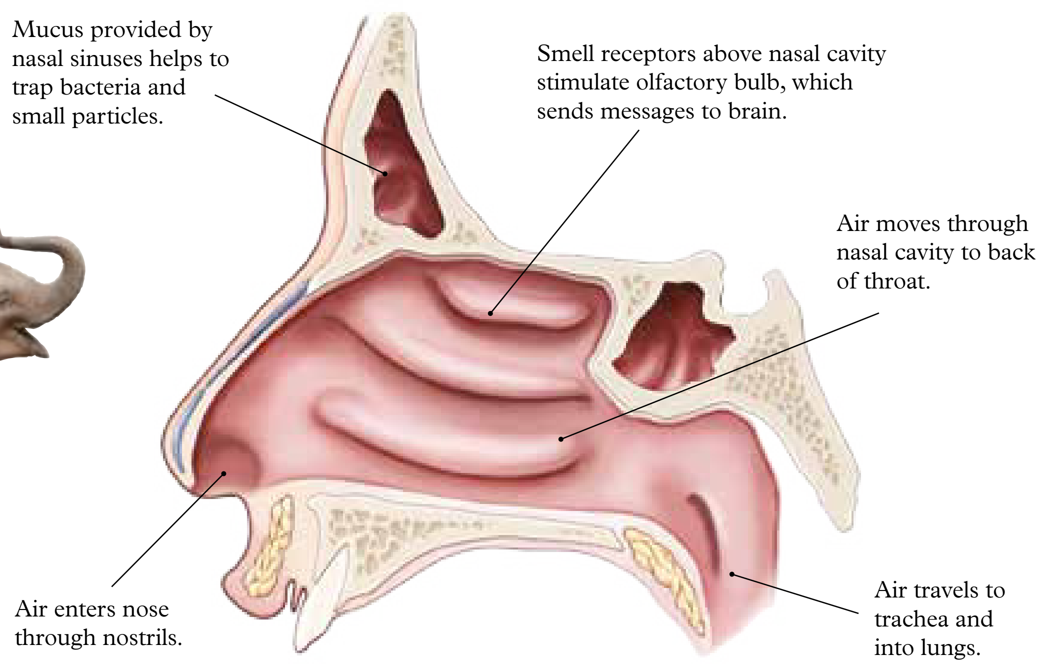


Figure 10 Smell receptors in human nostrils detect chemicals and send messages to the brain.

Touch

While the other four senses are in specific locations, touch is felt all over the body, through the skin. The inner layer of skin, called the dermis, contains many nerve endings that can detect heat, cold, pressure and pain. Information is collected by the different receptors and sent to the brain for processing and reaction.

Figure 11 The skin of a human fingertip has about 100 touch receptors.

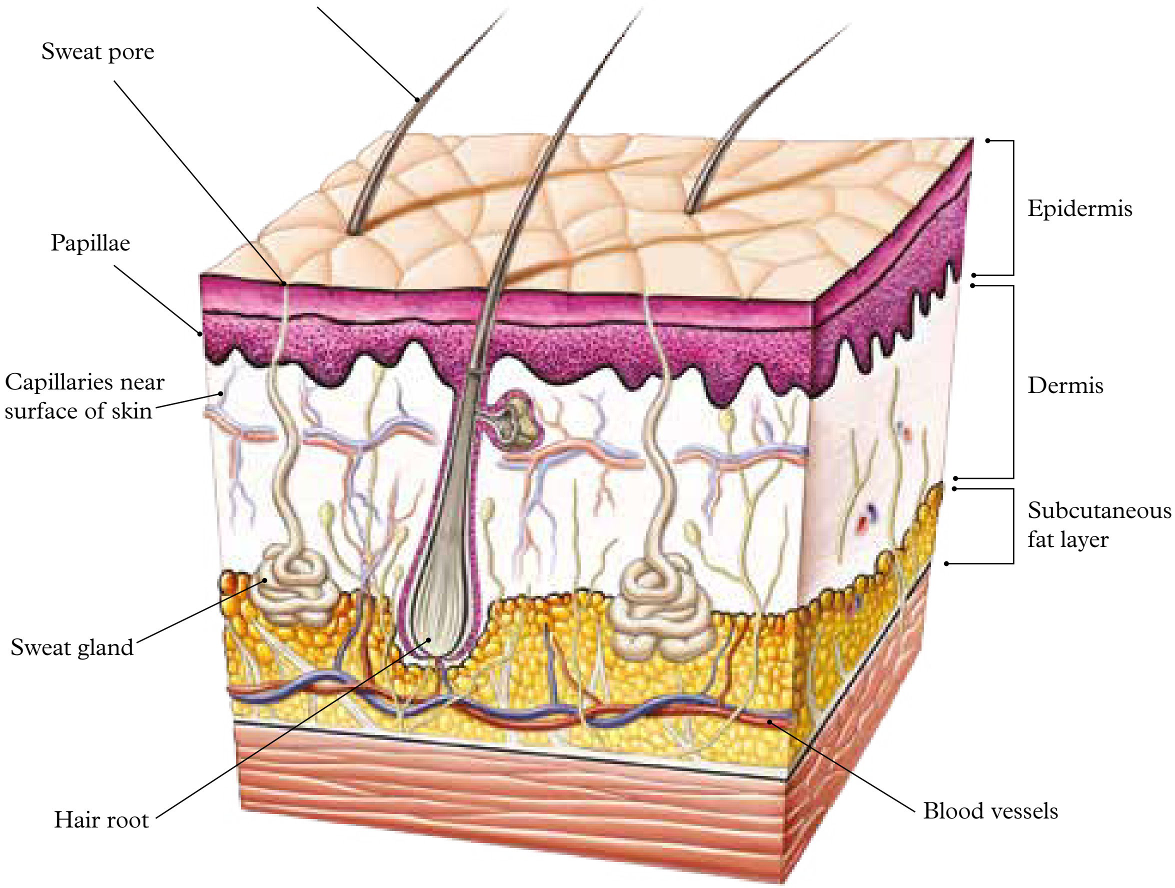


Figure 12 A cross-section of human skin

3.1 Check your learning

Remember and understand

1 **Define** the term 'stimulus'.

2 Stimuli can be changes in our immediate environment or changes within our bodies. **Describe** two examples of each.

3 **Identify** the five major sense organs.

Apply and analyse

4 **Describe** two situations in which each sense organ would need to respond.

5 **Compare** (similarities and differences between) the way you detect smell and the way you detect taste.

6 'A person has more than five senses.'
Evaluate this statement by:
- describing the five senses that are being referred to
- describing what happens to your balance when you spin around quickly (sense of balance)
- describing how your body reacts when you are sick (sensing bacteria)
- deciding whether the statement is correct.

3.2 Nerve cells are called neurons

In this topic, you will learn that:

- Neurons are cells in our body that enable messages to be passed quickly.
- A change is detected by the receptor and an electrical message is passed along the neuron to the synaptic terminal.
- Chemical neurotransmitters pass the message across the gap to the next neuron.
- The myelin sheath protects parts of the neuron and increases the speed of messages being sent.

neuron
a nerve cell

cell body
the main part of a cell that contains the nucleus/genetic material

axon
the part of a neuron (nerve cell) that carries an electrical message away from the cell body to the synapse

myelin sheath
a fatty layer that covers the axon of a nerve cell

dendrite
the part of a neuron (nerve cell) that receives a message and sends it to the cell body

Nerves

The basic unit of the nervous system is the nerve cell, or **neuron**. Scientists believe that we may have up to 100 billion neurons in our bodies, connected in paths called nerves.

Neurons have many highly specialised features. Each neuron has a large **cell body** that connects to a long thin **axon** (Figure 1). An axon carries nerve impulses away from the cell body. The axons connecting your spinal cord to your foot can be up to 1 m long.

At the end of the axon are small bulbs, called synaptic terminals. Each synaptic terminal releases information into the synapse (Figure 2). The next neuron receives these messages from the synapse via its dendrites.

Nerves work just like electrical wires and require insulation in the same way. The axons are covered by a fatty layer called the **myelin sheath**. The myelin sheath helps to speed up a nerve impulse along an axon by controlling its path. People with multiple sclerosis have damaged myelin sheaths. This means that the nerve impulse is disrupted, blocked or unable to move along the length of the axon. A person with multiple sclerosis can therefore have difficulties with movement.

Dendrites are nerve endings that branch out of the cell body. These highly sensitive, thin branches receive information from the synaptic terminal of other neurons, allowing nerve impulses to be transmitted.

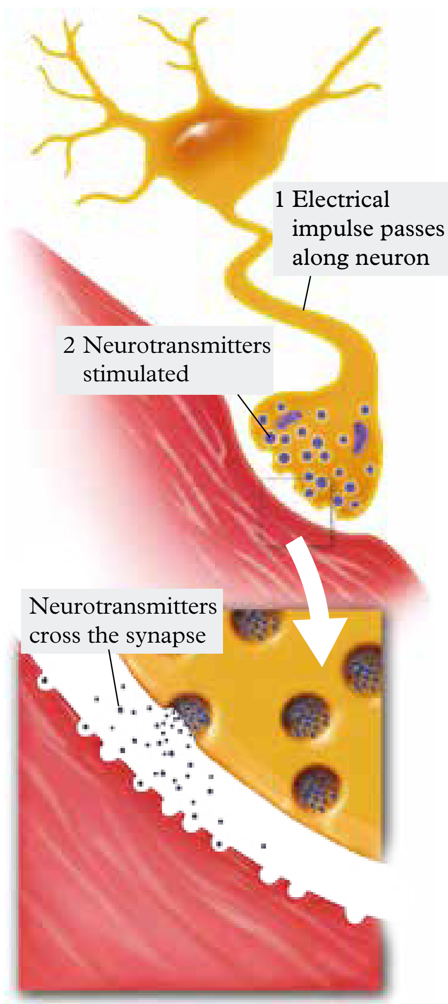


Figure 2 Electrical messages are converted to chemical messages (neurotransmitters), which cross the gap in the synapse.

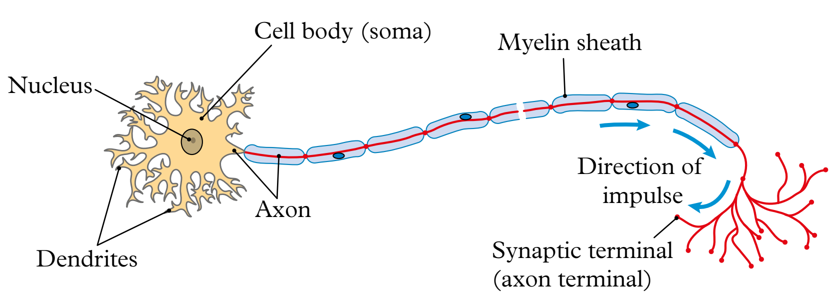


Figure 1 A typical neuron

CHALLENGE

3.2: Pipe cleaner neurons
Go to page 177.

Dendrites bring information to the cell body and axons take information away from the cell body. Information from one neuron flows to another neuron across a **synapse**. The synapse is a small gap separating neurons. When the message reaches the end of the axon, chemicals called **neurotransmitters** are released from the synaptic terminal and travel across the gap in the synapse to the dendrite of the next neuron. In this way, electrical messages are passed around the body.

There are three specialised types of neuron, all with different jobs.

> **Sensory neurons** (or afferent neurons) are sensitive to various stimuli, collecting information from either the body's internal environment or the outside world. Sensory neurons send the information they have collected to the central nervous system for processing.

> **Interneurons** (or connector neurons) link sensory and motor neurons, as well as other interneurons. Interneurons are the most common neuron in your central nervous system (brain and spinal cord). They only make connections with other neurons.

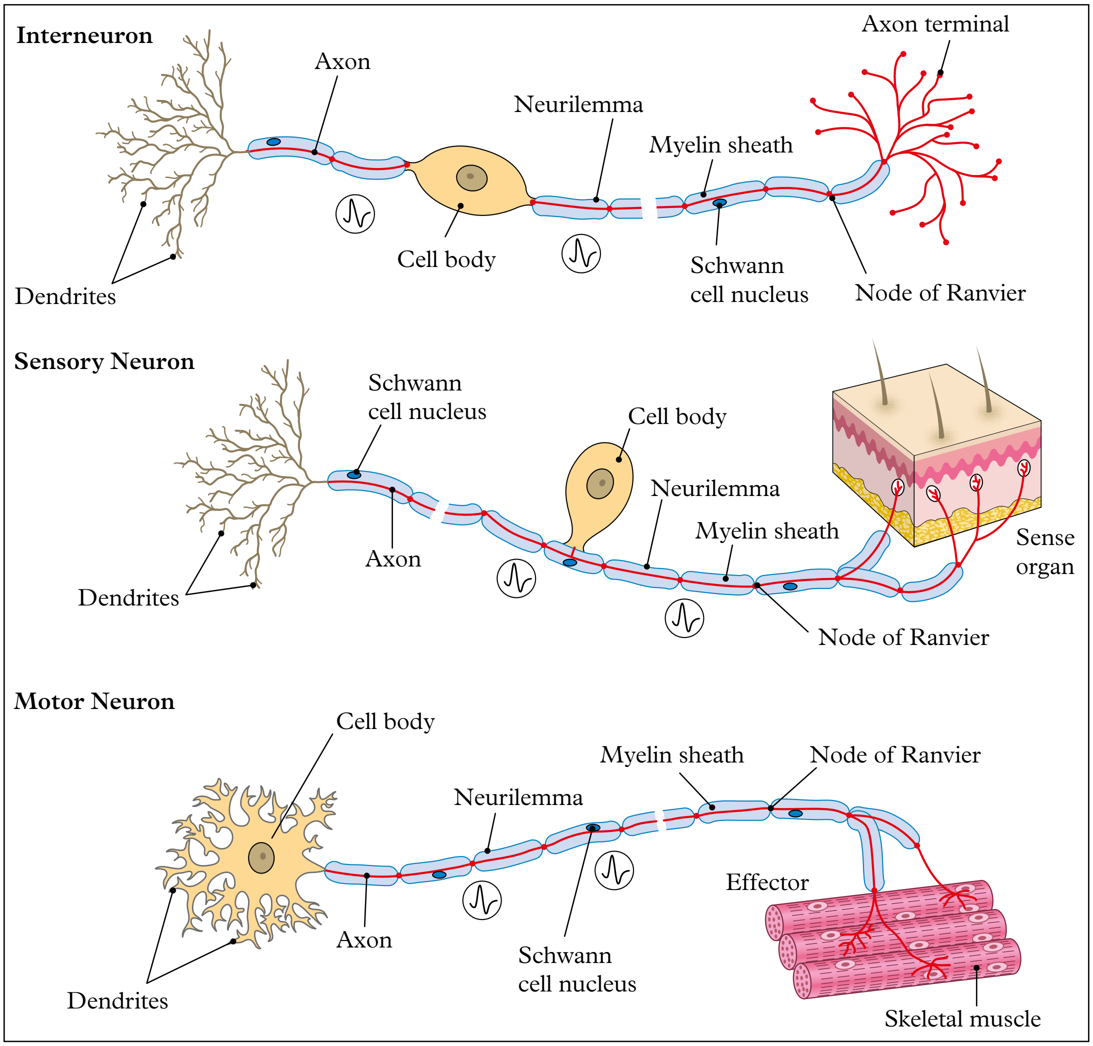


Figure 3 In these examples of an interneuron, a sensory neuron and a motor neuron, you can see how they are structured differently to send and receive different messages.

> **Motor neurons** (or efferent neurons) carry messages from the central nervous system to muscle cells throughout the body, which then carry out the response.

3.2 Check your learning

Remember and understand

1 With a partner, **create** a way to remember the difference between sensory neurons, motor neurons and interneurons. Be creative! Share your memory trick with the class.

2 **Describe** the features of a neuron that enable it to pass messages on to other neurons.

3 **Describe** where you will find sensory neurons that detect:

a smell **b** taste
c sound **d** touch
e light.

4 **Describe** the role of the myelin sheath.

Apply and analyse

5 Use a diagram to **explain** the problem that may result from damage to the myelin sheath.

6 **Compare** (the similarities and differences between) sensory neurons and motor neurons.

7 **Contrast** (the differences between) sensory neurons and interneurons.

synapse
a small gap between two neurons that must be crossed by neurotransmitters

neurotransmitter
a chemical messenger that crosses the synapse between the axon of one neuron and the dendrite of another neuron

sensory neuron
a nerve cell that carries a message from a receptor to the central nervous system

interneuron
a nerve cell that links sensory and motor neurons; also known as a connector neuron

motor neuron
a nerve cell that carries a message from the central nervous system to a muscle cell

3.3 The nervous system controls reflexes

In this topic, you will learn that:

- Receptors in the nervous system detect a stimulus and pass it on to control centres.
- The control centres initiate a message to the effectors, which causes a response.
- Reflexes are special pathways that allow a response to occur before the brain has time to think.

Video 3.3
Microscope skills

reflex
an involuntary movement in response to a stimulus

Stimulus–response model

Stimuli can be in many different forms. A stimulus may be pressure or heat on the skin, a puff of air or strong light in your eye. The stimulus is detected by receptors and the message gets sent to the spinal cord and the brain via sensory neurons. The spinal cord and brain are the control centre of the nervous system. Interneurons in this control centre pass the message on to other interneurons as your brain thinks about how you should respond to the stimulus. Eventually, you make a decision and the motor neurons pass the message on to the muscles. In this case, the muscles are called the effectors, as they are the cells that cause the body to respond. This simple pathway is called the stimulus–response model (Figure 1).

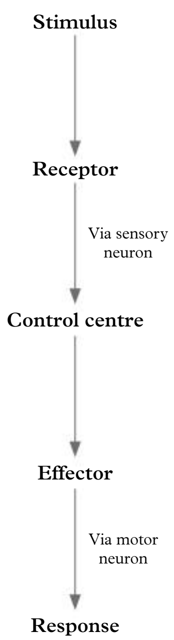


Figure 1 The stimulus–response model

Reflexes

If you have ever accidentally touched something very hot, you will remember how quickly you snatched your hand away. In fact, it would have been so quick that you didn't even have time to think about it – it was automatic.

A **reflex**, or reflex action, is an involuntary and nearly instantaneous movement in response to a stimulus.

During a reflex action, the sensory neuron carries the message from the receptor to the spinal cord. The interneuron then sends two messages at the same time: one to the brain and the other to the muscles via the motor neuron. This means the muscle is moving at the same time as the brain gets the message (e.g. that the object is hot). This makes reflexes even faster than usual responses. Most reflexes help us in survival situations. Can you think of the advantages of these reflexes?

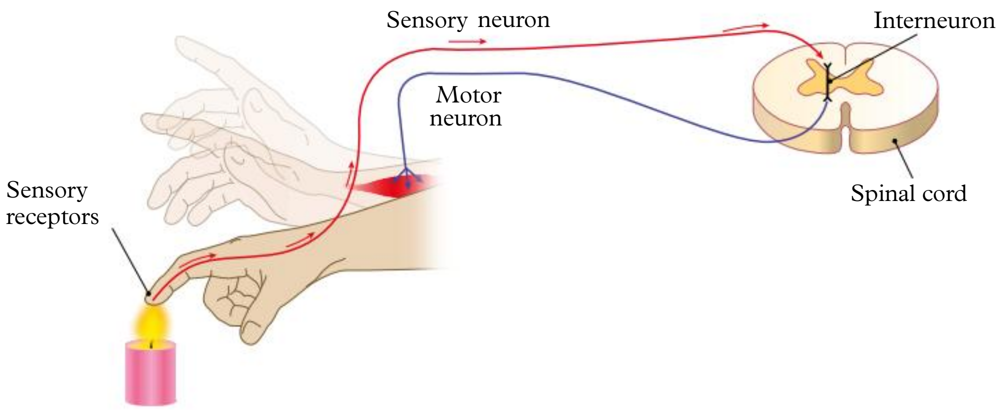


Figure 2 A reflex action ensures that your hand pulls away from the flame very quickly, even before you feel the pain.

CHALLENGE

3.3A: Testing reflexes
Go to page **177**.

CHALLENGE

3.3B: How fast is the nervous system?
Go to page **178**.

Figure 3 Grasp reflex. When an object is placed on a baby's palm, their fingers curl over and grasp it.

Figure 4 Sneezing reflex. When small particles land on receptors in the back of your nose, the muscles in your diaphragm force air out rapidly.

Figure 5 Startle reflex. When a newborn baby is startled, they will fling their arms out wide and grab anything they touch.

Figure 6 Plantar reflex. When a blunt object (such as the blunt end of a pencil) is moved along the underside of the foot, the toes usually curl downwards.

Figure 7 Patellar (knee-jerk) reflex. When a small section below the kneecap (the tendon that connects the muscle to the bone) is stimulated with a quick, firm tap, the foot will kick out.

Figure 8 Quick reflexes!

3.3 Check your learning

Remember and understand

1 **Define** the following terms.
  a stimulus
  b receptor
  c effector
  d response

2 **Describe** the stimulus–response model of regulation.

Apply and analyse

3 **Explain** why the brain is not involved in a reflex action.

4 **Explain** the advantage of a baby having the startle reflex.

5 If a person has a damaged upper spinal cord, they may not be able to feel their toes. **Analyse** whether this will affect their knee-jerk reflex (by describing how a person 'feels' their toes, describing the role of the spinal cord in a knee-jerk reflex and determining whether damage to the upper spinal cord will affect the messaging in a knee-jerk reflex).

3.4 The central nervous system controls our body

In this topic, you will learn that:

> Humans are constantly receiving stimuli from their environment through the peripheral nervous system.
> Neurons use electrical messages that are passed along to neurons in the brain and spinal cord that make up your central nervous system.

Video 3.4
The core of the nervous system

central nervous system
the brain and spinal cord

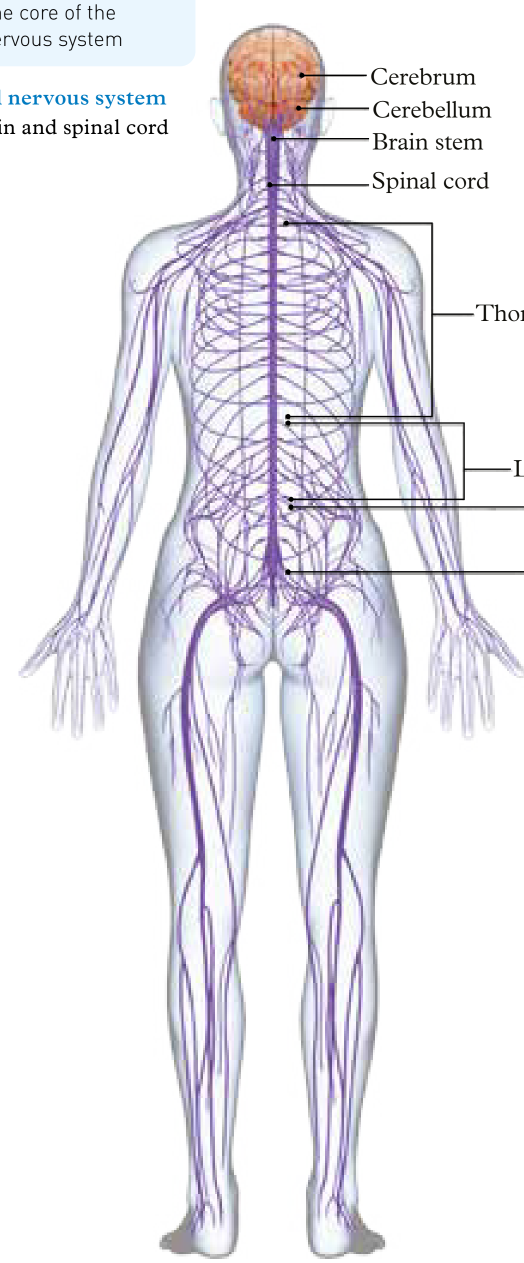


Figure 1 The nervous system of the body is made up of the central nervous system and the peripheral nervous system.

Central nervous system

The **central nervous system** is the control centre of the body. All incoming messages from your environment and your responses to them are processed through your central nervous system. The two main parts of the central nervous system are the brain and the spinal cord.

Brain

The brain is the processing centre of the body and is mainly concerned with your survival. It is a soft, heavy organ surrounded by a tough skull. The interneurons in the brain gather information about what is going on inside and outside the body. It then compares the information to events that have occurred previously, before making decisions about things such as internal changes and movements. The brain is also home to your memories, personality and thought processes.

Lobes of the brain

The cerebrum, or outer section of the brain, is divided into four lobes or sections. These lobes have specific functions.

> The frontal lobe is at the front of the brain. Its functions include emotions, reasoning, movement and problem-solving.
> The parietal lobe manages the perception of senses, including taste, pain, pressure, temperature and touch.
> The temporal lobe is in the region near your ears. It deals with the recognition of sounds and smells.
> The occipital lobe is at the back of the brain. It is responsible for the various aspects of vision.

SKILLS LAB

3.4: Sheep brain dissection
Go to page **179**.

Figure 2 The cerebrum (the large pink area) is divided into four lobes, each with a specific function.

Peripheral nervous system

The **peripheral nervous system** is a large system made up of all the nerves outside the central nervous system. The peripheral nervous system carries information to and from the central nervous system to the rest of the body, such as the limbs and organs.

The peripheral nervous system is divided into two parts.

- The **somatic nervous system** controls voluntary skeletal muscle movements, such as waving or reaching out to take an object.
- The **autonomic nervous system** controls involuntary actions, which happen without our conscious control. This includes heartbeat, digestion, respiration, salivation and perspiration. The autonomic nervous system maintains your body's internal environment (homeostasis).

The autonomic nervous system also has two parts: the sympathetic division and the parasympathetic division. These two divisions often have opposite effects. For example, the parasympathetic division slows down the heart rate, whereas the sympathetic division speeds up the heart rate. The systems work together to maintain a balance in the body.

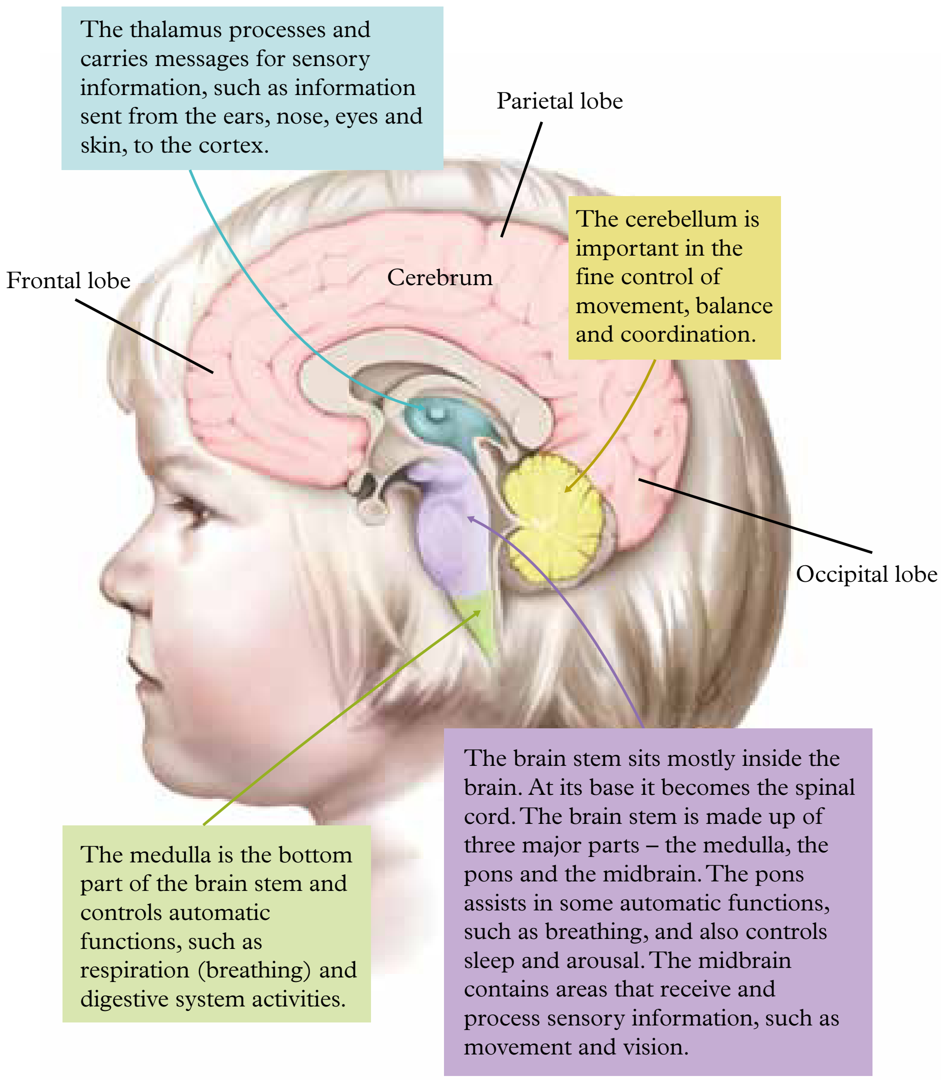


Figure 3 Structure of the human brain. The fourth lobe of the cerebrum, the temporal lobe (not shown here), is near the ears.

3.4 Check your learning

Remember and understand

1 **Identify** the two parts of the body that make up the central nervous system.

2 **Describe** the role or function of the peripheral nervous system.

Apply and analyse

3 Draw a scientific diagram of the brain that shows the four lobes. In each of the lobes:

 a write the functions that are carried out in that lobe

 b draw something to remind you of the functions carried out in that lobe.

4 **Describe** how the peripheral nervous system and the central nervous system work together. Use an example to illustrate your answer.

5 **Explain** why, if you slipped and hit the back of your head, everything might go black.

6 **Contrast** (the differences between) the somatic nervous system and the autonomic nervous system.

7 **Describe** the possible effect on behaviour that would occur if a person had damage to the frontal lobe of their brain.

peripheral nervous system
all the neurons (nerve cells) that function outside the brain and spinal cord

somatic nervous system
the part of the nervous system that controls the muscles attached to the skeletal system

autonomic nervous system
the part of the nervous system that controls involuntary actions such as heartbeat, breathing and digestion

3.5 Things can go wrong with the nervous system

In this topic, you will learn that:

- A slipped disc can press on the nerves in the spinal cord.
- When the myelin sheath is damaged in multiple sclerosis, the movement of the body can be affected.
- Motor neurone disease affects messages being passed to the muscles.
- Alzheimer's disease is caused by progressive damage to neuron functioning.

The nervous system plays a very important role in coordinating and regulating your body. Things that can go wrong with the nervous system include the spinal cord being damaged (paraplegia), things pressing on the nerves in the spinal cord (slipped disc), the myelin sheath in neurons being damaged (multiple sclerosis), the motor neurons failing (motor neurone disease) and damage to the neurons in the brain (Alzheimer's disease).

Spinal damage

Spinal injury is a major type of injury in Australia, especially in young men. These injuries commonly result from motor vehicle accidents, everyday falls and sports.

When the spinal cord is damaged, the messages from the neurons below the level of injury can no longer travel to the brain. This means the individual cannot receive messages from the sensors in this part of the body. It also means the messages from the brain cannot reach past the injury. How much of the body is able to move after a spinal injury depends on where the injury is in the spinal cord. If it is high up, most of the body is 'cut off' from the brain; if it is lower down, then the upper body and arms may be able to work as they normally would.

People with severe damage to the upper part of the spinal cord have quadriplegia – they are unable to use their arms or legs. If the injury is very high, they may even have trouble breathing on their own. People with severe damage below the arms have paraplegia – they are still able to use their arms but not their legs.

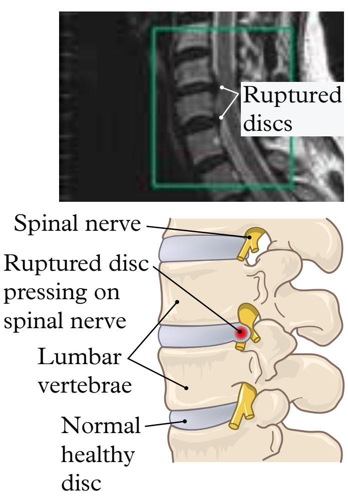


Figure 1 The vertebrae in your spine are separated from each other by fluid-filled discs. Rupturing of a disc can put pressure on the spinal nerves. Top: X-ray of spine, showing two ruptured discs. Bottom: A ruptured disc presses on the spinal nerve, causing pain.

Slipped disc

Your backbone consists of 26 bones, or vertebrae, that surround the nerves of your spinal cord. Between each vertebra is a sac called a disc, which is filled with a thick fluid, or gel, and allows the vertebrae to move. If a disc becomes weak and puts pressure on the nerves entering or leaving the spinal cord, this will cause pain or numbness along the nerve. Treatment usually involves pain relief, along with exercises that strengthen the muscles in the back. Occasionally, surgery is required to remove the damaged part of the disc.

Multiple sclerosis

The myelin sheath plays a very important role in ensuring the electrical message passes along the axon of a neuron. If the myelin sheath is damaged, the electric signal can be lost, like a broken wire in an electric circuit. Your immune system usually fights and kills bacteria and viral infections. In multiple sclerosis, the immune system mistakenly recognises myelin sheath cells as dangerous, and attacks and destroys them. This means messages to and from the senses (including the eyes, skin and bladder) and the muscles become lost. Muscles can become weak, and the sufferer can feel dizzy or tired, or have difficulty seeing properly. Most commonly, the symptoms appear for a short time, before disappearing completely, and then returning later on. This is called a relapsing–remitting cycle.

Motor neurone disease

In motor neurone disease (also known as amyotrophic lateral sclerosis, ALS), the neurons that send messages to the muscles become weak and eventually lose function. As the muscles grow weaker, they can cramp and become stiff. This usually starts in the muscles in the legs and arms, before progressing to the face and chest. This can affect the person's ability to talk and, eventually, to breathe. Neurons in the brain are also affected by this disease. Scientists do not know what causes the motor neurons to lose function. Research in this area is continuing.

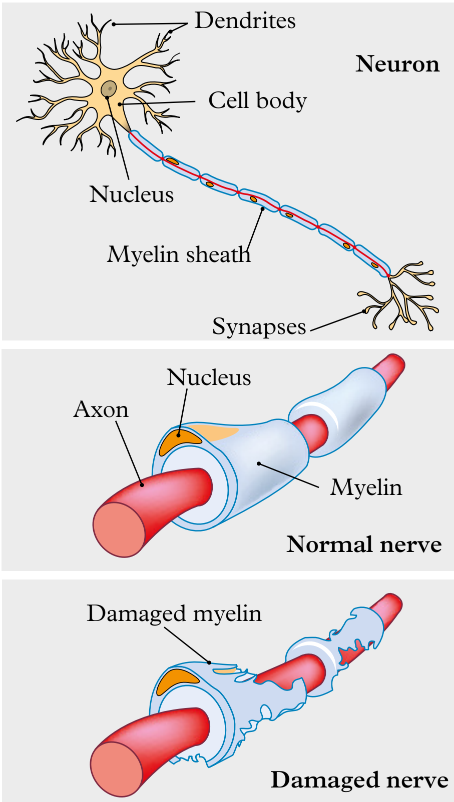


Figure 2 The myelin sheath surrounds the axon and helps electrical messages to move along the nerve. In multiple sclerosis, damage to the myelin sheath prevents the nerves from passing on messages.

Alzheimer's disease

Alzheimer's disease is caused by progressive damage to the neurons in the brain. This gradually affects memory, and the ability to reason or plan and carry out everyday activities. Problems with short-term memory mean that the sufferer cannot remember what happened a few hours ago, or what they are meant to be doing that day. The disease also has wider impacts. Sufferers can forget where they are and how to get home. This makes life very confusing for them and they can become upset very easily. Symptoms can vary from day to day, depending on tiredness or stress. The cause of Alzheimer's disease is not known. Research suggests that plaques develop around neurons in the brain, making it hard for them to transmit messages. Chemical changes in the neurons may be caused by genetic, environmental and health factors.

Figure 3 AFL legend Neale Daniher was diagnosed with motor neurone disease (MND) in 2013. Daniher's diagnosis has increased awareness and fundraising for MND.

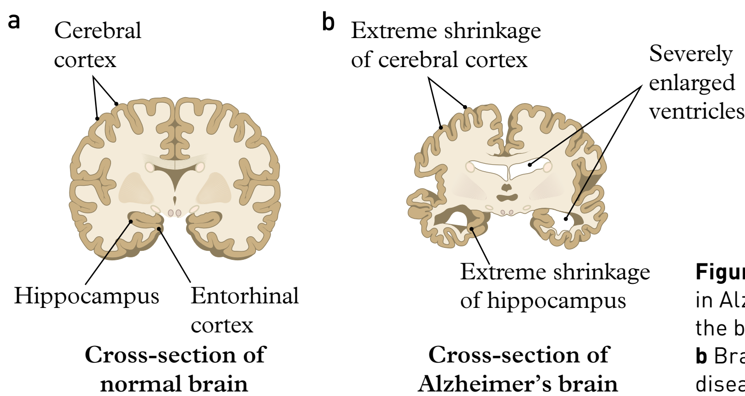


Figure 4 Damage to the neurons in Alzheimer's disease can cause the brain to shrink. **a** Normal brain **b** Brain of a person with Alzheimer's disease

3.5 Check your learning

Remember and understand

1 **Identify** the name of the individual bones that make up the spine.

2 **Contrast** quadriplegia and paraplegia.

3 **Describe** the role of a disc in the spinal column.

4 **Explain** why the destruction of the myelin sheath causes symptoms in multiple sclerosis.

5 **Identify** another name for motor neurone disease. **Describe** the role motor neurons usually play in a healthy nervous system.

Apply and analyse

6 Think about where you were and what you were doing one hour ago. **Describe** how you would be affected if you could not remember this.

3.6 The endocrine system causes long-lasting effects

In this topic, you will learn that:

- The endocrine system uses chemical messengers called hormones to maintain control and to regulate growth.
- Hormones travel through the bloodstream to receptors or target cells.
- The effects of hormones often last longer than the effects of the nervous system.

Video 3.6 The endocrine system

endocrine system
a collection of glands that make and release hormones

hormone
a chemical messenger that travels through blood vessels to target cells

target cell
a cell that has a receptor that matches a specific hormone

The **endocrine system** is a collection of glands that secrete (release) **hormones**. The hormones are secreted directly into the bloodstream and then travel around the body through the blood. Some cells in the body have receptors that match the hormone, like a lock to a key. These cells are called **target cells**. It only takes one hormone 'key' to cause a change in the target cell 'lock'.

The glands and organs of the endocrine system are spread throughout the body (see Table 1 and Figure 1).

Fight, flight or freeze?

If you are ever in a dangerous or frightening situation, you may experience a 'fight, flight or freeze' response. You break out in a cold sweat, your heart beats wildly, everything around you seems to slow down and your senses bombard you with information.

Most of these symptoms are triggered by the release of the hormone adrenalin (also called epinephrine). Adrenalin is constantly produced by the adrenal glands in small doses.

Table 1 Some organs and hormones of the endocrine system

Organ	Hormone	Target tissue	Main effects
Hypothalamus	Wide range of neurohormones	Pituitary gland	Sends messages from nervous system to the pituitary gland to control functions such as body temperature, hunger, thirst and sleep patterns
Ovaries	Progesterone	Uterus	Thickens wall of uterus to prepare for pregnancy
	Oestrogen	Body cells	Development of female sexual characteristics; aspects of pregnancy and foetal development
Testes	Testosterone	Male reproductive system, body cells	Development and control of male sexual characteristics; production of sperm
Pancreas	Insulin	Liver, most cells	Lowers blood glucose level
	Glucagon	Liver	Raises blood glucose level
Pituitary gland	Thyroid-stimulating hormone	Thyroid	Changes the rate of thyroxine release from the thyroid
	Antidiuretic hormone	Kidneys	Reduces the amount of water reabsorbed from the kidneys
	Pituitary growth hormone	Bones, muscles	Stimulates muscle growth; controls the size of bones
Thyroid gland	Thyroxine	Body cells	Affects rate of metabolism, and physical and mental development
Parathyroid glands	Parathyroid hormone	Blood	Regulates the amount of calcium in the blood
Adrenal glands	Adrenalin	Body cells	Increases body metabolism in 'fight or flight' response
Pineal gland	Melatonin	Skin cells	Involved in daily biological rhythms

CHALLENGE

3.6: Glands and organs of the endocrine system
Go to page **180**.

The adrenal glands are located above the kidneys. The usual function of this hormone is to stimulate the heart rate and enlarge blood vessels. However, when you are in danger, adrenalin takes on another role. It floods your system, causing an increase in the strength and rate of the heartbeat, raising your blood pressure and speeding up the conversion of glycogen into glucose, which provides energy to the muscles. In this way, adrenalin prepares your body for the extra effort required should you need to defend yourself (fight), run away (flight) or hide (freeze).

Panic attacks

Sometimes the 'fight, flight or freeze' response can be triggered without any obvious reason. This means adrenalin can flood the body, causing the heart to pound, breathing to become fast and shallow, and a flood of sensory information to stimulate the brain. When this occurs, lights appear brighter, sounds are louder and smells stronger. These sensory messages can become jumbled as the brain struggles to make sense of all the information. This combination of endocrine and nervous system responses is called a panic attack. These symptoms are not life threatening and will eventually disappear. Support from friends and family can help.

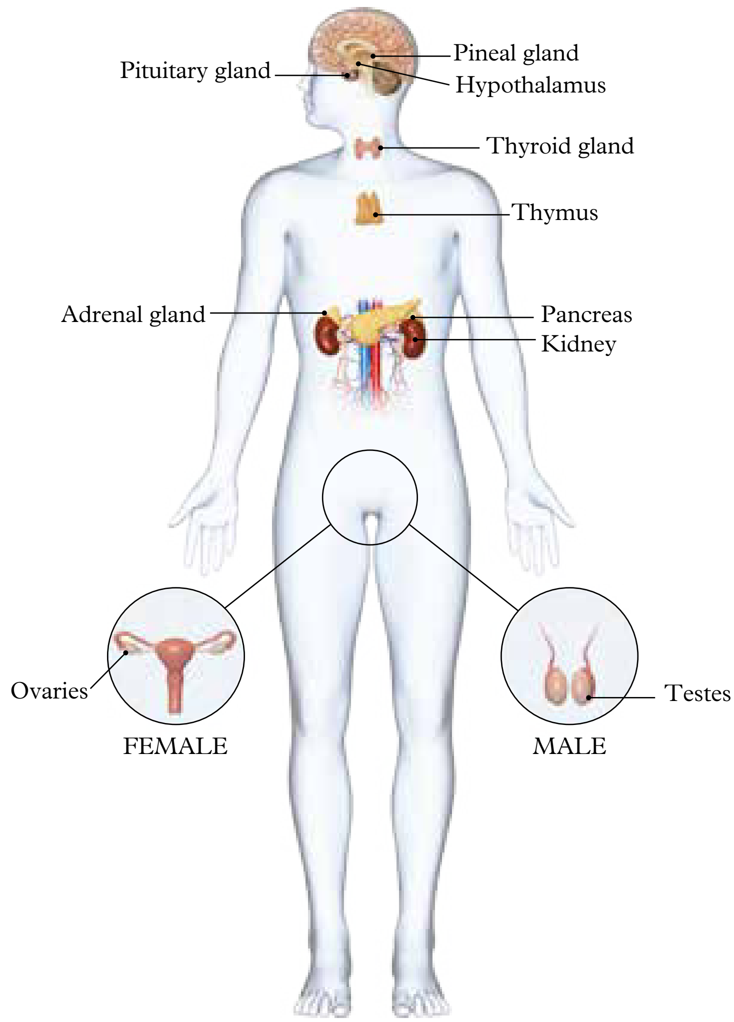


Figure 1 The human endocrine system

Figure 2 Adrenalin is responsible for the 'fight, flight or freeze' response in mammals and can help them to survive.

3.6 Check your learning

Remember and understand

1 **Identify** the name of the system in your body that is responsible for hormones.

2 **Describe** what is meant by the phrase 'fight, flight or freeze' and how it relates to hormones.

3 **Describe** the symptoms of a panic attack.

4 **Explain** why the endocrine system is referred to as a communications system.

Apply and analyse

5 **Compare** (the similarities and differences between) a hormonal response and a nervous response. **Describe** one advantage for each system.

6 **Explain** why telling someone to 'calm down' during a panic attack will not stop their symptoms. (HINT: Are they able to control their hormones?)

3.7 Homeostasis regulates through negative feedback

In this topic, you will learn that:

- The body needs to detect and correct changes in its levels of nutrients, water and temperature to stay healthy.
- The process of regulating the internal conditions of the body is called homeostasis.
- Negative feedback occurs when the body responds in a way that removes the initial stimulus.

Scientists have not yet discovered another planet that humans could inhabit. Humans can only survive in very specific environments. Our bodies have particular requirements, including the right amount of food and water, oxygen and carbon dioxide. If you were lost in a desert or in freezing temperatures, your body would try to maintain a temperature of about 37°C at all times, to keep all cells working efficiently. This 'business as usual' approach of responding to stimuli to maintain a stable state is called **homeostasis**.

homeostasis
the process by which the body detects and responds to stimuli to ensure a stable internal state is maintained

Figure 1 Homeostasis is your body's ability to regulate and maintain a stable condition (balance) inside your body, regardless of changes to the external environment.

Homeostasis

To maintain homeostasis, your body uses a mechanism that is similar to a thermostat in a heater. When temperature receptors on your skin and in the hypothalamus of your brain detect cooling down (stimulus), a message gets sent to a variety of effectors around your body. Effectors are glands or muscles that cause a change in the way your body functions. This may include muscles to make you shiver (to warm up) or blood vessels to redirect the flow of warm blood to the important organs in your body (heart, liver and brain).

If the temperature receptors detect that you are too hot (stimulus), then the effectors include your sweat glands and blood vessels.

Figure 2 When your body is stimulated by heat, homeostasis ensures you cool down by sweating.

EXPERIMENT
3.7: Experiencing homeostasis
Go to page **180**.

Your body responds by sending more blood, which is carrying heat, to your skin, where sweat is evaporating, carrying away the heat and cooling you down. This a **negative feedback mechanism** – the effectors respond and, as a result, remove the stimulus. If you are too hot, then your body tries to cool you down. If you are too cold, then your body works to warm you up.

Hormones at work

The rate of hormone production and secretion is often regulated by a negative feedback mechanism. If a stimulus is received that indicates something in the body is happening 'too much', the body has receptors to detect it. The body responds by producing a hormone to remove the stimulus and return the body to normal.

Blood glucose

As you eat, food gets broken down into smaller nutrients. All carbohydrates get broken down into simple sugars, including glucose. These glucose molecules travel through your blood and provide energy for cellular respiration (the reaction of glucose with oxygen to produce carbon dioxide, water and ATP). Too much glucose in the blood is not healthy, because it causes water to be lost from cells through osmosis. Your body tries to control the amount of glucose in your blood. If the concentration of glucose in your blood is too high (stimulus), then receptors in the pancreas detect it. They then release a hormone called insulin into the blood. Insulin travels throughout the body to insulin receptors on the target muscle and liver cells. These cells then act as effectors and remove glucose from the blood. This causes the blood glucose to decrease, removing the original stimulus. This is an example of negative feedback.

If blood glucose levels are too low, your body will use negative feedback to restore levels to a homeostatic state. Low glucose levels are detected by receptors in the pancreas (stimulus). This time, the hormone glucagon is released into the blood. Receptors for glucagon are also found on the effector cells in the liver and muscles. Glucagon binding to the receptors causes the muscle and liver cells to release stored glucose into the blood (response), increasing the amount of blood glucose once again.

negative feedback mechanism
a regulatory loop in which the stimulus causes a response that acts in the opposite direction to whatever is being regulated

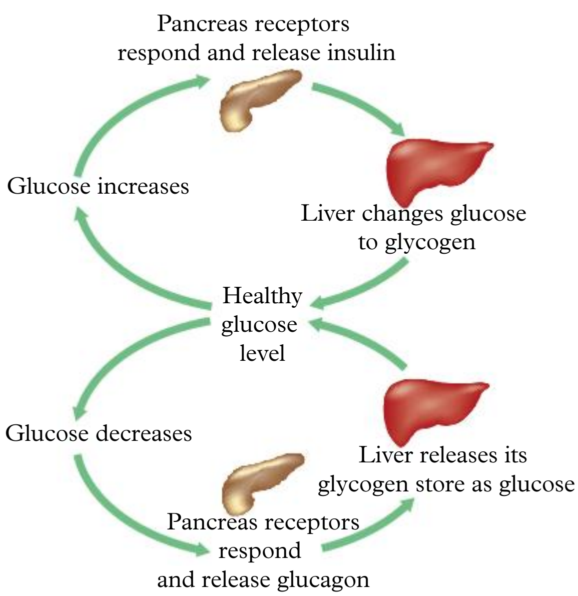


Figure 3 The pancreas and the liver work together to maintain healthy glucose levels in the body.

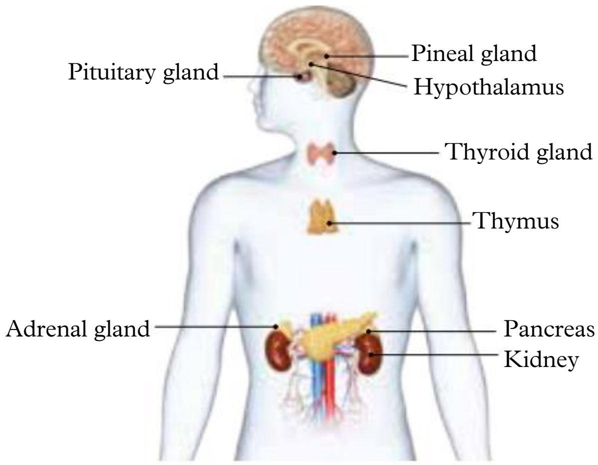


Figure 4 The pancreas is the endocrine organ responsible for the regulation of blood glucose levels.

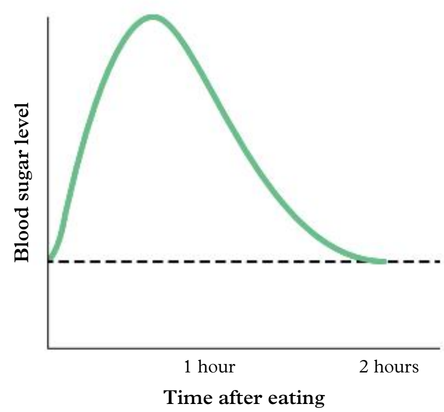


Figure 5 After you eat, your blood glucose levels increase. The body's response is to release insulin, which causes the muscle and liver effectors to remove the glucose and restore homeostasis.

Figure 6 Water controls the chemical reactions that occur in cells.

Water regulation

You may have noticed that when you drink lot of water, you need to visit the bathroom in the next hour. Your body uses homeostasis to control the balance of water in your body. Water is needed to control all the chemical reactions that occur in the cells. If there is too much or too little water, these chemical reactions will be affected and the cells can become damaged.

The water balance in your body is tightly controlled by the hypothalamus in your brain. If it has been a hot day, or you have been doing physical exercise and sweating, then your body may have lost a lot of water. Receptors in the hypothalamus of the brain detect changes in fluid levels in your blood and send a message to the pituitary gland at the base of your brain. The pituitary gland releases a chemical messenger called antidiuretic hormone (ADH) into your blood. This hormone travels all around your body until it reaches target effector cells in your kidney. The ADH binds to the receptors on the effector cells, causing them to reabsorb extra water from your urine. This makes your urine more concentrated or darker in colour. The extra water that was reabsorbed goes back into the blood, keeping the blood volume high. This is a form of negative feedback, as the response (reabsorbing water from the urine and returning it to the blood) results in a decrease of the stimulus (improving water levels in the blood).

Drinking a lot of water causes the blood volume to increase. This is also detected by receptors in the hypothalamus. This time the message to the pituitary gland is 'STOP producing ADH'. The lack of ADH is detected by the effector cells in the kidney, and they stop reabsorbing water from the urine. This means the urine has more water in it, and it becomes very clear and diluted.

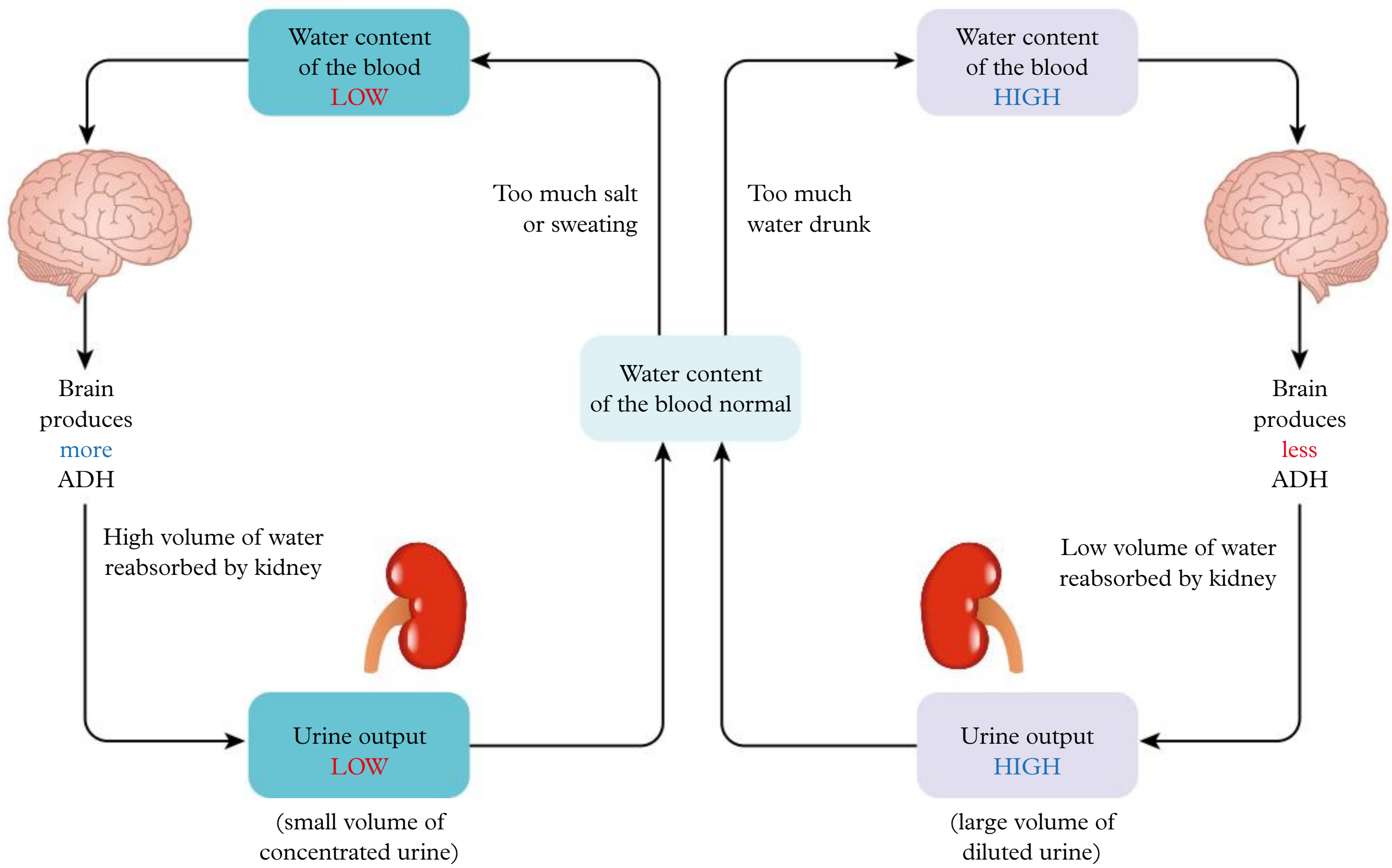


Figure 7 Water regulation in the human body

Oxygen and carbon dioxide homeostasis

Have you ever wondered why you become puffed when running a race? Oxygen and carbon dioxide in the blood are under strict homeostatic control. You need the oxygen for cellular respiration in a cell. Carbon dioxide is the waste product of this reaction.

Sprinting during a race causes the muscle cells in your legs to use a lot of glucose and oxygen and to produce a lot of carbon dioxide. The muscle cells release the carbon dioxide into the blood, where it forms carbonic acid. This is not good for your body. The acid content of the blood is measured by receptors in the medulla in the brain stem. If the level is too high from excess carbon dioxide, a message is sent through the nervous system to the muscles that control your breathing. This causes the diaphragm to move faster, increasing the rate of your breathing and making you feel puffed. The message also goes to the heart to make it beat faster. This makes the blood move faster, carrying the carbon dioxide to the lungs where it can be removed by breathing out. These two responses act as negative feedback, removing the stimulus of high levels of carbon dioxide in the blood.

Meditation often involves sitting or lying down and relaxing. This means the level of cellular respiration in muscles is low. Little oxygen is used and little carbon dioxide is produced. As a result, the levels of carbon dioxide in the blood decrease. The receptors in the medulla once again detect the change from the homeostatic state and signal the heart to slow its beat and the lungs to slow their breathing.

Figure 8 After a race, you may be puffed.

3.7 Check your learning

Remember and understand

1 **Define** the term 'homeostasis'.

2 **Describe** how your body responds to cold weather.

3 **Describe** how your blood sugar level changes when you eat.

4 **Describe** how your body responds to low blood sugar levels.

Apply and analyse

5 **Identify** the stimulus, location of receptors, effectors and response to high body temperature.

6 If a negative feedback loop reduces the effect of a hormone, **describe** what a positive feedback loop should do.

Evaluate and create

7 In type 1 diabetes, cells in the pancreas are unable to produce insulin. **Predict** what effect this would have on blood glucose levels. Research how people with type 1 diabetes ensure that their blood glucose levels remain at the homeostatic level.

8 **Describe** how and why your body responds to the following:

  a drinking a bottle of water

  b swimming 15 m under water

  c swimming in the ocean on a cold day.

Figure 9 When you meditate, the carbon dioxide levels in your body decrease.

//SCIENCE AS A HUMAN ENDEAVOUR//

3.8 Hormones are used in sport

Erythropoietin is a hormone normally produced by the kidneys to increase the number of red blood cells in the body. Athletes can use this version of a negative feedback mechanism naturally or artificially to increase their performance on the sporting field.

Many athletes and sporting clubs spend months training high in the mountains to help their performance in competitions. The air in the mountains is much thinner. Although it is still 21 per cent oxygen, it is harder for a person to fill their lungs as the particles in the air are spread out further. As a result, when a person first arrives at high altitude, their body struggles to get enough oxygen. This can make the person feel tired, as they are unable to burn the glucose in aerobic cellular respiration.

Negative feedback in action

The body normally produces just enough red blood cells to carry oxygen around the body. When red blood cells die, a hormone called erythropoietin is produced by the kidneys. The erythropoietin travels through the blood to receptors in the bone marrow. The effector bone marrow cells then produce more red blood cells to replace those lost.

Exercising at a high altitude stimulates the body to react as though there are not enough red blood cells to carry oxygen to the muscles. Erythropoietin is produced, causing the bone marrow to make extra red blood cells. It takes about three weeks for the extra cells to become noticeable. When the athlete returns to sea level to compete, the red blood cells remain active for up to a month. This means the athlete's blood is more efficient at carrying oxygen to muscles, making the athlete less likely to become fatigued (tired). Training at a high altitude uses the negative feedback mechanism to the athlete's advantage.

Some athletes bypass high-altitude training and inject erythropoietin directly into their blood. This is called blood doping. However, the amounts of hormone introduced into the blood are not controlled. This can cause an over-production of red blood cells, which strains the heart. The athlete is at risk of a heart attack or a stroke.

Figure 1 Training at a high altitude can increase an athlete's performance.

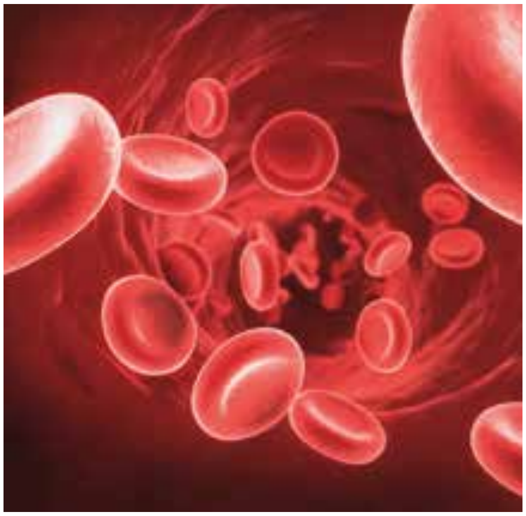


Figure 2 Erythropoietin increases the production of red blood cells.

Drug testing

Erythropoietin was first synthesised in the laboratory in the 1990s. Unfortunately, it was 10 years before drug testing could distinguish the artificial hormone from naturally occurring erythropoietin. In 2002, at the Winter Olympic Games in Salt Lake City, United States, the first athlete was identified as having a version of erythropoietin in their urine and blood.

Figure 3 In 2013, Lance Armstrong admitted to injecting erythropoietin to help him win world cycling events.

Medical uses of erythropoietin

Erythropoietin is produced in the kidneys. Any disease that affects kidney function will also affect the production of erythropoietin. As a result, a person with kidney disease will also have low levels of red blood cells. This is called anaemia. Symptoms of anaemia are a pale appearance and feeling tired when exercising. Regular injections of erythropoietin will increase the production of red blood cells and improve the person's health.

Figure 4 Anaemia can make you feel tired when exercising.

3.8 Develop your abilities

Evaluating the ethics in sports

Sport competition prides itself on fairness for all competitors. There are many ways to improve an athlete's chances of winning a competition, including training, special diets, shaving body hair and wearing special clothing that reduces air resistance. Some athletes undergo surgery to improve their ability to compete. This can include a golfer having laser eye surgery. A runner who has asthma is allowed to use a Ventolin inhaler, but other athletes are not permitted to use hormones to speed their recovery from an injury.

Evaluate the ethics of cheating in sports by deciding which of the following situations should be allowed and which should be banned. In each situation, **justify** your decision (by describing how the athlete would be advantaged, describing the potential dangers to the athlete, describing whether all athletes would have equal access, and deciding whether the situation could be described as cheating).

1 An athlete takes a dietary supplement that maximises their performance.
2 A swimmer wears an expensive swimsuit that minimises water resistance.
3 An athlete has genetically modified muscles.
4 An athlete takes hormones that increase recovery after injury by increasing muscle mass.

//SCIENCE AS A HUMAN ENDEAVOUR//

3.9 Pathogens cause disease

Infectious pathogens can disrupt the normal functioning of the body and cause disease. There are many types of pathogens, including bacteria, fungi, protozoans and viruses. Koch's postulates are used to provide evidence that a pathogen causes a disease. Penicillin and other antibiotics can be used to kill bacteria, but not viruses or other pathogens.

pathogen
a microbe that can cause disease

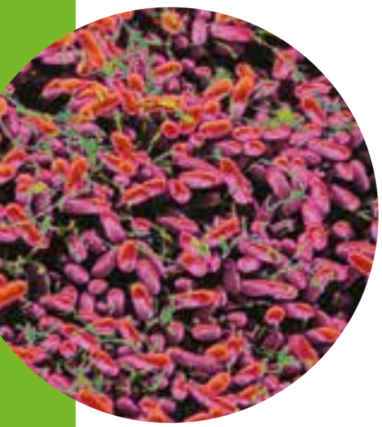


Figure 1 Some bacteria keep us healthy. Other bacteria are pathogens and interfere with the natural functioning of our body.

One of the first people in Western medicine to question the accepted idea of supernatural causes of disease was Hippocrates (460–377 BCE). He concluded that something in the air, soil, water and food caused diseases in humans and animals. His work was followed up by Claudius Galen (131–201 CE), who was a doctor to the gladiators, and used animal dissections to explore anatomy.

Girolamo Fracastoro (1478–1553) was an Italian astronomer and doctor who was one of the first to suggest that disease could be transmitted from person to person via small, invisible particles. He theorised that these particles could travel through the air, via contaminated clothing or by direct contact with the sick person. It took 200 years and the discovery of the microscope to confirm his theories and to develop the 'germ theory' used today.

Germ theory states that many diseases are caused by the presence and actions of specific micro-organisms. These micro-organisms are called **pathogens**. Germ theory was confirmed by Louis Pasteur and Robert Koch.

Robert Koch went on to develop a set of rules, known as Koch's postulates, that provide evidence that a pathogen causes a disease.

1 The micro-organism or other pathogen is present in all cases of the disease.
2 The pathogen can be isolated from the diseased host and grown in the laboratory.
3 The pathogen from a pure culture causes the disease when inoculated into a healthy susceptible laboratory animal.
4 The pathogen is re-isolated from the new host and is shown to be the same as the originally inoculated pathogen.

Australian scientists Barry Marshall and Robin Warren followed these postulates when they researched stomach ulcers in 1984. Together they discovered that a bacterium (*Helicobacter pylori*) was found in all patients with stomach ulcers. Most doctors at the time thought that no bacterium could survive in the acidic environment of the stomach. Marshall and Warren isolated the bacterium and injected it into mice, causing the disease in the mice. Unfortunately, many doctors still did not believe the research, so Barry Marshall ignored laboratory safety and swallowed a culture of the bacteria, causing the disease in himself.

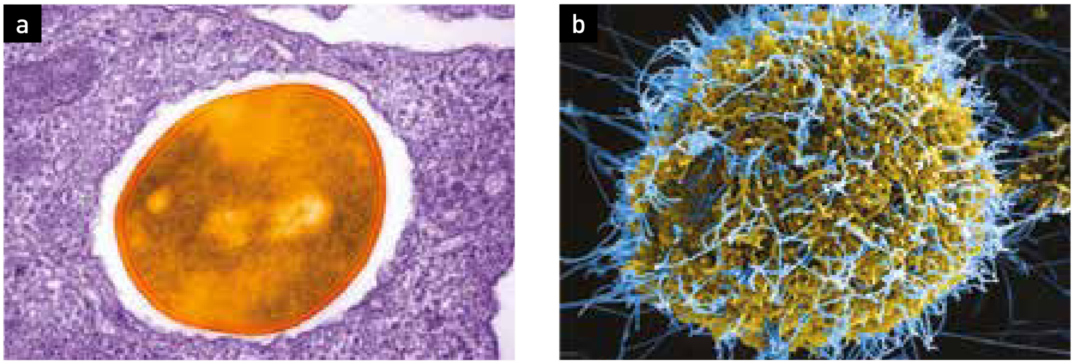


Figure 2 Most infections are caused by microscopic pathogens such as bacteria or viruses. **a** Bacteria are very small cells that are able to reproduce by themselves. They can release toxins that affect the normal functioning of our body. **b** Viruses are much smaller than bacteria and are unable to reproduce by themselves. Instead, they invade the host's cells and use the organelles to make new copies of themselves. This stops the host's cells from functioning properly.

CHALLENGE 3.9A: Investigating pathogens Go to page 181.

EXPERIMENT 3.9B: Investigating germ theory Go to page 182.

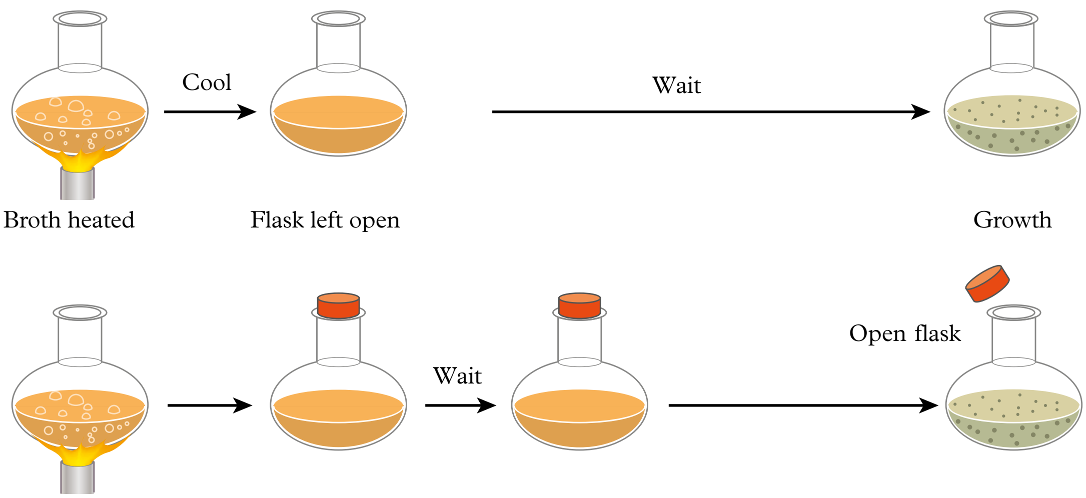


Figure 3 Louis Pasteur's experiments found that micro-organisms in milk were killed by heat. This process is called pasteurisation and is still in use today.

Treatment with antibiotics killed the bacteria and cured his stomach ulcer. Barry Marshall and Robin Warren were awarded the Nobel Prize in Physiology or Medicine in 2005.

Antibiotics

Before antibiotics were discovered, a single scratch from a thorn on a rose bush could become infected and kill a person.

In 1928, Alexander Fleming was trying to grow bacteria in his laboratory. When he returned from holidays he discovered that some Petri dishes he had left open on the bench were growing a mould similar to that found on bread. There were no bacteria growing near the mould. Being a good scientist, Fleming recognised that further investigation was necessary. He performed some experiments and discovered that the *Penicillium* mould was releasing a chemical that killed bacteria. Australian scientist Howard Florey was then instrumental in developing penicillin into a form that could be mass-produced. Both scientists were awarded the Nobel Prize in Physiology or Medicine for their work.

Penicillin works by breaking down the cell walls of bacteria. As human cells do not have a cell wall, they are unaffected. This means that penicillin will kill the bacteria in your body but not kill your own body cells. Viruses do not have cell walls. Instead, they have a protein coat that surrounds and protects them. This means penicillin does not affect viruses, such as influenza, coronaviruses or the common cold.

Most viruses cannot be treated by any readily available medicines.

Figure 4 Robin Warren (left) and Barry Marshall (right)

3.9 Develop your abilities

Identifying assumptions

Scientists are always asking questions and challenging what they know. Robin Warren and Barry Marshall asked questions and challenged the assumption that stomach ulcers were caused by stress. Everyone makes assumptions (accepting that something is true or certain without evidence) based on past experiences. It is a way of saving time and thinking space. We assume that the sun will rise in the morning, that the chair we sit on will not collapse and that food we have cooked will be hot. Making assumptions is not always a bad thing, as long as we are aware that we are making them. Asking questions is a way of identifying assumptions that are not true.

1 **Identify** the question that Robin Warren and Barry Marshall asked about stomach ulcers.

2 **Identify** how Warren and Marshall used each of Koch's postulates to find the cause of stomach ulcers.

3 **Identify** the assumption that other doctors had made about the cause of stomach ulcers.

4 **Identify** one assumption that you have made in the past week.

5 **Describe** the evidence you would need to convince yourself that your assumption in question 4 was incorrect.

6 **Describe** an invention or behaviour you would change if your assumption in question 4 was incorrect.

3.10 The immune system protects our body in an organised way

In this topic, you will learn that:

- The immune system acts to physically prevent pathogens entering your body.
- Pathogens that enter the body are identified and destroyed by the immune system.

immune system
a system of organs and structures that protect an organism against disease

white blood cell
an immune system cell that destroys pathogens

phagocyte
an immune system cell that surrounds, absorbs and destroys pathogens

The role of your **immune system** is to protect you against foreign invaders by physically stopping them from entering your body, and to identify and attack them if they do manage to enter. Your immune system has three lines of defence against pathogens, each with a different role.

First line of defence

The first line of defence is to stop pathogens from getting inside your body (Figure 1). It consists of the skin and mucous membranes.

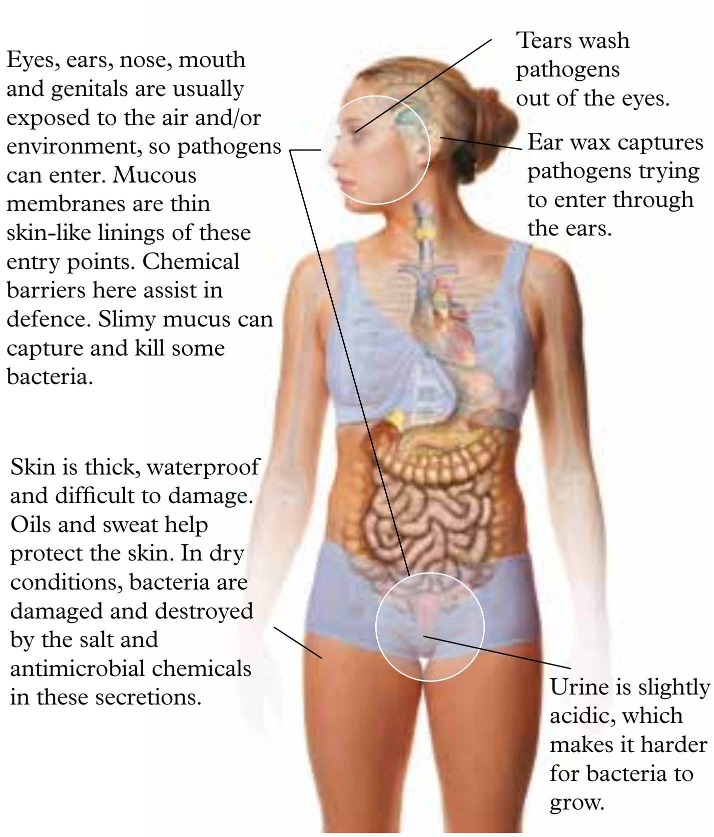


Figure 1 The skin and mucous membranes are the first line of defence against pathogens.

Second line of defence

Viruses, unlike bacteria, contain a protective coating that allows them to more easily slip through the first line of defence. If a pathogen gets inside your body, the body tries to remove it in one of two ways.

First, a general 'seek and destroy' approach occurs regardless of the type of pathogen. This is called a general or non-specific immune response. The key parts of the non-specific immune response are:

> blood clotting – to stop additional infection through skin damage

> inflammation – to increase the number of blood cells reaching an infected area

> fever – some pathogens cannot survive at high temperatures, so heating up the body is one way to destroy them.

Second, **white blood cells** are produced by the body to destroy pathogens. Inflammation increases the amount of blood reaching the infected area, so more white blood cells are able to attack the pathogen. The white blood cells may also release chemical messengers that increase the amount of fluid in the infected area, causing swelling.

There are different types of white blood cells. Each type has its own role but they all work together. **Phagocytes** (Greek for 'cells that eat') are part of the non-specific immune response. They surround and absorb pathogens, destroying them in a process called phagocytosis (Figure 2).

Third line of defence

Any pathogens that survive the non-specific secondary response are targeted according to their type. This is called a specific immune response.

CHALLENGE

3.10: Modelling infection and vaccination
Go to page 183.

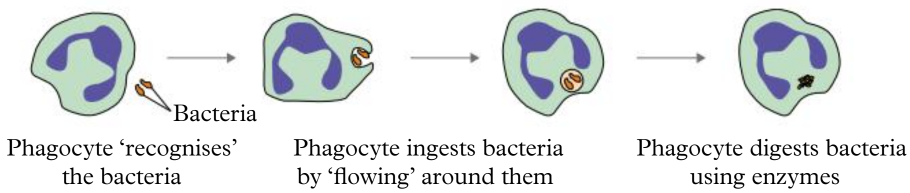


Figure 2 The process of phagocytosis

The specific immune response has two forms of attack. **B cells** produce special molecules called **antibodies**. These antibodies fit exactly onto a specific part of the pathogen (Figure 3). Each antibody will fit only one section of the pathogen. This causes the pathogens to become locked together and stops them invading.

T cells then recognise the same specific pathogen and attack and kill it. B and T cells may take up to a week to recognise and destroy a pathogen. This is why recovering from an illness takes time.

Both B and T cells keep some **memory cells** alive, just in case the pathogen tries to invade again. This means the pathogen will be attacked and killed before it can cause damage a second time. Your body will be protected from reinfection in the future. You are now **immune**.

Unborn babies obtain some natural immunity by receiving antibodies through the placenta from the mother. Antibodies are also passed to babies through breast milk.

Another way to acquire immunity is by ingestion or injection with specific small parts of the pathogen. This is called **vaccination**, or inoculation. A vaccine can be made up of:

- the dead pathogen
- a living but non-virulent (weakened) form of the pathogen
- parts of the broken-up pathogen
- genetic material from a viral pathogen.

Through vaccination, a person makes antibodies and memory cells that will recognise the pathogen in the future, which usually leads to immunity. Vaccinations are often given as a preventive measure. For instance, the influenza vaccine is recommended for people over 65 years of age because complications from influenza can be life-threatening in older people. Vaccination can also be given when there is an urgent need to provide immunity, such as preventing Covid-19. For example, the modified genetic material from the SARS-CoV-2 coronavirus can be used for vaccination. This means a person will have antibodies and T cells already activated in their body to prevent the virus from causing damage and Covid-19 symptoms.

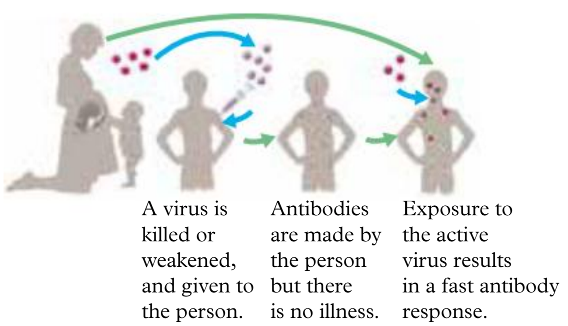


Figure 4 A person can become protected or immune actively through vaccination, or passively by antibodies being passed on to them in breast milk from their mother when they are a baby.

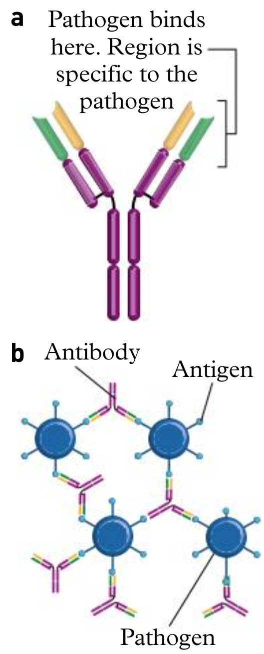


Figure 3 **a** Each antibody has a region that is specific to a particular pathogen. **b** Antibodies cause pathogens to clump together.

B cell
an immune system cell that produces antibodies in response to pathogens

antibody
a molecule produced by B cells that binds to a specific pathogen

T cell
an immune system cell that recognises and kills pathogens

memory cell
an immune system cell produced in response to an infection; retains the memory of how to fight the pathogen

immune
able to fight an infection as a result of prior exposure

vaccination
an injection of an inactive or artificial pathogen that results in the individual becoming immune to a particular disease

3.10 Check your learning

Remember and understand

1 **Describe** the body's major first line of defence.

2 **Describe** one other way the body can prevent pathogens from entering.

3 **Describe** in your own words how the non-specific immune response works.

Apply and analyse

4 **Compare** (the similarities and differences between) the second and third levels of defence.

5 **Compare** the different types of vaccines.

6 **Describe** how a vaccine prevents a person from 'catching' a disease.

7 Newborn babies cannot be vaccinated against whooping cough until they are 2 months old. The antibodies in breast milk are not enough to protect them from this deadly disease. **Explain** why it is important for everyone who comes into contact with the baby to be vaccinated against whooping cough.

3.11 Things can go wrong with the immune system

In this topic, you will learn that:

- Allergies result from an overactive immune system.
- Autoimmune diseases such as type 1 diabetes and rheumatoid arthritis are caused by the immune system attacking the rest of the body.
- HIV is a virus that specifically attacks T cells, resulting in acquired immune deficiency syndrome (AIDS).

The immune system coordinates attacks on pathogens that are trying to disrupt the body. The coordination of all the cells and chemical molecules is very complex, and can easily be disrupted.

allergy
an overreaction by the immune system in response to pollen, dust or other non-pathogens

anaphylaxis
a life-threatening overreaction by the immune system to a normally harmless substance

Hay fever and other allergies

Allergies result when your immune system mistakes a harmless substance as dangerous. This means the body overreacts. A common example is plant pollen, mainly from grass but also from trees, which can cause hay fever. When the pollen gets in your eyes or nose, your second and third lines of defence start attacking it. Inflammation occurs, resulting in an increased amount of blood reaching the area. Fluid leaks out of the blood vessels and the area becomes red and swollen. This also contributes to a runny nose and watering eyes, as your body tries to flush out the pollen.

Phagocytes also invade the area in an attempt to destroy the pollen. If you have been exposed to the pollen before, then your body will already have antibodies that speed up this reaction. In extreme cases, the person's throat will swell shut, making it difficult to breathe. The large amount of fluid leaking from the blood vessels can also cause the blood vessels to collapse. This life-threatening response is called **anaphylaxis**.

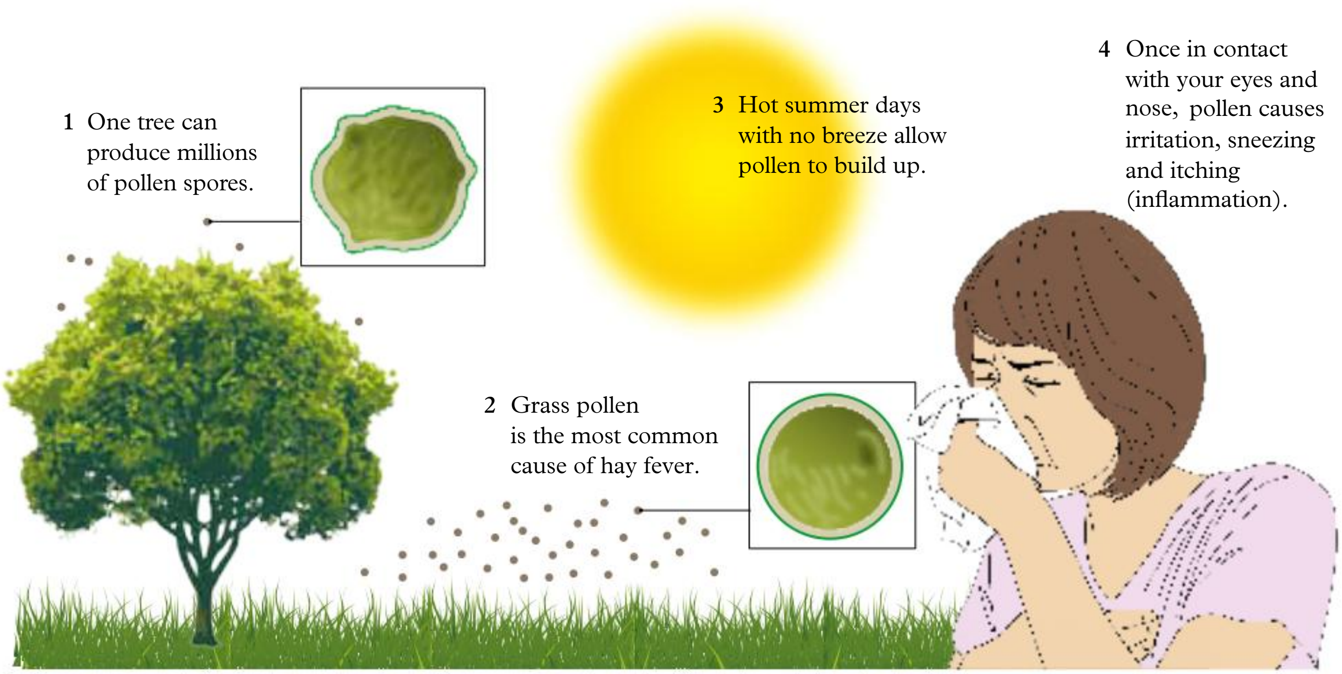


Figure 1 How hay fever happens

Figure 2 Epipens deliver adrenalin to people suffering anaphylactic shock.

Autoimmune diseases

Autoimmune diseases are a group of diseases that result from your body's immune system identifying healthy parts of your own body as a pathogen. **Rheumatoid arthritis** is an autoimmune disease in which the body produces B and T cells that attack the joints of the body. B cells produce antibodies, and T cells try to destroy the synovial membrane that lines the joint. This causes the joint to swell with fluid, which causes heat and pain for the sufferer.

Figure 3 Inflammation causes the joints of rheumatoid arthritis sufferers to swell and become painful.

Type 1 diabetes is also caused by an autoimmune reaction against the cells in the pancreas that produce insulin. As a result of attack by B cell antibodies and T cells, these pancreatic cells are destroyed. This means the person is unable to control their own blood glucose levels and instead must test their glucose levels regularly and inject artificial insulin when it is needed.

type 1 diabetes
an autoimmune disease in which the immune system attacks the insulin-producing cells in the pancreas

rheumatoid arthritis
an autoimmune disease in which the immune system attacks the joints of the body

HIV causes AIDS

The human immunodeficiency virus (HIV) infects a special type of T cells in the immune system. This makes the whole immune system ineffective. A person with HIV has a weakened immune system. This causes them to develop a range of infections that a normal immune system would be able to destroy easily. For example, simple fungal infections, viral eye infections and diarrhoea (loose bowel motions) can make a person infected with HIV very sick. Collectively these symptoms are called acquired immune deficiency syndrome (AIDS).

Figure 4 If the immune system is ineffective, opportunistic pathogens such as yeast can grow out of control.

3.11 Check your learning

Remember and understand

1 **Explain** why hay fever causes a runny nose and watery eyes.

2 **Explain** why hay fever is always worse the second time you are exposed to pollen.

3 **Explain** why a person with rheumatoid arthritis has swollen finger joints.

Apply and analyse

4 **Explain** why people with type 1 diabetes are unable to produce their own insulin.

5 **Contrast** HIV and AIDS.

6 **Explain** why eating even a small quantity of peanuts can cause death in some people.

REVIEW 3

Multiple choice questions

1 **Identify** which of the following is the stimulus.
  A a target cell that has a receptor
  B a hormone released into the bloodstream
  C a change in the environment that disrupts homeostasis
  D a response by the body that restores the homeostatic balance

2 Which of the following cells produce antibodies?
  A B cells
  B phagocytes
  C T cells
  D viruses

3 Select which of the following is not a pathogen.
  A fungi
  B bacteria
  C adrenalin
  D yeast

Short answer questions

Remember and understand

4 **Define** the following terms:
  a stimulus
  b homeostasis
  c pathogen.

5 **Describe** three ways the human body can receive a stimulus from the environment.

6 **Identify** two glands in humans that produce hormones.

7 **Explain** why the nervous system and the endocrine system are both described as communication systems.

8 **Describe** how hormones are transported in the body.

9 **Describe** three major features of the body's first line of defence.

10 **Describe** an example of an infectious disease.

11 **Describe** how an antibody is used by the body to prevent a pathogen from spreading around the body.

12 **Explain** why it is important to have certain vaccinations before travelling overseas. **Identify** two examples of diseases you may need to be vaccinated against.

13 **Explain** how the immune system's third line of defence remembers pathogens in case you are exposed to the pathogen a second time.

Apply and analyse

14 Use an example to **explain** how a negative feedback mechanism works.

15 Complete this sentence by inserting the missing words.
A person with diabetes has a problem with the hormone ___________, which is secreted by the ___________.

16 When a person drinks a litre of water, their body produces extra urine. Use the concept of homeostasis to **explain** why.

Figure 1 Drinking water after exercising is an important part of homeostasis.

17 Transmission of pathogens can cause mass outbreaks of a disease and affect large numbers of people. Examples are Covid-19, HIV, the SARS virus, swine flu, and the outbreak of cholera in Zimbabwe. Choose one disease and **explain** how it can spread so quickly. **Describe** what can be done to prevent the spread of such diseases.

18 **Explain** how the endocrine system assists your body to 'respond to the world'. **Explain** why your body also needs a nervous sytem.

Evaluate

19 **Explain** why holding your nose might help you to swallow something that tastes awful.

20 Predatory animals have their eyes on the front of their face, while their prey generally have eyes on the sides of their heads. **Explain** the advantage for predators in having eyes on the front of their face.

Figure 2 Jaguars prey on deer, reptiles and fish.

21 In Canada in 2006, a woman fought off a polar bear with her bare hands when it attacked her son. She literally wrestled the bear and won! **Explain** why this reaction could be attributed to the hormone adrenalin.

22 **Compare** viruses, bacteria and protozoa, which are all pathogens.

23 Given that people have usually caught a cold before, **explain** why we continue to catch colds.

24 Your body is constantly monitoring and controlling the numbers of pathogens in and on it. **Describe** what you can do to assist your body in controlling pathogens.

25 The hygiene hypothesis suggests that childhood exposure to microbes and certain infections helps the immune system develop. As a result of potentially being too hygienic, developed countries continue to see a rise in autoimmune conditions such as asthma and anaphylaxis. **Investigate** these conditions, and **outline** the role of the body's own immune response in causing the symptoms.

26 **Describe** in your owns words how the non-specific immune response works.

Social and ethical thinking

27 Babies can be vaccinated against a wide range of diseases in the first months and years of their lives. They are not old enough to choose to be vaccinated, so the decision is made by their parents or guardians. Find out which vaccinations are available and present the arguments for and against giving them to babies.

28 A person with Alzheimer's disease can often forget what has happened in the past 30 minutes. An example of this is forgetting they have already eaten their lunch. This means the person can become very frustrated and upset if they think they are being refused food. Their carers may explain (many times) that the person has already eaten, but this can upset the person more, as they think they are being lied to. Other carers may lie to the person and say that lunch will ready in five minutes. This settles the person, who will often forget about eating in that time. **Identify** which approach you would use. **Justify** your decision by describing the factors you considered when making your decision.

Critical and creative thinking

29 Draw a cartoon strip with at least five squares, **illustrating** a person receiving a stimulus and then responding.

30 **Create** a visual presentation on the role of the different types of white blood cells in attacking pathogens.

31 Alcohol blocks the production of ADH. Use critical thinking to **predict** the effect this will have on urine volume.

32 **Construct** a table that distinguishes between the different lines of defence.

33 Louis Pasteur found that heat could kill micro-organisms in milk. This discovery is still in use today. **Investigate** the use of heat in killing pathogens.

a **Identify** two reliable sources.

b **Summarise** one use of heat.

Research

34 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing.

» Stem cells for spinal injury

Nerve cells do not easily regenerate and so, to date, it has not been possible to repair damage to the spinal cord. Scientists have been researching the use of stem cells in the treatment of spinal cord injury. Identify the different types of stem cells. Describe how stem cells are used. Describe the advances that have been made in this field of research. Describe one of the issues that have affected such research.

» Type 2 diabetes

The incidence of type 2 diabetes is increasing. Compare type 1 and type 2 diabetes. Identify the factors that contribute to the cause of type 2 diabetes. Describe the complications that can result from diabetes. Describe what you can do to prevent type 2 diabetes.

» Artificial skin

Investigate the work of Australian scientists Dr Fiona Wood and Dr Marie Stoner on skin regeneration, including spray-on skin. Explain why their area of research is so important. Explain how this research is related to the increase in bushfires that is expected to occur with global warming.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 3 'Control and regulation'. Once you've completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Identify the five senses and the receptors associated with each type of stimulus. Relate the structures of the sense organs to the types of stimulus they receive.	☐	☐ Go back to Topic 3.1 'Receptors detect stimuli' Page 48
Describe the passage of information through a neuron, across the synapse and to the next cell. Explain how sensory, motor and interneurons communicate information around the body.	☐	☐ Go back to Topic 3.2 'Nerve cells are called neurons' Page 52
Describe the stimulus–response model. Relate reflex action with potentially life-saving actions.	☐	☐ Go back to Topic 3.3 'The nervous system controls reflexes' Page 54
Describe the roles of the central nervous system, peripheral nervous system, somatic nervous system and autonomic nervous system. List the lobes of the brain and describe their main functions.	☐	☐ Go back to Topic 3.4 'The central nervous system controls our body' Page 56
Provide examples of diseases and problems affecting the nervous system. Relate the importance of myelin sheath to motor neurone disease.	☐	☐ Go back to Topic 3.5 'Things can go wrong with the nervous system' Page 58
Describe the fight, flight or freeze response.	☐	☐ Go back to Topic 3.6 'The endocrine system causes long-lasting effects' Page 60
Describe the advantage of homeostasis. Explain how hormones regulate blood glucose.	☐	☐ Go back to Topic 3.7 'Homeostasis regulates through negative feedback' Page 62
Describe the function of erythropoietin and how athletes may use it to improve their performance in sporting events.	☐	☐ Go back to Topic 3.8 'Science as a human endeavour: Hormones are used in sport' Page 66
Provide examples of pathogens. Relate scientific discoveries to the development of the 'germ theory'.	☐	☐ Go back to Topic 3.9 'Science as a human endeavour: Pathogens cause disease' Page 68
Describe some of the body's first-line defence mechanisms against infection. Compare naturally acquired immunity with vaccinations.	☐	☐ Go back to Topic 3.10 'The immune system protects our body in an organised way' Page 70
Describe the immune response during an allergic reaction. Describe the common symptoms of rheumatoid arthritis and type 1 diabetes. Describe the cause of HIV and relate it to the development of AIDS.	☐	☐ Go back to Topic 3.11 'Things can go wrong with the immune system' Page 72

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CHAPTER

4

TECTONIC PLATES

Why does the Earth move?

4.1 Is the Earth shrinking or moving?

4.2 The Earth has a solid core

4.3 Boundaries between the tectonic plates can be converging, diverging or transforming

4.4 Tectonic plates can be constructive or destructive

4.5 Science as a human endeavour: What will the Earth look like in the future?

What if?

Clay plates

What you need:

Modelling clay

What to do:

1 Divide the clay into two equal portions.

2 Flatten out each portion to approximately 1 cm thick.

3 Gently slide the portions towards each other.

What if?

» What if one portion slides over the other?

» What if the two clay portions are jammed together?

» What if the two portions are moved apart?

4.1 Is the Earth shrinking or moving?

In this topic, you will learn that:

- Plate tectonics is a combination of two theories: continental drift and sea-floor spreading.
- Continental drift describes how the continents are continually moving.
- The theory of sea-floor spreading proposes that the middle of the ocean is spreading apart, moving very slowly in opposite directions.

Video 4.1
Why do Earth's plates move?

Figure 1 Alfred Wegener pioneered the theory of continental drift in his book *The Origin of Continents and Oceans*.

Many theories have tried to explain why there are earthquakes, mountains and deep-sea trenches over the surface of the Earth. One of the first theories was that the Earth was cooling down and therefore shrinking, causing 'wrinkles' to form on the surface. Like all theories, this idea was testable and was eventually changed and refined as new evidence became available.

Continental drift

One form of evidence is the similarities in shape between the coastlines of Africa and South America. They seem to fit together like a jigsaw puzzle. In the early twentieth century, German meteorologist Alfred Wegener put this idea and other evidence into a book in which he outlined the theory of **continental drift**. He proposed that the continents once all fitted together in a giant continent known as Pangaea.

Wegener proposed that Pangaea was a supercontinent that existed 220 million years ago. When it started to break up, the continents slowly drifted apart as they moved through the oceanic crust. He supported his claims with the evidence of coastline fit, similar fossils, rocks and landforms created by glaciers in now widely separated continents, and the reconstruction of old climate zones.

Tectonic plate movement

We now know that it is not just the continents that are moving. The large moving areas include both the continental and oceanic crusts. Geologists call these moving areas tectonic plates. 'Tectonic' means 'building', so tectonic plates are the 'building blocks' of the Earth.

The movement of the plates explains the existence of landforms such as **continental shelves** (flat areas under shallow water between the beach and the ocean) and deep trenches in the ocean floor. It also explains how earthquakes and volcanoes are distributed, and the very young age of parts of the sea floor. **Plate tectonics** is an example of how a scientific hypothesis can be suggested, discounted, modified and then revived.

continental drift
the continuous movement of the continents over time

continental shelf
a flat area under shallow ocean water at the edge of a continent

plate tectonics
the theory that the surface of the Earth consists of pieces, known as plates, that are continually moving

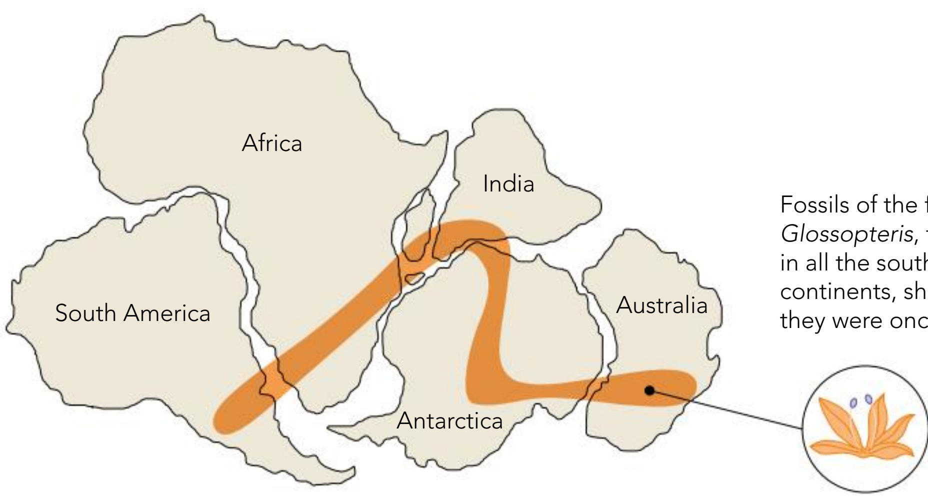


Figure 2 Given that the fossil fern *Glossopteris* cannot walk, swim or fly, how can its isolated occurrence in so many different parts of the world be explained?

CHALLENGE
4.1A: Reconstructing Pangaea
Go to page **183**.

CHALLENGE
4.1B: Milo convection currents
Go to page **184**.

Sea-floor spreading

The idea of **sea-floor spreading** was proposed by US geologist Harry Hess. His evidence came from the discovery of the Mid-Atlantic Ridge, a continuous mountain range in the middle of the Atlantic Ocean (Figure 3). Hess's original hypothesis was that the liquid mantle of melted rock (magma) under the tectonic plates is moving, creating convection currents. This moving mantle deep inside the Earth causes the tectonic plates to spread and move apart.

If convection currents occur within the Earth's mantle, then rising hot magma pushes up, creating a ridge crest. It is pushed to one side by more rising magma, and the ridge splits and moves apart. As it is pushed away, the surrounding rocks are under a lot of pressure, causing a rift zone and shallow earthquakes. A rift zone is an area where the lithosphere is being pulled apart (Figure 4). As the mantle rock moves away from the magma and ridge crest, it carries the sea floor with it, like a piggyback ride. The liquid magma rock cools, becomes denser and eventually sinks back into the mantle.

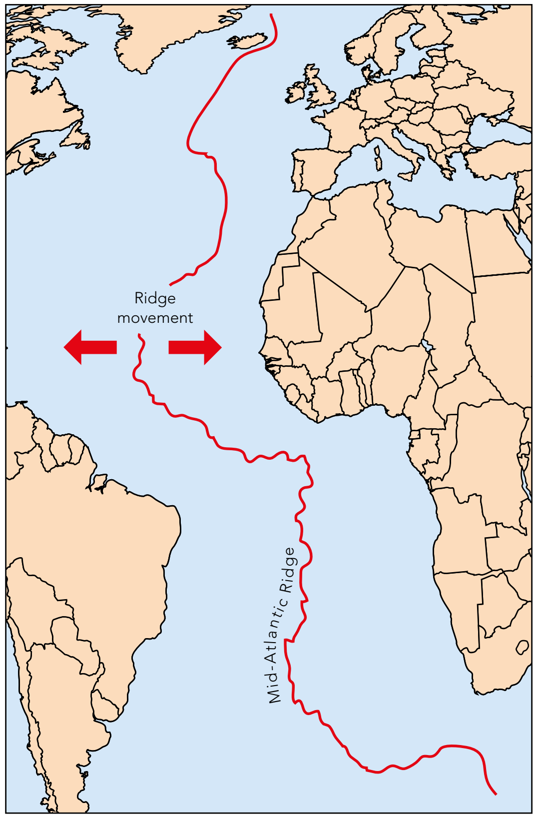


Figure 3 The Mid-Atlantic Ridge provided evidence of sea-floor spreading.

sea-floor spreading
the theory that the middle of the ocean is spreading apart, forming new oceanic crust

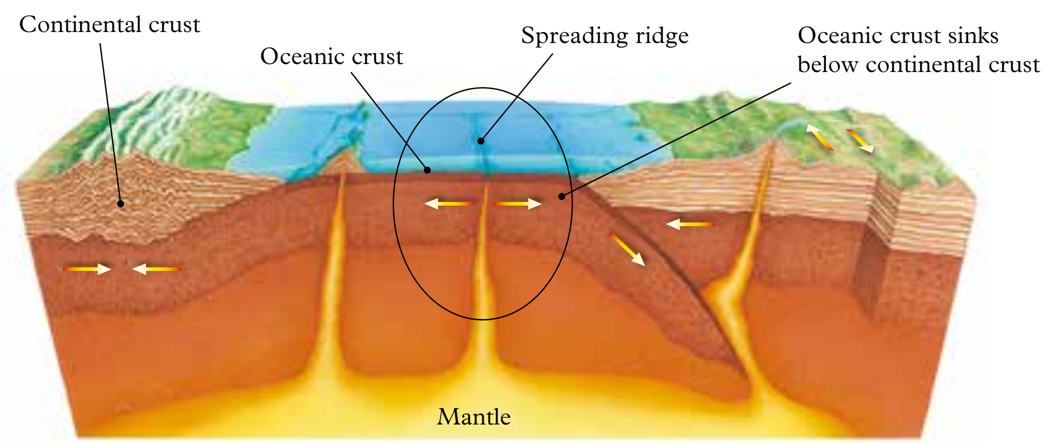


Figure 4 Tectonic plate movement. The rift zone is the circled area.

4.1 Check your learning

Remember and understand

1. Examine a world map. Apart from Africa and South America, **identify** the other regions of the world that look as if they could fit closely together.
2. **Define** the term 'mantle'.
3. **Describe** how convection currents move in the mantle.
4. **Define** the term 'tectonic plate'.
5. **Describe** how the rift zone forms at the top of a mid-ocean ridge.

Apply and analyse

6. **Contrast** continental drift and sea-floor spreading.
7. Considering the evidence that Wegener presented in support of continental drift, **explain** why many scientists at the time may have rejected the idea.

4.2 The Earth has a solid core

In this topic, you will learn that:

- The Earth is made up of several layers.
- We live on the crust (or lithosphere).
- Under the crust is the molten rock that makes up the mantle.
- The core has two layers: the outer core of liquid iron and nickel, and the inner solid core.

crust
the lithosphere, or outer layer of the Earth

mantle
the layer of molten rock beneath the Earth's crust

What is the Earth made of?

Although the Earth is described as a solid planet, it began as a ball of molten materials. Scientists believe the Earth and other planets are the result of an explosion billions of years ago. According to this theory, the Earth began as a molten fragment from this explosion. The Earth's surface has continued to slowly change and is still changing – many rocks have worn down to form soil and sand, mountains and valleys have formed, and the land and oceans have changed shape. Some of this change is caused by weathering and erosion at the surface. Other changes are due to the movement of the molten rocks from deeper down, which in places push their way up to the surface and also move sections of the Earth's crust.

If you could journey deep inside the Earth, you would find that it is made of several layers (Figure 1).

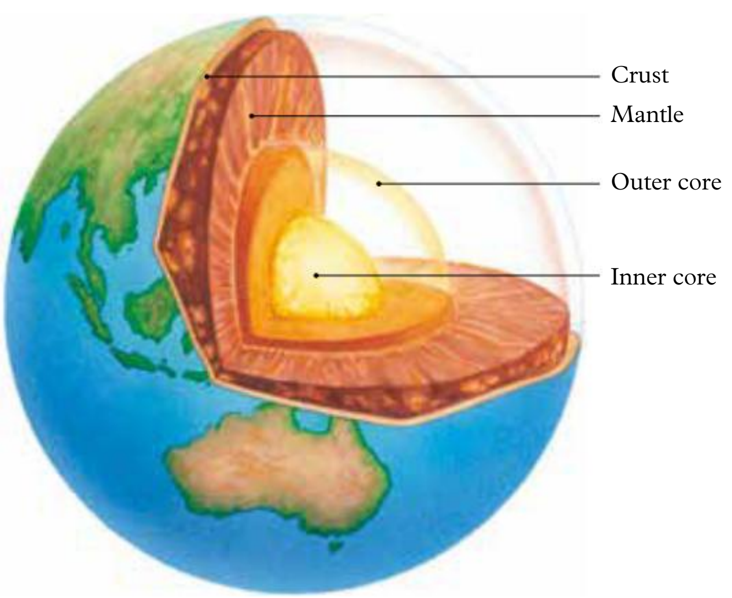


Figure 1 Layers of the Earth

Crust

The **crust** (or lithosphere) is the outer layer (7–50 km thick) of the Earth. It is a thin, brittle outer coating, like the shell of an egg. It is made up of rocks and minerals, and approximately 70 per cent of it is covered by oceans. The crust is not smooth: it has hills, mountains, valleys, oceans and deserts. It is thickest under the continents and thinnest under the oceans (Figure 2). Compared to the rest of the Earth's layers, the crust is very thin.

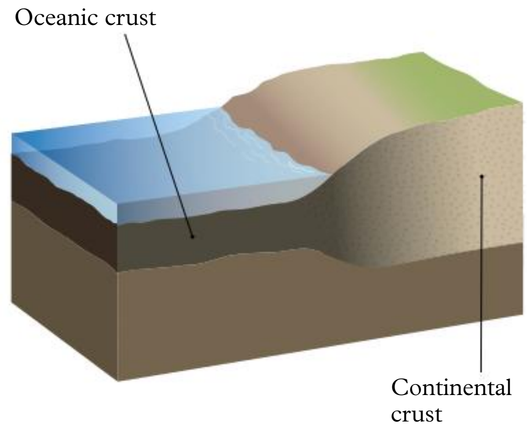


Figure 2 The oceanic crust is thinner beneath the ocean than beneath the continents.

Mantle

The **mantle** is below the crust. It is about 2800 km thick. Temperatures near the crust are about 500°C and at the bottom of the mantle reach 3000°C. Although the bottom of the mantle is solid, nearer the top the rock slowly moves. The top part of the mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes.

EXPERIMENT

4.2A: Cooling and layers
Go to page **185**.

CHALLENGE

4.2B: Modelling the parts of the Earth
Go to page **186**.

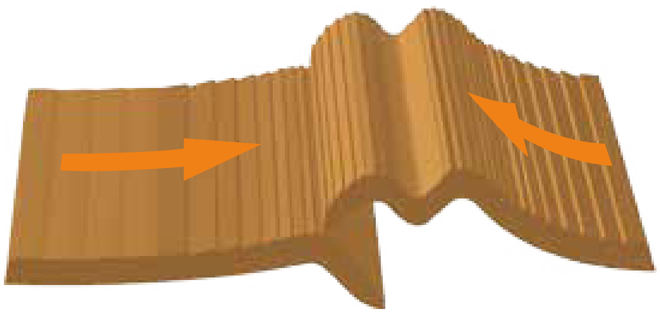


Figure 3 Colliding plates cause the Earth's surface to buckle.

Core

The **core** is the centre of the Earth. It consists of the outer core and the inner core. The outer core is made mainly of metals, not rock; the main metal is iron, possibly with some nickel. It is very hot and liquid, with temperatures ranging from 4000°C to 6000°C. The heat comes from nuclear reactions, and some of the heat is left over from when the Earth was formed. The outer core gives the Earth its north and south poles and magnetic field. The temperature of the inner core is almost 10 000°C, but it does not melt or boil because of the force of the rest of the Earth pushing down on it. Of course, no geologist has ever seen the core. Even the deepest mines only penetrate a few kilometres of the Earth's crust.

The moving crust

The crust is broken into a number of pieces, called **tectonic plates**. These plates float on the semiliquid **magma** at the top of the mantle. The speed of movement is similar to that of fingernail growth: between 1 cm and 10 cm per year. Sometimes the tectonic plates crash into one another, causing one plate to slide under the other. The plate on top buckles under pressure, pushing the land upwards (Figure 3). For example, the Indo-Australian Plate is sinking under the Eurasian Plate. This has caused the Eurasian Plate to buckle, pushing up the world's highest mountain range, the Himalayas.

Convection currents

In liquids and gases, thermal energy can move by **convection**. Tiny currents, called **convection currents**, carry the thermal energy. It is the convection currents in the magma that cause the tectonic plates to move. The mantle closest to the Earth's core gains thermal energy. This means the molecules in the magma move faster. Because they move faster, they take up more space and become less dense. As a result, the heated magma near the core begins to rise to the surface, leaving room for cooler magma to take its place. The heated magma cools as it reaches the Earth's crust. As it cools, it is pushed to one side as more heated magma arrives. This causes the tectonic plates that form the crust to move. Cool magma is more compact and dense, and so it sinks, following the convection cycle.

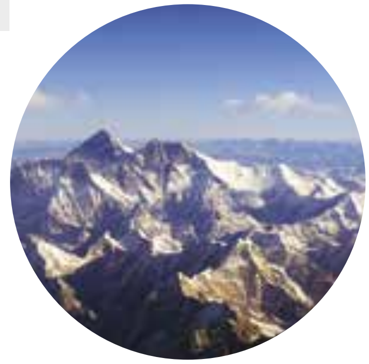


Figure 4 The Himalayan Mountains have been pushed up by pressure from beneath the Earth.

core
the centre of the Earth

tectonic plate
a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

magma
semiliquid rock beneath the Earth's surface

convection
the transfer of thermal energy by the movement of molecules in air or liquid from one place to another

convection current
the current or flow of air or liquid that results from the transfer of thermal energy by convection

4.2 Check your learning

Remember and understand

1 **Identify** the layer of the Earth that contains tectonic plates.

2 If the Earth's radius is about 6370 km, use the information about the crust and the mantle to **calculate** the thickness of the Earth's core.

Apply and analyse

3 **Describe** the forces that cause the movement of the tectonic plates.

4 'The Earth's crust is the same thickness everywhere.' **Evaluate** this statement (by comparing the approximate thickness of the Earth's crust at two extremes – the Andes and Victoria – and deciding whether the statement is likely to be correct).

5 Examine Figure 3. **Evaluate** whether this diagram could be used to model the formation of the Andes Mountains (by describing how the Andes are formed, comparing this to the diagram and deciding whether it is an accurate representation).

4.3 Boundaries between the tectonic plates can be converging, diverging or transforming

In this topic, you will learn that:

- At transforming boundaries, tectonic plates slide past one another.
- At converging boundaries, plates come together, forming mountains or subducting.
- At diverging boundaries, tectonic plates move apart.

Video 4.3
What happens when Earth's plates move?

transforming boundary
the boundary between two tectonic plates that are sliding past each other

fault
a fracture in rock where the tectonic plates have moved

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

Plate tectonics explain a wide range of features of the Earth. These features, once studied separately, can now be unified by a single concept: plate behaviour at plate boundaries. There are three general types of plate boundaries, based on the direction of plate movement.

Transforming boundaries

One plate can slide past another along a single fault line. This is called a **transforming boundary** (Figure 2). A **fault** is a fracture in rock where movement has occurred.

The two plates involved in a transforming boundary can become jammed over a period of time until the pressure builds up and the plates slip. This slipping causes earthquakes, such as the large earthquake that destroyed San Francisco in 1906, where the rock of the transform fault slipped by up to 5 m.

Plate material is not created or destroyed: the plates just slide against each other.

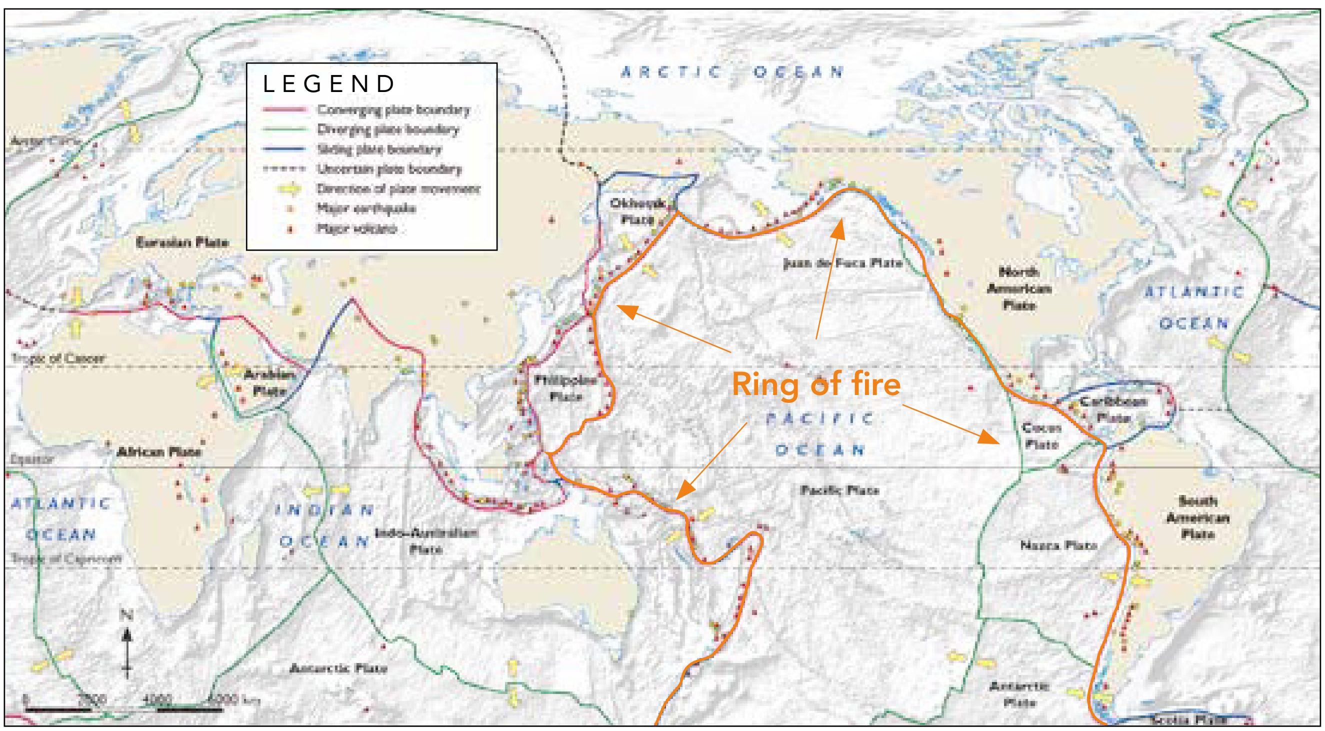


Figure 1 The ring of fire is an area around the Pacific Ocean where a large number of volcanoes are found. This provides hints of a tectonic boundary.

CHALLENGE
4.3: Modelling plates
Go to page **186**.

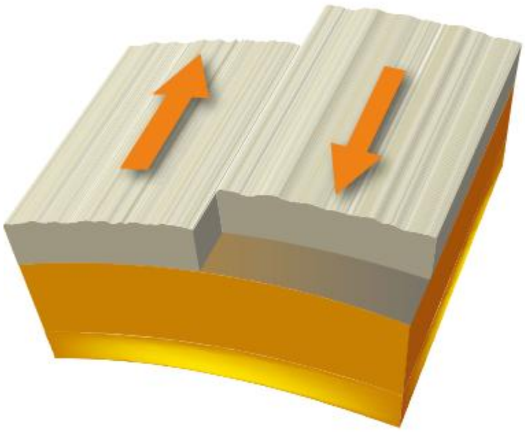


Figure 2 Transforming boundary: one plate slides against another

Figure 3 Satellite image of the Southern Alps, New Zealand. The Alpine Fault, a transforming boundary, runs along the western edge of the snowline on the South Island.

Converging boundaries

At converging plate boundaries, two plates move towards each other. There are generally three types of converging boundaries, depending on the plates involved. If one plate is denser (the particles are more tightly packed together), it will sink beneath the other plate. This is known as **subduction**. Mountain ranges, volcanoes and trenches can all be formed by **converging boundaries**.

Many of the world's major landforms are formed by the collision of plates at converging boundaries.

Ocean-to-continent collision

When oceanic crust collides with continental crust, the denser oceanic landform is subducted or pushed downwards into the mantle. The top crust is pushed upwards and creates a line of mountains along the crumpled edge (Figure 5). It can also create volcanoes as heat rises up through cracks in the crust. An **ocean trench** may form at the line of plate contact.

Figure 4 The San Andreas Fault, which runs along the western coast of California, USA

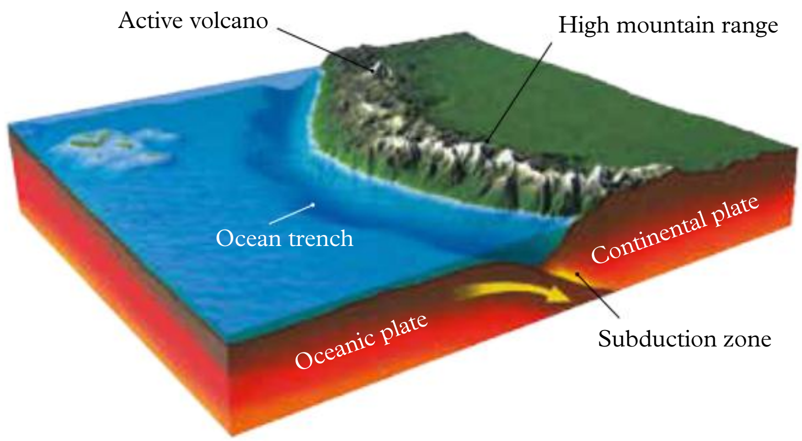


Figure 5 Ocean-to-continent collision causes subduction, and creates mountains, volcanoes and ocean trenches.

subduction
the movement of one tectonic plate under another tectonic plate

converging boundary
the boundary between two tectonic plates that are moving together

Continent-to-continent collision

When two continental plates collide, they have similar densities, so no subduction takes place. Instead, the edges of the two plates crumple and fold into high mountain ranges (Figure 6).

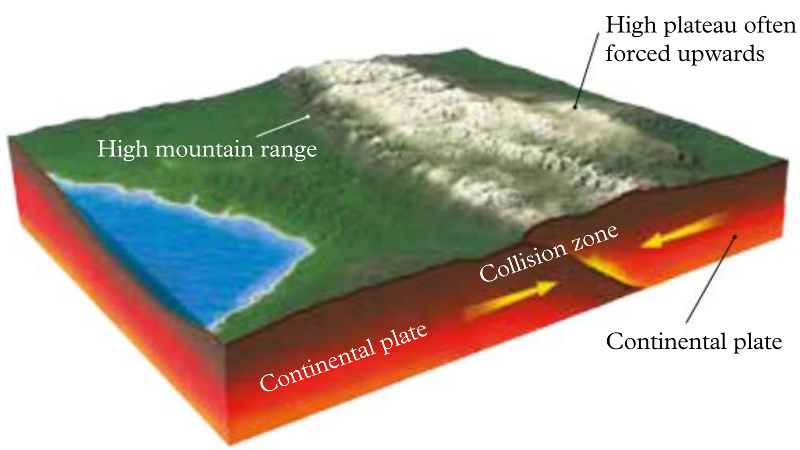


Figure 6 Continent-to-continent collision creates high mountain ranges.

Ocean-to-ocean collision

When two oceanic plates collide, the older, denser crust subducts below the newer crust, creating a deep ocean trench. The subduction also creates a line of undersea volcanoes that may reach above the ocean surface as an island arc (Figure 7).

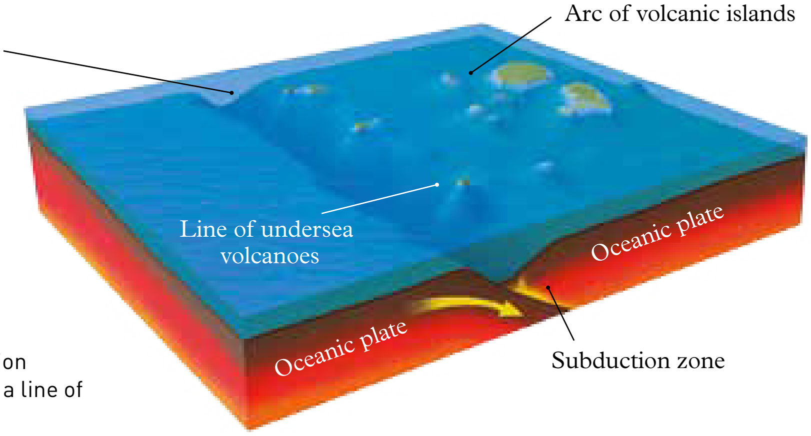


Figure 7 Ocean-to-ocean collision causes subduction and creates a trench and a line of undersea volcanoes.

Diverging boundaries

diverging boundary
the boundary between two tectonic plates that are moving apart

rift valley
a deep valley that forms as a result of tectonic plates moving apart on land

mid-ocean ridge
a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

Diverging boundaries are plate boundaries that are moving apart. They form different features than those of converging and transforming boundaries. These spreading boundaries can occur in the middle of the ocean or in the middle of land. The breaking up of the supercontinent Pangaea was probably due to diverging plate boundaries. Hot rising mantle rock from deep within the Earth might be the first step in a continent breaking apart. As the mantle rock rises, the continental crust is lifted and thins out. Cracks form and large slabs of rock sink into the Earth, forming a **rift valley** like those found in East Africa.

Figure 8 The East African rift valleys may represent the initial stages of the breaking up of a continent.

Making oceans

As the divergence process continues, the continental crust separates and a narrow sea or lake may form. The Red Sea between the Arabian and African Plates is thought to be a diverging boundary at this stage of development (Figure 9). Eventually, oceans are formed and a **mid-ocean ridge** is created (Figure 10).

Mid-ocean ridges are very wide, up to 4000 km. Sea-floor spreading occurs at a rate of only 5 cm per year, but none of the ocean floor is dated as older than 180 million years.

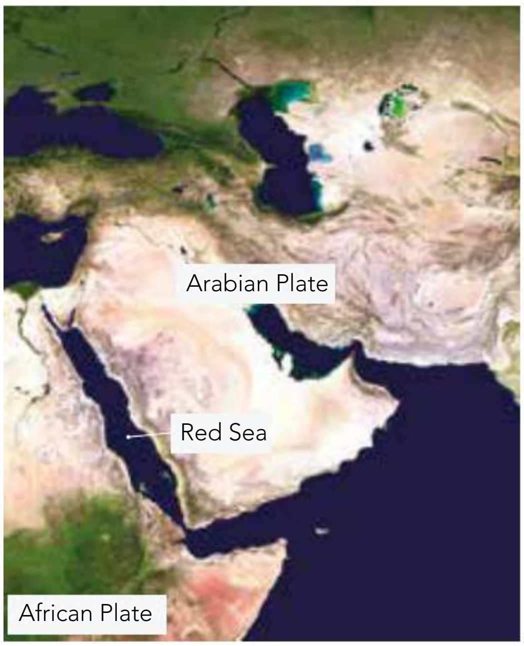


Figure 9 The Red Sea has formed as the African and Arabian Plates have diverged.

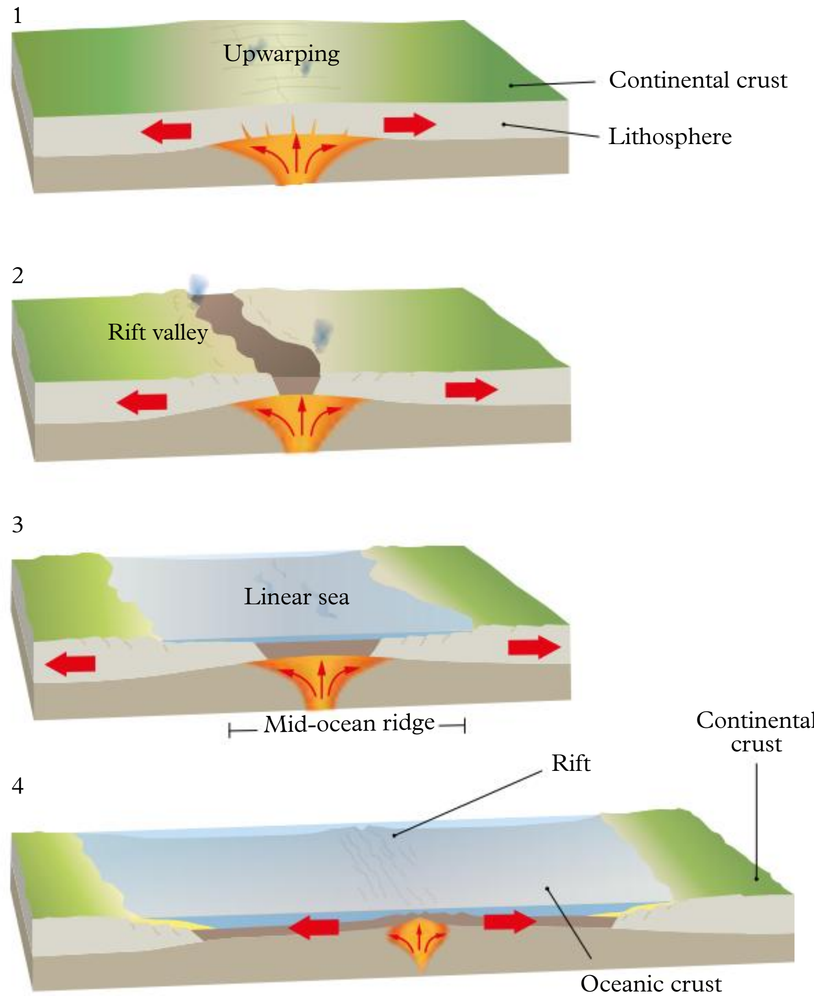


Figure 10 How diverging boundaries form oceans

4.3 Check your learning

Remember and understand

1. **Describe** the type of plate movement that happens at a transforming boundary.
2. **Describe** what causes the continental crust to spread and break at a diverging boundary.
3. Use Figure 1 to **describe** where the major mid-ocean ridges are located.
4. Use Figure 1 to **describe** where the diverging plate boundaries are located.
5. **Identify** the factor that determines which plate subducts at a converging boundary.
6. **Explain** how diverging boundaries can produce earthquakes and volcanic activity.
7. Transforming boundaries are sometimes called strike–slip fault zones. **Explain** why both names are appropriate.

Apply and analyse

8. Use the location of the tectonic plates in Figure 1 to **describe** the location of volcanoes. **Compare** these to the location of earthquakes.

4.4 Tectonic plates can be constructive or destructive

In this topic, you will learn that:

- Movement of tectonic plates can cause destructive earthquakes or tsunamis.
- Molten mantle can escape from volcanoes and become lava.
- Lava can form new islands.

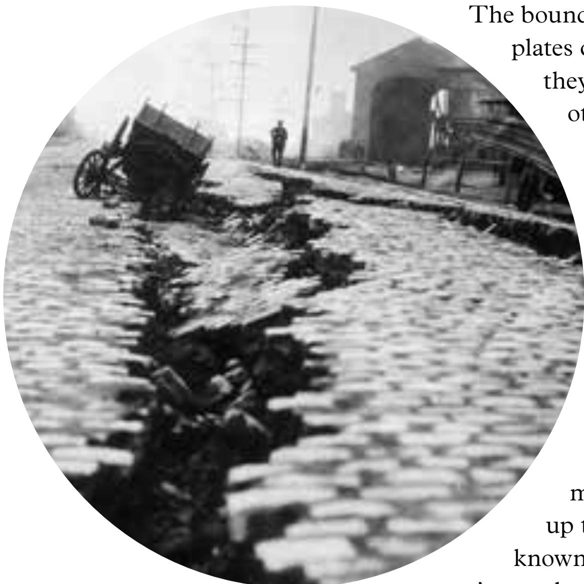


Figure 1 The San Francisco earthquake in 1906 destroyed much of the city.

The boundaries between the tectonic plates create a lot of pressure as they try to move against each other. This pressure can be released suddenly in the form of an earthquake, which in turn can form a tsunami.

Earthquakes can cause tsunamis

Undersea earthquakes can move the sea floor and push up the water to form a wave known as a **tsunami** (Figure 3). An earthquake in northern Japan in 2011 was magnitude 9.0 on the Richter scale. The earthquake was centred 140 km off the coast and sent a 10 m high wall of water towards coastal towns and cities. The tsunami wave also travelled away from Japan, right across the Pacific Ocean, and was experienced as far away as North and South America, the Pacific Islands and even in northern Australia as a small wave.

Japan is the most seismically active country in the world because it lies near the boundaries of three tectonic plates: the Pacific, Eurasian and Philippine Plates. The force of a tsunami can be enormous, enough to demolish buildings, and lift cars and even small ships.

tsunami
a series of large waves that result from an underwater earthquake

Volcanoes causing tsunamis

Volcanoes pose great danger to those who live near them. The volcanic eruption of Krakatoa, Indonesia, in 1883 caused a tsunami that raced

Figure 2 Volcanic eruptions can cause tsunamis.

CHALLENGE

4.4: Volcanic bubbles
Go to page **187**.

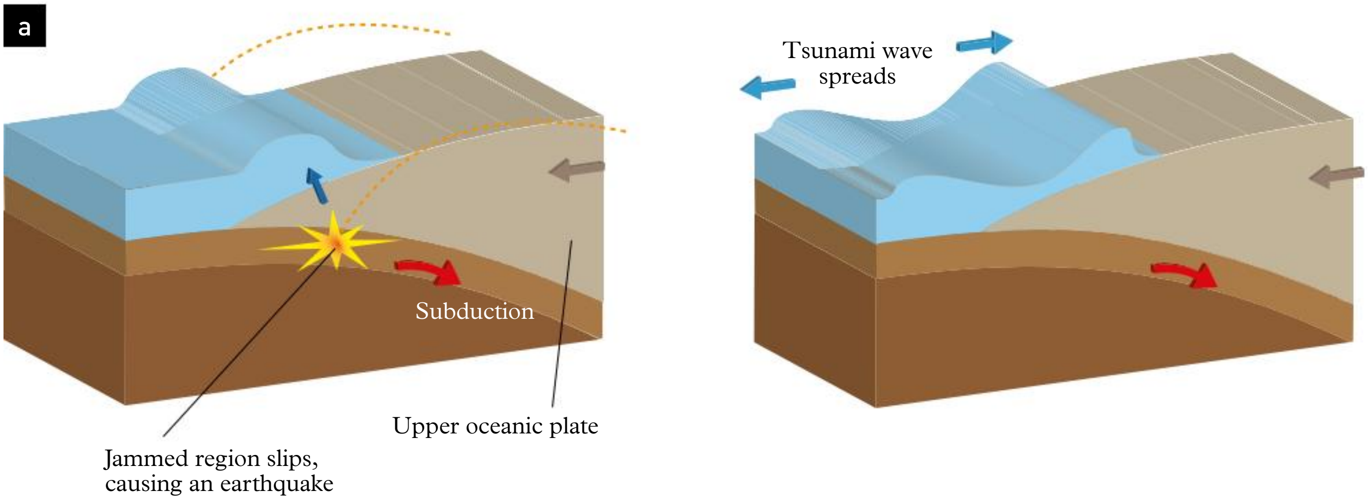


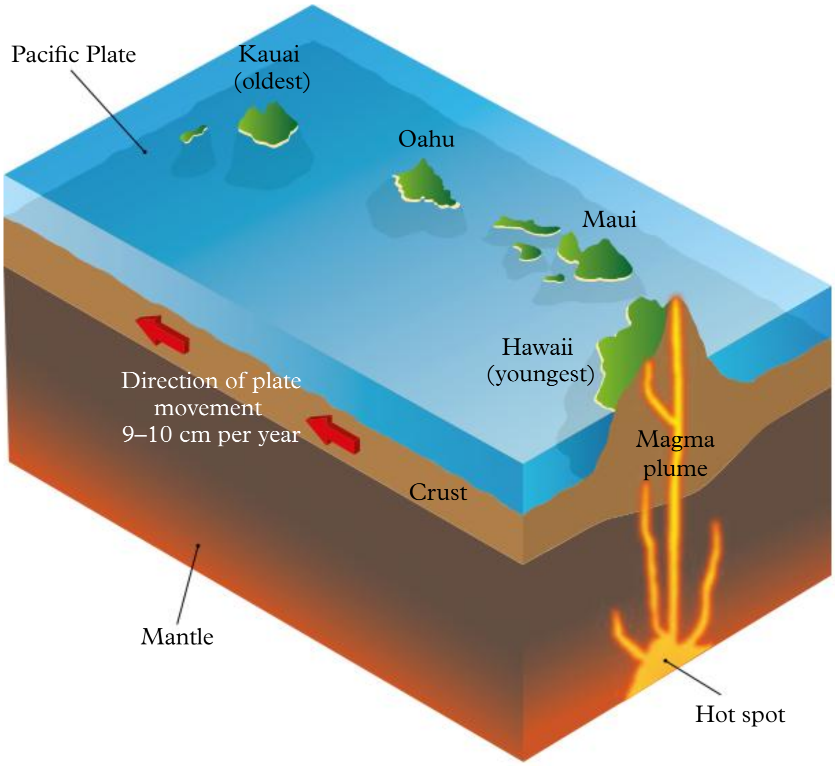
Figure 3 a How an earthquake causes a tsunami **b** The aftermath of the earthquake and tsunami in northern Japan in 2011

across the ocean and crashed onto nearby islands, killing 36 000 people. The blast was heard 5000 km away and ash rose 80 km into the atmosphere.

Volcanic eruptions spew lava and ash onto the surrounding land. When this material is broken down by the action of wind and water, and mixed with organic material from plants and animals, it forms some of the richest soil in the world. So, in spite of the dangers, people continue to live near volcanoes because of the fertile soil they provide.

Hawaiian Islands

The Hawaiian Islands are in the centre of the Pacific Plate (see Figure 1, page 82). Hawaii is not near a mid-ocean ridge, yet it has frequent volcanic activity. Most geologists believe this volcanic activity is caused by the movement of the Pacific Plate over a 'hot spot' beneath the plate. This is where a plume of hot magma from the mantle comes up through a thin area in the crust and creates a volcano. In the case of the Hawaiian Islands, the hot spot formed



an undersea volcano (Figure 4). Over time, the volcano grows until it pokes above the ocean surface and creates an island. As the plate moves over the hot spot, other islands are formed over millions of years and an island 'chain' is created.

The centre of a plate usually lacks earthquakes, volcanoes or folded mountain ranges because it is a long way from a plate boundary, although these landforms are still possible in areas of weakness or thinning. The theory of plate tectonics and what happens at the plate boundaries corresponds with the distribution of earthquakes and volcanoes around the world. Consider Australia's location and the limited number of earthquakes and extinct volcanoes on our continent.

Figure 4 How the Hawaiian Islands were formed. (Only the largest islands are shown.) Hot spots result from magma pushing through the thin crust of the Earth.

Figure 5 Evidence of volcanic activity on the Hawaiian islands: **a** rocks that appear to flow into the sea formed from old lava flows, **b** mountains rising out of the sea, **c** and **d** volcanic rock formations, **e** steam rising from craters and **f** lava flowing from active vents

Earthquakes in Australia

Unlike New Zealand, Australia is located in the centre of the Indo-Australian Plate. It is thought that the plate formed when two smaller plates fused, 43 million years ago. Although we think of tectonic plates as being fixed, two large earthquakes (measuring 8.6 and 8.2 on the Richter scale) beneath the Indian Ocean in 2012 suggest that these two plates may be breaking apart again. The age of the tectonic plate on which Australia is located, and Australia's central position on the plate, have both resulted in minimal earthquake activities.

However, there are still over 300 magnitude 3.0 or greater earthquakes in Australia every year. Our plate, the Indo-Australian Plate, is moving north towards the Eurasian, Philippine and Pacific Plates. This creates stress within our plate, and release of this stress creates earthquakes.

One of Australia's worst earthquakes was of magnitude 5.6 and struck near the city of Newcastle in New South Wales on 28 December 1989. It killed 13 people and injured 160. Larger earthquakes have occurred in Australia, but the damage depends on how close they are to the surface and to large cities. A huge earthquake in the outback is unlikely to cause large loss of human life.

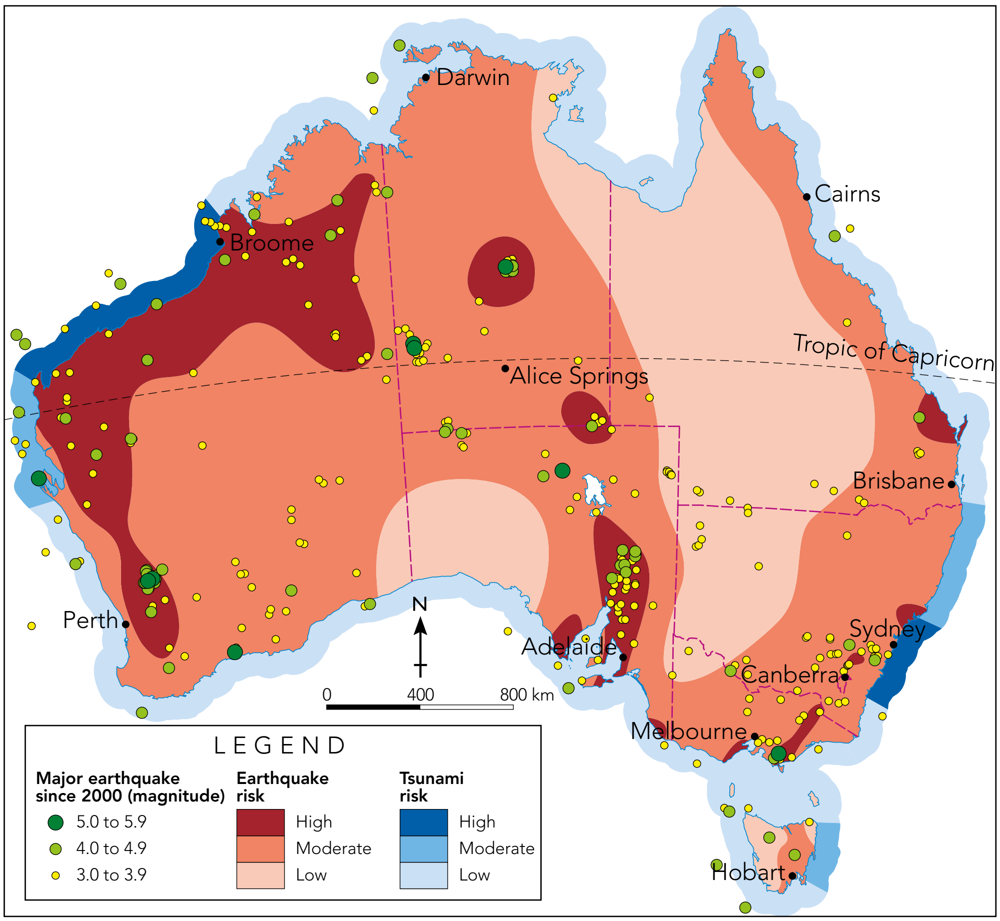


Figure 6 Australia: earthquake and tsunami risk

4.4 Check your learning

Remember and understand

1 **Describe** two ways the movement of plate tectonics can be destructive.

2 **Describe** a tsunami.

3 **Describe** where most earthquakes occur. **Explain** why earthquakes occur in these regions.

4 **Explain** how the movement of tectonic plates can be constructive.

5 **Explain** why there are few large earthquakes in Australia.

Apply and analyse

6 Use the concept of sea-floor spreading to **explain** why the soil in Australia is considered old.

//SCIENCE AS A HUMAN ENDEAVOUR//

4.5 What will the Earth look like in the future?

Plate tectonics is an ongoing process that will have a major effect on the shape of Earth's continents over the next 50 million years and beyond. If the motion of the continents continues at the same rate as today, portions of California will separate from the rest of North America, the Mediterranean Sea and Italy's 'boot' will disappear, Australia will move north and become linked to the rest of Asia, and mainland Africa will separate from East Africa and a new sea will form.

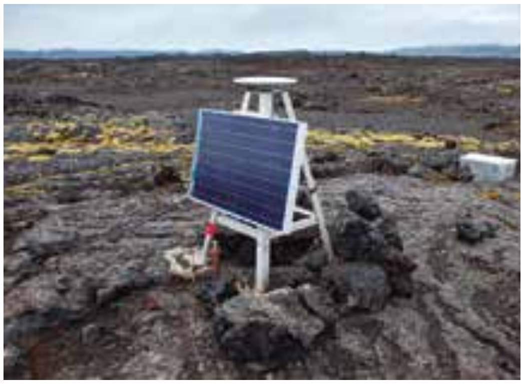


Figure 2 A global positioning satellite base station

A future Earth

The theory of plate tectonics proposes that the Earth's continents are moving at the rate of a few centimetres each year. This is expected to continue, and so the plates will take up new positions. Forecasting future continental motion is a popular field in geology and draws on new insights, theories, measurements and technologies.

Geologists can measure changes in the continents' positions with great precision, using global positioning satellites (GPS) and small base stations in remote areas of the planet (Figure 2). Base stations are carefully selected to represent known locations and act as calibrators for GPS systems.

At present, the continents of North and South America are moving west from Africa and Europe (Figure 3). Researchers have used computers to model how this plate movement will continue in the future. Since the theory of plate tectonics was proposed, geologists have worked hard to discover what it reveals about the Earth's past. The supercontinent of Pangaea was the result.

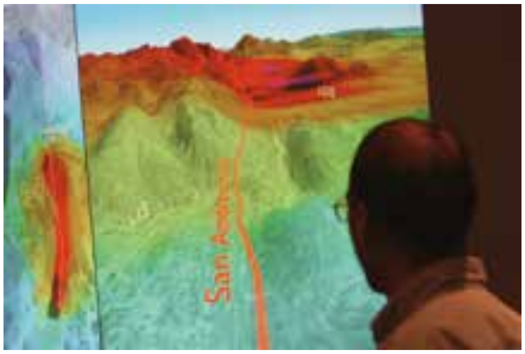


Figure 1 Scientists produce maps and animations that help to explain the Earth's geology to many people.

In the 1970s, US geologist Robert Dietz proposed that, 10 million years from now, Los Angeles will be moving north and passing San Francisco. For his predictions, he focused on the San Andreas Fault in California. Some modelling predicts that Africa will continue drifting north, joining up with Europe and eliminating the Mediterranean Sea, replacing it with the Mediterranean Mountains. The continents of North and South America may continue to move across the Pacific Ocean until they begin to merge with Asia. This new supercontinent might be known as Amasia (Figure 4).

US geologist Christopher Scotese and his colleagues have mapped out the predicted positions of the continents several hundred million years in the future, as part of the Paleomap Project. According to their predictions, in 250 million years North America will collide with Africa, while South America will join with South Africa. The result will be the formation of a new supercontinent, Pangaea Ultima, encircling the old Indian Ocean (Figure 5). The massive Pacific Ocean will stretch halfway around the planet.

The formation of another supercontinent will dramatically affect the environment. The collision of plates will result in mountain forming, changing climate patterns, decreasing global

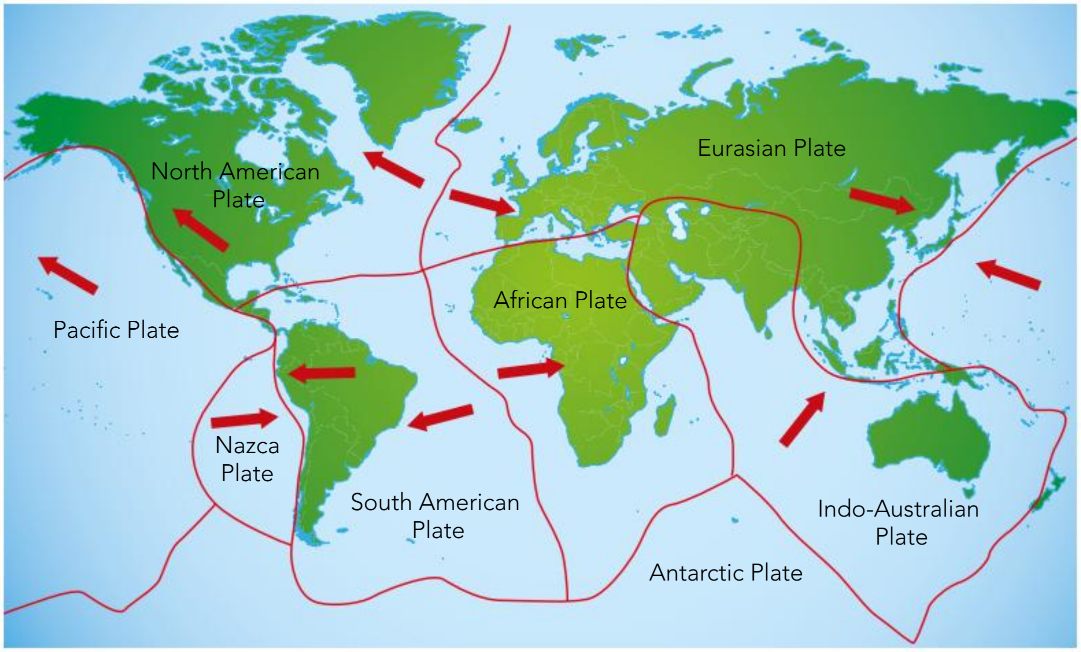


Figure 3 The present-day movement of the world's tectonic plates

temperatures and increasing atmospheric oxygen. These changes will have significant effects on organisms as massive extinctions occur and different organisms emerge. The supercontinent will insulate the Earth's mantle, concentrating the flow of heat and resulting in more volcanic activity. Rift valleys will form, causing the supercontinent to split up once more.

Scientists believe that, in the next few decades, progress in geology is likely to reveal more about the Earth's inner workings, making plate forecasting easier.

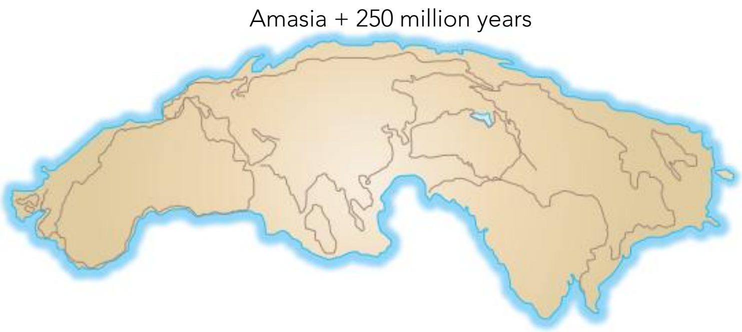


Figure 4 Amasia is a possible supercontinent modelled by geologists.

Figure 5 Pangaea Ultima: the world in 250 million years, according to predictions by Scotese

4.5 Develop your abilities

Evaluating the Christopher Scotese model

All scientists make predictions and hypotheses that can be evaluated to determine their truth or viability. This requires criteria to be developed and applied, to test the limitations of the model and determine whether modifications are needed.

Answer the following questions to critically **evaluate** the quality of Christopher Scotese's model.

1 **Identify** the direction the Indo-Australian plate is moving in Figure 3.
2 **Identify** the direction the North American plate is moving in Figure 3.
3 **Describe** how this movement will affect the position of North America in 250 million years.
4 **Compare** your conclusion to that of Scotese's model.
5 **Contrast** the amount of data used in your conclusion and the amount of data that would have been available to Scotese.
6 **Identify** three questions you could ask Scotese and his colleagues, to clarify their conclusions.
7 **Identify** one form of evidence or data that would cause you to disagree with the model proposed by Scotese and his colleagues.

REVIEW 4

Multiple choice questions

1 **Identify** which two of the following have led to our understanding of plate tectonics.
   - A continental drift
   - B subduction
   - C sea-floor spreading
   - D magnetometers

2 **Identify** the type of plate collision where subduction is most likely to occur.
   - A continent to mantle
   - B continent to continent
   - C ocean to ocean
   - D ocean to continent

3 What type of natural disaster can be caused by an undersea earthquake?
   - A hurricane
   - B volcanic eruption
   - C tsunami
   - D bushfire

Short answer questions

Remember and understand

4 Match the following terms with their definitions.

Term	Definition
Mantle	Central part of the Earth
Crust	Layer of hot, semi-molten rock below the crust
Oceanic crust	Theory that states that the continents move through oceanic crust
Continental crust	Theory that states that large plates of the Earth's crust gradually move
Plate tectonics	Less dense crust containing continents
Tectonic plate	Hot liquid rock that comes up from the mantle
Continental drift	Thin, semi-rigid outer layer of the Earth
Convection current	Large area that may include continent and sea floor
Magma	Dense crust under the sea floor
Core	Movement of liquids or gases caused by the rising of hot material

5 **Define** the following terms:
   - a subduction
   - b rift valley
   - c transform fault
   - d diverging boundary
   - e converging boundary
   - f ocean trench
   - g mid-ocean ridge
   - h sea-floor spreading.

6 **Describe** Pangaea and what happened to it.

7 **Identify** the evidence that Alfred Wegener used to support his theory of continental drift.

8 **Describe** what provides the force for moving the tectonic plates over the surface of the Earth.

9 **Describe** the cause of major volcanic eruptions and earthquakes.

10 If Australia moves north to collide with Indonesia and Malaysia, **describe** the geographical features that will form and how our climate will change.

Apply and analyse

11 Most earthquakes occur at plate boundaries. **Explain** how an earthquake can occur in the middle of a plate.

12 **Explain** why continental crusts cannot be subducted.

13 **Explain** how sea-floor spreading accounts for the young age of the sea floor.

14 The Himalayas formed when India collided with the Eurasian Plate. Mount Everest, the highest mountain on the Earth, is 8848.86 m high and continues to be uplifted at a rate of about 1 cm per year. Assuming there is no erosion, **calculate** the height of Mount Everest in 1 million years if it maintains its current rate of increase.

15 Examine Figure 1, which shows a topographic image of the Mid-Atlantic Ridge. **Explain** how this provides evidence of sea-floor spreading.

Figure 1 The Mid-Atlantic Ridge

16 If part of the Pacific Plate is moving at a rate of 10 cm per year, **calculate** how far it would move in:
  a 100 years
  b 10 000 years
  c 1 million years.

17 **Explain** why modern GPS systems are useful for predicting future plate movements.

Evaluate

18 Once there was one supercontinent called Pangaea. Initially it split into two. One part, Laurasia, moved north while the other, Gondwanaland, moved south. Laurasia gave rise to Europe, Asia and North America. Gondwanaland gave rise to Africa, South America, Australia, India and Antarctica. **Evaluate** the climate changes each continent faced as it drifted to its current position, and **explain** why, today, many plants and animals share physical similarities with those that originally inhabited the Gondwanaland subcontinents.

Social and ethical thinking

19 In 2009 there was a series of small earth tremors in the Italian city of L'Aquila. Six scientists (three seismologists, a vulcanologist and two seismic engineers) provided advice to the city that an ongoing series of small- and medium-sized tremors did not necessarily mean a large earthquake was going to occur. As a result, the citizens did not take precautions, and many were living indoors on the night the 5.9 magnitude earthquake hit. The scientists were charged with manslaughter for the deaths of 308 people, because they had failed to predict the earthquake. Their initial conviction was eventually overturned. **Evaluate** the fairness of this trial by:
- describing how the local townspeople would have reacted if the scientists had warned of the impending earthquake
- describing how the local townspeople would have reacted if the scientists had not offered any advice
- describing the accuracy of earthquake predictions
- deciding whether the scientists should have offered any advice to the townspeople.

Figure 2 The earthquake that struck L'Aquila in 2009 was one of the deadliest in Italy.

Critical and creative thinking

20 **Create** a poster or multimedia presentation about a famous earthquake or volcanic eruption. **Describe** the facts of the earthquake or volcanic eruption and what plate movement caused it, along with the social, environmental and economic impacts and the subsequent recovery process.

21 The Mariana Trench is located where the Pacific Plate is subducting under the Mariana Plate. Its average depth is 11 km below the surface of the water. Surprisingly, ocean explorers have found life at the bottom of the Mariana Trench. Research the organisms that live so deep and how they survive.

22 Imagine you could travel into the future, to a time when your local environment is drastically different from how it is today. Base your imagined scenario on the plate movements described in the text. Write a travel brochure for a future tourist destination or journey on this new Earth.

Research

23 Choose one of the following topics to research. Some questions have been included to get you started. Present your findings in a format of your own choosing, giving careful thought to the information you are communicating and your likely audience.

» Subduction zones

The subduction of one plate under another is well understood by scientists today, but how this process begins is not. Explain what geologists mean by subduction. Identify which plates are involved in subduction. Describe what happens to the plates during subduction. Describe the geological features that are associated with subduction zones.

» The Earth's crust

The lithosphere and the asthenosphere are different internal layers of the Earth. Define the term 'lithosphere'. Describe the asthenosphere. Describe how the two 'spheres' interact. Identify and describe other 'spheres' of the Earth. Explain how they interact with the lithosphere and the asthenosphere.

» Convection currents

Although the theory of convection currents in the Earth's mantle is the most widely accepted theory about what drives plate movement, there are several other theories. Describe one other theory that explains the movement of tectonic plates. Describe the evidence that supports the theory. Identify who proposed the theory. Critically analyse this theory to explain why it is less accepted than the theory of convection currents.

» Magnetic striping

Magnetic striping was considered by some to be the final proof of plate tectonics. Explain magnetic striping. Identify where it exists. Describe how it is linked to sea-floor spreading. Explain what it tells us about the age of rocks and Earth's history.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 4 'Tectonic plates'. Once you've completed the chapter, use the table to reflect on your ability to complete each task.

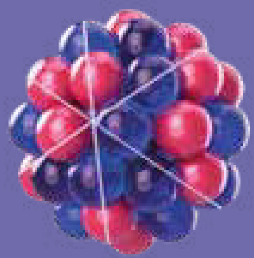
	I can do this.	I cannot do this yet.
Define continental drift, continental shelves, sea-floor spreading and plate tectonics. Describe evidence that supports the theory of plate tectonics. Explain the process of sea-floor spreading.	☐	☐ Go back to Topic 4.1 'Is the Earth shrinking or moving?' Page 78
Define crust, mantle, core, tectonic plates and magma. Describe the layered structure of Earth and explain why the crust floats on the magma.	☐	☐ Go back to Topic 4.2 'The Earth has a solid core' Page 80
Describe the interactions between plates that occur at transforming, converging and diverging boundaries. Relate each of the types of boundaries with characteristic land formations.	☐	☐ Go back to Topic 4.3 'Boundaries between the tectonic plates can be converging, diverging or transforming' Page 82
Describe how the Hawaiian Islands may have formed from a hotspot. Provide examples of natural events that occur because of plate interactions. Relate constructive and destructive boundaries with diverging and converging boundaries.	☐	☐ Go back to Topic 4.4 'Tectonic plates can be constructive or destructive' Page 86
Describe the directions of and likely collisions between the main continental plates. Provide examples of technologies that are used to observe and predict plate tectonics.	☐	☐ Go back to Topic 4.5 'Science as a human endeavour: What will the Earth look like in the future?' Page 90

CHAPTER 5

MATTER

Is radiation good or bad?

5.1 All matter is made up of atoms



5.2 Atoms are made up of subatomic particles

5.3 Atoms have mass

5.4 Electrons are arranged in shells

5.5 Ions have more or less electrons

5.6 Isotopes have more or less neutrons

5.7 Isotopes can release alpha, beta or gamma radiation

5.8 The half-life of isotopes can be used to tell the time

5.9 Science as a human endeavour: Radiation is used in medicine

What if?

Aluminum atoms

What you need:

Strip of aluminium foil, scissors, microscope

What to do:

1 Each piece of aluminium foil contains atoms of aluminium. Use the scissors to cut your piece of aluminium in half.

2 Cut one of the pieces in half again.

3 Repeat step 2 until your piece of aluminium is too small to cut.

4 Examine the piece of aluminium using the microscope.

What if?

» What if you were able to continue to cut the piece of aluminium until just one atom remained? (Could you see it under the microscope?)

» What if you could see inside the aluminium atom? (What would you see?)

5.1 All matter is made up of atoms

In this topic, you will learn that:

- All matter is made up of atoms.
- Scientists refine models over time.

Although we cannot see atoms, there is much evidence that this basic form of matter exists.

In around 450 BCE, the Greek philosopher Democritus said:

> By convention there is colour, by convention sweetness, by convention bitterness, but in reality there are atoms and the void.

Democritus was a natural philosopher. He did not carry out experiments, but proposed hypotheses based on thought and reasoning. Over the next 1500 years, scientists tried many experiments to detect these invisible particles that make up all life on Earth.

atomic theory
the theory that all matter is made up of atoms

By the 1780s, French chemist Antoine Lavoisier was convinced that matter could not be created or destroyed. Like many scientists of the time, he was interested in the study of mixtures in 'invisible' air. He burned hydrogen with oxygen and found that water was produced, confirming that water is a molecule, H_2O, rather than a single atom.

Figure 1 Antoine Lavoisier measured the composition of chemical compounds.

English scientist John Dalton was fascinated by this research and in 1810 he stated:

> Matter, though divisible in an extreme degree, is nevertheless not infinitely divisible. That is, there must be some point beyond which we cannot go in the division of matter ... I have chosen the word 'atom' to signify these ultimate particles.

Dalton was one of the first scientists to consider the link between elements and atoms. He was the originator of what is now called the **atomic theory**.

Dalton's atomic theory

One of the pieces of evidence that Dalton published was the weights of atoms compared to that of the lightest atom, hydrogen. He assigned weights to atoms such as oxygen, carbon and nitrogen, using the results of chemical analysis carried out by other chemists on compounds such as ammonia (NH_3), water (H_2O) and carbon dioxide (CO_2).

Evidence such as this led Dalton to propose the law of simple multiple proportions. It means that when elements combine, they combine in simple ratios (see Figures 2 to 5). For example:

- 2:1 in water – two hydrogen atoms and one oxygen atom bond to form one water molecule (H_2O)
- 1:4 in methane – one carbon atom and four hydrogen atoms bond to form one methane molecule (CH_4)
- 2:3 in aluminium oxide – two aluminium atoms bond with three oxygen atoms to form a molecule (Al_2O_3).

This might seem obvious to us, but only because of Dalton's atomic theory. This theory gave scientists a way to explain the evidence about atoms.

CHALLENGE

5.1: What is the ratio of atoms in a compound?
Go to page **187**.

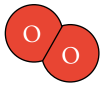


Figure 2 An oxygen molecule is made up of two oxygen atoms.

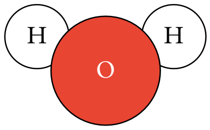


Figure 3 A water molecule is made up of one oxygen atom and two hydrogen atoms.

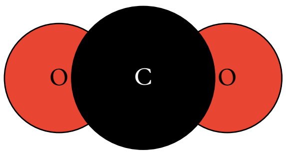


Figure 4 Carbon dioxide is made up of one carbon atom and two oxygen atoms.

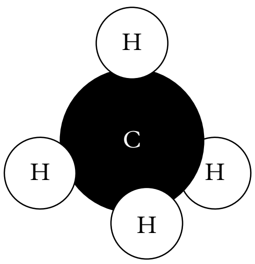


Figure 5 Methane is made up of one carbon atom and four hydrogen atoms.

Evidence supports atomic theory

A scientific theory is written to explain existing evidence and observations. A good theory supported by a range of evidence can be used to make testable predictions. Ever since Dalton first proposed his atomic theory, it has been used to make predictions, and evidence that was not available in Dalton's time supports his theory.

> Elements can join together to form compounds.
> Water always contains twice as much hydrogen as oxygen.
> When chemicals react with each other, the total mass of the chemicals does not change.
> Pure oxygen has the same properties wherever it is found on the Earth or even in space.
> Gases, some of which are invisible, have mass and different gases have different masses.
> Modern scanning tunnelling microscopes produce images of surfaces that look 'bumpy'.
> Under a microscope, tiny particles of pollen in water move in strange ways as if bumping into invisible objects.

Figure 6 An ammonia molecule

5.1 Check your learning

Remember and understand

1 **Compare** (the similarities and differences between) a philosopher such as Democritus and a scientist such as John Dalton.

2 Scientists use 'chemical formulas' to represent different types of molecules. For example, Al_2O_3 is the chemical formula for aluminium oxide. **Identify** the chemical formulas for each of the following substances:
  a carbon dioxide
  b ammonia
  c methane.

3 The chemical formula of water is H_2O. **Explain** what the '2' in the formula means.

4 Draw and label a carbon dioxide molecule.

Apply and analyse

5 **Explain** why it is important that scientists record the methods used in their experiments.

6 It wasn't until around 1906 that many other scientists finally became convinced that Dalton's ideas were correct and that atoms really existed. **Explain** why many scientists initially doubted his hypothesis.

7 Choose two of the forms of evidence given on this page and **explain** how they could be used as evidence of the existence of atoms.

5.2 Atoms are made up of subatomic particles

In this topic, you will learn that:

- The Rutherford model of atoms suggests that an atom has a central nucleus containing positively charged protons, and neutrons with no charge.
- Negatively charged electrons travel around the space outside the atom's nucleus.
- Atoms have no overall charge.

subatomic particles
particles that are smaller than atoms

electron
a negatively charged particle in the nucleus of an atom

Thomson plum pudding model
an early model of the atom in which the positively charged nucleus has negatively charged electrons scattered through it, like a plum pudding

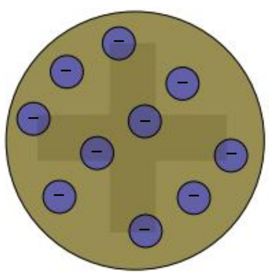


Figure 1 Thomson's plum pudding model of the atom

Discovering more about atoms

A century after Dalton proposed his theory, in the early twentieth century, the physicist Joseph John Thomson discovered that atoms were actually divisible and were made up of even smaller **subatomic particles** (particles that are smaller than atoms). His experiments showed that inside the atom are far smaller, negatively charged particles, which we now call **electrons**.

He also showed that an atom contains positively charged material, although it was not yet clear what this material was. From this discovery, and knowing that oppositely charged objects attract each other and move towards each other, Thomson suggested that the atom is like a plum pudding, in which the positively charged material is the 'cake' and the electrons are the fruit. The positive and negative charges are mixed uniformly througout the atom in what was called the **Thomson plum pudding model** of the atom (Figure 1).

Rutherford's experiments on atoms

Ernest Rutherford was born in New Zealand in 1871. His experiments changed the way people thought about the inside of the atom. In 1911, he supervised Hans Geiger and Ernest Marsden, who carried out what is known as the 'gold foil' experiment (Figure 2). They set up a very thin layer of gold foil and fired a stream of alpha particles at it. Alpha particles are very small, positively charged radioactive particles that contain energy. Detectors were set up around the gold foil to record the path of the radioactive particles. This would identify whether the particles had gone straight through the foil or had been deflected (made to change course) by the gold atoms in the sheet of gold foil. If the plum pudding model was correct (that the positive and negative charges were distributed uniformly throughout the atom), then the alpha particles should shoot straight through the neutral (no charge) gold foil by passing through the gaps between the gold atoms (Figure 3).

Two aspects of the results surprised the scientists. The first evidence was that, while most of the alpha particles did pass straight through the gold foil, some alpha particles were deflected in different directions (Figure 4). Even more surprising was the second piece of evidence. A small number of the alpha particles bounced straight back in the direction that they had come from.

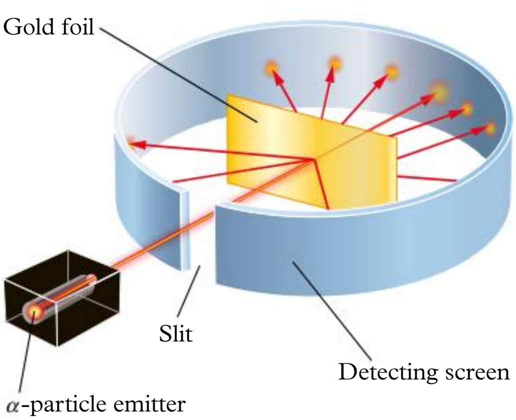


Figure 2 Rutherford's gold foil experiment. Note the large deflection of some particles.

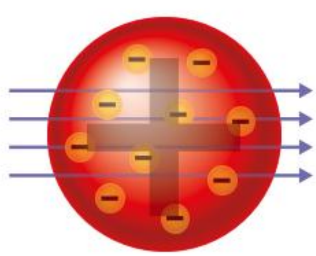


Figure 3 If the 'plum pudding' model of the atom were correct, it would be expected that most of the alpha particles would move through the gold with only minimal deflection.

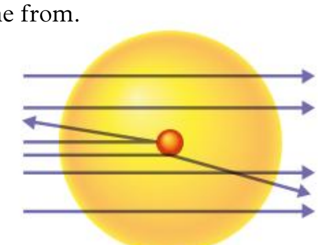


Figure 4 The gold foil experiment showed that some alpha particles were deflected.

CHALLENGE
5.2A: How can you tell what is inside?
Go to page **188**.

CHALLENGE
5.2B: Rutherford model of the atom
Go to page **188**.

Rutherford concluded that, instead of being like a plum pudding, a gold atom must contain a lot of space, with a small positive charge in the centre that deflected the positive alpha particles. With his gold foil experiment, Rutherford had discovered a small, positively charged nucleus in the centre of the gold atoms.

Rutherford's model of the atom

Rutherford's model has been supported by further research on the structure of the atom. The current accepted model of an atom is as follows.

- The **nucleus** of an atom is made up of protons and neutrons.
- **Protons** carry a positive electric charge.
- **Neutrons** are neutral – they have mass but no electric charge.
- Electrons have a negative electric charge.

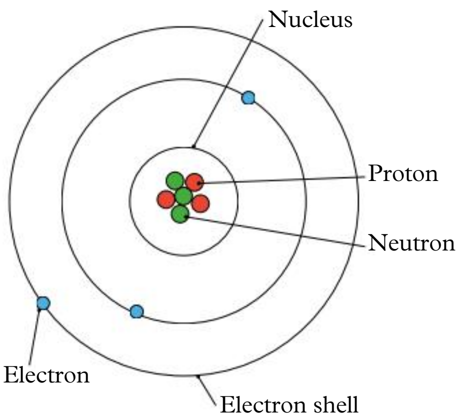


Figure 5 A two-dimensional model of an atom of the element lithium.

- The mass of the atom is almost entirely due to the mass of the protons and neutrons in the nucleus; electrons have very little mass in comparison.
- Electrons move around in the space outside the nucleus.

Huge parts of atoms are empty space. If you expanded one atom to the size of the Melbourne Cricket Ground, the nucleus of that atom would be no bigger than a pinhead.

An important thing to know is that, overall, an atom has no electrical charge. In other words, there is always the same number of positive protons as negative electrons in any atom.

nucleus
the centre of an atom, containing protons (positive charge) and neutrons (no charge)

proton
a positively charged subatomic particle in the nucleus of an atom

neutron
a neutral (no charge) subatomic particle in the nucleus of an atom

Figure 6 Imagine the size of a pinhead compared to the Melbourne Cricket Ground.

5.2 Check your learning

Remember and understand

1 Use the evidence described to **explain** why Rutherford concluded that:
   a an atom contains a lot of space
   b there is a central area of positive charge.
2 **Describe** Thomson's plum pudding model of the atom.
3 **Describe** the most important new understanding of the structure of the atom that Rutherford inferred from his experiment with alpha particles.
4 Name and **describe** three types of particles we now know are inside an atom.

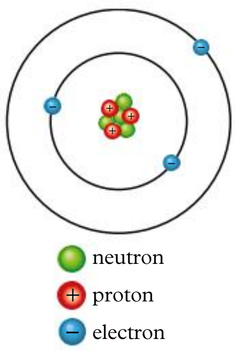
Evaluate and create

5 Working with a partner, **create** a three-dimensional model of an atom from modelling clay or other suitable materials. Make sure you label all parts correctly and state which model of the atom you are representing.

5.3 Atoms have mass

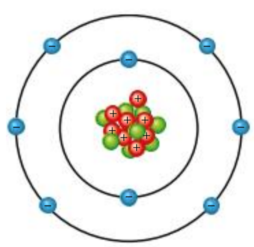
In this topic, you will learn that:

- The mass of an atom is made up of the protons and neutrons in the nucleus of the atom.
- Because atoms are so small, their mass is measured using a relative mass scale.
- Atoms are given their names according to the number of protons in their nucleus.



Lithium
Number of protons = 3
Atomic number = 3
Number of neutrons = 4
Mass number = 7
Number of electrons = 3

Figure 1 A lithium atom, with mass number 7 and atomic number 3



Oxygen
Number of protons = 8
Atomic number = 8
Number of neutrons = 8
Mass number = 16
Number of electrons = 8

Figure 2 An oxygen atom, with mass number 16 and atomic number 8

mass number
a number that represents the total number of protons and neutrons in the centre of an atom

Size is relative

A gold atom might seem heavy if you compare it to a helium atom. But if you compare it to an elephant, an atom is extremely small! To measure something by comparing it with something else is called relative measurement.

Relative scales are often helpful when objects or events are being compared. Relative scales are used when it is more important to know the differences between objects and events than the actual measurement (size, mass, time). The following conversation uses relative measurements.

> 'Mum, Chloe's been in the shower twice as long as I was.'
>
> 'I know, but you used three times as much shampoo.'

Being able to compare the masses of different atoms is important when investigating the behaviour of different atoms and elements. It is not so helpful to know the actual mass of atoms, partly because the mass is so small.

Mass number

On the relative atomic scale, the mass of a proton is given a value of 1. Neutrons have almost the same mass as protons, so they also have mass of 1 on this scale. Therefore, the mass of an atom (its mass number) can be worked out by counting how many protons and neutrons there are in the nucleus. Remember that electrons aren't included in the mass number, because they are so light in comparison to the particles in the nucleus.

For example, a helium atom that contains two protons and two neutrons has a relative mass of 4. A carbon atom that contains six protons and six neutrons has a relative mass of 12. The total number of protons and neutrons in an atom is also called the **mass number**.

Atoms are given different names according to the number of protons they have in the nucleus. Because atoms are always neutral (no overall charge), the number of electrons in an atom is always the same as the number of protons (the atomic number). Figures 1 and 2 show examples of two common atoms.

Atomic number = number of protons

Protons determine names

There are many ways to group the different types of atoms. As the mass of an atom is too small to be easily measured, and some atoms have similar properties, scientists use the number of protons to give an atom its name. An atom with 8 protons is always called oxygen, while an atom with 19 protons is always called potassium.

Representing atoms

When it is important to show the number of particles within each atom, the method of representation shown in Figure 3 can be used. The elements can be presented in a **periodic table** (Figure 4). In a periodic table, the elements are arranged according to the number of protons in their atoms. The vertical columns, called **groups**, consist of elements that behave in similar chemical ways. The horizontal rows are called **periods**.

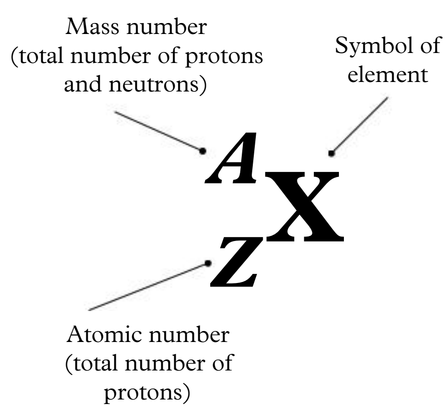


Figure 3 The conventional representation of an element

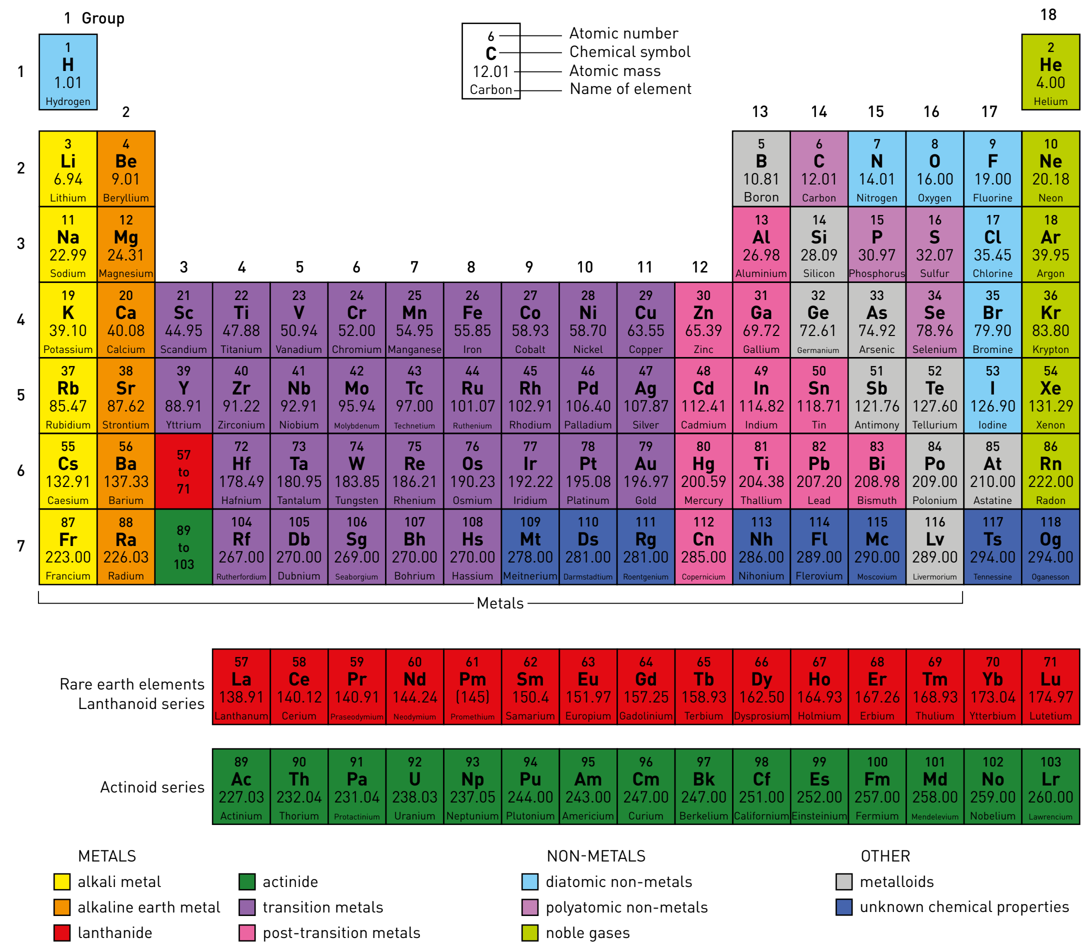


Figure 4 A periodic table of the elements

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to similar properties

group
a vertical list of elements in the periodic table that have characteristics in common

period
(in chemistry) a horizontal list of elements in the periodic table

5.3 Check your learning

Remember and understand

1 Table 1 shows the numbers of subatomic particles in a range of atoms.

a Complete the table.

Table 1 Atoms and subatomic particles

Atom name and symbol	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
Calcium (Ca)	20	40	20	20	20
Fluorine (F)	9	19	9		
Sodium (Na)	11		11	12	
Argon (Ar)		40	18		
Sulfur (S)			16	16	

b **Explain** how you were able to calculate the number of neutrons in the argon atom.

c **Explain** how you were able to work out the atomic number and the mass number of the sulfur atom.

2 **Identify** the subatomic particle that is not in the nucleus of the atom.

3 **Identify** the element that is located in period 3, group 15 of the periodic table.

Apply and analyse

4 Imagine that the elements do not have names and are identified only by their atomic numbers. **Describe** the possible complications this would cause.

5 The atomic number of a nitrogen atom is 7 and the mass number is 14. **Calculate** the number of electrons in this neutral atom.

6 **Identify** the atom that has twice as many protons as an oxygen atom.

Evaluate and create

7 **Investigate** what uranium-235 atoms are used for, and how many protons and neutrons are inside the nucleus of the atom.

5.4 Electrons are arranged in shells

In this topic, you will learn that:

- The Bohr model describes how, within an atom, the electrons move in specific areas of space called electron shells.
- Each shell can contain a limited number of electrons.
- When an electron gains energy, it moves to an outer shell of higher energy. When the electron moves back to a lower-energy shell, the excess energy is given off as light.
- The number of electrons in the outer shell is called its valency.

Interactive 5.4
Electron configuration

Figure 1 Niels Bohr proposed the idea of electron shells.

electron shell
a defined area of space in which electrons move around an atom's nucleus

Bohr model
a model of the atom in which electrons orbit the nucleus in a series of defined orbits known as shells

electron configuration
a numerical way of showing the number of electrons in each electron shell around a particular atomic nucleus

Arranging electrons

After Rutherford had refined his model of the atom, another scientist, Niels Bohr, concluded that the electrons in the atom do not behave exactly like the planets around the Sun, but move about the nucleus in circular orbits that are at certain distances from the nucleus. The more energy the electrons have, the further their orbit is from the nucleus. These sets of orbits are known as **electron shells**. There is a limit to the number of electrons that can be in any of the shells. This special arrangement of electrons around an atom is called the **Bohr model**.

Bohr also stated that the electrons of an atom are normally located as close to the nucleus as possible, because this is a lower-energy state and is more stable. Therefore, electrons fill the shells closest to the nucleus first.

The arrangement of electrons in an atom is called its **electron configuration**. Shells closest to the nucleus are smaller and therefore hold fewer electrons than larger shells on the outside of the atom. Table 1 shows the maximum number of electrons each shell can contain. For the first 20 elements, the third shell can only hold eight electrons. For atoms with atomic numbers greater than 20, the third shell can accommodate up to 18 electrons. You will only have to consider the first 20 elements (up to calcium) in terms of electron configuration.

The electronic configurations of oxygen and calcium are compared in Figure 2.

These electronic configurations are often represented by **shell diagrams** that show the electron shells as circles. The electrons are shown in pairs. The outermost occupied shell of uncharged atoms is known as the **valence shell**. The number of electrons in the valence shell of an atom determines the chemical properties of the element, and affects how the atom will bond with other atoms.

Table 1 Electron configurations for electron shells of an atom

Electron shell	Maximum number of electrons in shell
First	2
Second	8
Third	Up to calcium: 8 Above calcium: 18
Fourth	32

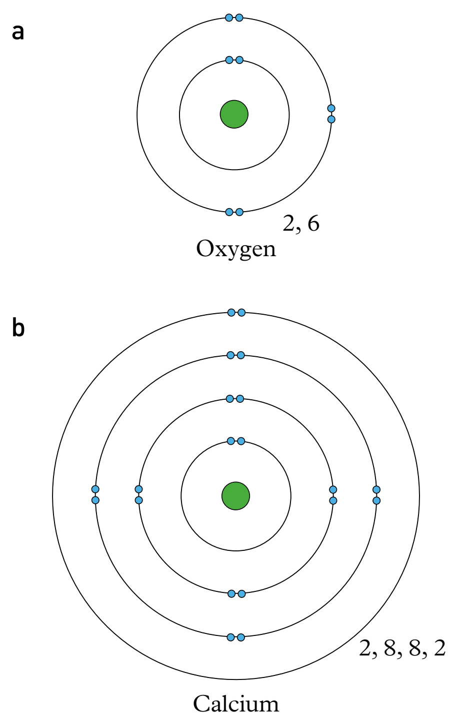


Figure 2 The electron configurations for **a** oxygen, period 2, group 16; and **b** calcium, period 4, group 2

EXPERIMENT
5.4: Flame tests
Go to page **189**.

In Topic 5.3 you examined how the periodic table is arranged into groups (columns) and periods (rows). This arrangement is determined by the electronic configuration, and therefore the chemical properties of the element. The group number tells you the number of electrons in the valence shell. For example, atoms in group 1 have one electron in their outer shell. Atoms in group 17 have seven electrons in their outer shell. This can be seen in Figure 3. The periods of the periodic table indicate the number of electron shells that are occupied. For example, oxygen is in period 2, group 16. This means it has two electron shells, with six electrons in the outer valence shell (as you saw in Figure 2).

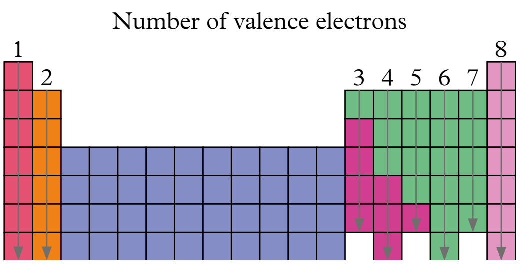


Figure 3 The valence electrons

Evidence for electron shells

Many substances give off coloured light when a small sample is introduced into a flame. This light can be seen through a spectroscope – an instrument that breaks the light up into a pattern of coloured lines. This pattern is known as an **emission spectrum** (Figure 4) and is unique for each element. Bohr explained this by saying that a particular atom is given energy in a flame. The electrons absorb the exact amount needed to jump from their normal shell to one further out from the nucleus. He described the electrons as being excited. Because this higher energy state is unstable, the electrons then jump back to their normal levels almost instantly. The extra energy that the electrons no longer need is released as light energy. The wavelength of the light (and therefore its colour) represents the energy difference between each electron shell. This unique combination of colours (or spectrum) is linked to a particular type of atom (element) with its unique number of electrons arranged in shells. This spectrum is therefore like the 'fingerprint' of that element. This is how flame tests work.

shell diagram
a diagram that shows the number of electrons in each electron shell around a particular atomic nucleus

valence shell
the outermost electron shell in an atom that contains electrons

emission spectrum
the pattern of wavelengths (or frequencies) that appear as coloured lines in a spectroscope; it is unique to each element

Figure 4 The emission spectrum of hydrogen

5.4 Check your learning

Remember and understand

1 In the Bohr model of the atom, **identify** the maximum number of electrons that the second electron shell can contain.

2 **Explain** why the second shell can contain more electrons than the first shell.

Apply and analyse

3 A potassium atom contains 19 protons.

a **Identify** the number of electrons in a potassium atom. **Explain** how you determined your answer.

b Draw the electron configuration of a potassium atom according to the Bohr model.

c Use the periodic table to **identify** the number of electrons in the valence shell of a potassium atom.

d **Explain** how the electrons in potassium atoms can be made to jump into the fifth electron shell.

4 Complete Table 2.

Table 2 Atomic number and electron configuration of some elements

Element	Atomic number	Electron configuration
Helium		
Carbon	6	
Neon		2,8
	1	
Magnesium		
	17	
		2,8,3

5 Robert Bunsen (1811–1899) was a German chemist who investigated the coloured flames given off by heated elements. From the results of the flame tests you did in Experiment 5.4, **identify** the atom that caused the yellow colour Bunsen saw when he was heating glass.

6 **Identify** the element that is in period 3, group 1. Draw its electron configuration.

5.5 Ions have more or less electrons

In this topic, you will learn that:

- Electrons have a negative charge.
- When an atom loses electrons, it forms a cation (positve charge).
- When an atom gains electrons, it forms an anion (negative charge).

ion
an atom that is charged because it has an unequal number of electrons and protons

Atoms and ions

Atoms are neutral. This means that the amount of negative charge within the atom is always the same as the amount of positive charge. This is because the number of protons (positive) is always the same as the number of electrons (negative). However, if electrons are lost or gained from the outside of the atom, there will no longer be the same number of protons and electrons, and the atom becomes an ion. The process of forming **ions** is called ionisation.

Ionisation can happen when atoms come together to form chemical bonds. It can also happen when atoms are exposed to radiation. When ions are formed, it is the electrons in the outer electron shell (the valence shell) that are affected. Normally when ions are formed, the resulting ion has a full outer shell of electrons. This is because a full outer shell of electrons is a very stable arrangement. For example, the first three shells of a chloride ion are stable, with 2, 8 and 8 electrons respectively (Figure 1).

For example, an atom that originally had two electrons in its valence shell, such as magnesium, would lose both these electrons to achieve a full outer shell – it is easier to lose two electrons than to gain six.

An atom with seven electrons in its outer shell, such as chlorine, would gain one electron to complete this outer shell with eight electrons – it is easier to gain one electron than to lose seven.

Calculating ion charge

When an ion is formed, the number of protons in the atom stays the same, because protons are located in the nucleus and are not affected by changes occurring on the outside of the atom. When electrons are gained or lost, an imbalance is formed between the number of positive charges and the number of negative charges.

Electrons are negatively charged, so when an atom gains an extra electron, the charge on the whole atom becomes negative.

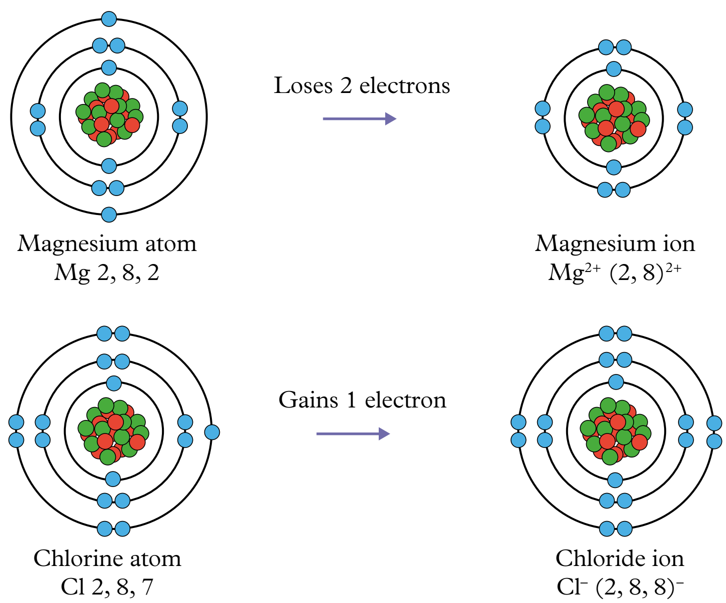


Figure 1 How magnesium and chloride ions are formed

If two electrons are gained, then there is an overall charge of negative two. A negatively charged ion is called an **anion**.

If an electron is lost from an atom, the resulting ion will have a charge of positive one because there are more protons than electrons. One electron lost means there is effectively one extra proton. A positively charged ion is called a **cation**.

Table 1 contains some examples of anions and cations.

anion
a negatively charged ion formed when an atom gains electrons

cation
a positively charged ion that results from an atom losing electrons

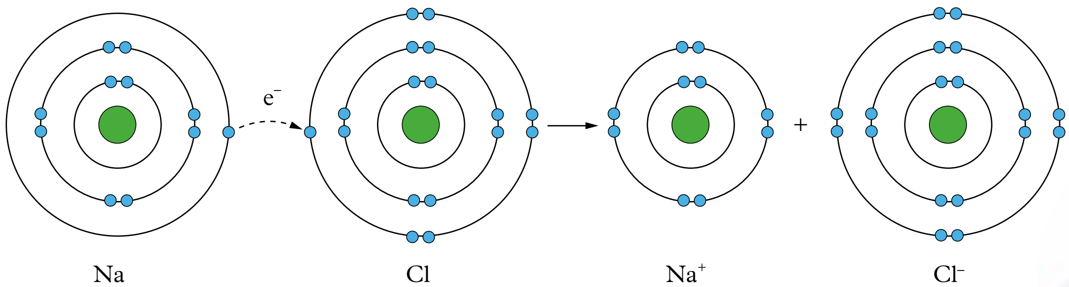


Figure 2 A sodium atom loses an electron to become a positively charged cation. Chlorine gains an electron to become a negatively charged anion. In this way, salt (sodium chloride, NaCl) is formed.

Figure 3 To remember the difference between cations and anions, think of a positive CATion.

Table 1 Examples of positive and negative ions

Name and symbol of atom	Electron configuration of atom	Electron configuration of ion	Metal or non-metal?	Change	Charge of ion	Name and formula of ion
Oxygen (O)	2,6	2,8	Non-metal	Gained 2 electrons	−2	Oxide (O^{2-})
Chlorine (Cl)	2,8,7	2,8,8	Non-metal	Gained 1 electron	−1	Chloride (Cl^-)
Sodium (Na)	2,8,1	2,8	Metal	Lost 1 electron	+1	Sodium (Na^+)
Calcium (Ca)	2,8,8,2	2,8,8	Metal	Lost 2 electrons	+2	Calcium (Ca^{2+})

5.5 Check your learning

Remember and understand

1 **Define** the term 'cation'.

2 **Use** an example from the periodic table to **explain** how an anion is formed.

Apply and analyse

3 **Describe** the patterns you observe in Table 1 for each of the following:
- a names of the negative ions
- b electron configurations of the ions
- c differences between the metals and non-metals.

4 **Use** the groups in the periodic table to **identify** the charges on the following ions:
- a potassium (atomic number 19)
- b aluminium (atomic number 13)
- c nitride (produced from nitrogen atoms with atomic number 7).

Evaluate and create

5 **Explain** why the elements neon (atomic number 10) and argon (atomic number 18) do not normally form ions.

6 **Explain** the relationship between the groups in the periodic table and the ions that are formed.

Figure 4 Atoms have a positively charged nucleus orbited by negatively charged electrons.

5.6 Isotopes have more or less neutrons

In this topic, you will learn that:

- An isotope is a different form of the same element with fewer neutrons in the nucleus of the atom.
- The periodic table lists the relative atomic mass of an atom, which represents the average mass of all the isotopes of that atom.

Atomic mass and isotopes

The periodic table lists the atomic masses of the elements. These masses are not whole numbers and are not the same as the mass numbers of the atoms (although they are close). They are a more accurate way of comparing the masses of the atoms of different elements. But why are many of them not whole numbers? We certainly cannot have part of a proton or part of a neutron in an atom. Electrons do have some mass, but not enough to make much difference to the overall mass of the atom. So where do these atomic masses come from?

Generally, not all the atoms within an element have the same mass. This is because they are not identical. Why is this? What do they have in common and what is different?

All the atoms of an element have the same number of protons – their atomic number. The atomic number is used to identify the element. For example, all carbon atoms have six protons in their nucleus, so their atomic number is 6. In the periodic table of the elements (Figure 1), you can see that the elements are listed in order of their atomic number. However, although all the atoms of one particular element have the same number of protons, they may have different numbers of neutrons.

Isotopes

Neutrons help to make the nucleus more stable. For most elements, the number of neutrons in the atoms can vary. For example, most carbon atoms have six neutrons in their nucleus but some have seven or eight. The different forms of the atoms of an element that have different numbers of neutrons are called **isotopes**.

Remember, the number of protons in an element never changes. If there is a different number of protons, it is a different element.

isotope
an atom of a particular element that has more or fewer neutrons in its nucleus than another atom of the same element

21 Sc 44.95 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.95 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.70 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc
39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (98) Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium
57 to 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury
89 to 103	104 Rf (205) Rutherfordium	105 Db 105 Dubnium	106 Sg (271) Seaborgium	107 Bh (272) Bohrium	108 Hs (277) Hassium	109 Mt (276) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (280) Roentgenium	112 Cn (285) Copernicium

Figure 1 Some atomic numbers and atomic masses in the periodic table

CHALLENGE
5.6: Calculating relative atomic mass
Go to page **190**.

Carbon-12 is the most common form of carbon atom in the natural world. Of all the natural carbon on the Earth, only 1.1 per cent is carbon-13 atoms (6 protons and 7 neutrons), and an even smaller quantity is carbon-14 atoms (6 protons and 8 neutrons).

Like most elements, carbon has more than one naturally occurring isotope (Figure 2). In these cases, chemists use the average mass of the isotopes of the element for calculations. This average mass is termed the **relative atomic mass** of the element. For example, almost all carbon atoms exist as the carbon-12 isotope and only a very small proportion is present as the two heavier isotopes. Therefore, the relative atomic mass is only just above 12. The relative atomic masses of the elements are usually shown in the periodic table, correct to one or two decimal places. Be careful not to confuse atomic masses in the periodic table (which are decimals) with their atomic numbers (which are always integers).

relative atomic mass
the average mass of an element, including the mass and prevalence of its different isotopes

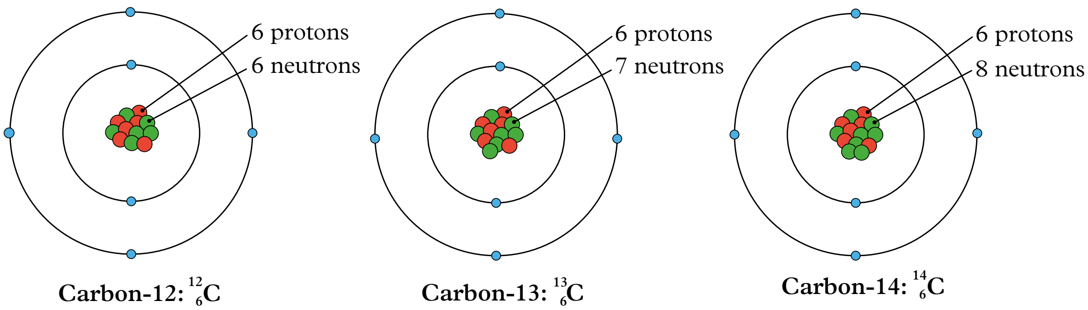


Figure 2 The three isotopes of carbon

Figure 3 Marie Curie was one of the first scientists to study isotopes, some of which are radioactive. Her notebook is still radioactive over 100 years later.

5.6 Check your learning

Remember and understand

1 **Define** the term ‘isotope’.

2 **Explain** the meaning of ‘mass number’ and how this name arose. Use an example to assist your explanation.

3 **Explain** why the atomic number of an element is always a whole number but the relative atomic mass of an element is often not a whole number.

Apply and analyse

4 Use your knowledge of isotopes and a copy of the periodic table to complete Table 1.

5 One atom has 5 protons and the other has 6 protons. Is this an example of a pair of isotopes? **Justify** your answer (by providing your reasons).

Table 1 Isotope details

Isotope symbol	Isotope name	Atomic number of element	Number of protons	Number of neutrons	Number of electrons in uncharged atom
$^{238}_{92}U$					
	Oxygen-16				
			10	20	
				36	29
		30		34	

6 **Identify** which of the atoms below are isotopes of the same element. Also **identify** the name and symbol of the element.

Option 1: 5 protons, 5 neutrons

Option 2: 5 protons, 6 neutrons

Option 3: 6 protons, 6 neutrons

Evaluate and create

7 A student wrote that all the atoms of an element are identical. **Evaluate** whether this is correct (by defining the terms ‘atom’ and ‘element’, comparing the isotopes of carbon, and deciding whether the isotopes are identical).

5.7 Isotopes can release alpha, beta or gamma radiation

In this topic, you will learn that:

- Some isotopes are unstable and may decay.
- Radioactive decay produces alpha, beta and/or gamma radiation.
- The half-life of an isotope is the time it takes for half the remaining unstable isotopes to decay.

radioactive decay
the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide
a radioactive isotope

alpha particle
a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

beta particle
a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

gamma rays
high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

Isotopes and radioactive decay

In Topic 5.6, you learned about isotopes. Hydrogen, for instance, has three isotopes: hydrogen-1 ($^{1}_{1}H$), hydrogen-2 ($^{2}_{1}H$) and hydrogen-3 ($^{3}_{1}H$).

While the number of neutrons can vary, having too many or too few neutrons results in an unstable nucleus that decays radioactively. In the first 20 elements, stable nuclei have a similar number of neutrons and protons.

This process of decay causes the emission of radiation and is known as **radioactive decay**. Hydrogen-1 and hydrogen-2 are stable, but hydrogen-3 is unstable and breaks down. Therefore, hydrogen-3 is a radioactive isotope and is called a **radionuclide**. Radionuclides occur naturally but they can also be manufactured in a nuclear reactor.

Types of nuclear radiation

Alpha (α), beta (β) and gamma (γ) radiation all originate from an unstable nucleus. An **alpha particle** is identical to a helium nucleus. It contains two protons and two neutrons. Americium-241, which is commonly used in smoke detectors, is an example of an alpha particle emitter. Its nucleus decays to neptunium-237, which is a more stable isotope.

The decay of americium-241 to neptunium-237 can be shown in a nuclear equation:

$$^{241}_{95}Am \rightarrow ^{237}_{93}Np + ^{4}_{2}\alpha$$

In a nuclear equation, the mass numbers on each side of the arrow add to the same value. In this case, they both add to 241. This demonstrates that the total mass of the particles before and after the decay is the same.

Beta particles are produced when a neutron in the nucleus decays into a proton and an electron. The electron is the beta particle that leaves the atom. An example of beta decay is the decay of carbon-14 to nitrogen-14:

$$^{14}_{6}C \rightarrow ^{14}_{7}N + \beta$$

The beta particle has very little mass, so the mass of the new nucleus formed is very similar to the original carbon-14 nucleus. As the beta particle is released, a neutron in effect becomes a proton, so the atomic number of the resulting nucleus increases by one.

Gamma rays are high-energy electromagnetic rays, similar to X-rays, that are emitted after alpha particle or beta particle emission when the nucleus is still excited.

An example is when cobalt-60 decays to form nickel-60:

$$^{60}_{27}Co \rightarrow ^{60}_{28}N + \beta + \gamma$$

Figure 1 Smoke detectors contain a radioactive source, usually americium-241.

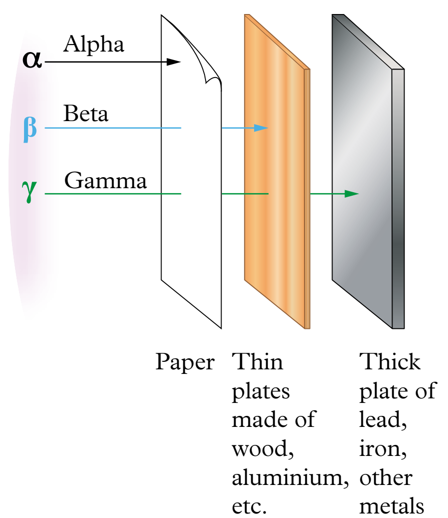


Figure 2 The relative penetrative power of alpha, beta and gamma radiation. Alpha particles are stopped by paper. Beta particles are stopped by aluminium foil. Gamma rays can only be stopped by lead.

CHALLENGE
5.7: Modelling radioactive decay
Go to page **190**.

Cobalt-60 is an artificially produced radioisotope that is used in medical radiotherapy, sterilisation of medical equipment and irradiation of food. Because gamma radiation is an electromagnetic wave (rather than particles, such as alpha and beta radiation), it is highly penetrating and can cause cell damage deep within the body if exposure levels are high.

Radioactive half-life

Radioactive decay is a random process, so we cannot predict which radioactive nuclei in a sample will decay at any given moment. However, the rate of radioactive decay follows a pattern. As a radioactive sample decays, less and less of the original radioactive atoms are left and more of the alternative stable atoms are formed. This means the radioactivity level drops. The **half-life** of a radioactive material is the time taken for half the radioactive nuclei in a sample to decay into the stable atoms (see examples in Table 1). This is also equivalent to the time taken for the radioactivity to drop to half of its original value.

When the radioactivity reaches one-half of its original level, one half-life has passed. When it reaches one-quarter of its original level, two half-lives have passed, and the pattern continues. A graph of radioactive decay against time gives a characteristic shape called an exponential decay curve (Figure 3). Worked example 5.7 shows how to calculate the half-life of a radioactive element.

Table 1 Half-lives of important medical radionuclides

Radionuclide	Half-life
Bismuth-213	46 minutes
Technetium-99m	6 hours
Lutetium-177	6.7 days
Iodine-131	8 days
Chromium-51	28 days
Strontium-89	50 days

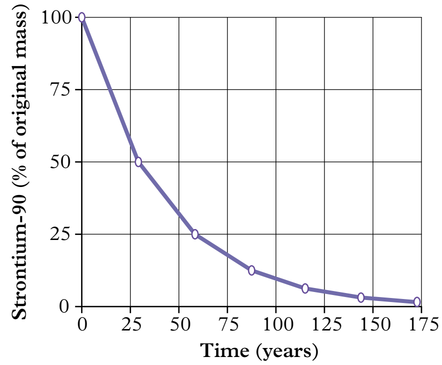


Figure 3 A radioactive decay curve for strontium-90, which has a half-life of 28.8 years

half-life
the time it takes the radioactivity in a substance to decrease by half

Worked example 5.7: Calculating half-life

Strontium-90 is a radioactive element that has a half-life of 28.8 years. If 1000 g of strontium-90 was purchased in 2020, calculate:

a the amount of strontium-90 left after 1 half-life

b the number of years it would take for the strontium-90 to decay to 125 g.

Solution

a After 1 half-life, half of the 1000 g would have decayed.

Remaining strontium-90 $= \frac{1}{2} \times 1000$ g

$= 500$ g

b To calculate the number of years it would take 1000 g to decay to 125 g, the number of half-lives needs to be determined.

Starting strontium-90 mass (0 years) = 1000 g

1 half-life (28.8 years) = 500 g

2 half-lives (57.6 years) = 250 g

3 half-lives (86.4 years) = 125 g

Therefore, the time for 1000 g of strontium-90 to decay to 125 g = 86.4 years

5.7 Check your learning

Remember and understand

1 **Explain** the meaning of each of the following terms.

- **a** isotope
- **b** radioactive decay
- **c** radionuclide
- **d** half-life

2 Write the conventional representation of an isotope for each of the following in the form $^{A}_{Z}$X. You may need to use the periodic table to determine the atomic number of the elements.

- **a** iodine-131
- **b** cobalt-60
- **c** technetium-99
- **d** fluorine-18

3 A number of the elements have radioactive isotopes. In each case, it is the nucleus of the atom that is unstable. **Describe** how you could protect yourself from each of the following types of radiation.

- **a** alpha radiation
- **b** beta radiation
- **c** gamma radiation

Apply and analyse

4 At 3:00 pm, 80 000 atoms of a radionuclide were sitting on the bench. At 3:10 pm, after 10 minutes of radioactive decay, there were only 5000 of the original atoms left. (The others had decayed into a more stable isotope.) **Calculate** the half-life.

Evaluate and create

5 **Investigate** one radioactive isotope that is used in medicine. State the symbol for the isotope and its uses.

5.8 The half-life of isotopes can be used to tell the time

In this topic, you will learn that:

- Background radiation exists all around us, from radioactive material and in the form of cosmic rays from the Sun and space.
- The rate at which a radioactive material decays can be used to determine how long the material has been outside a living organism.

Carbon dating

Whether a nucleus is stable depends on the number of neutrons and protons in the nucleus. There is no easy formula that can be used to predict the stability of individual atomic nuclei, but some nuclei, such as carbon-12 nuclei, with six protons and six neutrons, are very stable. However, carbon-14, with eight neutrons in its nucleus, is less stable and will decay over time, giving out radiation to form a different atom. It's very slightly radioactive, but safe.

Carbon-14 is being formed all the time as cosmic rays enter Earth's upper atmosphere. Plants absorb this carbon-14 when they photosynthesise and the carbon-14 then enters the food chain. Therefore, all living organisms, including humans, contain a certain amount of radioactive carbon-14 while they're alive. However, when an organism dies and stops eating new carbon-14, the carbon-14 in its body begins to decrease at a reliable rate, with a half-life of 5730 years. We can measure the amount of carbon-14 to determine the age of many old artefacts up to 50 000 years old, including cave paintings and ancient scrolls. This method is called **carbon dating**.

carbon dating
a method of estimating the age of organic material, by comparing the amount of carbon-14 in the material with the amount in the atmosphere, knowing the rate at which carbon-14 decays over time

Figure 1 A Geiger counter is used to detect radiation.

Carbon dating is the most common way of dating ancient artefacts, and plant and animal material. It was used to measure the age of the Shroud of Turin (Figure 2), a linen cloth believed by many to have been used to wrap the body of Jesus Christ after his crucifixion. Carbon dating indicated that the Shroud of Turin was not as old as claimed.

The decay of radioactive isotopes is often very slow. For example, 10 g of carbon-14 today would take 5730 years until half of it had decayed. The remaining 5 g would take another 5730 years to reduce to 2.5 g, and another 5730 to reduce to 1.25 g. Unless the amount of carbon is measured over an extremely long period, it might seem that no change is occurring. Only sensitive equipment can detect the radiation being released during the decay process.

Some other radioactive atoms decay incredibly quickly. For example, half of a sample of the isotope lithium-8 decays in less than 1 second. Uranium-235 takes a very long time to decay: it would take 700 million years to reduce to half of the original amount.

In science, there are many situations where change takes place over a range of time scales.

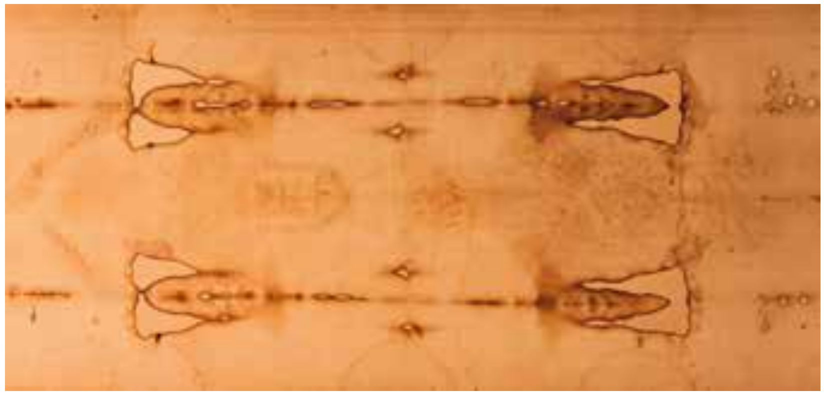


Figure 2 Carbon dating of the Shroud of Turin indicated that it was less than 2000 years old.

What makes radioactive decay special is that it is a random process. It is impossible to predict how long a particular atom will take to decay, giving out radiation as it does so. With billions of atoms in any one sample, the overall rate of decay can be predicted. Think about a glass of water evaporating. It is impossible to predict when one particular water molecule will escape from the liquid, but overall it can be predicted how long the water will take to evaporate.

5.8 Check your learning

Remember and understand

1. **Explain** why carbon-12 atoms are more stable than carbon-14 atoms.
2. **Explain** why an isotope that decays very quickly would be considered more dangerous than an isotope that decays slowly.
3. **Describe** one way you might absorb new carbon-14 atoms into your body.

Apply and analyse

4. In 1988, carbon dating indicated that the Shroud of Turin was in fact created in the Middle Ages (between 1260 and 1390).
   a. **Explain** how carbon dating is used to determine the age of an object.
   b. **Explain** why this method dated the shroud to a range of years rather than a single year.
5. Carbon dating can be used to determine the age of objects less than 50 000 years old.
   a. **Explain** why carbon dating cannot be used to determine the age of older objects (by calculating the number of half-lives that will have passed, and describing whether the remaining carbon-14 could be detected).
   b. **Identify** another radioactive isotope with a longer half-life that could be used to date objects that are older than 50 000 years.

Figure 3 Carbon dating can be used to work out the age of an object.

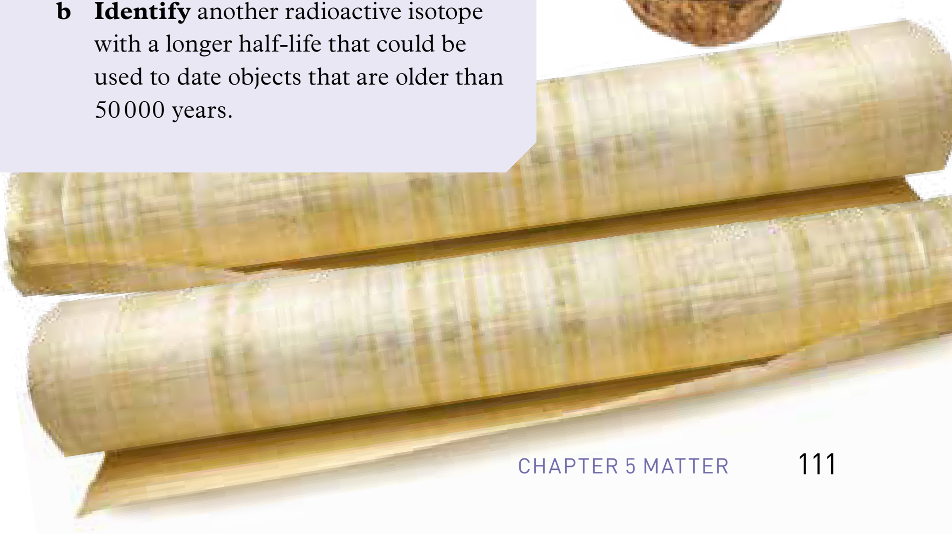


Figure 4 How can we determine the age of objects that might be older than 50 000 years?

//SCIENCE AS A HUMAN ENDEAVOUR//

5.9 Radiation is used in medicine

The radiation produced by isotopes can damage the cells in our body, or it can be used to identify and cure diseases. Nuclear medicine is a diagnostic imaging method often used in X-ray departments in hospitals or clinics.

Effects of radiation

The main reason that radiation can be harmful is that it can cause atoms in other substances to become ions. The emitted alpha and beta particles have enough mass and/or energy to remove electrons from the outside of atoms, which changes the properties of the atoms. This process also causes the release of reactive particles, called free radicals. If this occurs in our bodies, these free radicals can go on to damage other important molecules in the body. If DNA is damaged, this can have serious effects, because DNA is the molecule that contains instructions for other biochemical processes. It is also a molecule that can reproduce itself, so the effect of one damaged DNA molecule can be multiplied thousands or even millions of times as copies of the affected DNA are created. Many cancers linked to radiation start in this way.

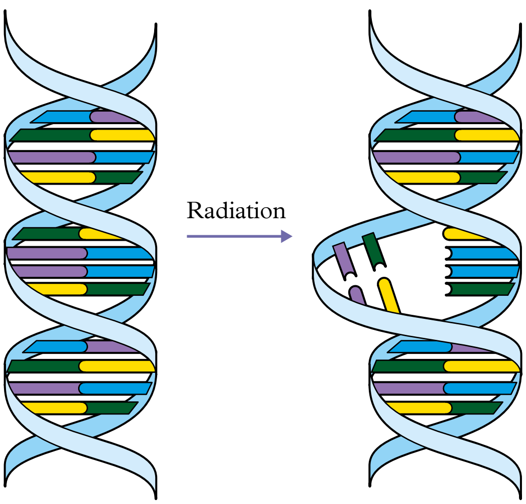


Figure 1 Radiation can damage the structure of DNA molecules.

RADIATION AND MEDICINE

Despite the damage that can be caused by radiation, it has many uses in medicine. The most common medical application is the use of X-rays to identify damaged or broken bones. Less common is the injection of a radioactive isotope into a patient. The radiation accumulates at the site of a cancer or other damaged tissue, and is detected by special monitors.

Figure 2 X-rays use radiation to make images of the bones in the body.

Radiation therapy uses the ability of radioactive isotopes to kill off cancer cells. Cancer cells are normal cells that have had their DNA slightly changed. This change is not enough to kill the cancer cell. Instead, it allows the cancer cell to grow very quickly. Radiotherapy uses radioactive isotopes to cause more damage to the cancer cells. Most commonly, the radioactive particles released by the isotope are directed at the site of the cancer. Eventually, when the cancer cells are damaged enough, they die (a process called apoptosis).

CAREERS IN RADIATION

A nuclear medicine technologist uses medical imaging to help radiologists diagnose illnesses. Before the first patient arrives, the technologist must measure the amount of radioactivity delivered to the department. The isotope, in liquid form, is drawn up into the required amounts and added to 'cold' kits so that the day's scans can be performed. A cold kit is a vial containing a particular chemical agent that, once introduced into the human body, will travel to a particular organ. Each test uses a particular compound, which travels to a known organ of the body based on its chemical composition and the way it is introduced into the body.

Most people referred to nuclear medicine departments require bone scans. These may be performed to diagnose cancer, investigate the extent of arthritis, screen for fractures that do not show on a plain X-ray, or look at infection of bone.

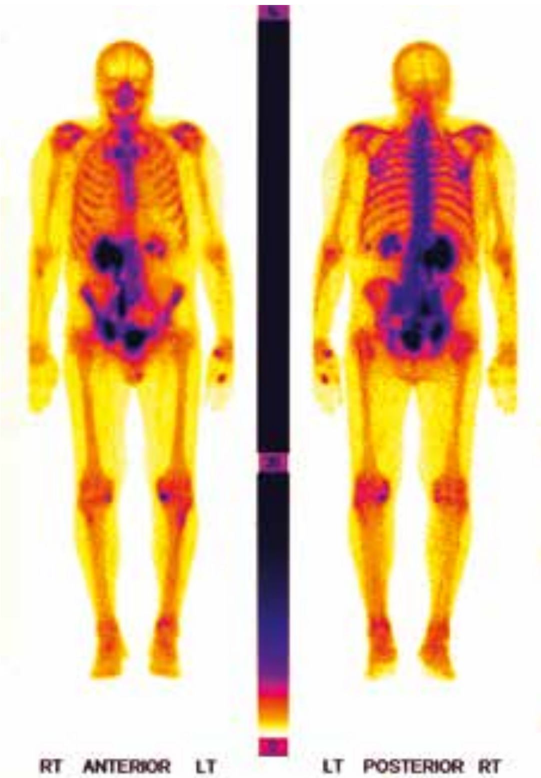


Figure 3 A technetium-99m bisphosphonate bone scan shows up abnormalities within bones.

In other cases, the blood is of interest. The blood of a patient can be 'labelled' – mixed with a small amount of radionuclide. This is used to locate the site of an internal bleed. Once the bleed has been located, surgeons can operate knowing exactly where to begin finding the haemorrhaging vessel so that it may be sealed to prevent further blood loss.

The nuclear medicine technologist typically performs a number of these tests each day, looking at a variety of pathologies. Nuclear medicine technologists must be familiar with many organs in the body, in order to know whether the images obtained appear normal or abnormal. There is also the opportunity to learn about the various treatments for different conditions patients can have. Although a nuclear medicine technologist may learn to interpret images and determine what pathology a person has, they are are not qualified to make a formal diagnosis. They must present the images to the radiologist, who makes the diagnosis. Nuclear medicine technologists have a close working relationship with radiologists, surgeons and nurses.

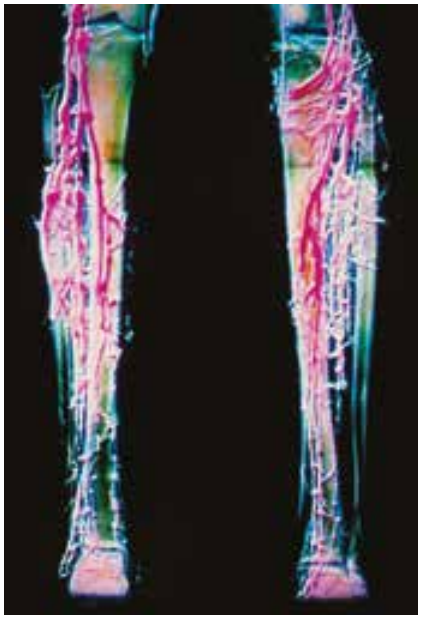


Figure 4 Radioactive dye injected into the blood shows blood flow in the blood vessels.

5.9 Develop your abilities

Asking questions

In critical thinking, you are encouraged to ask many questions. However, it can sometimes be difficult to think of the right questions to ask. The best questions will have the following characteristics.

- Specific questions are useful to ask yourself, to help identify assumptions that you or someone else may be making. For example: 'How do I know this?', 'What is the evidence that supports this?', 'Who wrote this?' and 'Why did they write this?'.
- Open questions are best when they are directed at someone else. An open question does not have a yes or no answer. Instead, it encourages the person to explain their response. For example: 'How do you feel about …?', 'Where do you think this idea came from?' and 'What makes you say that?'.

1 Write three questions that you could ask yourself or someone else about the radiation discussed in this chapter. They could be questions that identify any assumptions or biases that are held about radiation or cancer treatment.

2 Write three open questions that you could ask a nuclear medicine technologist about radiation or cancer treatment.

If you have access to a nuclear medicine technologist, ask them the questions you wrote in question 2. Alternatively, ask someone in your class to answer the questions you wrote in question 1. A good question will make them think critically before they provide an answer.

REVIEW 5

Multiple choice questions

1 The nucleus of an atom is:
  A made of protons and neutrons
  B made of electrons and neutrons
  C made of protons and electrons
  D always negatively charged.

2 Rows of the periodic table are called:
  A groups
  B periods
  C valences
  D electron configurations.

3 Use the periodic table on page 101 to **identify** the correct statement about calcium.
  A It is in period 2.
  B It has an atomic number of 20 and a mass of 40.08.
  C Its electron configuration is 2,8,6,2.
  D It has six electron shells.

Short answer questions

Remember and understand

4 **Describe** what the '2' in the chemical formula CO_2 represents.

5 **Describe** where each of the following particles is found in an atom, and **identify** its charge as positive, negative or neutral.
  a proton
  b neutron
  c electron

6 Complete the following sentence.
'When an atom is uncharged, the number of protons and the number of electrons present are _________.'

7 **Explain** why the mass numbers of isotopes are whole numbers but the relative masses of most atoms are not whole numbers.

8 **Explain** how the electrons are arranged, in the Bohr model of an atom.

9 **Compare** a cation and an anion.

10 **Define** 'half-life'.

11 Titanium is element 22 in the periodic table. It has five naturally occurring isotopes. **Compare** (the similarities and differences between) the isotopes of titanium.

12 **Describe** a beta particle. **Identify** its symbol, including the atomic and mass numbers in the correct positions.

13 **Explain** what is meant when a substance is described as radioactive.

Apply and analyse

14 **Explain** why molecules of water are impossible to see, even with a powerful microscope.

15 $^{238}_{92}U$ is an isotope of uranium that is used in nuclear reactors. In an uncharged atom, calculate how many:
  a protons are present
  b neutrons are present
  c electrons are present.

16 Only 0.7 per cent of the uranium atoms in naturally occurring uranium exist as uranium-235. The other isotopes present are uranium-234 (0.01 per cent) and uranium-238 (99.3 per cent). **Identify** the symbols for the other two uranium isotopes.

Figure 1 Uranium-238 has a relative atomic mass of 92.

17 According to the Bohr model of the atom, the electronic configuration of the uncharged atoms of a particular element is 2,8,8.
  a **Calculate** the atomic number of the element.
  b **Identify** the element.
  c **Describe** the electron configuration of the next element on the periodic table. **Justify** your answer (by **explaining** how you made your decision).

18 Sketch a radioactive decay curve for a substance that starts with an activity of 1600 counts per minute and has a half-life of 2 hours.

19 If a radioactive substance decays from 400 counts per minute to 50 counts per minute in 9 hours, **calculate** its half-life.

Evaluate

20 Tellurium is element number 52. It has a relative atomic mass of 127.6. The next element, iodine, has a relative atomic mass of 126.9.

a **Identify** the symbols for the isotopes of tellurium-127 and iodine-127.

b **Explain** why the atoms of these two elements can have the same mass number.

21 Scientists have had to infer what the inside of an atom is like from indirect evidence, in the same way that astronomers have worked out the temperature and composition of stars. **Describe** the advantages and disadvantages of using indirect evidence to develop theories in science.

22 **Contrast** a scientist and a natural philosopher.

23 **Describe** how the Bohr model gives us much more information than Dalton's early theory of the atom.

Social and ethical thinking

24 Radiation can be used as a form of treatment to kill cancerous cells. However, this treatment can also damage cells in other parts of the body, causing side effects such as nausea, hair loss and fatigue. **Describe** what is meant by the expression 'The end justifies the means'.

Critical and creative thinking

25 A primary school student who was learning about solids, liquids and gases was told by her teacher that everything around her is made of particles that she cannot see. Her response was that this is silly, because if you can't see it, it can't be there. **Identify** three critical thinking questions that the student may want to ask her teacher.

26 **Create** a poster that shows the different models of the atom, from the original theory that it was a solid particle, as proposed by English chemist John Dalton, to the Bohr model. Use the internet to find images of the scientists involved and their models. Place copies of these onto your poster. **Investigate** the year in which each model was proposed and include a timeline.

27 Use your understanding of atoms and elements to **describe** reasons for the following.

a Carbon dioxide is a heavier gas than oxygen.

b Hydrogen and oxygen can be produced from water.

c The relative atomic mass of argon (atomic number 18) is higher than the relative atomic mass of potassium (atomic number 19).

d Beta particles can be stopped by a few millimetres of aluminium foil, but gamma rays will pass through aluminium foil.

Research

28 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

» Targeted alpha therapy

Targeted alpha therapy (TAT) is a new therapy for the control of some cancers. Describe how this form of therapy works. Describe the types of cancer that are treated by this method. Describe how widespread its use is. Identify the risks associated with this form of radiotherapy and how are they reduced.

» Henri Becquerel

Henri Becquerel shared a Nobel Prize with Marie Curie and her husband, Pierre, for their work in discovering radioactivity. Describe his contribution to this important work. Identify the scientific units that are named after him.

Figure 2 Henri Becquerel

» CERN

The European Organization for Nuclear Research (CERN) is based on the border of France and Switzerland. It has been responsible for developing scientists' understanding of atoms. Identify the countries that collaborate in this project. Describe the types of scientists who work at CERN. Describe the work that is occurring at CERN. Describe the Large Hadron Collider.

Figure 3 Part of the Large Hadron Collider

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 5 'Matter'. Once you've completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Define atomic theory and describe evidence that supports atomic theory. Explain why theories such as atomic theory develop over time.	☐	☐ Go back to Topic 5.1 'All matter is made up of atoms' Page 96
Define electrons, Thomson plum pudding model, nucleus, protons and neutrons. Describe the Rutherford model of an atom.	☐	☐ Go back to Topic 5.2 'Atoms are made up of subatomic particles' Page 98
Describe how the elements are ordered on the periodic table. Explain the difference between atomic number and mass number.	☐	☐ Go back to Topic 5.3 'Atoms have mass' Page 100
Describe the Bohr model of an atom. Explain why electron shells are filled from the inside out. Draw shell diagrams for the first 20 elements of the periodic table.	☐	☐ Go back to Topic 5.4 'Electrons are arranged in shells' Page 102
Define ion, anion and cation. Relate the number of electrons in the valence shell to whether the atom will become an anion or a cation.	☐	☐ Go back to Topic 5.5 'Ions have more or less electrons' Page 104
Define isotope and relative atomic mass. Describe the structure of an isotope compared to an atom. Explain how the relative mass of an element is calculated.	☐	☐ Go back to Topic 5.6 'Isotopes have more or less neutrons' Page 106
Define radioactive decay, radionuclide, alpha radiation, beta radiation and gamma radiation. Describe the relationship between a half-life and the number of atoms of a substance.	☐	☐ Go back to Topic 5.7 'Isotopes can release alpha, beta or gamma radiation' Page 108
Describe how the half-life of a radioisotope can be used to determine how old something is and explain how carbon dating works.	☐	☐ Go back to Topic 5.8 'The half-life of isotopes can be used to tell the time' Page 110
Describe the effects of radiation on the human body. Provide examples of the use of radiation in medicine.	☐	☐ Go back to Topic 5.9 'Science as a human endeavour: Radiation is used in medicine' Page 112

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CHAPTER 6

CHEMICAL REACTIONS

Why do some chemicals explode?

6.1 Endothermic reactions absorb energy and exothermic reactions release energy

6.2 Acids have a low pH. Bases have a high pH

6.3 Acids can neutralise bases

6.4 Acids react with metals to produce hydrogen and a salt

6.5 Metals and non-metals react with oxygen

6.6 Science as a human endeavour: Fuels are essential to Australian society

What if?

Lemon juice

What you need:

Universal indicator, lemon juice, test tube

What to do:

1. Pour a small amount of lemon juice into a test tube.
2. Add 1 cm of universal indicator to the test tube. What colour did the universal indicator become?

What if?

» What if water was used instead of lemon juice?

» What if detergent was used?

6.1 Endothermic reactions absorb energy and exothermic reactions release energy

In this topic, you will learn that:

- Energy is required to break up reactants and can be 'stored' in products.
- Exothermic chemical reactions release energy in the form of heat and light.
- Endothermic reactions take energy from their surroundings to manufacture the products.

Video 6.1
Endothermic and exothermic reactions

When atoms form chemical bonds with each other to form molecules, energy is released. Chemical bonds can be broken by adding more energy (e.g. heat). Stable molecules, such as water, require a large amount of energy to break the chemical bonds between the atoms. Unstable molecules, such as hydrogen peroxide (hair bleach), require very little energy to break the chemical bonds between the atoms.

You may have noticed that a test tube or beaker sometimes feels warmer or cooler when the starting reactants rearrange their atoms to become the product molecules. This is because, in a chemical reaction, either chemical energy is converted to heat energy (so the test tube feels hot) or heat energy is converted to chemical energy (so the test tube feels cold).

exothermic reaction
a chemical reaction that releases energy in the form of heat or light

Energy changes in reactions

Before a chemical reaction can occur, energy is first needed to break the chemical bonds between the atoms in the reactant. This energy usually comes from the surrounding environment, such as the friction of a match striking the matchbox, or a match lighting a fire. Once those bonds are broken, the atoms will start to rearrange themselves to form the new product.

endothermic reaction
a chemical reaction that absorbs energy in the form of heat

Exothermic reactions

In an **exothermic reaction** (*exo* means 'to give out'; *thermic* means 'heat'), the product molecules are more stable than the reactant molecules. This means the atoms go from a high-energy reactant molecule to a low-energy product molecule (Figure 1a). The extra energy from an exothermic reaction is released, usually as heat, light or both. An exothermic reaction can be as fast as a match burning or as slow as the rusting of iron.

Endothermic reactions

The opposite of an exothermic reaction is an endothermic reaction. **Endothermic reactions** occur when low-energy molecules react to produce high-energy molecules. If the reactant molecules gain energy from

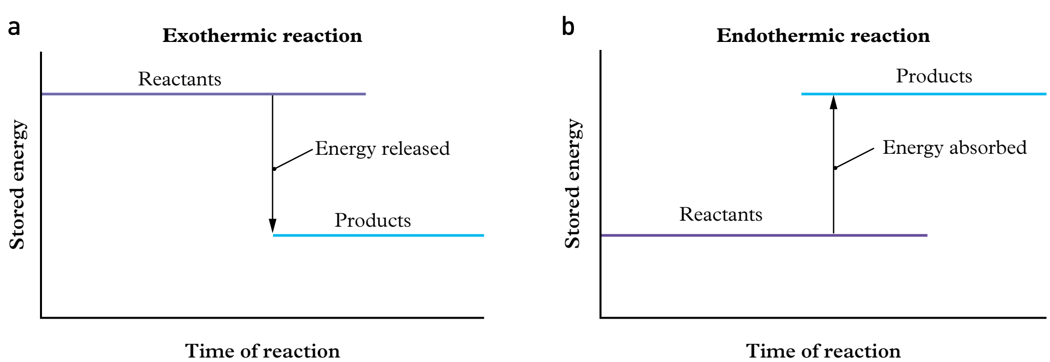

Figure 1 a In an exothermic reaction, energy is released and the products have less stored energy than the reactants. **b** In an endothermic reaction, energy is absorbed from the surroundings and the products have more stored energy than the reactants.

EXPERIMENT

6.1: Energy changes
Go to page **191**.

their surroundings (e.g. from the Sun, from a Bunsen flame or thermal energy from the surrounding environment) then the atoms can form new higher-energy molecules (Figure 1b). An example of this is photosynthesis. The atoms in water and carbon dioxide gain energy from the Sun to form the high-energy glucose molecule. As the atoms gain energy from their environment, the surrounding molecules can lose thermal (kinetic) energy and become cooler.

Using energy changes

A familiar example of processes that involve energy changes is the use of heat and cold packs. Heat packs are used for treating sore muscles. They work by dilating (widening) the blood vessels and allowing the soft tissues to relax. One type of instant heat pack uses a supersaturated **solution** of sodium acetate. This means it contains more sodium acetate than would normally dissolve at a particular temperature. Bending the pack is enough to cause the sodium acetate to form crystals. This is an exothermic reaction as the crystals are lower-energy molecules than the solution. The extra energy is released as heat.

Cold packs reduce the swelling and pain caused by injuries. Instant cold packs usually contain ammonium nitrate, which undergoes an endothermic reaction when the inner bag is broken. This causes the salt to dissolve in water, removing heat energy from the water and using it to make ammonium nitrate solution, which is a high-energy molecule. This cools the water and makes the bag feel cold.

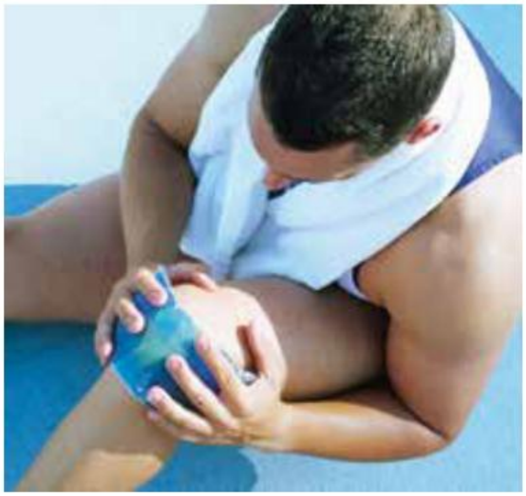

Figure 2 Athletes use instant cold packs to reduce swelling and pain.

solution
a mixture of a solute dissolved in a solvent

Figure 4 When gas burns in a Bunsen burner, energy is released as heat and light.

6.1 Check your learning

Remember and understand

1 **Identify** the following as either exothermic or endothermic processes. **Justify** your answers (by **identifying** the key factors and **comparing** them to the definition of exothermic or endothermic).
  - **a** a candle burning
  - **b** ice changing to water
  - **c** a cake baking

2 **Identify** three examples of exothermic chemical reactions.

3 Complete the following sentences.
During an exothermic reaction, the temperature of the surroundings ___________. The chemical energy of the products is ___________ than the energy of the reactants. An example of an endothermic reaction is ___________.

4 **Explain** how the reaction in an instant heat pack can be used to help an athlete.

Apply and analyse

5 **Explain** the changes to the thermal kinetic energy of surrounding molecules during an exothermic reaction.

6 The energy changes of a chemical reaction are shown in Figure 3. From this graph, **identify** whether the reaction is an endothermic or exothermic reaction. **Justify** your answer.

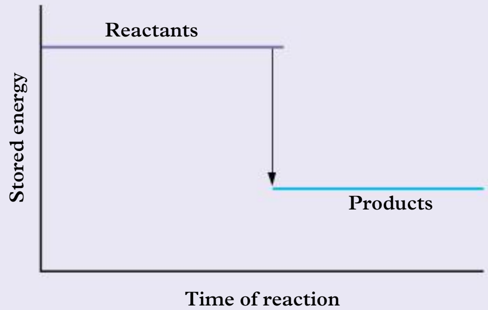

Figure 3 Energy change in a chemical reaction

6.2 Acids have a low pH. Bases have a high pH

In this topic, you will learn that:

- Acids taste sour and contain at least one hydrogen ion.
- Bases taste bitter and feel soapy to touch.
- A base that dissolves in water is called an alkali.
- A pH scale is used to describe the strength of an acid (less than 7) or a base (more than 7).
- An indicator is used to determine the pH of a solution.

alkali
a base that dissolves in water

alkaline solution
a solution that consists of a base dissolved in water

indicator
a substance that changes colour in the presence of an acid or a base

litmus paper
a paper containing an indicator that turns red when exposed to an acid and blue when exposed to a base

universal indicator
a solution that is used to determine the pH (amount of acid or base) of a solution

Figure 1 Sodium hydroxide, a base, is used to make soap.

Acids

Acids are commonly found around us. Unripe fruits taste sour because of the presence of acid. Weak acids in fruit include citric acid in oranges and lemons, tartaric acid in grapes, malic acid in green apples and oxalic acid in rhubarb. Vitamin C is ascorbic acid. Sour milk and yoghurt contain lactic acid. Vinegar is acetic acid. Lemonade contains carbonic acid.

Acids are a group of chemical compounds, all with similar properties. As well as tasting sour, acids produce a prickling or burning sensation if they touch your skin. All acids contain at least one hydrogen atom that can be released as an ion and they react with many metals.

Acids can be strong or weak (see Table 1). Strong acids are dangerous because they can burn through objects. Weak acids are safer, and we can eat and drink some of them. Acids also act as a preservative by preventing the growth of microorganisms.

Bases

Bases are the 'chemical opposite' of acids. They are bitter to taste and feel slippery or soapy to touch. Bases that dissolve in water are called **alkalis**, and solutions that are formed by these soluble bases are described as **alkaline solutions**.

Bases have many uses. They react with fats and oils to produce soaps. Some bases, such as ammonia solution, are used in cleaning agents. One very effective base is household cloudy ammonia. Sodium hydroxide is used in the manufacture of soap and paper. It is also used in drain cleaner. Calcium hydroxide is used to make plaster and mortar.

Table 1 Examples of common acids and bases

ACIDS	
Strong	**Weak**
Hydrochloric acid, HCl	Ethanoic acid, CH_3COOH
Nitric acid, HNO_3	Carbonic acid, H_2CO_3
Sulfuric acid, H_2SO_4	Phosphoric acid, H_3PO_4
BASES	
Strong	**Weak**
Sodium hydroxide, $NaOH$	Ammonia, NH_3
Potassium hydroxide, KOH	Sodium carbonate, Na_2CO_3
Barium hydroxide, $Ba(OH)_2$	Calcium carbonate, $CaCO_3$

How to tell if a substance is an acid or a base

It is possible to identify acids and bases by taste, touch and smell, but it is often not safe to do so. A safer alternative is to use an indicator.

An **indicator** is a substance that changes colour in the presence of an acid or a base. Some of these substances are found in plants.

In the laboratory, scientists use **litmus paper** and **universal indicator**. Litmus paper is the most common indicator for quickly testing whether a substance is an acid or a base. Litmus paper turns red in acidic solutions and blue in basic solutions. Universal indicator is a mixture of different indicators and is more accurate because it indicates the strength of the acidic or basic solution that it is testing.

CHALLENGE

6.2A: Testing with pH paper
Go to page **192**.

EXPERIMENT

6.2B: What if plants were used to create an indicator?
Go to page **193**.

Strong and weak acids (strength)

There are two types of acids. There are strong acids (such as hydrochloric acid) and weak acids (such as ascorbic acid). Strong acids donate their hydrogen ion more easily, which makes them more acidic than weak acids.

Concentrated and dilute acids (concentration)

Concentrated acids have a large number of acid molecules per litre of solution. Dilute acids have a smaller number of acid molecules per litre of solution. Strength and concentration of an acid are not the same.

pH scale

The **pH scale** describes the relative acidity or alkalinity of a solution (Figure 2). All acids have a pH less than 7. The pH of an acid depends on the strength and concentration of the acid. A strong, concentrated acid may have a pH of less than 1. A weak, dilute acid may have a pH between 6 and 7. If a solution is **neutral** – that is, it is neither an acid nor a base – it has a pH of 7. Pure water has a pH of 7 because it is neutral.

Bases have pH values greater than 7. Strong bases, such as caustic soda (sodium hydroxide), can form solutions with a pH of up to 14.

pH scale
a scale that represents the acidity or alkalinity of a solution; pH < 7 indicates an acid, pH > 7 indicates a base, pH 7 indicates a neutral solution

neutral
having a pH of 7, so neither an acid nor a base; an example is water

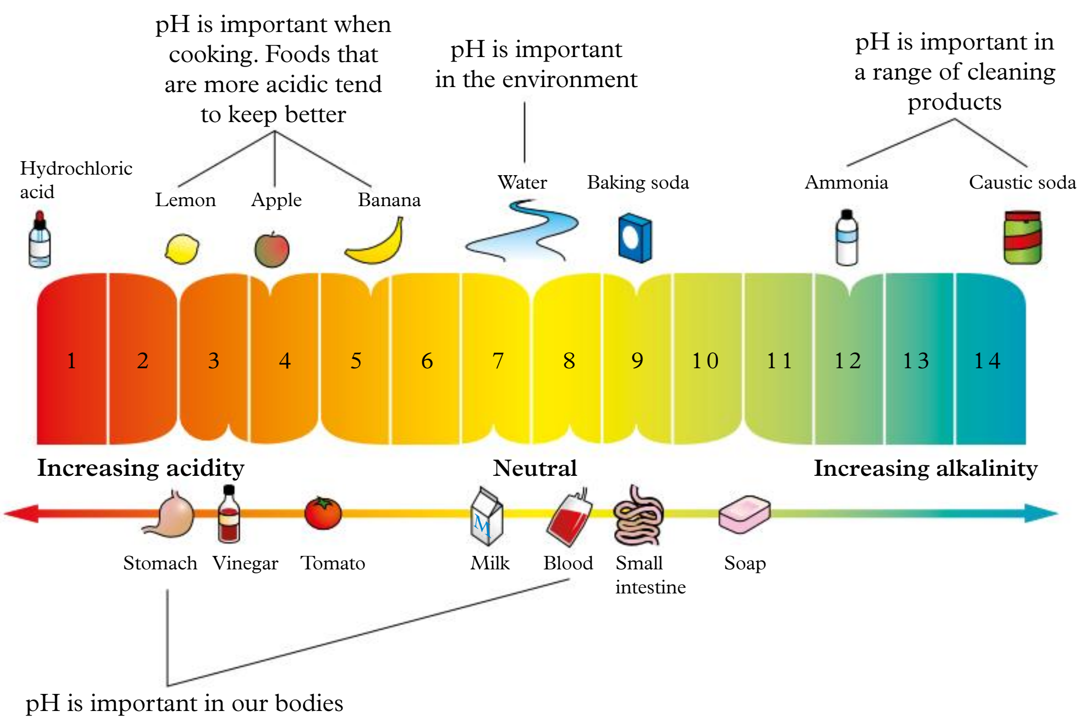

Figure 2 The pH scale

Figure 3 Many cleaning products are alkaline solutions.

Figure 4 Some vegetables, such as red cabbage, can be used to make pH indicators.

6.2 Check your learning

Remember and understand

1 **Identify** three properties of acids.
2 **Identify** three properties of bases.
3 **Identify** one substance that has a pH of 7.
4 **Define** the term 'indicator' as it is used in chemistry.
5 **Describe** the colour of litmus paper in a solution of:
   a an acid   **b** a base.

Apply and analyse

6 **Contrast** (the differences between) the pH of an acid and a base.
7 **Contrast** a strong acid and a concentrated acid.

Evaluate and create

8 **Investigate** other types of indicators and their pH ranges. Based on your research, decide what kind of indicator would be suitable for testing each of the following items and **predict** their pH.
   a lemon juice
   b black coffee
   c vinegar
   d ammonia

6.3 Acids can neutralise bases

In this topic, you will learn that:

- In a neutralisation reaction, acids and bases react to produce water and a salt.
- If the base contains carbonate, then carbon dioxide is also produced.
- The increasing level of carbon dioxide in Earth's atmosphere is forming carbonic acid in the oceans.

Reactions of acids

All acids have certain reactions in common. A general reaction is a word equation that summarises the reaction, without naming a particular acid. General reactions help you to learn the common reactions of acids. You can also use them to predict the products of a reaction if you know the reactants being used.

Acids reacting with bases

When an acid and a base react, they neutralise each other to form a substance called a **salt**. This is not necessarily the salt you will find on your dinner table. A chemical salt is a substance that contains a metal cation (positive ion) and a non-metal anion (negative ion) in a repeating lattice arrangement. Water is also produced in this reaction. This type of reaction is called a **neutralisation** reaction:

acid + base → salt + water

Different acids and bases will produce different salts in neutralisation reactions. For example, citric acid will produce salts called citrates, and sulfuric acid will produce salts called sulfates.

When hydrochloric acid reacts with sodium hydroxide, the salt sodium chloride (which is common table salt) and water are produced. The word equation is:

hydrochloric acid + sodium hydroxide →
sodium chloride + water

salt
a compound that contains a metal cation and a non-metal anion

neutralisation
a reaction in which an acid and a base combine to produce a metal salt and water

Figure 1 The fizzy sensation when you eat sherbet is caused by citric acid reacting with sodium bicarbonate in your mouth to produce carbon dioxide gas.

Acids reacting with metal carbonates or bicarbonates

When an acidic solution reacts with a metal carbonate or bicarbonate, it produces a salt, carbon dioxide and water. The general reaction is:

metal carbonate + acid →
salt + carbon dioxide + water

For example, citric acid ($C_6H_8O_7$) reacts with sodium bicarbonate ($NaHCO_3$) to produce carbon dioxide. This reaction is used in sherbet and causes the fizzy sensation in your mouth when you eat it.

Acidic oceans and coral carbonates

Rising carbon dioxide levels in the Earth's atmosphere have caused the oceans to become acidic. Our oceans are a major carbon 'sink', absorbing much of the carbon dioxide (CO_2) in the atmosphere. Since the Industrial Revolution (beginning in the eighteenth century), people have been burning fossil fuels in large amounts (e.g. for electricity production, manufacturing and transportation), which has increased the level of carbon dioxide in the atmosphere by 47 per cent. This extra carbon dioxide has been dissolving into the ocean and forming carbonic acid, making it more difficult for coral reefs to survive.

EXPERIMENT

6.3A: Neutralisation reactions
Go to page **194**.

CHALLENGE

6.3B: Making sherbet
Go to page **194**.

Coral reef ecosystems are a bit like rainforests: they are home to a huge diversity of species. Coral reefs also help protect coastlines from erosion. But coral reefs around the world are now struggling. One problem is that the coral itself is built from a base called calcium carbonate ($CaCO_3$), which is most stable when the water is pH 8.0 to 8.5. When fossil fuels are burned, carbon dioxide is released into the atmosphere, and some then dissolves in the ocean and causes the ocean's pH to decrease very slightly. This affects the ability of molluscs (such as sea snails) and crustaceans (such as lobsters), to produce protective shells, which are also made of calcium carbonate. A lower pH of ocean water also affects many species of marine organisms that reproduce by ejecting sperm and eggs. If the number of successfully fertilised eggs decreases and some of these species die out, this will affect the entire food chain and therefore the diversity of species that can survive. The Bering Sea near Alaska has the lowest pH of any ocean in the world: pH 7.7.

Figure 2 Coral reefs are made of the weak base calcium carbonate, which dissolves in acid.

Figure 3 Species that live in coral reefs are affected by the acidity of the ocean currents.

6.3 Check your learning

Remember and understand

1 **Identify** the two products of a neutralisation reaction between an acid and a base.

2 **Identify** the gas that is produced when an acid and a carbonate react.

3 **Explain** the major cause of the increasing acidity of the oceans.

Apply and analyse

4 **Identify** how the pH of the ocean changes as the amount of carbonic acid increases.

5 **Identify** the chemical word equations for two of the reactions you have investigated.

Evaluate and create

6 **Explain** how the acidity of the oceans would be affected if carbon dioxide levels in the atmosphere stopped increasing and became stable. **Justify** your answer (by describing how the current levels of carbon dioxide affect the oceans and describing the long-term consequences if carbon dioxide levels are maintained at this level).

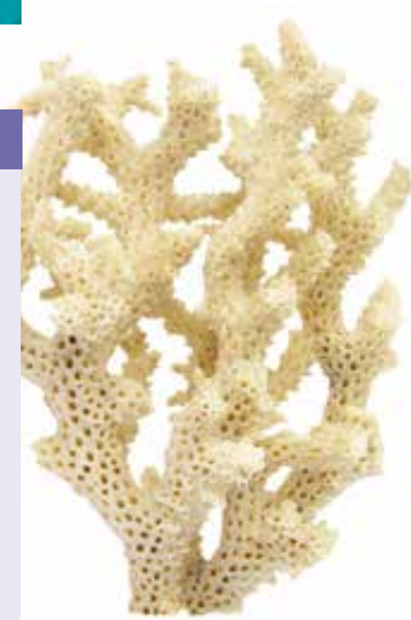

Figure 4 Bleached coral

6.4 Acids react with metals to produce hydrogen and a salt

In this topic, you will learn that:

- Acids can react with metals to produce hydrogen and a salt.
- Acid rain can affect metal objects, marble statues and limestone buildings.

Video 6.4A Acid rain

Video 6.4B Acid lakes

Chemical reactions are happening all the time. They affect living and non-living systems and involve all sorts of substances. Understanding these chemical reactions allows us to control some of them, start others, or use them to our advantage.

Acids reacting with metals

When an acid reacts with a metal, hydrogen gas is produced, as well as a salt. The general reaction is:

metal + acid → salt + hydrogen

Some metals, such as magnesium, react rapidly with acids. Magnesium reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas. The word equation is:

magnesium + hydrochloric acid →
magnesium chloride + hydrogen

Other metals, such as lead, need to be heated before they react with acids, such as hydrochloric acid.

Metal etching

The reaction between metals and acids is used in many industries. One example is the use decorative metal for jewellery, belt buckles or artwork. A design is drawn on the metalwork and a protective resin is applied to the area. When the remaining areas are exposed to a strong acid, a reaction occurs that causes the metal to become a salt. The protected areas do not react, allowing the design to appear.

Undesirable acid–base reactions

One problem caused by carbon dioxide and certain other gases in the atmosphere is acid rain.

As rainwater condenses from water vapour in the air and falls, it can dissolve carbon dioxide from the atmosphere. A product of this reaction is a weak acid, called carbonic acid (H_2CO_3). As a result, rainwater isn't pure water: it's a dilute weak acid with a pH of 5 or 6.

Vehicles, factories and volcanoes all give off pollutants that enter the atmosphere. These pollutants include sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), which may also dissolve to produce much stronger acids such as sulfuric acid (H_2SO_4) and nitric acid (HNO_3) in rain. The result is acid rain. Acid rain can have a pH as low as 3. Acid rain damages many types of stone, plastic and metal. It also changes the pH of soil, which can kill the plants that live there.

Acid rain is corrosive to building materials, marble and limestone (Figure 1).

Figure 1 Acid rain damage on a limestone statue

EXPERIMENT

6.4: What if a metal was protected from an acid? Go to page **195**.

Figure 2 Acid rain damage on a roller door

Many buildings have metal components that are corroded by acid rain (Figure 2). Vulnerable metals include bronze, copper, nickel, zinc and certain types of steel. Scientists have determined that acid rain with a pH of 3.5 can also corrode mild steel, galvanised steel and some stainless steel. This interaction between a metal and its environment is called **corrosion**.

The stronger the acid, the more quickly it is able to cause damage to the metal (Figure 3).

One way to protect statues and bridges is to cover the exposed areas with a protective resin, such as the one used in metal etching. This acts as a barrier between the acid and the metal, preventing a reaction from occurring.

corrosion
the gradual destruction of materials by a chemical reaction with their environment

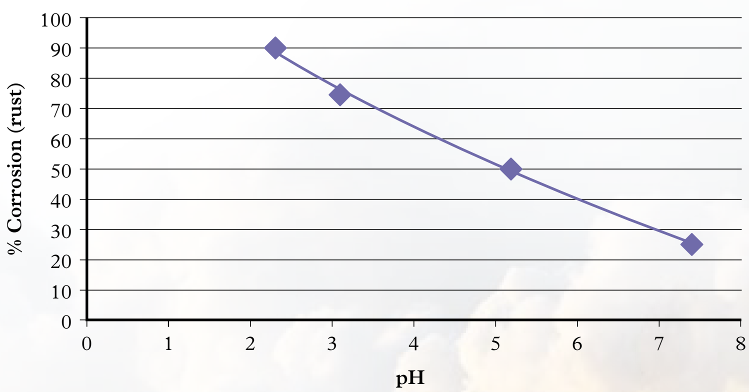

Figure 3 Corrosion at different pH levels, in the same time period

6.4 Check your learning

Remember and understand

1 **Identify** the products of the reaction between an acid and a metal.

2 **Identify** the equation for hydrochloric acid reacting with magnesium metal.

3 **Define** the term ‘corrosion’.

4 **Identify** the acid that is formed in water when levels of carbon dioxide in the air increase.

Apply and analyse

5 **Explain** why acid rain with a lower pH can cause more damage on a metal bridge than acid rain with a higher pH.

6 **Explain** how you could protect the metal numbers on the front fence of your house from corrosion.

Evaluate and create

7 Design an A4 poster that educates people about acid rain and how they can protect their property from its effects. Consider how you will communicate your points clearly to help people understand.

Figure 4 Industrial pollution contributes to acid rain.

6.5 Metals and non-metals react with oxygen

In this topic, you will learn that:

- When metals react with oxygen, metal oxides are produced.
- When non-metals react with oxygen, non-metal oxides are produced.
- Combustion (or burning) occurs when a fuel (containing carbon and hydrogen) reacts with oxygen to produce carbon dioxide, water and a large amount of heat very quickly.

Reactions involving oxygen

Oxygen is an element that is key to our survival. We rely on oxygen to provide us with energy through cellular respiration (see Chapter 2). Oxygen makes up 21 per cent of our atmosphere and it is a key component in many exothermic chemical reactions.

Metals reacting with oxygen

metal oxide
a molecule containing a metal and oxygen

When a metal element reacts with oxygen, a **metal oxide** is formed:

metal + oxygen → metal oxide

Some metals are more reactive than others. When these metals react with oxygen, they produce a lot of heat in an exothermic reaction. For example, if magnesium metal is briefly exposed to a flame or is heated, it will react with the oxygen in the air, producing a brilliant white light (Figure 1). Never watch this reaction directly, because the light can damage your eyes.

Figure 1 Burning magnesium produces a dangerously bright white light.

The word equation for this reaction is:

magnesium + oxygen → magnesium oxide

For less reactive metals, such as iron, the chemical reaction still produces heat, but it is slow. When an iron object is left out in air and moisture, the iron molecules in contact with the oxygen become oxidised and form iron oxide. This is the flaky, red-brown rust that forms on the surface of objects.

iron + oxygen → iron oxide

The problem with rust is that it is porous. Liquid water can penetrate through the rust to the metal below, as can oxygen. This allows the chemical reaction to continue and the metal oxide can continue to form, often unseen beneath the surface.

Figure 2 Oxidation of iron forms iron oxide, or rust.

Non-metals reacting with oxygen

Some non-metal elements react with oxygen, which is also a non-metal. The result is generally a molecular compound. Consider the following reactions:

hydrogen + oxygen → water
carbon + oxygen → carbon dioxide

EXPERIMENT

6.5: Combustion and candles
Go to page **196**.

Both reactions give out a lot of heat energy. The first reaction can cause explosions and the second is what happens when coal burns. The products of these reactions are described as **non-metal oxides**.

Combustion reactions

When you see something burn, you are witnessing a substance reacting with oxygen in a chemical reaction. The amount of energy released in this exothermic reaction can be huge. It is in the form of heat energy and light energy – which we see as a flame – and sometimes sound energy as well. The products of these reactions are always carbon dioxide and water.

What happens when fuels burn?

In science, a **fuel** is a substance that will undergo a chemical reaction in which a large amount of chemical energy is produced at a fast but controllable rate. It is an exothermic reaction. We use fuels such as the methane in natural gas to produce heat and/or electricity, and fossil fuels to run engines and motors.

When a fuel reacts in the presence of oxygen, it is called a **combustion reaction**. These reactions produce carbon dioxide and water.

Hydrocarbons are very common fuels that only contain the elements hydrogen and carbon. When hydrocarbons burn in unlimited air, carbon dioxide and water are produced. Petrol, diesel and LPG are all hydrocarbons.

hydrocarbon fuel + oxygen → carbon dioxide + water vapour + lots of energy

When the oxygen supply is more limited, for example when a candle burns in a poorly ventilated space, less heat energy is released and poisonous carbon monoxide gas is produced. Carbon monoxide can be deadly: it replaces the oxygen in our blood, which can kill.

hydrocarbon fuel + limited oxygen → carbon monoxide (poisonous) + water vapour + some energy

Figure 3 Burning coal produces carbon dioxide.

Figure 4 Oxygen is involved in combustion reactions.

non-metal oxide
the product of a reaction between a non-metal and oxygen

fuel
a substance that undergoes a chemical reaction producing large amounts of energy

combustion reaction
an exothermic reaction between a fuel and oxygen that produces heat, carbon dioxide and water

hydrocarbon
a molecule that contains only carbon and hydrogen atoms

6.5 Check your learning

Remember and understand

1 **Identify** the two elements that are in hydrocarbons.
2 **Identify** the products of a combustion reaction.
3 **Identify** the products of a combustion reaction where oxygen is limited.

Apply and analyse

4 **Explain** why the presence of rust suggests that a metal object is weakened.
5 **Explain** why we do not notice the heat produced when an iron object rusts.
6 When carbon dioxide reacts with water, the product is carbonic acid. Write a word equation for this reaction.
7 The fuels used in cars, trucks and buses are generally liquefied petroleum gas (LPG), petrol or diesel. These fuels are mainly hydrocarbons. **Explain** why scientists are warning that excessive use of these vehicles is contributing to the enhanced greenhouse effect.

Evaluate and create

8 Consider your response to question 7 and use the internet to identify one argument for and one argument against the use of petrol cars in Australia. **Evaluate** each argument (consider the reasoning and evidence behind them).

//SCIENCE AS A HUMAN ENDEAVOUR//

6.6 Fuels are essential to Australian society

The combustion of hydrocarbon fuels has become an essential part of Australian society. However, our reliance on fuels has consequences. Increasingly, scientists are developing technology to improve the efficiency of combustion and reduce its effect on our environment.

How do we use fuels?

Fuels are the substances we use to produce heat and/or electricity, and to run engines and motors. When choosing a fuel for a particular use, cost, safety and efficiency are considered. Fuels can also be chosen according to the amount of pollution they release compared to the amount of energy they can produce.

In most applications, the reactions used are combustion reactions. Power stations, generators, engines and motors are designed so that the combustion of fuels is controlled. Examples of fuels we typically use in vehicles, aircraft and generators are petrol, diesel and kerosene.

If you have a gas stove and a gas hot water service, then the fuel you are using is natural gas, which is mainly methane. Coal and natural gas are fuels that are mainly used in power stations. Australia has huge supplies of brown coal and a good supply of natural gas.

Figure 1 Coal is used as a fuel in Australia.

ETHANOL AS A BIOFUEL

In Australia, drivers can purchase a fuel called E10, which contains up to 10 per cent ethanol. Ethanol is a type of alcohol that contains carbon, hydrogen and oxygen, and has the formula C_2H_5OH. The formula is written in this way to show how the atoms are bonded. Look at Figure 2 and see if you can work out the system used for writing the formula. In this diagram, the atoms are represented by the chemical symbols, and the lines represent chemical bonds.

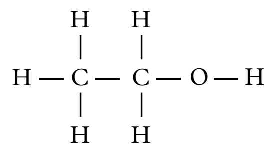

Figure 2 The chemical structure of ethanol. The letters represent the elements carbon, hydrogen and oxygen. The lines represent bonds between the atoms, keeping them together as one molecule.

Ethanol blends are being increasingly used for road vehicles in many countries.

Why are these alcohols suitable for use in this way? One reason is that ethanol mixes well with petrol and burns well in engines. The equation for the combustion of ethanol is:

ethanol + oxygen → carbon dioxide + water + energy

Another reason is that ethanol burns more 'cleanly' than petrol because ethanol contains an oxygen atom. By 'bringing' its own oxygen, ethanol ensures oxygen is always in plentiful supply.

Ethanol is seen as a more sustainable fuel, because it can be produced by fermenting plant material, such as corn, sugar beet or even wheat stubble. Mixing ethanol into petrol (to make E10 fuel) will help decrease the rate at which we consume the hydrocarbon oils obtained from crude oil, which is a non-renewable resource.

Petrol is called a fossil fuel because it is made from crude oil, which is produced when dead plants and animals are compressed underground without oxygen for millions of years. Alcohols such as ethanol are biofuels because they come from plant material that has been grown recently. While biofuels are renewable, which is a good thing, they also compete with food crops for land and water, which pushes up the price of food and worsens hunger in very poor parts of the world.

DISADVANTAGES OF BIOFUELS

A 2016 report by Oxfam suggests that making use of biofuels compulsory could not only cause more problems for the environment, but it could also increase poverty.

The biggest difficulty is that land is needed to produce the biofuels crops. This would result in further clearing of natural forests, but these forests help remove carbon dioxide from the atmosphere. Although the growth of biofuel crops will temporarily absorb carbon dioxide as the plants grow, their combustion will ultimately release the carbon dioxide back into the atmosphere.

Also, the use of agricultural land to grow biofuel crops will prevent the use of that land for food production. This will limit food production and drive up the cost of food, contributing to food insecurity, hunger and inflation, which will hit poor people hardest.

Figure 3 Large areas of Amazonian rainforest are being cleared to grow soybeans for biofuel.

Figure 4 Sugar cane can be fermented to produce biofuel.

6.6 Develop your abilities

Evaluating ethics

The study of ethics can be approached in many ways. In an approach known as consequentialism, the outcome is used to judge whether an action is good or bad. An action that brings more advantages than disadvantages is considered good, while an outcome that produces more overall harm is considered bad.

1 **Describe** the different people affected by the production and use of biofuels.

2 **Describe** the advantages and disadvantages of producing and using biofuels for each of these people.

3 Use a consequentialism approach to **evaluate** the ethics of using biofuel in your family car (by deciding whether there is an overall benefit or harm to the majority of people or the planet).

A deontology approach to ethics uses a set of moral rules to decide whether a decision is good or bad. For example, a moral rule may be that clearing of rainforests is bad, or that increasing poverty is bad. The outcome of the decision is not considered as important as whether the decision is morally good or bad.

4 **Identify** two moral rules that could be considered good.

5 **Apply** these rules to the production of biodiesel.

REVIEW 6

Multiple choice questions

1 An endothermic reaction can be best explained as:
  A a reaction that releases energy
  B a reaction that absorbs energy
  C a slow reaction
  D a fast reaction.

2 Which of the following is an acid?
  A water
  B a substance with pH 1
  C a substance with pH 7
  D a substance with pH 14

3 The products of a combustion reaction are:
  A water vapour and a salt
  B water vapour, salt and carbon dioxide
  C water vapour and carbon dioxide
  D water vapour and a metal salt.

Short answer questions

Remember and understand

4 **Describe** the characteristics of an acid.

5 **Identify** two acids and two bases.

6 **Identify** each of the following statements as either true or false.
  a Reactants are the substances made in chemical reactions.
  b All neutralising reactions produce CO_2.
  c Bushfires are endothermic reactions.
  d Sour lollies contain a base.
  e Sulfur dioxide will dissolve in water to form an alkali.

7 Write a word equation for the reaction between citric acid and sodium bicarbonate.

8 Write a word equation for the reaction between citric acid and sodium metal.

9 Many lollies are deliberately made sour. **Describe** whether a weak acid or a weak base would be added to the lollies in order to achieve this taste.

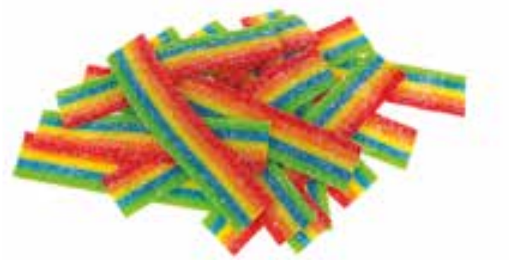

Figure 1 What makes these lollies sour?

10 In an exothermic reaction, the products contain less stored energy than the reactants. **Describe** what has happened to the remaining energy during the reaction.

11 **Define** the term 'corrosion'.

12 **Identify** the name and the formula of two gases that contribute to the formation of acid rain.

13 **Describe** how a metal gate could be protected from corrosion.

Figure 2 Metal can corrode quickly in coastal areas.

14 **Identify** the number of atoms of carbon, hydrogen and oxygen in a molecule of ethanol (CH_3CH_2OH).

15 **Identify** the products when methane burns in an excess supply of oxygen.

16 **Define** the term 'biofuel'.

Figure 3 Biofuels can be used to power cars.

Apply and analyse

17 Consider the following equation:

potassium hydroxide + sulfuric acid →
potassium sulfate + water

  a **Identify** the reactants and the products in this reaction.
  b **Identify** the type of reaction.
  c **Describe** what you could add to the reaction mixture to show that all the acid has been used up in the reaction.

18 Two clear chemicals have lost their labels. You know that one is an acid and the other is a base. **Explain** how you could correctly identify each chemical.

19 **Consider** two changes that occur as the following chemicals interact with each other:

a iron filings in vinegar

b carbon dioxide dissolves in water (containing universal indicator) to form a solution of carbonic acid (H_2CO_3).

For each of the situations above, **describe** the reaction in terms of:

i the expected observations

ii a word equation.

Evaluate

20 **Identify** the process that occurs in instant cold packs as a chemical or physical change. **Justify** your answer (by comparing chemical and physical changes, describing the changes that occur in an instant cold pack, and deciding whether the cold pack change matches the chemical or physical change).

Figure 4 Do instant cold packs undergo chemical or physical change?

21 A student told another student that they should never drink orange juice, because it contains acid. **Evaluate** this claim (by defining the term 'acid', identifying whether any of the components in orange juice is an acid, and deciding whether the student is correct).

22 Maia was asked to give an example of an endothermic reaction. She said that a candle burning was an endothermic reaction, because she had to use heat energy from a burning match to light the candle. **Evaluate** this claim.

23 **Create** a poster on the effects of increased CO_2 levels in the environment. Include any relevant diagrams or images.

Social and ethical thinking

24 The UK government has pledged to ban the sale of new petrol and diesel cars by 2030, as have many other countries in Europe. Use a consequentialism approach to **discuss** the ethics of banning the sale of petrol and diesel vehicles in Australia by the year 2030.

Critical thinking

25 Carry out a PNI ('positive', 'negative', 'interesting') analysis on the effect of acids on our lives.

26 Imagine all the chemical interactions and changes that occur during the baking of a loaf of bread in an oven fuelled by LPG gas. **Describe**, in less than 100 words, the chemical changes that occur in this process. Include the exothermic processes that produce the heat for the oven and the endothermic processes within the food itself.

Research

27 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

» Phosphoric acid

Phosphoric acid has a wide variety of uses, including fertiliser, rust remover and food additive. It is even an ingredient of cola drinks. **Describe** how it is produced and more about its uses.

Figure 5 Phosphoric acid is used to produce many products, such as this fertiliser.

» pH of blood

If the pH of our blood is too low or too high, we can become seriously ill. Identify the name given to the medical conditions in which the pH of blood becomes too low or too high, and describe the effects of these conditions.

» Explosives

The history of the development of explosives is fascinating. Identify the person who discovered them. Describe when explosives were first used and how they work. Identify the main chemicals used and the different types of these chemicals. Explain the part Alfred Nobel played in the development of explosives.

» Carbon footprints

Describe what is meant by the phrase 'carbon footprint'. Identify the chemical reactions that contribute to an increase in carbon dioxide in the atmosphere. Identify the other gases that contribute to the enhanced greenhouse effect. Describe how carbon footprints are measured. Describe what is meant by the phrase 'carbon offset'.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 6 'Chemical reactions'. Once you've completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Define and describe exothermic and endothermic reactions in terms of energy released or absorbed. Provide examples of exothermic and endothermic reactions. Explain that the energy stored in chemical bonds can be released when bonds break.	☐	☐ Go back to Topic 6.1 'Endothermic reactions absorb energy and exothermic reactions release energy' Page 118
Define alkalis, alkaline, indicator, litmus paper, universal indicator, pH scale and neutral. Provide examples of acids and bases. Explain the structure of the pH scale (7 is neutral, <7 is acidic, >7 is basic).	☐	☐ Go back to Topic 6.2 'Acids have a low pH. Bases have a high pH' Page 120
Describe key characteristics of neutralisation, acid–metal carbonate and bicarbonate reactions. Explain how the oceans are becoming more acidic.	☐	☐ Go back to Topic 6.3 'Acids can neutralise bases' Page 122
Define corrosion. Explain the characteristics of the reaction between an acid and a metal. Describe the processes in corrosion of metal.	☐	☐ Go back to Topic 6.4 'Acids react with metals to produce hydrogen and a salt' Page 124
Describe the key characteristics of a metal or non-metal reacting with oxygen and a combustion reaction. Relate combustion reactions to exothermic reactions.	☐	☐ Go back to Topic 6.5 'Metals and non-metals react with oxygen' Page 126
Describe the differences between hydrocarbons and alcohols in terms of their chemical composition. Provide examples of fuels used in Australia.	☐	☐ Go back to Topic 6.6 'Science as a human endeavour: Fuels are essential to Australian society' Page 128

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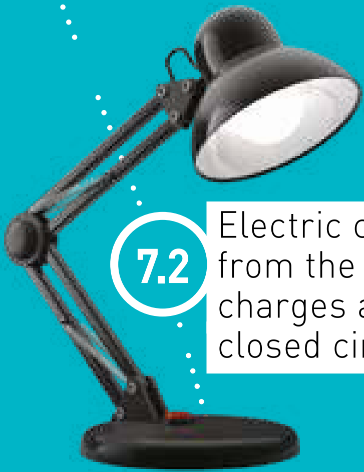
CHAPTER 7

ELECTRICITY

How does electricity light a lamp?

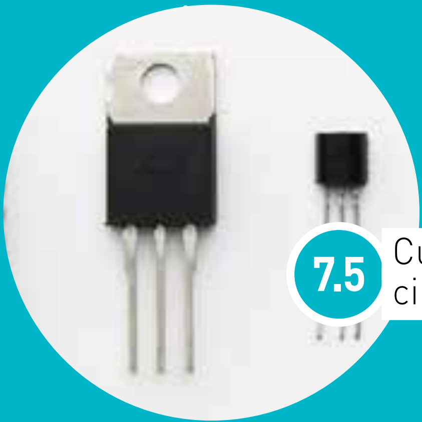
7.1 Electricity is the presence and flow of electric charges



7.2 Electric current results from the movement of charges around a closed circuit

7.3 Current can flow through series and parallel circuits

7.4 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit



7.5 Current and resistance in a circuit can be altered

What if?

Water magic

What you need:

Wool cloth, plastic rod, puffed rice

What to do:

1 Rub the plastic rod with the wool and then place it near the puffed rice.

What if?

» What if you placed the rod near a thin stream of water from a tap?

» What if you placed the rod near small pieces of paper?

7.1 Electricity is the presence and flow of electric charges

In this topic, you will learn that:

- Electrostatic charges occur when electrical charges are unable to move.
- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- A conductor allows the charges to flow easily.
- An insulator restricts the movement of the charges.

'Electricity' is a general term related to the presence and flow of charged particles. An electric charge can be either positive or negative. It is produced by subatomic particles (parts of atoms) such as electrons, which carry a negative charge, or protons, which carry a positive charge.

Electrostatic charge

Objects are normally uncharged – their atoms usually have equal numbers of protons and electrons. But when two objects are rubbed together, some of the electrons may be transferred from one object to the other. This causes the object with fewer electrons to become positively charged and the one with extra electrons to become negatively charged. You can also see this with friction – for example, if you rub a balloon against a woollen jumper, take off synthetic clothing or walk across synthetic carpet. In all these cases, the positive or negative electric charge stays on the charged object without moving. This is called an **electrostatic charge**. When the charges on an object are the same (both positive or both negative), then they are described as 'like charges'. If the charges are different (one positive and one negative), then they are described as 'unlike charges'.

Important rules to learn about electrostatics:

> Like charges repel.
> Unlike charges attract.
> Charged objects attract neutral objects.

When charged objects are close to each other, the small negative electrons are attracted to the positively charged object (unlike charges attract). If these two objects are brought close enough, the electrons will try to jump across the gap as a spark. This is what happens when the air particles in a cloud rub against each other and become charged. If the charges build up enough, a large spark (lightning) will move between the charges in the clouds or towards the neutral ground (charged particles and neutral objects are attracted to each other).

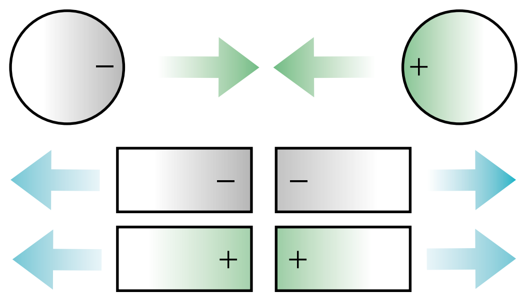


Figure 1 Like charges repel, unlike charges attract.

The **van de Graaff generator** is a machine that produces an electrostatic charge by rubbing a belt (Figure 2). It is used to accelerate particles in X-ray machines, food sterilisers and process machines, and in nuclear physics demonstrations.

Electrical energy and circuits

When electric charges become separated, they have **electrical energy**. This means they are in a state of excitement, and the positive and negative charges try to get back together again. If a closed circuit is provided, the electrons will move along the wire to the positive charges and, as they do so, the electrical energy may transform into some other forms of energy, such as light or thermal energy.

However, it is difficult to continually rub things together to separate charges and give them electrical energy. A **dry cell** (e.g. a torch battery) or a **wet cell** (e.g. a car battery) uses a chemical reaction to continually separate charges and produce current electricity through wires.

van de Graaff generator
a machine that produces an electrostatic charge

electrostatic charge
an electrical charge that is trapped in an object such as a balloon

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

dry cell
an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

CHALLENGE
7.1A: Demonstrating electrostatics
Go to page **196**.

CHALLENGE
7.1B: Separating charges with a van de Graaff generator
Go to page **197**.

Figure 2 In a van de Graaff generator, electrostatic charge is produced when a belt rubs between rollers. This spreads the charge over the metal dome, which is then transferred to the person touching it. The person's hair follicles become charged, making them repel each other. This makes the hair stand up.

A closed conducting pathway is called an **electric circuit**. As electrically charged particles move around an electric circuit, they carry energy from the energy source (such as a battery) to the device that transforms the energy (such as a light globe, motor or heater). An example of the movement of electrical energy in a simple circuit is shown in Figure 3.

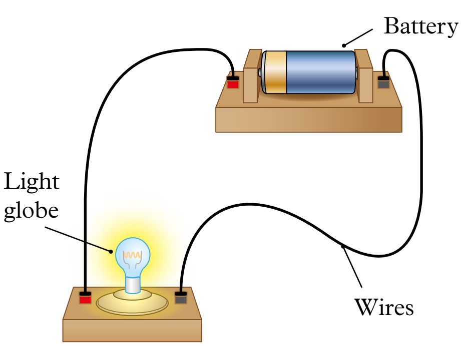


Figure 3 A simple circuit: electric charges move from the battery through the wires to the light globe.

Electrical conductors and insulators

An **electrical conductor** is a material through which charged particles are able to move. An **electrical insulator** is a material that does not allow the movement of charged particles. Most wires are made of copper (a metal) with a plastic coating around the outside. Copper is an electrical conductor – electrons are able to move through it easily. However, plastic is an electrical insulator. The wire is coated in plastic to prevent the charge being 'lost' to the surroundings as it passes through the wire.

Some substances are better **insulators** or better conductors than others. It depends on how easily the substance allows electrons to move through it – that is, it offers less or more resistance to the movement of charges. Air is a good resistor, as it is difficult for charged particles to move freely through it.

Some substances, such as germanium and silicon, are insulators in their pure form but become conductors if they are combined with a small amount of another substance. These materials are called **semiconductors**.

Within a single silicon chip, very thin layers of silicon can be combined with other substances to make that layer a conductor. Complex microcircuits used in computing are made in this way.

electrical conductor
a material through which charged particles are able to move

electrical insulator
a material that does not allow the movement of charged particles

insulator
a substance that prevents the movement of thermal or electrical energy

semiconductor
a material that conducts electricity more than an insulator and less than a conductor; its conductivity can be changed by adding other substances to it

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

7.1 Check your learning

Remember and understand

1 **Identify** the charge on the following particles:
  a protons
  b electrons.
2 **Describe** how objects can become electrostatically charged.
3 **Describe** an electric circuit.
4 **Identify** the three parts of the electrical circuit shown in Figure 3.
5 **Explain** the purpose of a battery in a circuit.

Apply and analyse

6 **Contrast** a conductor and an insulator.
7 **Describe** how a semiconductor works.
8 If living organisms are good conductors and air is a good resistor, **explain** why it is important not to stand outside in open land during a lightning storm.

7.2 Electric current results from the movement of charges around a closed circuit

In this topic, you will learn that:

- An electric circuit contains an energy source (a battery), a pathway (usually wires) and a load.
- Current can be unidirectional (direct current or DC) or constantly reversing direction (alternating current or AC).
- Current (measured in amperes) is a measure of the number of electrons that pass a point each second.
- The pathway of the charges can be represented by a circuit diagram.

Interactive 7.2
Symbols used in circuit diagrams

Video 7.2A
Building a circuit

Video 7.2B
Using an ammeter and voltmeter

Figure 1 A switch in an electrical device such as this lamp creates a 'gap' in the electric circuit to stop the flow of electricity.

electric current
the flow of electrical charge through a circuit

circuit diagram
a diagrammatic way to represent an electric circuit

positive terminal
the point in the circuit where electrons flow into

negative terminal
the point in the circuit where electrons flow out from

Electric circuits

The pathway travelled by electrical energy is called an electric circuit. Electric circuits must have an energy source, wires to carry the charges, and a 'load', which is any device that converts the electrical energy into heat, light or kinetic energy. Many devices have 'gaps' called switches to control the flow of electricity in a circuit.

Moving charges

An **electric current** results from the movement of negatively charged electrons in an electric circuit. The electrons move, or are conducted, from the negative terminal of the energy source to the positive terminal. For historical reasons, the direction of the current is given as the flow of positive charge from the positive terminal of the energy source to the negative terminal. This imaginary flow of positive charge is referred to as a conventional current (Figure 2). There are two types of current used in electrical circuits. In an alternating current (AC), the flow of electrons reverses direction 50 times every second, in Australia. This type of current is used in electrical power points. In direct current (DC), the electrons flow in one direction only. This current is found in battery-powered circuits.

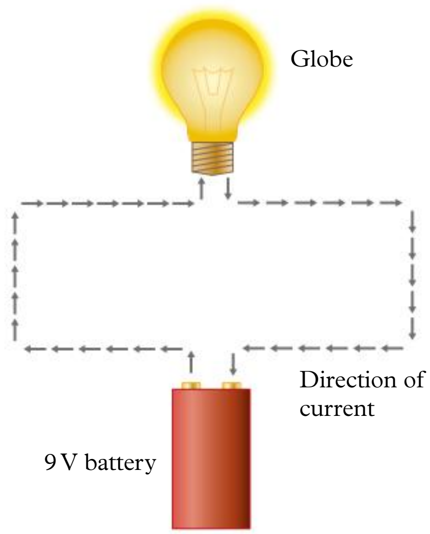


Figure 2 Conventional current in an electric circuit

Circuit diagrams

Circuits are represented by **circuit diagrams**. Each component of a circuit is represented by a symbol (Figure 3). The circuit illustrated in Figure 4a includes a globe, a battery, connecting wires, a switch and a meter, such as an ammeter, to measure the electric current. This circuit is represented in a circuit diagram in Figure 4b. Connecting wires are usually shown as straight lines, and when they meet at junctions they are often (but not always) shown joined at right angles. The longer line on the battery represents the **positive terminal** and the shorter line represents the **negative**

CHALLENGE
7.2A: Making a simple torch circuit
Go to page **197**.

CHALLENGE
7.2B: Connecting circuits
Go to page **198**.

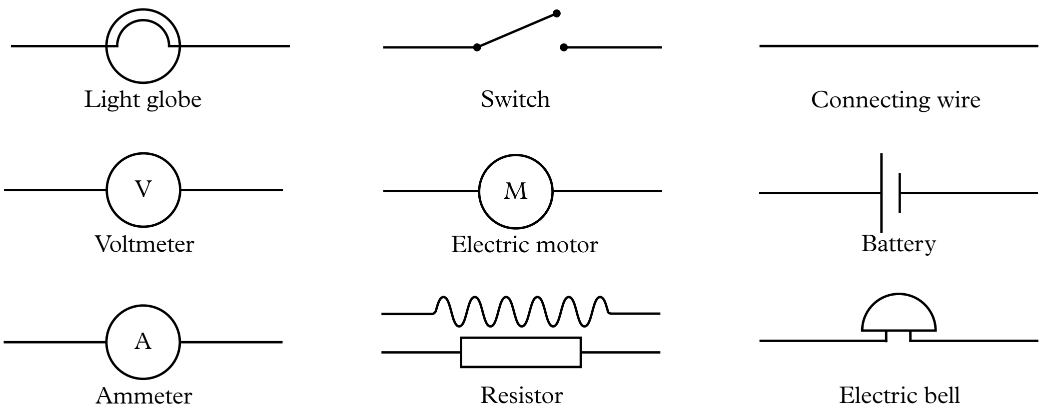


Figure 3 Some symbols used in circuit diagrams

terminal. These terminals are where the wires are connected. When drawing a circuit diagram, you should use a ruler and a pencil. All lines should be connected, to indicate that there are no breaks in the circuit. A break in the circuit means the current is not flowing.

Measuring electric current

Electric current, or the flow of charge, is measured by counting the number of electrons that go past a point in the circuit in 1 second. The unit of measurement for current is amperes (symbol A). An ampere is a large unit of current, so smaller units such as the milliampere (1000 mA = 1 A) are often used. Traditionally an ammeter (Figure 5a) was used to measure the current passing a particular point in an electric circuit. The ammeter must be connected into the circuit so that the current flows through it. More recently, a multimeter (Figure 5b) is used to measure many different aspects of a circuit, including the current.

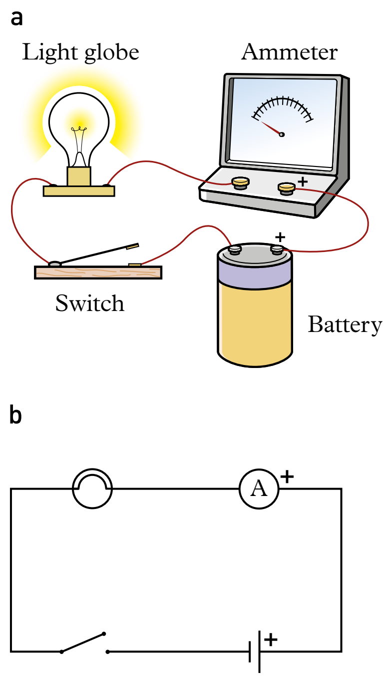


Figure 4 a A simple circuit **b** A circuit diagram of the simple circuit

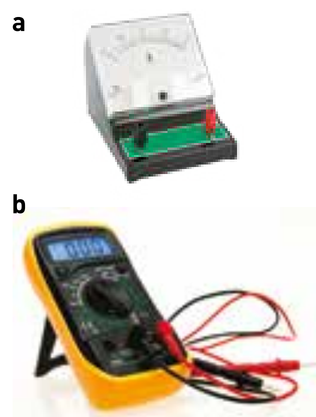


Figure 5 a An ammeter or **b** a multimeter is used to measure electric current.

7.2 Check your learning

Remember and understand

1 **Identify** and **describe** the role of each of the main parts of a circuit.

2 **Identify** the subatomic particle that moves in an electric circuit.

3 **Describe** how you could stop the charged particles flowing in a circuit.

4 **Contrast** AC and DC.

5 **Identify** the direction of:

  a conventional current

  b electrons in a circuit.

6 **Describe** how an ammeter or multimeter must be connected, to measure the current in a circuit.

Apply and analyse

7 **Identify** which of the globes in Figure 6 will transform electrical energy into light energy.

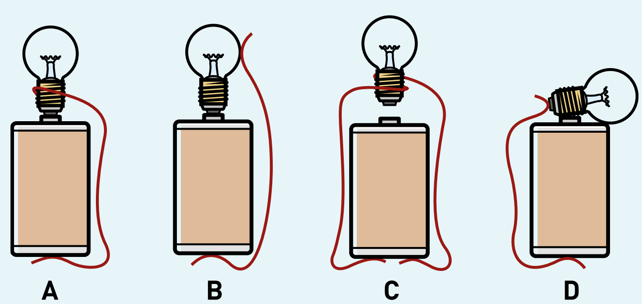


Figure 6 Which globe will work?

7.3 Current can flow through series and parallel circuits

In this topic, you will learn that:

- In a series circuit, the loads are connected one after the other, and the current is the same throughout the circuit.
- In a parallel circuit, the loads are parallel to each other, and the current is shared between them.
- A short circuit occurs when the electrical energy can move through an easier path with less resistance.

parallel
a way of connecting loads (e.g. lights) in an electric circuit so they are all connected to the battery separately; they are in parallel to each other

Types of circuit

When two or more globes are connected in a circuit, two different types of connection are possible. In a series circuit, the globes are connected one after the other so that the current goes through one globe and then through the next (Figure 1a). In a parallel circuit, the circuit has two or more branches and the current splits between the branches (Figure 1b) and comes back together afterwards.

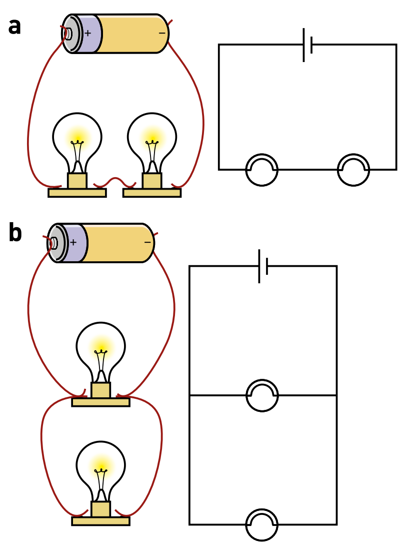


Figure 1 a In a series circuit, the current is the same everywhere in the circuit. **b** In a parallel circuit, the sum of the current going through globe A and globe B is equal to the total current from the battery.

Comparing series and parallel circuits

series
describes an electric circuit that is arranged with the loads (e.g. lights) connected in a row, so the electrical energy passes through one load at a time

If two globes are connected in a circuit in **series**, then all the current (the electrons) passes through both globes. This means the current is always the same at all points in a series circuit.

However, if two globes are connected in **parallel**, the current splits. This means when the electrons reach the point where the wire splits, they will travel along one path or the other. Part of the current passes through each globe, and the currents join together again after passing through the globes. This means the currents going through each globe must be added together to determine the total amount of current coming from the battery.

In a series circuit, a break at any point in the circuit (e.g. from a switch) affects all the globes in the circuit. In a parallel circuit, a break in one of the branches of the circuit affects only the current (and globe) in that branch.

In a household, lights and appliances are connected in parallel, so that:

> some appliances can be on while others are off (achieved by inserting switches)

> if one appliance fails, the others will still work.

Figure 2 Traditionally, party lights were a series circuit. This meant that when one light broke, all the lights went out. Now, most modern party lights are arranged in a parallel circuit.

CHALLENGE

7.3A: Making series and parallel circuits
Go to page 198.

CHALLENGE

7.3B: Short-circuiting an electric current
Go to page 199.

Batteries in series and in parallel

Batteries may be connected in series or in parallel, in a similar way to globes. When batteries are connected in series, each electron picks up a certain amount of energy as it passes through the first battery and then an additional amount as it passes through the second battery. This arrangement allows electrons to be given larger amounts of energy. For instance, a simple torch normally has two 1.5 V batteries connected in series. As each electron passes through both batteries, it collects a total of 3.0 units of energy to light the torch globe.

When batteries are connected in parallel, each electron passes through either one battery or the other. So each electron collects the same amount of energy as it would from one battery on its own. The advantage of this arrangement is that the two batteries last longer than either one of them would in the same circuit on their own. Worked example 7.3 shows how to calculate currents.

Worked example 7.3: Calculating currents

If the current leaving a battery is 6 A, calculate the current travelling through two identical lamps if they are connected (a) in series, or (b) in parallel.

Solution

(a) If the lamps are connected in series, all the electrons flow through each lamp. Therefore, the current in each lamp is 6 A.

(b) If the lamps are connected in parallel, the electrons are divided between the wires. This means the current is divided equally between the lamps.

6 A ÷ 2 lamps = 3 A in each lamp

Figure 3 A sudden increase in current will cause a fuse or safety switch to break the circuit. This stops the current from flowing and may prevent electrocution.

Short circuit

A **short circuit** occurs when a current (moving electrons) flows along a different path from the one intended. This can be caused by damage to the insulation that usually surrounds the wires or by another shorter conductor, such as water, providing an easy path for the electrons. Electric charges will always take the path of least resistance. This means that large currents can flow through any short path or conductor that allows the electrons to move most easily. Short circuits are dangerous because they can also lead to wires heating up from the fast flow of electrons, causing damage or even fire.

Fuse

A **fuse** is a switch or thin piece of wire that burns up quickly when electrons flow too fast in a circuit. This causes a break in the circuit so the electrical energy stops flowing. This is a safety mechanism to prevent damage to appliances from the high current, and to prevent loss of life.

short circuit
when electrical current flows along a different path from the one that was intended

fuse
a wire of high resistance; it will melt if too much current flows in the circuit

7.3 Check your learning

Remember and understand

1 **Contrast** the movement of current in a series circuit and a parallel circuit.

2 Look at the party lights in Figure 2.
 a **Describe** how you could determine whether the globes are connected in series or parallel.
 b Draw a circuit diagram showing the possible connection of some of the globes.

3 **Describe** the advantage of having a safety switch or fuse in the electric circuits of your house

Apply and analyse

4 Three lamps were connected in series to a battery that produced a 12 A current. **Calculate** the current flowing in each lamp.

5 **Describe** how the household appliances are connected in your house (in series or in parallel). **Justify** your answer (by explaining how series and parallel circuits behave and providing an example that matches your explanation).

6 Double adaptors and power boards enable you to connect additional appliances to a power point. **Explain** whether the double adaptors or power boards are more likely to be series or parallel connections. **Justify** your answer.

Evaluate and create

7 An electrician wanted to connect four identical lamps to a 6 A source so that two lamps had a current of 6 A and the other two lamps had a current of 3 A each. Draw a circuit diagram to show a possible arrangement of the lamps the electrician could use.

7.4 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit

In this topic, you will learn that:

- Voltage is a measure of the difference in electrical potential energy carried by charged particles at different points in a circuit.
- Voltage can be measured using a voltmeter or multimeter in parallel to the circuit.
- Resistance is a measure of how difficult it is for current to flow through part of the circuit.

Voltage

Each charged particle has energy as it moves in an electric circuit. This potential energy can be transformed into sound as it moves through a speaker, or into light and heat if it moves through a globe. This means the charged particle (electron) has different amounts of energy before and after the speaker or globe. This difference in energy is called potential difference or **voltage**.

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

Voltage is measured by a voltmeter or a multimeter in the unit volts (symbol V). To measure the potential difference in a circuit, voltmeters are set in parallel across the two points in the circuit that you want to measure (Figure 2).

Figure 1 Each unit of charge in this battery has 1.5 joules of energy.

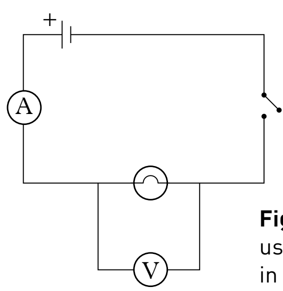


Figure 2 A voltmeter is used to measure voltage in a circuit.

Batteries add energy to the charged particles. The amount of energy added by the battery can be determined by connecting a voltmeter in parallel to the battery. In a 1.5 V battery, each unit of charge (electron) receives 1.5 joules (symbol J) of energy as it passes through the battery.

In a series circuit, the potential energy contained by each electron must be divided between the different loads. This means a 12 V battery connected to two identical globes in series may transfer 6 V of energy to each globe. If the two globes are connected in parallel, each electron moving in a globe is able to transform all the 12 V into light and heat. Worked example 7.4A shows how to calculate voltage.

Worked example 7.4A: Calculating voltage

If a 6 V battery is connected to two lamps, calculate the voltage that can be transformed in each lamp if they are connected (a) in series, or (b) in parallel.

Solution

(a) If the lamps are connected in series, the electrons must divide the voltage (potential energy) between the lamps. Therefore, the voltage transformed in each lamp will be 3 V.

$$6 \text{ V} \div 2 \text{ lamps} = 3 \text{ V in each lamp}$$

(b) If the lamps are connected in parallel, the electrons will separate at the fork in the wires and carry all the energy to each lamp. This means the voltage (potential difference) transformed will be 6 V in each lamp.

SKILLS LAB
7.4A: Using Ohm's law to find resistance
Go to page **199**.

SKILLS LAB
7.4B: Understanding resistor colour codes
Go to page **200**.

EXPERIMENT
7.4C: Investigating Ohm's law
Go to page **201**.

Resistance

The amount of current flowing in a circuit is determined by the **resistance** of the circuit. The electrical resistance of a material is a measure of how difficult it is for charged particles to move through. Electrons collide with the atoms in the wires and the various other components of a circuit, and some of their electrical energy is converted or transformed into heat. Most connecting wires are thick and made of good conductors. This means they have very low resistance, so hardly any energy is lost by the electrons. However, the wires in a toaster are designed so that a lot of the electrons' energy is transformed into heat – so much that the wires glow red-hot and brown the toast.

Resistors are devices that are deliberately placed in circuits to control or reduce the size of the current. Resistance is measured by a multimeter in units called ohms (symbol Ω). Worked example 7.4B shows how to calculate resistance.

A potentiometer is another type of variable resistor with a dial that rotates. A light dimmer is a potentiometer, as is the temperature control on an oven.

Figure 3 Many types of resistor are available. The resistance of carbon resistors is indicated by the coloured bands on their plastic case.

Ohm's law

Georg Ohm, a German physicist, discovered the relationship between voltage, current and resistance. Ohm found that the voltage drop across a fixed-value resistor is always directly proportional to the current through the resistor. This means that as the voltage goes down, the current will also go down. This relationship is known as Ohm's law and is written as:

$$V = IR$$

resistance
a measure of how difficult it is for the charged particles in an electric circuit to move

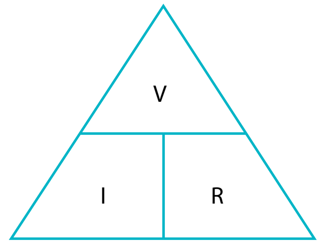


Figure 4 The Ohm's law triangle can be used to remember the equations for Ohm's law. To find resistance, cover the *R* – the other two letters show you the formula to use. The *V* is over the *I*, so $R = \frac{V}{I}$.

Worked example 7.4B: Calculating resistance

If a 9 V battery produces 6 A of current, calculate the resistance of the circuit.

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

Solution

If V = 9 volts, and I = 6 amperes, then

$$R = \frac{9 \text{ volts}}{6 \text{ amperes}} = 1.5 \text{ ohms}$$

Therefore, the resistance in the circuit is 1.5 ohms.

7.4 Check your learning

Remember and understand

1 **Define** the term 'voltage'.
2 **Describe** the voltage across two lamps when they are connected:
   a in series
   b in parallel.

Apply and analyse

3 **Identify** the three equations that can be obtained by rearranging the Ohm's law triangle.
4 **Calculate** the current flowing through a 44 Ω resistor when it has a voltage drop of 11 V across it.
5 **Calculate** the change in voltage across a 25 Ω resistor when a current of 50 mA (0.05 A) flows through it.
6 **Calculate** the value of a resistor that has a voltage drop of 8 V across it when a current of 0.4 A flows through it.
7 Use Table 1 on page 200 to find the value of a resistor that has three coloured bands of:
   a red, white, black
   b yellow, green, red
   c brown, blue, orange.

7.5 Current and resistance in a circuit can be altered

In this topic, you will learn that:

- Diodes allow current to flow in one direction only.
- Rectifiers are a type of diode that convert alternating current to direct current.
- LEDs are diodes that emit light.
- Photoresistors alter their ability to conduct electricity according to the amount of light they are exposed to.
- Some thermistors reduce their resistance as they are heated.

Figure 1 Diodes come in all shapes and sizes, depending on their role in the circuit.

rectifier
a device that coverts AC to DC, commonly composed of diodes

light-emitting diode (LED)
a type of diode that emits light of a particular colour

Diodes

Many materials can alter their ability to conduct electricity. A diode is a semiconductor device that allows current to flow in one direction only. Most diodes are made of specially treated silicon. The symbol for a diode in a circuit diagram is shown in Figure 2. You can think of the triangle as an arrow that shows the direction that the diode allows the conventional current (from positive to negative) to flow.

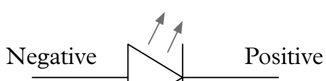


Figure 2 Think of the triangle as an arrow that shows the direction that the diode allows the conventional current (from positive to negative) to flow.

When the diode is connected correctly, and the voltage is above the minimum threshold, current will flow through the circuit. If the diode is reversed, the current will try to travel in the opposite direction, but the diode will resist the current (Figure 3). This will stop the flow of all charges in the circuit.

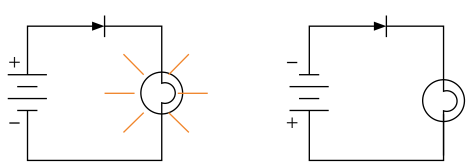


Figure 3 The diode allows current to flow in one direction only.

Some diodes can only carry small currents, of much less than 1 A. Bigger currents produce too much heat, which would destroy the diode. Most diodes are connected in series with a resistor so that the current is below the maximum allowed by the diode.

Silicon diodes are useful for converting AC to DC. Such a device is called a **rectifier**. A lot of electrical equipment operates on DC instead of AC, but it is convenient to plug them into AC power points. For example, a hair dryer plugs into an AC power point, but most hair dryers contain a rectifier circuit that converts the AC to DC before it flows to the heating elements and the fan motor.

Light-emitting diodes

A **light-emitting diode (LED)** is a special type of diode that not only restricts current flow to one direction only, but also emits light of a particular colour (Figure 5) when a current flows through it. Typically, the light from LEDs is one of the visible colours (commonly red, yellow or green), infrared (IR) light or ultraviolet (UV) light. The remote controls of televisions and DVD players send their messages via infrared LEDs. Red LEDs are also widely used on electrical equipment to show that the power is on or to indicate a particular setting. They are also used in torches, and garden and vehicle lights. LEDs are replacing incandescent globes in traffic lights, where they appear as dots of coloured light.

LED televisions use the light from the LEDs behind a screen of liquid crystals. The LEDs produce a light that shines through the pixels to create an image. Because LEDs are more energy efficient, LED TVs are thinner than normal liquid crystal display (LCD) televisions.

CHALLENGE
7.5A: Investigating with a remote control
Go to page **202**.

CHALLENGE
7.5B: Lighting up LEDS
Go to page **202**.

CHALLENGE
7.5C: Wiring a house
Go to page **203**.

Figure 4 Robot vacuum cleaners send infrared beams around a room to tell the robot the size of the room and if there are any drop-offs, such as stairs.

Light-dependent resistors

Light-dependent resistors (LDR) (or photoresistors) use light to change the amount of electric current that moves through the circuit. The more light that shines on a photoresistor, the less it resists the movement of electrons and the more the current is allowed to flow through the circuit (Figure 6a). This property is called **photoconductivity**. In the dark, a photoresistor has a very high resistance (thousands of ohms), while light can reduce the resistance to a few hundred ohms. This means more light causes more current.

Photoresistors are used in camera light meters, night lights and solar street lamps. When light falls on the photoresistor in a street lamp, it turns the lamp off.

Temperature-dependent resistors

Temperature-dependent resistors (or **thermistors**) are devices that change their resistance when the temperature varies. This affects the amount of current that can flow through the circuit. Most commonly, the higher the temperature, the lower the resistance (Figure 7a). Thermistors are often included in programmable circuits that detect the amount of current flowing and use it to display the temperature (as in thermometers) or to turn an object on or off.

Figure 5 Light-emitting diodes (LEDs) are more efficient, longer lasting and use less power than light globes, making them useful for a wide range of applications.

light-dependent resistor (LDR)
a resistor that changes its resistance according to the amount of light it is exposed to

photoconductivity
a property of light-dependent resistors, where the amount of electricity passing through the resistor is dependent on the amount of light it is exposed to

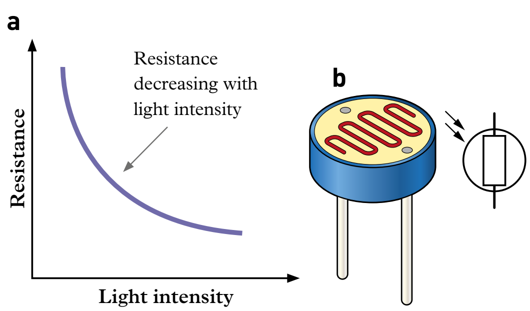


Figure 6 a The resistance of an LDR decreases when more light shines on it. **b** An LDR and its circuit symbol

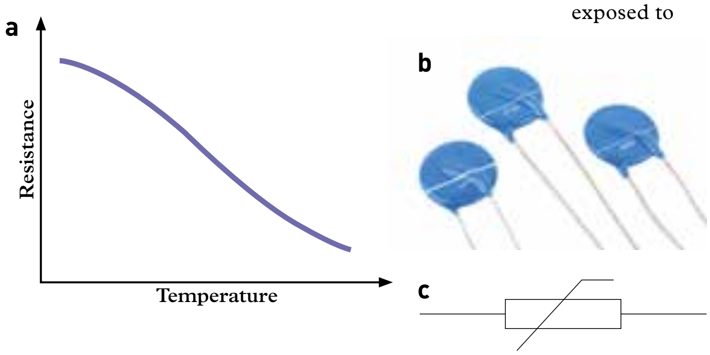


Figure 7 a The resistance of a thermistor changes with temperature. **b** Thermistors **c** Thermistor circuit symbol

7.5 Check your learning

Remember and understand

1 **Describe** the role of the following devices in a circuit.
   a LED
   b photoresistor
   c thermistor

2 **Describe** the role of a resistor that is connected in series with a diode. Draw a circuit using circuit symbols showing the correct arrangement of these components.

Apply and analyse

3 **Compare** a photoresistor and a thermistor.

4 **Explain** why an electrical device such as a toaster would need a rectifier.

5 A television remote control usually has an infrared LED that converts electrical energy into infrared energy. **Identify** the device the television must have to communicate with the remote.

temperature-dependent resistor
a resistor that varies the flow of current according to the temperature it is exposed to

thermistor
a temperature-dependent resistor that varies the flow of current according to the temperature it is exposed to; commonly used for temperature control

REVIEW 7

Multiple choice questions

1 The units of voltage, current and resistance, respectively, are:

A amps, ohms, volts
B ohms, volts, amps
C volts, amps, ohms
D volts, ohms, amps.

2 The potential energy that can be transformed in a lamp is also known as:

A current
B voltage
C resistance
D load.

3 A 50 Ω resistor is connected to a 10 V battery. The current flowing through it is __________ amps. If the voltage is doubled, then the current will be __________ amps.

A 5 A, 2.5 A
B 0.2 A, 0.1 A
C 5 A, 10 A
D 0.2 A, 0.4 A

Short answer questions

Remember and understand

4 Draw a circuit diagram for a circuit containing a battery, globe and switch. **Identify** the direction of electron flow and the direction of conventional current.

5 Match each circuit symbol shown in Figure 1 with its name.

ammeter battery globe switch

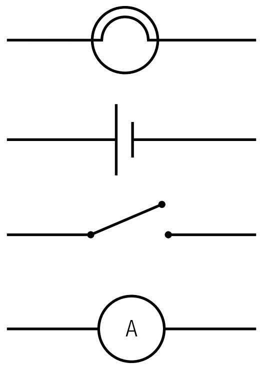


Figure 1 Circuit symbols

6 **Describe** the role of an ammeter.

7 If you don't connect the conducting wires to a globe correctly, the globe doesn't light up. Use the terms 'insulators' and 'conductors' to **explain** this observation.

8 **Define**:

a LED
b rectifier.

9 **Compare** current and voltage.

10 **Describe** how current moves in a parallel circuit.

11 **Contrast** a voltmeter with a multimeter.

12 **Describe** the relationship between current, voltage and resistance.

13 **Describe** how voltage changes through a series circuit.

14 **Identify** the circuit in Figure 2 as either a parallel circuit or a series circuit.

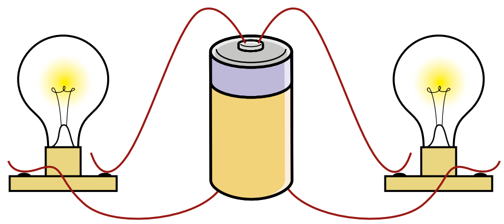


Figure 2 What type of circuit is this?

Apply and analyse

15 Draw a circuit diagram that shows a battery and a switch, with a globe on either side of the switch.

a **Describe** whether or how the circuit will be affected if the switch is placed before both globes.

b **Identify** the direction of electron flow and the direction of conventional current in the circuit.

16 Two identical bulbs are set up in a parallel circuit. **Describe** what would happen if a third identical bulb is connected in parallel.

17 Use Table 1 on page 200 to **calculate** the value of a resistor with the following coloured bands (in order):

a green, brown, black
b brown, yellow, red.

18 Use Table 1 on page 200 to **calculate** the coloured bands on a 7.9 MΩ resistor.

19 The lights in Figure 3 are connected in series. **Describe** what will happen if one globe fails.

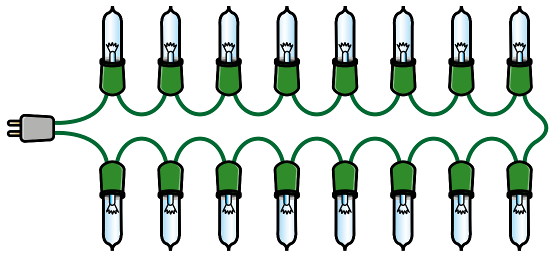


Figure 3 Lights connected in series

20 **Calculate** the current flowing through a 30 Ω resistor when it has a voltage drop of 12 V across it.

21 **Calculate** the voltage drop across a 50 Ω resistor when a current of 25 mA flows through it.

22 **Calculate** the value of a resistor that has a voltage drop of 18 V across it when a current of 0.3 A flows through it.

23 **Explain** why electrical current flows more easily in conductors.

Evaluate

24 Power lines carry electricity from power stations to cities and towns. They experience a voltage loss due to the high resistance along the lines according to Ohm's law. **Describe** how the current in power lines could be changed to minimise this voltage loss due to resistance.

25 **Explain** why a voltmeter is connected in parallel and an ammeter is connected in series in a circuit.

26 Use the correct symbols to draw a circuit consisting of a 6 V DC supply, an LED and a 100 Ω resistor connected in series. Add a voltmeter to measure the voltage drop across the LED.

27 **Evaluate** the claim: 'Resistance increases as voltage decreases.'

Social and ethical thinking

28 LEDs are gradually replacing incandescent street lights and traffic lights because they are more energy efficient. Unfortunately, this makes the lights much brighter, which can interrupt the sleep or migration patterns of local wildlife, including the bogong moth.

The bogong moth is a major food source of the pygmy possum. When the moths are attracted to the LED lights in the city, this diverts them away from the pygmy possum's habitat, and so the possums fail to get the food they need to survive.

Discuss the ethical dilemma caused by use of LED lights by:

- describing the advantages of using LED lights
- describing the disadvantages of using LED lights
- deciding whether the advantages are more important than the disadvantages (consequentialism) or whether some rules should not be broken (deontology).

29 Less than 3 per cent of batteries that are purchased in Australia are recycled. This means 97 per cent of batteries get sent to landfill, where they contaminate soil and water with toxic matter. Lithium batteries can also cause fires and explosions if they are inappropriately stored, damaging native habitats and homes. Evaluate the importance of recycling batteries and using rechargeable batteries to avoid damaging the environment.

Critical and creative thinking

30 In a storm, a tree has been blown over onto the main power line to your neighbourhood. The electricity supply is cut. **Describe** your day without mains electricity.

31 **Use** your understanding of current and voltage to model the flow of electricity through a circuit. You might use people or even an animation as your model.

Research

32 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing.

» Seeing the light

Research incandescent light globes. Identify what is meant by 'incandescent'. Describe the materials that these globes are made of. Explain why the filament must contain an inert gas like argon. Describe the temperature the filament needs to be heated to so that it gives off light. Describe the efficiency of incandescent light globes.

Figure 4 Incandescent light globes

» Light-emitting diodes

Describe diodes and how they work. Describe light-emitting diodes (LEDs) and explain why they are used in traffic lights. Evaluate the benefits of using LEDs. Identify other applications of LEDs. Compare their longevity to that of compact fluorescent globes and incandescent globes.

Figure 5 LEDs are used in traffic lights.

» Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp-free. Describe the different types of energy-efficiency practices that humans have used through the ages.

Figure 6 Solar panels improve energy efficiency.

Reflect

The table below outlines criteria for successfully understanding Chapter 7 'Electricity'. Once you have completed this chapter, reflect on your ability to do the following:

	I can do this.	I cannot do this yet.
Describe the difference between static electricity and electric current. Identify the key components of an electric circuit.	☐	☐ Go back to Topic 7.1 'Electricity is the presence and flow of electric charges' Page 134
Explain why circuit diagrams are used to represent circuits and draw appropriate circuit diagrams. Explain how an ammeter measures current.	☐	☐ Go back to Topic 7.2 'Electric current results from the movement of charges around a closed circuit' Page 136
Describe the differences in arrangement of series and parallel circuits. Measure current using an ammeter.	☐	☐ Go back to Topic 7.3 'Current can flow through series and parallel circuits' Page 138
Describe how voltage is shared in series circuits and the same in parallel circuits. Measure voltage using a voltmeter.	☐	☐ Go back to Topic 7.4 'Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit' Page 140
Describe how a diode restricts current to one direction. Describe how resistance can be altered by light or temperature.	☐	☐ Go back to Topic 7.5 'Current and resistance in a circuit can be altered' Page 142

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How do motors convert electrical energy to movement?

CHAPTER

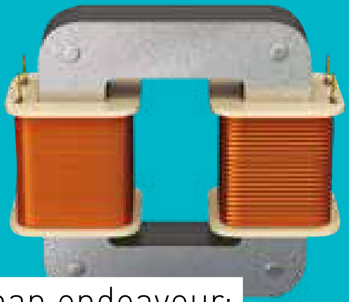
8

8.1 Wires carrying an electric current generate a magnetic field

ELECTROMAGNETISM

8.2 Electricity and magnets are used to produce movement

8.3 Magnetic fields and movement are used to generate electricity



8.4 Science as a human endeavour: Electromagnetic fields are used in technology and medicine

What if?

The power of magnetic fields

What you need:

Bar magnet, A4 paper, iron filings

What to do:

1 Place the bar magnet on the table.
2 Use the paper to cover the magnet.
3 Sprinkle iron filings over the paper and observe how they arrange themselves in a series of lines.

What if?

» What if the horseshoe magnet was used?
» What if both magnets were used?

8.1 Wires carrying an electric current generate a magnetic field

In this topic, you will learn that:

- A magnetic field is generated when charged particles move through a wire.
- The direction of the magnetic field can be determined by the right-hand grip rule, where the thumb points in the direction of the current (towards the negative terminal) and the fingers curl in the direction of the magnetic field.

right-hand grip rule
a rule used to predict the magnetic field direction around a current-carrying wire or the magnetic field of a solenoid; the right thumb indicates the current direction and the curled fingers give the magnetic field direction; also known as the right-hand curl rule

Magnetic fields

A magnetic field exists in the space surrounding a magnet. When iron or steel enters the magnetic field, it experiences a force. The shape of the magnetic field can be made visible by sprinkling iron filings around the magnet. The closer the iron filings are to the magnet, the stronger the magnetic force.

Using electricity to create magnetic fields

Magnets are not the only objects that generate magnetic fields. When Danish physicist Hans Christian Ørsted discovered that a wire carrying an electric current caused a compass to move when the current was switched on, he concluded that electricity could cause magnetism. A single current-carrying wire creates a circular magnetic field that gets weaker as the distance from the wire increases (Figure 1).

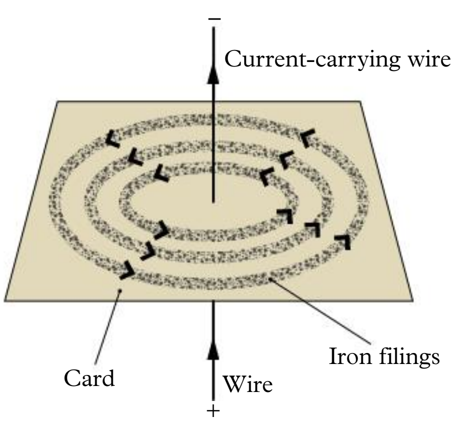


Figure 1 The magnetic field around a straight current-carrying wire is circular.

When a small compass is placed in the field, the needle shows the direction of the magnetic field.

Just like the magnetic field around a magnet, the magnetic field around an electrical wire carrying current has direction. The field around the outside of a magnet is always said to be moving from the north pole to the south pole of the magnet. To determine the direction of the magnetic field around an electrical wire, use the **right-hand grip rule** (also called the right-hand curl rule) (Figure 2).

Place your right hand so that your thumb is pointed along the wire in the direction of the conventional current, which traditionally is towards the negative terminal of the battery. Now curl your fingers. The way your fingers curl gives the circular direction of the magnetic field.

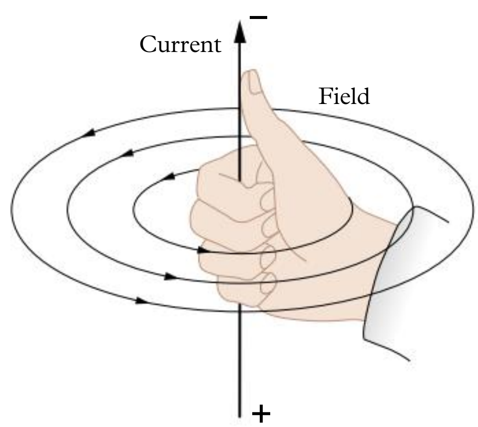


Figure 2 The right-hand grip rule. The way the fingers point around the wire gives the direction of the magnetic field. The direction in this diagram is anticlockwise.

EXPERIMENT

8.1: Creating magnetic fields
Go to page **204**.

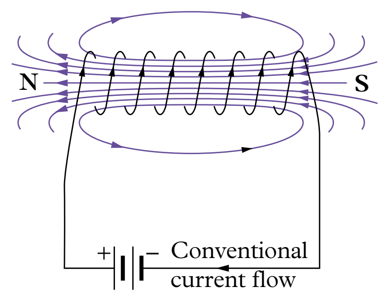
Electromagnets

To create a stronger, straighter magnetic field, you can loop a long, single, current-carrying wire into coils (Figure 3a). Such a coil of loops is known as a **solenoid**. The magnetic field produced by this arrangement is very similar to that of a bar magnet. To determine the direction of the magnetic field in this case, use the right-hand grip rule on any one of the loops of the solenoid to get the direction of the field around this loop. This will give the direction of the magnetic field inside and around the outside of the solenoid. This means the magnetic field inside the solenoid moves towards the north pole, and the magnetic field around the outside of the solenoid moves out from the north end and around the outside to the south end (just like a bar magnet).

To create an even stronger magnetic field, a soft iron core can be added inside the solenoid (Figure 3b). Pure iron is easily magnetised. If the current is switched on, the core becomes magnetised and strengthens the magnetic effect of the solenoid. If the current is switched off, the magnetic field is reduced. This is an example of an electromagnet, which is a type of magnet that can be turned on and off. The versatile nature of electromagnets has enabled many devices to be invented (Figure 4).

solenoid
a coil of wire that can carry an electric current; an iron core can be added to make an electromagnet

a



b

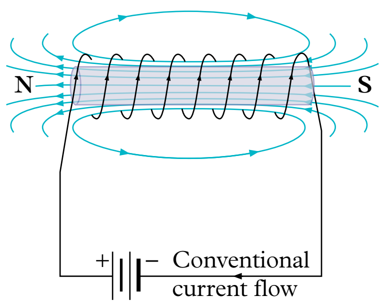


Figure 3 a A stronger magnetic field is created when a long, single, current-carrying wire is looped into coils. **b** An iron core increases the strength of the electromagnet.

Figure 4 The ability to switch the magnetic fields of electromagnets on and off has made them useful for many devices.

8.1 Check your learning

Remember and understand

1 **Describe** how two bar magnets could be arranged to produce:
  a attraction
  b repulsion.
2 **Describe** what happens to the strength of the magnetic field as you come closer to a current-carrying wire.
3 **Describe** how the right-hand grip rule can be used to show the direction of the magnetic field around a current-carrying wire.

Apply and analyse

4 An electromagnet made by a student will pick up three paperclips, but it is not strong enough to pick up four paperclips. **Describe** two ways the student could modify the electromagnet so it can pick up four paperclips.
5 **Describe** how the strength of the magnetic field around a solenoid could be increased.
6 **Explain** why all electrical wiring on a ship should be kept away from the ship's compass.

8.2 Electricity and magnets are used to produce movement

In this topic, you will learn that:

- All electric motors use electrical current and magnets to generate movement.
- The magnetic field produced by a current-carrying wire interacts with the magnetic field surrounding a magnet to exert a force on the wire.
- The right-hand slap rule can be used to determine the direction the wire will move.

right-hand slap rule
a rule used to predict the force on a current-carrying wire in a magnetic field; the right thumb indicates the current direction, the outstretched fingers follow the magnetic field direction and the palm of the hand pushes in the direction of the force

armature
coils of current-carrying wire in a motor or generator

brushes
a pair of contacts that bring current into an armature (motor) or take current out of an armature (generator)

split ring commutator
a device in a DC motor or a DC generator that reverses the current flow in an armature every half turn to maintain rotation (motor), or that converts the AC generated in the armature to a DC output (generator); most consist of two shells or half-rings that rub against the brushes

The magnetic field generated by an electrical current can be used to move another magnet. For this to occur, the direction of the magnetic field must be known.

Right-hand slap rule

If a current-carrying wire is placed at right angles to a separate magnetic field, such as that of a strong magnet, the magnetic field of the wire will exert a force on the magnet. In some places, the two magnetic fields will attract each other, and in others the magnetic fields will repel each other. This results in an unbalanced magnetic field that pushes on the electrons moving in the wire, causing the wire to move.

The direction the wire moves can be predicted by the **right-hand slap rule**. The right thumb points in the direction of the conventional current (towards the negative terminal of the battery) and the straight fingers point in the direction of the external magnetic field (from the magnet's north pole to the south pole). The direction the palm faces is the direction the wire will be pushed (Figure 1).

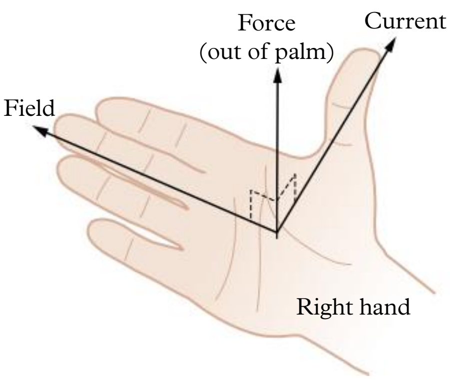


Figure 1 The right-hand slap rule. The thumb represents the current, the fingers represent the external magnetic field and the palm pushes in the direction of the force.

Electric motors

The force on a single wire is not particularly useful. To create a more effective force, the single wire can be looped into coils, similar to the solenoid. If this coil has current moving through it, then it will generate a magnetic field. If the magnetic solenoid is placed in another magnetic field, the forces between the magnets will cause either the magnet or the solenoid to rotate. Such a device is an electric motor.

It is possible that you've used an electric motor already today. A hairdryer uses an electric motor to drive the fan that blows hot air over your hair. Electric motors attached to fans are also used in heaters and air conditioners to blow warm or cold air around a room or inside a car. A washing machine, a clothes dryer, a blender and a fan in a computer all use electric motors to create rotation. Each of these devices uses a current-carrying solenoid and a magnet to generate movement.

Figure 2 shows how an electric motor works. The coil of wire, called an **armature**, usually consists of many turns but is shown in the diagrams as a single loop for clarity. The pivots at each end of the armature are omitted for clarity.

The coil is connected to the DC power supply using **brushes** and a **split ring commutator** (SRC).The direction of the conventional current is shown by the arrows. The right-hand slap rule on each side of the diagram shows the direction of forces on the sides of the coil. The downward forces on the left side and the upward forces on the right side create an anticlockwise rotation. However, once the coil rotates past the vertical, these forces need to be reversed to maintain smooth rotation.

CHALLENGE
8.2A: Observing magnetic force
Go to page **205**.

CHALLENGE
8.2B: Building an electric motor
Go to page **206**.

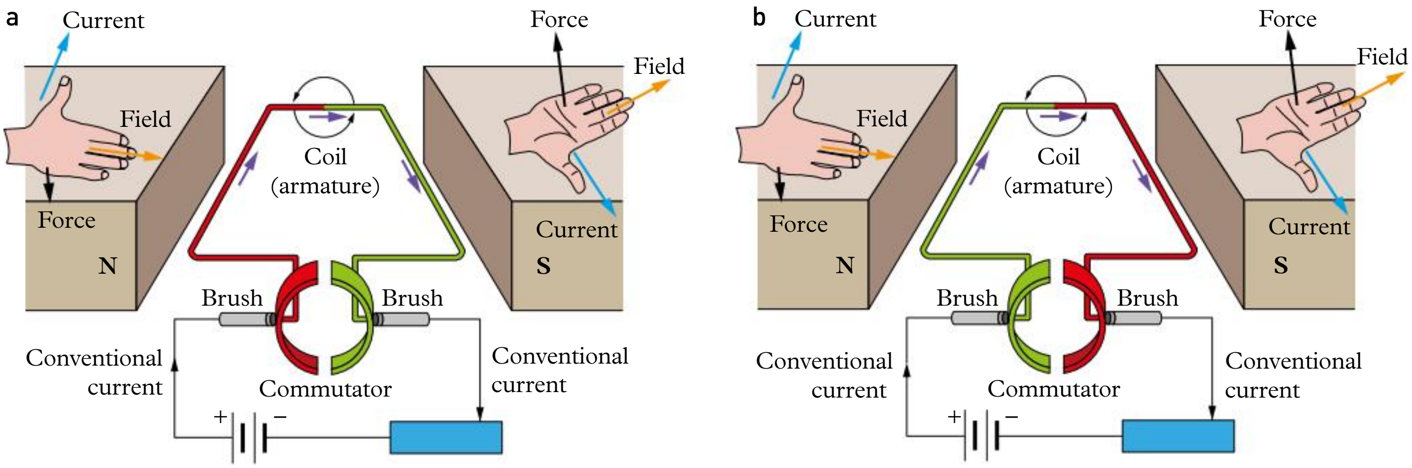


Figure 2 How an electric motor works **a** The force pushes the red wire down and the green wire up. **b** The coil has now turned over. The force pushes the green wire down and the red wire up.

The commutator does this job by connecting to the opposite brush after each half turn (180° rotation) of the coil. Figure 2b shows the same coil turned over 180°. The red side is now on the left and the green side is on the right.

The commutator has also rotated 180° and now connects to the opposite brush, which has the effect of reversing the direction of the current in the coil. Therefore, the direction of rotation is maintained.

Most electric motors are more complicated than this simplified example. They often have several sets of coils, all at slightly different angles to each other, and electromagnets are often used instead of permanent magnets.

8.2 Check your learning

Remember and understand

1 Figure 3 shows the major components of an electric motor, numbered 1–5. Match each of the labels below with its correct number.
- **a** permanent magnet
- **b** armature coil
- **c** split ring commutator
- **d** brush
- **e** DC power supply

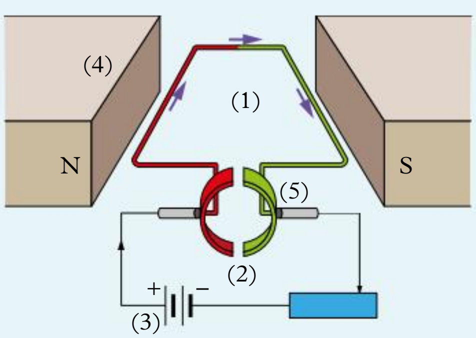


Figure 3 The major components of an electric motor

2 In an electric motor, **describe** the role of the following structures.
- **a** split ring commutator
- **b** brushes
- **c** armature

Apply and analyse

3 **Describe** the direction of rotation (either clockwise or anticlockwise) of the electric motor shown in Figure 3. **Justify** your answer (by describing the right-hand slap rule used to identify the forces, describing the direction of wire movement and deciding whether this is clockwise or anticlockwise).

Evaluate and create

4 Draw a diagram that shows the best arrangement of a single current-carrying wire and a strong magnet in order to produce the maximum force on a wire.

5 Draw a diagram that shows the arrangement of a single current-carrying wire and a strong magnet in order to produce zero force on the wire when current is flowing.

8.3 Magnetic fields and movement are used to generate electricity

In this topic, you will learn that:

- Electromagnetic induction involves generating electric current from movement between coils of wire and a magnet.
- A dynamo generates direct current (DC) and an alternator generates alternating current (AC).
- The generated current can be increased by increasing the number of coils or the speed of movement.

Electromagnetic induction

If a wire is connected to a sensitive ammeter, and a horseshoe magnet is moved up and down around the wire, an electric current will flow in the wire. This happens even when no external power is supplied to the circuit. It doesn't require electricity because electricity is generated by the moving magnetic field. This process is known as **electromagnetic induction**. This effect is due to the magnetic field exerting a force on the moving electrons inside the wire, which pushes the electrons along the wire. This flow of electrons contributes to an electric current. When the magnet is pushed in the opposite direction, the electrons are pushed along the wire in the other direction and the current reverses. This constantly reversing current is known as **alternating current (AC)**. The same effect is achieved if the magnet is held still and the wire is moved up and down. The voltage driving the current can be increased by:

> increasing the speed of the movement
> using a bundle of wires rather than a single wire
> positioning the wires at a right angle to the magnetic field.

electromagnetic induction
the production of voltage (and hence a current) in a circuit, by the magnetic field through the circuit or by the relative movement of the magnetic field and the circuit; all dynamos and generators use this principle

alternating current (AC)
electrical current that flows first in one direction, then in the opposite direction, then back in the first direction and so on; electrical energy is usually generated in this form in a power station

generator
a machine that uses the electromagnetic effect to separate charges and produce electricity

The generator

A more efficient way of generating electricity is to wrap one long wire into a coil and rotate it in a magnetic field. This is the reverse of an electric motor. In fact, if a simple motor is disconnected from the power and made to spin, it becomes a **generator** and generates electricity. The faster the coil is spun and the greater the number of turns in the coil, the greater the voltage generated.

Figure 1 A bicycle dynamo has a rotating magnet and a stationary coil. As the bicycle moves, the bike's rotating wheel turns the magnet, which induces enough electricity to run the bicycle's lights.

CHALLENGE
8.3: Producing electricity with a generator
Go to page 207.

Such a device is called a generator, although the names **dynamo** and **alternator** are also used. A dynamo generates **direct current (DC)**, which flows in one direction only (Figure 1). An alternator generates alternating current (AC) (Figure 2).

dynamo
a generator that produces direct current (DC) through the use of a split ring commutator

alternator
a generator that produces alternating current (AC) through the use of slip rings

direct current (DC)
the type of current that flows in one direction only; electrical energy is produced in this form by a battery or a generator

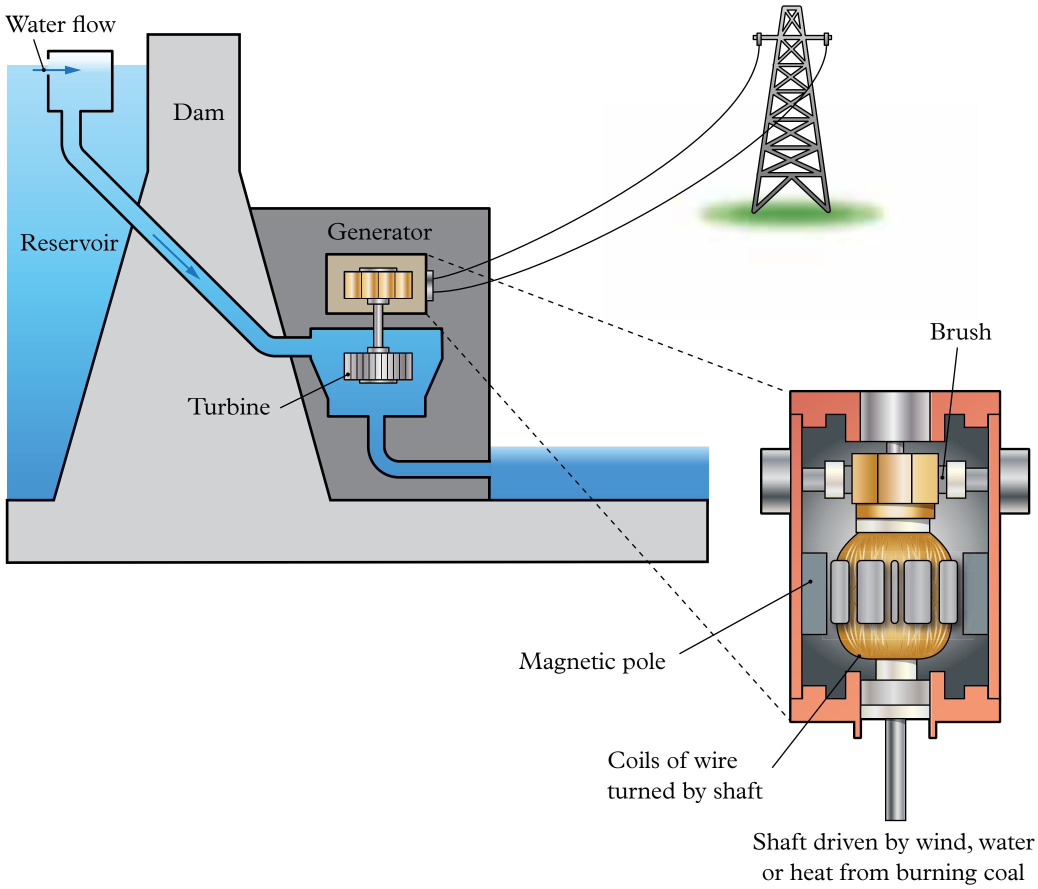


Figure 2 Most power plants use wind, water or heat from coal to turn the shaft of the generator. This causes the large loops of wire to turn between magnets, generating a current (usually AC).

8.3 Check your learning

Remember and understand

1 **Describe** how the voltage driving a current can be increased in a generator.

2 **Contrast** a dynamo and an alternator.

3 **Explain** how a generator works, to a student in Year 7. Write down your explanation.

Apply and analyse

4 **Identify** which of the following will generate electricity.

a a bar magnet moving in a coil

b a bar magnet moving away from a coil

c a coil being lowered over an upright bar magnet

d a bar magnet being held still inside a coil

e a current being turned on in a coil that is above another coil

f an iron core being inserted into a coil

5 **Explain** how the motor you built in Challenge 8.2B could be used to generate electricity.

//SCIENCE AS A HUMAN ENDEAVOUR//

8.4 Electromagnetic fields are used in technology and medicine

Current moving through a coiled wire generates a magnetic field. If the direction of the current continually changes (alternating current), so too does the direction of the magnetic field. A constantly changing magnetic field can generate a current in a nearby wire coil. This process occurs in transformers and wireless chargers.

Transforming current

The movement of a wire or coil in a magnetic field or vice versa is not the only way to generate electricity. Michael Faraday was a poorly educated book binder who developed an interest in science by reading the books he was working on. In 1831, Faraday began a series of experiments on electromagnetic fields. He wrapped two insulated coils of wire around opposite ends of a large iron ring and found that when a current was passed through one coil of wire, a current appeared briefly in the other coil of wire. This current only lasted while the first wire's current was being turned on or off. If the current in the first coil constantly changed direction, such as in an alternating current, the current in the second wire also constantly changed direction. Therefore, electricity could be passed between wires without the wires touching each other. If the first coil of wire had more turns of wire than the second coil of wire, then the voltage passed on would be less in the second coil. This is what happens in a **transformer** (Figure 1). The current and voltage are changed or transformed. Many electrical devices operate on less than the 240 V that come from an electrical power point in Australia. For example, many computers have an electrical cord with a small black box attached, which transforms the 240 V into a smaller voltage that the computer can use (Figure 2).

transformer
a device that changes the voltage at which energy is transmitted by an alternating current; usually consists of two coils of wire (primary and secondary), an iron core and an AC power source

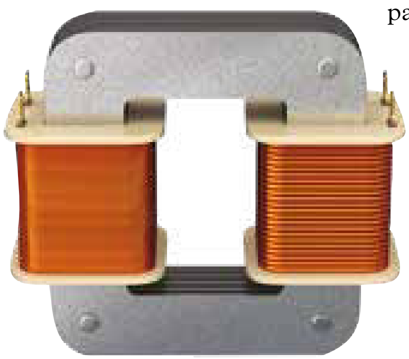


Figure 1 A transformer

Figure 2 A laptop computer has a transformer in its power cord.

WIRELESS CHARGING

The process of transferring an electric current through coils of wire is used in wireless charging devices. Alternating current flows through coils of wire in the charging device. The resulting magnetic field generates a current in a coil in the receiving device, such as a mobile phone. When the current is converted into direct current, it recharges the battery in the device. Although wireless chargers are convenient, the current generated is lower than when charging devices directly wth a cord. If the coils of wire on the wireless charger are not directly aligned with the coils in the phone, most of the energy is lost as heat. Figure 3 shows the process of wireless charging for a mobile phone.

MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) involves placing a human body inside a strong, stable magnetic field. The magnetic field is usually generated by a large cylindrical coil of specially made wire in a bath of liquid helium, and the patient is positioned in the centre of the coil (Figure 4). The liquid helium is at –269°C.

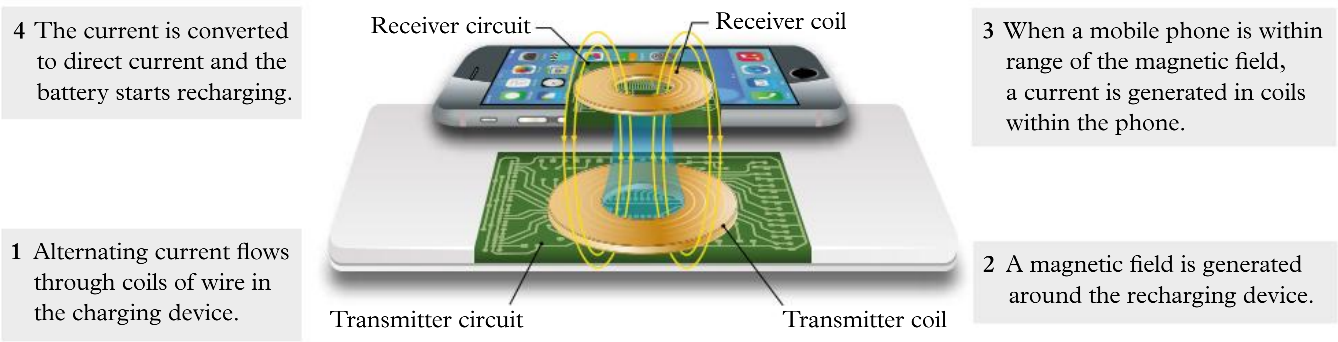


Figure 3 Wireless charging: alternating current generates a magnetic field, which generates a current in the mobile phone.

This very low temperature decreases the resistance of the wire to electric current so that it can conduct electricity indefinitely without any loss. Once current is flowing in the coil, it produces a strong magnetic field. The magnetic field causes the protons in the water (H_2O) in the person's body (we consist of 60 per cent water) to align with it.

Extra small coils are also placed around the person and brief pulses of current are passed through the coils. These current pulses produce additional magnetic fields, which vary in strength and direction throughout the patient's body. This causes the protons in water to temporarily change their alignment with the main magnetic field. The amount the protons shift varies according to where they are in the body. The way the protons respond to these additional magnetic fields also depends on their chemical environment. These subtle changes in alignment can be detected and converted to an image of the internal structure of the body (Figure 5). In this way, medical specialists can identify any damaged or diseased tissues or organs and decide on appropriate treatment for the patient.

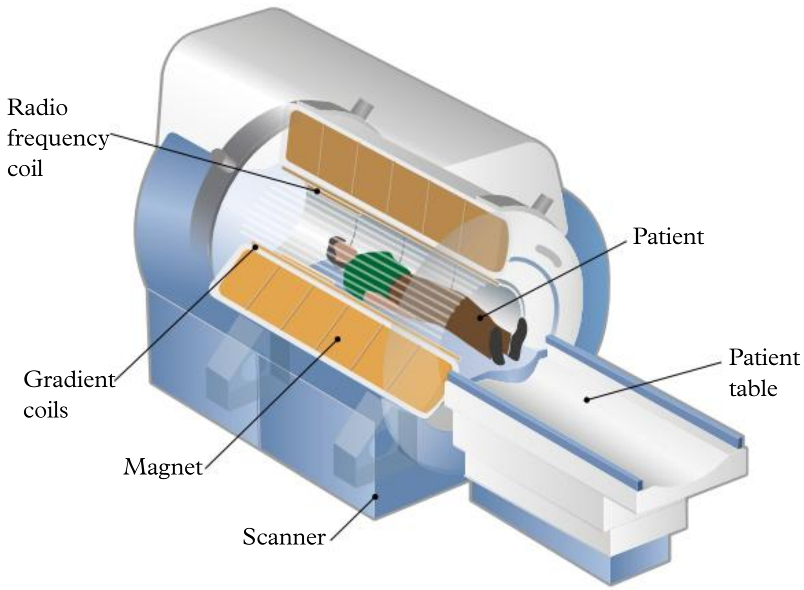


Figure 4 An MRI machine uses a magnetic field to generate images of the body's internal structure.

Figure 5 The brighter area of this MRI image indicates an abnormality in the brain.

8.4 Develop your abilities

Assumptions about high-voltage wires

Some people consider that the magnetic fields generated by current moving through wires is a reason not to live near high-voltage wires, or the generators in windmills or transforming stations. Use your critical thinking skills to answer the following questions.

1. **Identify** possible assumptions or biases that you might have about the dangers of high-voltage wires.
2. **Describe** how these assumptions could affect any decisions you might make about living near high-voltage wires.
3. **Evaluate** the accuracy of your assumptions, by:
   - describing the factors or arguments that could be made, that would cause you to change your view
   - identifying whether these factors or arguments are correct
   - deciding whether your assumptions are accurate or you should change your opinion.
4. **Describe** the importance of using critical thinking to avoid bias when making decisions.

REVIEW 8

Multiple choice questions

1 The right-hand grip rule:
  A is used to determine the direction of force on a current-carrying wire
  B has the thumb pointing in the direction of the electron movement
  C is used to determine the direction of the magnetic field around a current-carrying wire
  D has the palm of the hand pointing in the direction of the current.

2 The current generated by electromagnetic induction can be increased by:
  A increasing the number of coils in the solenoid or increasing the movement of the magnet
  B increasing the number of coils in the solenoid or decreasing the movement of the magnet
  C decreasing the number of coils in the solenoid or increasing the movement of the magnet
  D decreasing the number of coils in the solenoid or decreasing the movement of the magnet.

Short answer questions

Remember and understand

3 Copy and complete the following paragraph with the most appropriate words or phrases.
A ___________ is able to attract objects made of iron or ___________. A magnet has two ___________: north and ___________. A current-carrying wire has a magnetic ___________ around it. The direction of the field is given by the ___________ rule. In an electromagnet, many___________ of wire are wrapped around an iron ___________.

4 **Identify** each of the following statements as true or false. If a statement is false, rewrite it to make it true.
  a The direction of a magnetic field is the way the south pole of a compass will point.
  b The fingers of the right-hand grip rule indicate the direction of the magnetic field of a solenoid.
  c The split ring commutator in a DC electric motor reverses the current direction in the armature every half-turn to keep it rotating in the same direction.
  d A changing magnetic field generates no current.
  e An alternator is used to generate a current that flows in one direction only.

5 **Define**:
  a electromagnet
  b alternator
  c dynamo
  d electric motor.

6 **Describe** how to use:
  a the right-hand grip rule
  b the right-hand slap rule.

7 **Describe** how the magnetic field changes when iron is added to the centre of a solenoid.

8 **Describe** one way to increase the strength of the magnetic field of an electromagnet.

9 **Define** the abbreviation ‘MRI’.

10 **Describe** how a phone can be charged wirelessly.

Apply and analyse

11 **Contrast** the way an alternating current is generated and the way a direct current is generated.

12 Figure 1 shows an electric bell. **Explain** how the bell works when the switch is pressed.

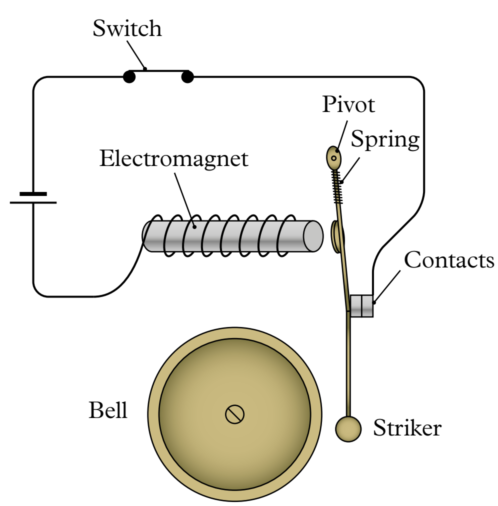


Figure 1 An electric bell

13 The current-carrying wire in Figure 2 has a magnetic field travelling in a clockwise direction. Use the right-hand grip rule to **determine** whether the current is moving into or out of the page.

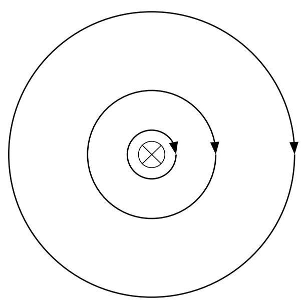


Figure 2 A current-carrying wire with a magnetic field

14 Use the right-hand slap rule to **identify** whether the wire in Figure 3 moves up or down.

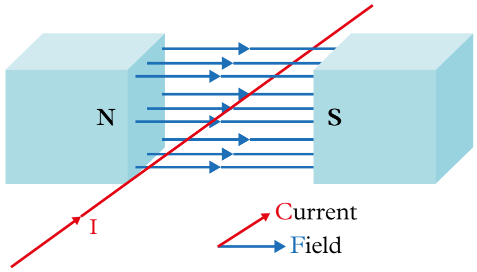


Figure 3 A straight current-carrying conductor

15 Use the right-hand slap rule to **identify** whether the wire in Figure 4 is carrying current from a to b or from b to a.

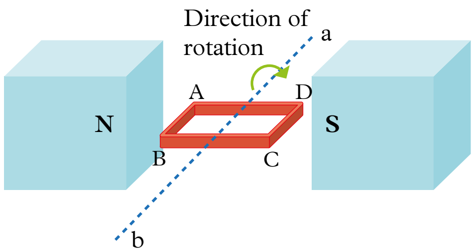


Figure 4 A wire carrying current

Evaluate

16 a **Describe** how a mobile phone charger charges a phone.

b Sketch a diagram to show two sets of coils and an iron core, like those inside a mobile phone charger. **Identify** which set would connect to the power point and which set would connect to the phone.

c **Identify** the other electronic components a mobile phone charger must contain.

17 A radio-controlled car works with a remote control.

a **Describe** how this remote-controlled car works.

b **Identify** the electronic components the remote control is likely to have.

c **Identify** the electronic components that are required for the toy car to move.

18 The amount of electricity generated from spinning a dynamo depends on the magnetic field strength, the size of the coil and the rotation speed. Design an experiment to **investigate** all three of these variables. Write an aim, list of equipment, hypothesis and method. You don't need to carry out the experiment. Carefully **explain** in your method section how each variable is tested, one at a time, while the other variables remain constant.

Social and ethical thinking

19 A mobile phone charger that is switched on at the power point is constantly using energy, even when no phone is placed on it to be charged. **Evaluate** the ethics of maintaining this energy use when your phone is fully charged (by describing the advantages and disadvantages of leaving the phone charger on, deciding whether you are using an 'ends justifies the means' consequentialism approach or a 'rules-based' deontology approach, and deciding whether the phone charger should be left on).

Figure 5 A phone charger

Critical and creative thinking

20 Electricity can be generated by moving either a magnet or a solenoid. This can be achieved by moving water in a hydroelectric scheme, wind in windmills or coal-powered steam. Develop a set of criteria that could be used to **evaluate** the effectiveness of each of these methods. **Describe** the limitations you have included in your definition of 'effectiveness'. For example, did you limit the criteria to how the electricity was generated, or did you consider the environmental impacts? **Justify** your decision.

Research

21 Choose one of the following topics to research. Some questions have been included to get you started. Present your findings in a format of your own choosing, giving careful thought to the information you are communicating and your likely audience.

» Synchrotron

A synchrotron is a huge scientific instrument that accelerates electrons to a very high speed. The electrons are forced to move in a circular path by large electromagnets. The direction of travel of an electron is the reverse of the direction of conventional current. Identify the arrangement of the north and south magnetic poles and the direction of the electron beam if the electrons are to be pushed to the right. Research this phenomenon to see if your arrangement is correct. If you were incorrect, describe the error(s) of judgement you made.

» Wind turbines

Describe how a wind turbine generates electricity. Identify the factors that affect the amount of electricity generated. Contrast the different types of wind generators. Identify how the efficiency of the different types of wind generators may vary.

» Hairdryers

A hairdryer generates heat and uses a fan to push the warm air over hair. Describe how a hairdryer works. Describe how the heat is generated. Describe how electricity is used to move the fan. Describe how the amount of heat can be increased. Describe how the speed of the fan can be increased.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 8 'Electromagnetism'. Once you've completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Use the right-hand grip rule to determine the direction of the magnetic field around an electrical wire. Discuss how increasing the coils of wire and using iron can create stronger magnetic fields.	☐	☐ Go back to Topic 8.1 'Wires carrying an electric current generate a magnetic field' Page 148
Describe how an electric motor works, by explaining the functions of the armature, brushes and spit ring commutator. Use the right-hand slap rule to determine the direction the wires will move.	☐	☐ Go back to Topic 8.2 'Electricity and magnets are used to produce movement' Page 150
Describe the process of electromagnetic induction. Distinguish between alternating current and direct current.	☐	☐ Go back to Topic 8.3 'Magnetic fields and movement are used to generate electricity' Page 152
Explain how a constantly changing magnetic field can generate a current in a nearby wire coil. Explain how the hydrogen atoms in water are affected by changing electromagnetic fields and how this is used in magnetic resonance imaging (MRI) to generate images for the diagnosis of disease.	☐	☐ Go back to Topic 8.4 'Science as a human endeavour: Electromagnetic fields are used in technology and medicine' Page 154

Check your Student obook pro for these digital resources and more:

Quizlet Live
Compete in teams to test your knowledge.

Chapter quiz
Test your understanding with one of three chapter quizzes.

CHAPTER 9

EXPERIMENTS

Science lab rules

Being safe in the lab is essential to prevent you and others from getting hurt. Whenever you are in the lab, you must always follow the rules below.

DO:

- wear a lab coat for practical work
- keep your workbooks and paper away from heating equipment, chemicals and flames
- tie long hair back whenever you do an experiment
- wear safety glasses while mixing or heating substances
- tell your teacher immediately if you cut or burn yourself
- tell your teacher immediately if you break any glassware or spill chemicals
- wash your hands after any experiments
- listen to and follow the teacher's instructions
- wear gloves when your teacher instructs you to.

DON'T:

- run in a laboratory
- push others or behave roughly in a laboratory
- eat in a laboratory
- drink from glassware or laboratory taps
- look down into a container or point it at a neighbour when heating or mixing chemicals
- smell gases or mixtures of chemicals directly; instead, waft them near your nose and only when instructed
- mix chemicals at random
- put matches, paper or other substances down the sink
- carry large bottles by the neck
- enter a preparation room without your teacher's permission.

Learning and working in a laboratory

*

Working in a science laboratory requires you to use a variety of special skills. Many of these you may not use anywhere else. You must know how to identify, prepare and clean up equipment safely to prevent chemicals contaminating future experiments, or harming yourself or someone else.

Wearing lab coats and safety glasses, having hair tied back

Figure 1 Wearing a lab coat and safety glasses is an essential part of completing any experiment.

How to clean equipment

Figure 2 Place warm water in the equipment (e.g. beaker).

Figure 3 Add a small amount of detergent.

Figure 4 Use a brush or cloth to wipe around the equipment.

Figure 5 Clean test tubes using a small bottle brush.

Figure 6 Tip out water and rinse the equipment with fresh water to prevent contamination for the next experiment.

Figure 7 Place the equipment upside down to drain.

What to do with broken glass

Figure 8 Tell your teacher. Place the glass in a special glass bin. Alternatively, wrap the glass in newspaper and dispose of it in the normal rubbish.

CAUTION!
Do not use your hands to pick up the glass.

How to clean up common spills

Figure 9 If it is safe, wipe the spill up with paper towel and dispose of it in the normal rubbish. Can you spot what's wrong with this image? When cleaning up spills, wear gloves to protect your hands!

Figure 10 Let your teacher know straight away if there is a chemical spill. Follow your teacher's directions. Laboratories should have a special spill kit that may be used in these circumstances.

CAUTION!
Tell your teacher first. Wear safety glasses and gloves when cleaning up spills.

Safely smelling chemicals

CAUTION!
Check with your teacher if it is safe to smell the chemical, and only proceed if it is.

Figure 11 Hold the chemical slightly away from your face. Use your hand to gently waft a small amount of air above the container towards your face.

How to light a Bunsen burner

CAUTION!
Remember to keep your hand below the flame.

Figure 12 Place the Bunsen burner on a heatproof mat.

Figure 13 Connect the rubber hose firmly to the gas tap.

Figure 14 Close the air hole by turning the collar.

Figure 15 Light a match and place it above the barrel, with your hand below the flame.

Figure 16 Open the gas tap fully.

Figure 17 The Bunsen burner will now have a yellow (safety) flame.

1.1 What if the absorbency of different paper towels was compared?

EXPERIMENT

Aim

To measure and compare the absorbency of different brands of paper towel, which vary in their cost per square centimetre.

Materials

- 5 different brands of paper towel (one must be a home brand)
- Small beaker of water with a dropper
- 250 mL beaker
- 100 mL measuring cylinder
- Scissors
- Ruler and pencil
- Calculator
- Stopwatch

Method

1. Cut a 20 cm by 20 cm square from one sheet of each brand of paper towel.
2. Record the brand, price, number of sheets and the dimensions of each sheet in centimetres.
3. Fill the measuring cylinder with water to the 100 mL mark, using the dropper for the last 2–3 mL. Ensure that your eyes are level with the scale, to avoid parallax error.
4. Immerse the square of paper towel in water for 10 seconds. Use the stopwatch for timing. Hold the paper towel above the measuring cylinder, without squeezing the towel, for another 10 seconds, then remove it and place it in the large beaker.
5. Record the level of water left in the measuring cylinder and, hence, the volume of water absorbed by the paper towel in 10 seconds.
6. Repeat steps 1–5 for two other sheets of the same brand of paper towel.

Inquiry

What if the absorbency of more expensive paper towels was compared to home brand paper towels?

Answer the following questions with regard to your inquiry question.

- Identify the brands of paper towel that you will test.
- Write a hypothesis (If … then … because …) for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a valid test. Describe how you will control these variables.
- Identify the materials you will need for your experiment.
- In your logbook, write down the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

- Calculate the total surface area and the cost per square centimetre for each paper towel, and record your results in the table.
- The total surface area of the paper towel roll is calculated as follows:

  $A = l \times w \times$ number of sheets of paper towel
- The cost of paper towel per square centimetre is calculated as follows:

$$\text{Cost of paper towel} = \frac{\text{cost of roll}}{\text{total area of roll}}$$

- Calculate the average volume of water absorbed per 20 cm square and record your results in the table.
- The average volume of water absorbed per 20 cm square is calculated as follows:

$$\text{Average volume of water} = \frac{\text{volume 1} + \text{volume 2} + \text{volume 3}}{3}$$

- Draw a bar graph to show the average volume of water absorbed for each brand.
- In your graph, place the brands in order from least expensive to most expensive. On each bar, state the price per square centimetre of that brand.

Discussion

1. State the reasons for the following.
   a. Three readings were taken each time and then averaged.
   b. The same-sized square was used each time.
   c. The cost of the paper towel per square centimetre was calculated and used instead of the total cost of the roll.
   d. Each square of paper towel was allowed to drip for precisely 10 seconds before removing it from the water.
2. Compare (the similarities and differences between) the absorbency of the different brands to the predictions you made in your hypothesis.
3. Evaluate the validity (by identifying any variables that might not have been controlled) and reliability (by describing whether you or other scientists will achieve the same results) of this experiment.
4. Identify the limitations of these results (by describing how testing with other solutions may achieve different absorbency).

Conclusion

From your graph, identify any apparent relationship between the cost of the paper towel per square centimetre and its absorbency. Provide evidence (by mentioning values) from your results to support your answer.

1.2 Avoiding errors and improving accuracy

CHALLENGE

What you need

- Ruler
- Electronic scales
- Item from pencil case
- Analogue clock

What to do

1 Measure the following line.

Record the value in your logbook.

2 Use the electronic scales to measure the mass of an item from your pencil case (such as a pen). Make four measurements and record them in an appropriate table in your logbook.

3 Working in groups of three, read the time on an analogue clock, with each person reading from a different perspective. One person should read the clock from directly in front of the clock. Another person should stand to the right of the first person at an acute angle. The other person should stand to the left of the first person at an acute angle. Each person should read the clock and note the time.

Questions

1 Compare your measurement of the line in step 1 to the person's next to you. Identify any differences in the values you measured. Explain a possible error that might account for differences in measuring with rulers. Describe how you could minimise this error.

2 a Identify any differences in the mass values you measured in step 2. (Are they closely grouped together?) Explain a possible error that might account for differences in measuring with electronic scales. Describe how you could minimise this error.

b Calculate the average of the mass measurements. Compare the average measured value with the individual measurements. Describe how the average would be affected by one value that was much lower than the other values.

3 a Describe any differences in the clock time that was read from different positions.

b Identify the type of error that the differences represent.

c Describe how this type of error could be avoided.

Figure 1 Your reading of an analogue clock can be affected by where you stand.

2.1A Making a biosphere

CHALLENGE

What you need

- Pond water containing macro-invertebrates (e.g. water fleas, pond snails)
- Aquatic plants
- Mud or sand from a pond
- Large glass jar with a lid
- Electronic balance

What to do

1. Work in pairs and take turns with observations and note-taking.
2. Take the large glass jar and partly fill it with mud or sand from a pond and some pond water. Make sure there are some small macro-invertebrates in your pond water.
3. Add some small pieces of aquatic plants to the jar.
4. Seal the jar with an airtight lid and then weigh the jar and contents.
5. Place the jar near a well-lit window, but not in the direct sunlight or it may warm up too much.
6. Check your biosphere every few days and write down some observations about what you see happening.
7. Weigh the jar and contents when you have finished the experiment.

Questions

1. Describe how the weight of your jar and contents changed over time. Explain what might have caused any change.
2. Plants are important in a biosphere because they make oxygen and sugar from carbon dioxide, water and sunlight. Identify the name of this process.
3. Animals consume sugar and oxygen to produce carbon dioxide. Identify the name of this process.
4. Describe how the processes you named in questions 2 and 3 are related.
5. Use the internet to research other home-made biospheres and suggest some improvements you could make to the design of your experiment.

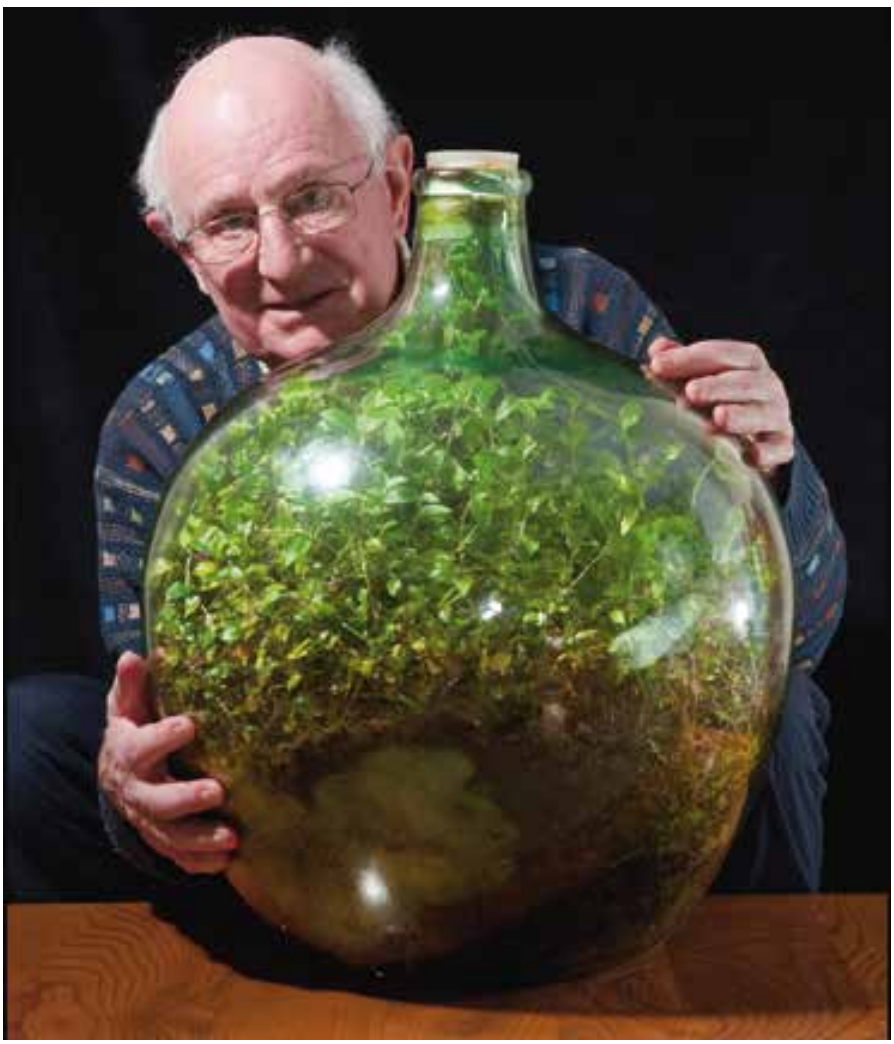


Figure 1 This biosphere has only been watered once in 53 years.

2.1B Purification of water

EXPERIMENT

Aim

To find out how effective natural systems can be at filtering water.

Materials

> 3 medium-sized plastic pots with drainage holes
> Gravel
> Sand
> Soil
> Plants (native grasses)
> Mixture of castor oil, dirt, small pieces of paper, water, salt
> Plastic bucket
> Water
> Timer
> 3 containers to collect the water drained from the pots

Method

A few weeks in advance, prepare one plastic pot with a layer of gravel, then sand and finally dirt. Plant some native grasses in this pot. You will need to wait until the grasses have become established in the pot before proceeding with this experiment.

1 Prepare two plastic pots: Pot 1 with gravel, then sand, and finally a layer of dirt; Pot 2 with just gravel. Label the pot with native grasses as 'Pot 3'. You should now have three pots, as in Figure 1. Sit each pot in a container.

2 Mix the castor oil, dirt, small pieces of paper, water, salt and any other materials you wish to include in a bucket of water. The mixture should be very cloudy and have an odour.

3 Pour an equal amount of the mixture into each of the three pots and collect the solution that filters out of the base of each pot. Record how long it takes the solution to finish flowing out of the base of each pot.

Results

Record in a table:

> the time it took for the water to finish draining through the pots
> your observations of the odour and quality of the drained water.

Discussion

1 Compare (the similarities and differences between) the water that was filtered through each pot (by summarising your key observations in 2–3 sentences and the time it took for most of the water to move through the layers).

2 Explain what factors may have contributed to the differences you observed between the flow rate of drained water in respect to:
   a the cloudiness of the drained water
   b the odour of the drained water.

3 Describe how this knowledge could be used in maintaining the water quality of streams and rivers in national parks.

Conclusion

Explain the effect that different soil types and the presence of native grasses have on the quality of water available.

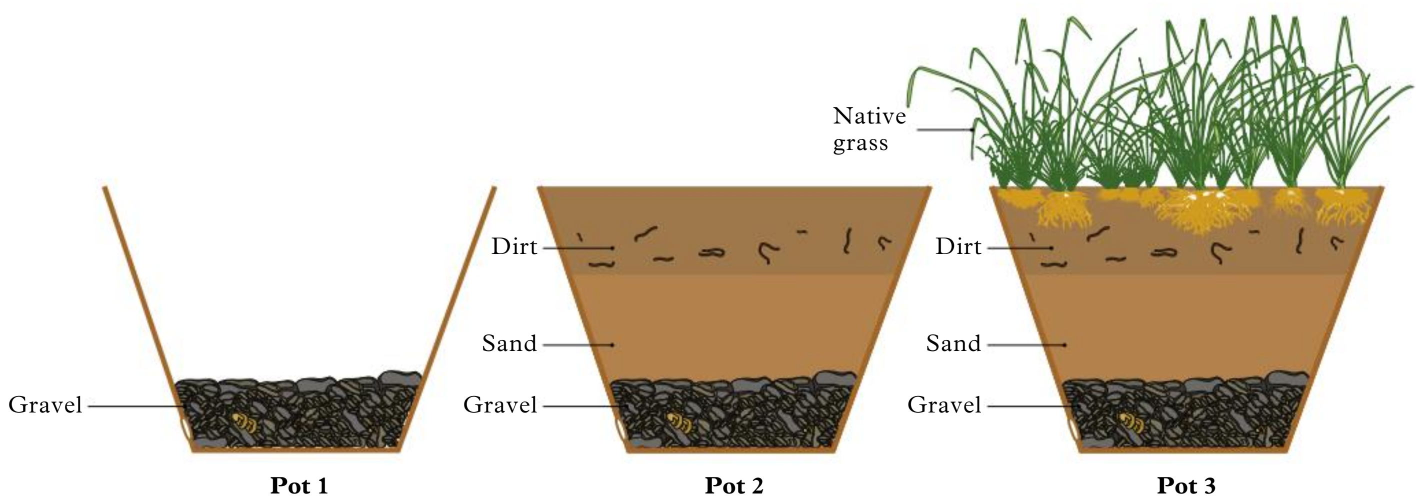


Figure 1 Experimental set-up

2.2 What if more seeds were planted in a pot?

EXPERIMENT

Aim

To investigate some factors that affect competition in plants.

Materials

> Packets of seeds (a variety of vegetables or flowers is needed)
> Small plot (20 × 20 cm) in a garden, divided into thirds, or 3 medium-sized pots containing good-quality potting mix
> Measuring cylinder or graduated jug for watering

Method

1 Prepare the plots (or pots) so the soil is moderately deep and smooth. Label them A, B and C.
2 In plot A, plant six seeds of the same type, spread evenly apart.
3 Water the soil in all plots each day as evenly as possible with the same amount of water.
4 Record the growth of the seeds. If possible, take photographs each week or every few days when the seeds begin to germinate. If the seeds become seedlings (small plants), measure their heights and record the results in a table.

Inquiry

Choose one of the following questions to investigate.

> What if more of the same seeds were planted close together in plot B?
> What if different seeds were planted between the original seeds in plot C?

Answer the following questions in relation to your inquiry.

> Identify the types of seeds that you will test.
> Write a hypothesis (If … then … because …) for your inquiry.
> Identify the (independent) variable that you will change from the first method.
> Identify the (dependent) variable that you will measure and/or observe.
> Identify two variables that you will need to control to ensure a valid test. Describe how you will control these variables.
> Identify the materials that you will need for your experiment.
> Write down the method you will use to complete your investigation in your logbook.
> Draw a table to record your results.
> Show your teacher your planning for approval before starting your experiment.

Results

Record all results. You could take photos showing the progress of growth and/or record the average heights of plants of different species and record them in a table.

Discussion

1 Identify one piece of beneficial advice that you would give another student who wants to carry out the experiment.
2 Compare (the similarities and differences between) the growth of the plants in each plot (by summarising your key observations in 2–3 sentences).
3 Use evidence from your results to describe any competition between the seeds as they germinated. Use statements such as, 'The plants in plot … grew … than the plants in plot … This implies that …'
4 Identify one other factor that might have affected the growth of the seeds. Describe how this factor could have affected the results of your experiment.
5 Describe how the competition you observed would affect organisms in the natural environment.

Conclusion

Write a conclusion about the factors that affect competition between germinating seeds.

Figure 1 What factors affect the growth of seeds?

2.3 Bead and candy counting

CHALLENGE

What you need

- Small beads (at least 15) with holes
- Hard-shell candies (at least 40)
- Cotton thread
- Paper bag
- A4 graph paper
- Pencil
- Ruler

What to do

PART A: CAPTURE–RECAPTURE

1. Place a random number of beads in a paper bag.
2. Draw 10 beads out of the bag. For each bead, thread a short strand of cotton through the hole of the bead and tie a knot around the bead. Place the 10 beads back into the bag. This is equivalent to tagging the beads and releasing them.
3. Mix the beads in the bag and draw another 10 beads out of the bag. Count the number of 'tagged' beads you collected in the 'recapture'.
4. Use the formula to determine how many beads are in the bag.

$$\text{Total number of beads} = \frac{N_1 \times N_2}{M_2}$$

where N_1 is the number of beads drawn out the first time (10), N_2 is the number of beads drawn the second time (10) and M_2 is the number of tagged beads drawn during the second draw.

5. Count the number of beads that are actually in the paper bag.

PART B: QUADRATS

1. Divide the graph paper into 20 equal-sized sections.
2. Spread a large handful of hard-shell candies over the graph paper. These represent insects in an ecosystem.
3. Count the number of 'candy insects' in four of the sections. Include the candies that are on the top lines or left lines of the squares. Do not include the candies that are on the bottom lines or right lines of the sections. Divide the number counted by 4 to determine the average number of candy insects in each section.
4. Multiply the average number of candy insects in each square (from step 3) by 20 to determine the size of the population in the ecosystem.
5. Count the number of candies that were actually spread over the graph paper.

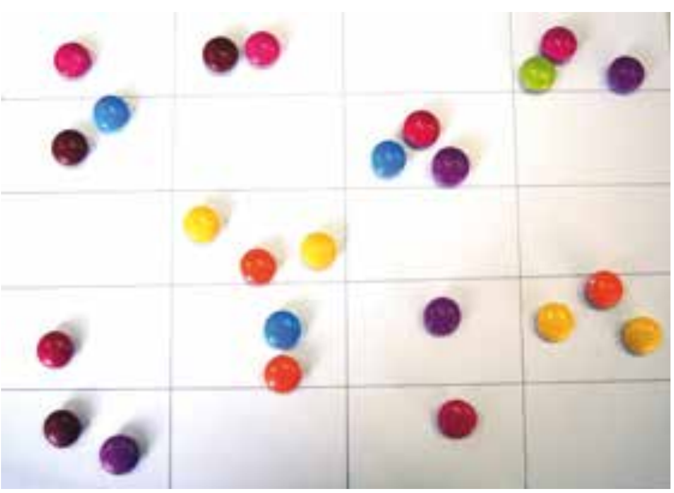


Figure 1 Counting the number of hard-shell candies.

Questions

1. Identify the types of organism populations that could be counted using:
   a. capture–recapture
   b. quadrats.
2. Describe the accuracy of the capture–recapture method in determining population size (by comparing the number of candies determined in Part A step 4 to the 'true value' counted in Part A step 5).
3. Explain which of the following animals would be more likely to be recaptured:
   - an animal that was fed and treated well during the first capture
   - an animal that became frightened and was roughly handled during the first capture.

   Justify your answer (by describing how each animal will react the next time it sees or smells a trap, and deciding which behaviour is more likely to lead to them being recaptured).
4. Describe the accuracy of the quadrat method in determining the population size.
5. Identify the size a quadrat would need to be to measure a population of fully grown trees.

2.4 Rabbit and fox chasey

CHALLENGE

What you need

- Large packets of popcorn
- Material to represent rabbit tails
- Outdoor space
- Container
- Measuring wheel
- Timer

What to do

Many scientists use simulations or modelling to determine how populations will be affected by the introduction of a new species.

PART A: RABBIT POPULATIONS

1 Measure an area of 30 m^2 outside in the schoolyard. Count out 40 pieces of popcorn. Randomly throw handfuls of the counted popcorn through the area.

2 Select five students to represent rabbits. Each 'rabbit' should tuck a piece of material into his or her belt to represent a tail. In order to survive, each rabbit must collect at least five pieces of popcorn as they cross the measured area in the 15-second 'season'. The retrieved popcorn is placed in a container at the finish line and is removed from the available resources.

3 Simulate a second season by adding another 30 pieces of popcorn and having the rabbits collect popcorn during another 15-second period. After the second season, any rabbit that survives then 'reproduces'. This involves selecting another student to join the simulation as a rabbit. The simulation is repeated, using popcorn in varying amounts to represent the food production in good and poor years, until 'starvation' begins to reduce the population.

4 Record your data for six seasons in Table 1. Highlight the seasons that are droughts (poor food supplies) and those that are bumper years (good food supplies).

Figure 1 How does food affect a rabbit population?

Table 1 Population of rabbits over many seasons

Season	1	2	3	4	5	6
Number of rabbits at end of season						

PART B: INTRODUCING FOXES

1 Repeat the simulation from Part A but this time with additional students modelling foxes. A fox must catch a rabbit in order to survive. A fox catches a rabbit by removing the cloth tail hanging from the rabbit's belt (similar to flag football).

2 Record your data for six seasons in Table 2.

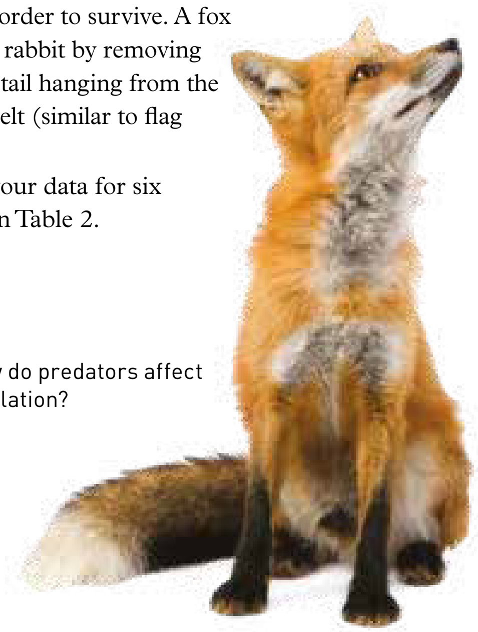


Figure 2 How do predators affect a rabbit population?

Table 2 Populations of rabbits and foxes over many seasons

Season	1	2	3	4	5	6
Number of rabbits at end of season						
Number of foxes at end of season						

Questions

1 Graph the results of the model as a bar graph showing the number of each animal at the end of a time period.

2 Identify how the following factors were represented in the model.
   a increased food supplies
   b decreased food supplies
   c competition or predator populations

3 Use data from the modelling to explain the effect of:
   a increased food supplies
   b decreased food supplies
   c competition on predator populations.

4 Explain the characteristics in a population that will help some animals to survive.

2.5A Photosynthesis role play

CHALLENGE

This is a group activity.

What you need

- Balloons (6 black, 12 white, 18 red)
- Balloon pump
- Torch

What to do

1. Work in groups of nine: one student has 6 black (carbon) balloons, four students have 3 white (hydrogen) balloons each, three students have 6 red (oxygen) balloons each and one student holds a torch.
2. In 10–15 minutes, develop a creative and entertaining way to show the process of photosynthesis.
3. Perform your role play of the process of photosynthesis for the rest of the class.

Questions

1. Explain why photosynthesis is described as a 'synthesis' reaction.
2. Describe the entry of energy and the final location of the energy in a food chain.
3. 'The energy from the Sun can be thought of as *disordered* energy which becomes *ordered* in the form of glucose and ATP.'
   Explain what you think this sentence means (by writing it in your own words).

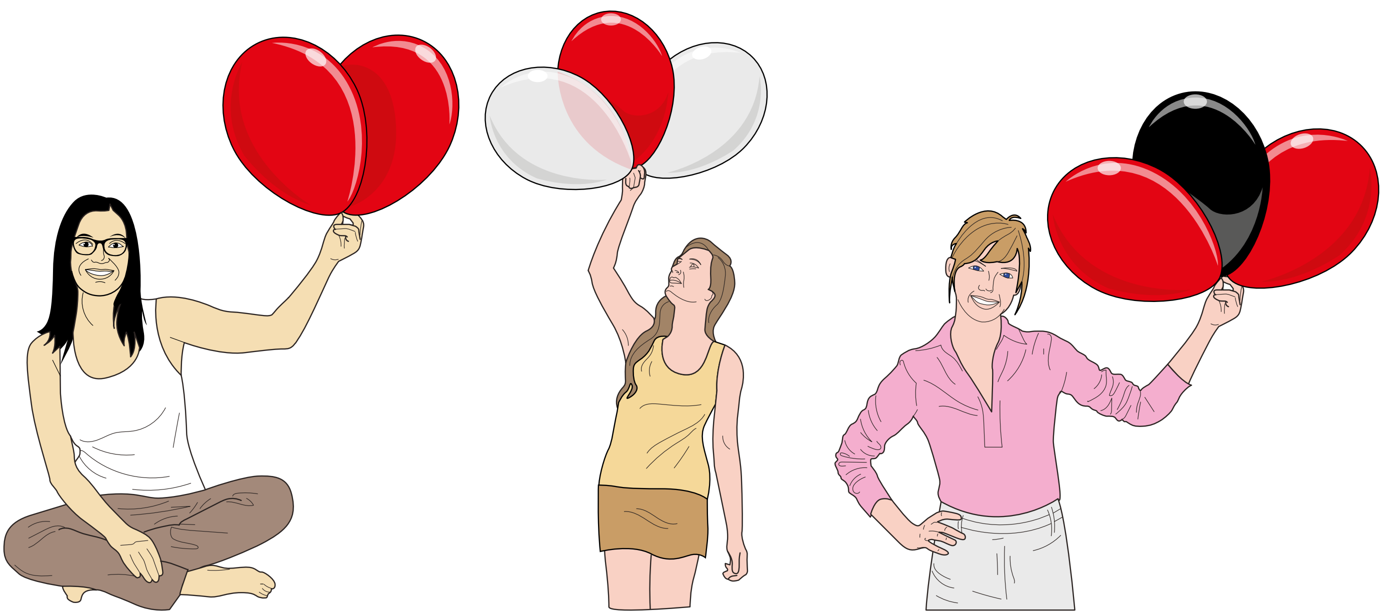


Figure 1 Modelling photosynthesis

2.5B Inputs and outputs of photosynthesis

EXPERIMENT

Aim

To examine the role of carbon dioxide in photosynthesis.

Materials

- Bromothymol blue solution in a dropper bottle
- 4 test tubes with rubber stoppers
- 2 test-tube racks
- Measuring cylinder
- Timer
- Water
- *Elodea canadensis* water plant
- Strong light source
- Clean straws
- Paperclip

Method

1 Add 2 drops of bromothymol blue solution to 15 mL of water in all test tubes.

2 Using the straw, blow into each test tube. The solutions should change from blue to yellow. This indicates the presence of carbon dioxide from your breath in the water.

3 Label the test tubes A, B, C and D. Prepare them as explained in Table 1. Place test tubes A and B in one rack, and test tubes C and D in the other rack.

Table 1 Test tube set-up

Test tube	Set-up
A	Place the paperclip on the end of an *Elodea* plant to weigh it down, and place the plant into the test tube. Place the stopper on the test tube.
B	Place the stopper on the test tube (with no *Elodea*).
C	Place the stopper on the test tube (with no *Elodea*).
D	Place the paperclip on the end of an *Elodea* plant to weigh it down, and place the plant into the test tube. Place the stopper on the test tube.

4 Expose test tubes A and B to sunlight or a bright light for 20 minutes. Record any colour change. Count any bubbles that may have formed on the *Elodea* plants.

5 Place test tubes C and D in a closed (dark) cupboard for 20 minutes. Record any colour changes and count any bubbles.

Results

Record all your observations in an appropriate table.

Discussion

1 Identify why the bromothymol blue changed from blue to yellow when you blew through the straw.

2 Describe what would happen to the bromothymol blue if the carbon dioxide was removed from the water.

3 Identify which test tube you would expect photosynthesis to occur in. Justify your prediction (by defining photosynthesis, identifying the organism responsible for photosynthesis and deciding which test tube contains the factors needed by the organism to carry out photosynthesis).

4 Identify the test tubes in which you would expect no changes in colour to occur. Justify your prediction (by describing the reactants and products of photosynthesis, identifying which reactant or product will cause a colour change and deciding which test tubes will not change).

5 Compare your results with your predictions. Use evidence from your results to justify your answer.

6 You may have observed bubbles forming around the *Elodea* leaves in test tube A. Identify this gas.

7 Identify one variable that was difficult to control in this experiment. Describe how you could control the variable next time.

Conclusion

Describe the photosynthesis reaction and where it occurs.

2.5C Effect of carbon dioxide on starch production

EXPERIMENT

CAUTION! Take care when using methylated spirits: it is highly flammable. Do not use near a flame. Use only a hotplate and water bath to heat the methylated spirits.

Aim

To find out how the concentration of carbon dioxide affects the amount of starch produced in leaves grown in different conditions.

Materials

- 3 soft-leaved plants (e.g. geranium) of same size, shape and colour, in seedling pots
- Alka-Seltzer tablet
- Soda lime (solid)
- Iodine solution (iodine in potassium iodide) in a dropper bottle (approximately 0.1 M)
- 3 large bell jars or 3 large clear plastic bags with twist ties to close them
- Petroleum jelly
- Methylated spirits
- 5 × 250 mL beakers
- Large pot (to act as a boiling water bath) that can hold three 250 mL beakers
- Boiling water
- Hotplate
- 4 Petri dishes
- Tablespoon
- Tongs
- Timer
- Paper towel
- Marker pen

Method

1. Label the three plants A, B and C. Place the plants in a cupboard for 3 days before the start of the experiment. Water the plants immediately before use.
2. Place plant A in a bell jar with a 250 mL beaker half-filled with water. Add an Alka-Seltzer (antacid) tablet to the beaker. The tablet will produce carbon dioxide gas. Seal the bell jar with petroleum jelly.
3. Place plant B in another bell jar. Put two tablespoons of soda lime in a Petri dish and place it in the jar. The soda lime will remove carbon dioxide from the air. Seal with petroleum jelly.
4. Put plant C in the third bell jar. Seal with petroleum jelly.
5. Place all three plants in a sunny place. The plants must have the same amount of sunlight and water. Leave the plants for two or three days.

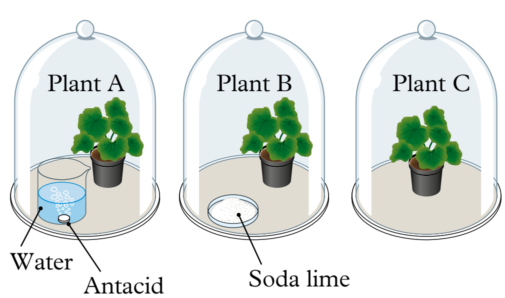


Figure 1 Experimental set-up

6. Remove the plants from the bell jars. Break off one leaf from each plant and put it into a Petri dish marked to match the plant label (i.e. A, B or C).
7. Half-fill the large pot with boiling water to make the water bath. Transfer the leaves into three labelled 250 mL beakers matching samples A, B and C. Half-fill each beaker with boiling water and place all three beakers in the water bath. Put the water bath on the hotplate and gently boil for no longer than 2 minutes, to soften the leaves. Return the leaves to their Petri dishes. Use the tongs to remove the beakers from the pot.
8. Half-fill a 250 mL beaker with methylated spirits and place it into the water bath.
9. Reheat the water bath on the hotplate. When the methylated spirits is hot, add the sample A leaf to the beaker.
10. Leave the leaf for 5 minutes or until the chlorophyll has been removed from the leaf.
11. Remove the leaf with tongs, dry it on the paper towel and return it to the Petri dish.
12. Repeat steps 9–11 for the other two leaves.
13. Place several drops of iodine solution on each leaf. Observe each leaf over a light source (e.g. light box) and describe the iodine solution's colour change on the leaf. Draw each leaf to show the colour of the iodine solution.

Results

Include your observations and diagrams in an appropriate format.

Discussion

1. Identify the level of carbon dioxide in each of the following bell jars:
   A (Alka-Seltzer), B (soda lime), C (no Alka-Seltzer or soda lime).
2. Identify the bell jar that contained the control plant. Justify your answer (by identifying the independent variable in this experiment, identifying the bell jar that the other plants will be compared to, and describing why this plant is used for a comparison).
3. Explain how the rate or speed of photosynthesis is affected by:
   a. low carbon dioxide levels
   b. high carbon dioxide levels.
4. Explain how the amount of glucose produced through photosynthesis affects the level of starch in a plant.
5. Explain why iodine was used to test for starch.
6. Compare the amount of starch that was produced in low carbon dioxide levels with the amount produced in high carbon dioxide levels.

Conclusion

Describe the effect that increasing or decreasing the amount of carbon dioxide has on photosynthesis.

2.6 Food for thought

CHALLENGE

What you need

- 2 L bottle of coloured water
- 10 mL and 100 mL measuring cylinders
- 4 plastic cups
- Dropper

Figure 1 Parts of a food chain: Sun, grass, cricket, eagle and fungus

What to do

1 Work in groups of five to represent five different parts of the food chain: the Sun, native grass (producer), a cricket (herbivore), a wedge-tailed eagle (top consumer), and a fungus (decomposer).

2 Use the bottle of coloured water to represent the Sun's energy. The total energy available from the Sun is equal to the volume in the bottle (i.e. 2000 mL).

3 Give a cup to each person representing a part of the food chain.

4 Through photosynthesis, the plant receives 3 per cent of the solar energy available to it: 3 per cent of 2000 mL = 60 mL. Measure and pour 60 mL of coloured water into the plant's cup.

5 The herbivore receives 10 per cent of the energy: 10 per cent of 60 mL = 6 mL. Measure out 6 mL from the plant's cup and pour this into the herbivore's cup.

6 The top consumer receives 10 per cent of this energy: 10 per cent of 6 mL = 0.6 mL. Measure out 0.6 mL from the herbivore's cup and pour this into the top consumer's cup.

7 When the top consumer dies, the decomposer will get 10 per cent of its energy: 10 per cent of 0.6 mL = 0.06 mL. This can be represented by adding a single drop into the decomposer's cup.

Questions

1 Identify the organism that would have been 'most satisfied' by the amount of energy/food it received.

2 Identify the organism that would have been 'least satisfied' by the amount of energy/food it received.

3 Explain what happened to the remaining 1940 mL of 'energy' from the Sun that did not pass into the plant.

3 Identify the amount of 'energy' the herbivore received. Describe how 90 per cent of the insect's (cricket's) energy was used.

4 Identify which consumer in the food chain will have to eat the most food to gain enough energy to survive. Justify your answer (by comparing the amount of food each organism can collect from the organism before them in the food chain and deciding which organism needs the greatest amount of food to survive).

2.8 Natural disasters in Australia

CHALLENGE

What you need

> Large map of Australia
> Colour-coded pins or small cardboard squares (e.g. red for bushfires, blue for floods, brown for droughts)
> Copy of Table 1

Table 1 Some natural disasters in Australia, 1974–2020

Year	Nature of disaster	Location
December 1974	Cyclone Tracy	Darwin, NT
February 1983	Ash Wednesday bushfires	Victoria and South Australia
1989	Earthquake	Newcastle, NSW
February 1993	Heatwave	South-eastern Australia
1997	Landslide	Thredbo, NSW
2003	Bushfires	Canberra, ACT
June 2007	Storm and flood	Hunter Valley and central coast, NSW
February 2009	Black Saturday bushfires	Victoria
December 2010–January 2011	Flooding	Queensland and Victoria
February 2011	Cyclone Yasi	Queensland
October 2013	Bushfires	New South Wales
February 2015	Cyclone Lam	Northern Territory
March 2017	Cyclone Debbie	Queensland
March 2018	Bushfires	New South Wales
September 2019 – March 2020	Bushfires	Queensland, New South Wales, Victoria, ACT, South Australia and Western Australia

What to do

1 Work in small groups to place pins or attach squares of the appropriate colour to the map at the part of the map affected by each natural disaster.
2 If a large area is involved, place a number of pins or squares across the area.

Questions

1 Identify the areas that were more affected by these natural events than others.
2 A student suggested that monsoonal rains should have been included in this map. Evaluate this suggestion (by defining 'natural disaster', describing monsoonal rains and deciding whether monsoon rains are classified as a natural disaster).
3 Describe the positive and negative effects of these events.
4 Identify and describe patterns in the alternation of floods and droughts.

Figure 1 Bushfires occur frequently in Australia.

2.9 Field trip

CHALLENGE

The abiotic features of the environment determine the vegetation in an ecosystem.

Choose an ecosystem, such as a woodland, grassland or rainforest. After a short study of the vegetation, measure the abiotic factors and form a conclusion about how these factors determine the type and height of the vegetation. You may need the following materials and equipment.

> Thermometer (for temperature)
> Wet/dry thermometer (for humidity)
> Anemometer (for wind speed)
> Light meter (for light)
> Rod (for measuring soil depth)
> Cobalt chloride paper (for soil moisture)
> Soil pH kit or pH paper

Note: Data loggers may be used if preferred.

What to do

1. Observe the plants around you. Describe what you see. You could take photos, draw diagrams or write descriptions.
2. Examine the leaves of the plants. List three of their characteristics and how this feature could give the plant an advantage over other plants.
3. Choose one species of plant. Record its common name, its scientific name and, if possible, the family of plants to which it belongs. Sketch a leaf of this plant.
4. Describe how your chosen plant is adapted to the conditions in the ecosystem.
5. Measure the abiotic factors shown in Table 1, for your chosen ecosystem.

Table 1 Abiotic factors in an ecosystem

Abiotic factor	Reading
Temperature	
Wind speed	
Humidity	
Light intensity	
Soil depth	
Soil colour	
Soil moisture	
Soil pH	

6. For each observation and measurement you made, analyse and evaluate its significance. It might be appropriate to research and analyse the history of the area you are studying.

Questions

1. Describe the abiotic conditions in the environment you examined.
2. Describe the vegetation in this ecosystem.
3. Describe how this environment may be affected by increased human population in the future.

Figure 1 Open temperate woodlands allow some sunlight to reach the ground, which allows grasses to grow. Water can be a limiting factor in these areas.

Figure 2 Increased rainfall and open areas allow undergrowth to develop.

Figure 5 Air temperature is an abiotic factor.

Figure 3 Plants that survive in drier areas have unique adaptations such as thin, needle-like leaves.

Figure 4 The level of acid in the soil can affect the growth of a plant.

3.1 Testing your senses

CHALLENGE

PART A: TEMPERATURE RECEPTORS

What you need

- Very warm water
- Room temperature water
- Warm water (no hotter than 50°C; use the thermometer to check)
- Ice cubes
- 3 ice-cream containers
- Thermometer
- Timer

What to do

1. Half-fill one container with cold water and add the ice cubes.
2. Half-fill the second container with room temperature water.
3. Half-fill the last container with very warm water.
4. Place one hand in the iced water and the other in the very warm water for 2 minutes.
5. Remove your hands from the iced and very warm water and place them (at the same time) in the room temperature water.

Questions

1. Identify the stimulus experienced by the hand in very warm water.
2. Contrast (the differences between) the information provided by the temperature sensors in the hand when it moved from:
   a. the iced water to the room temperature water
   b. the very warm water to the room temperature water.
3. Evaluate the effectiveness of the temperature receptors on the skin of your hand (by comparing the messages sent to the brain by both hands and deciding whether the temperature receptors provide an accurate measure of the water temperature).
4. Explain why scientists use a thermometer rather than their hands to test the temperature of solutions.

PART B: TOUCH RECEPTORS

What you need

- 2 toothpicks
- Ruler
- Modelling clay
- Blindfold

What to do

1. Work in pairs. One person puts on the blindfold.
2. Place the toothpicks 50 mm apart in the modelling clay.
3. Using the modelling clay, place the pointed ends of the toothpicks gently on the blindfolded person's finger. Ask them whether they feel one or two points.
4. If two points are felt, move the toothpicks closer together and repeat step 3.
5. Repeat steps 3 and 4 until the blindfolded person reports 'one point' for the first time.
6. Record the distance between the two pointed ends of the toothpicks in a table.
7. Repeat this procedure for the palm of the hand, back of the hand and forearm.

Questions

1. Contrast (the differences between) the 'two point' distances on different areas of the skin.
2. Identify the part of the body that was able to detect the closest toothpicks.
3. Identify which skin areas have the most touch receptors. Justify your answer (by describing how touch receptors work, describing how a receptor might mistake two toothpick points for a single touch, and using your answers to questions 1 and 2 to decide which area of skin has the most touch receptors).

3.2 Pipe cleaner neurons

CHALLENGE

What you need

- 5 different-coloured pipe cleaners representing different parts of the neuron (cell body, axon, dendrites, myelin sheath, synaptic terminal)
- A3 or A4 paper
- Sticky tape
- Red felt-tipped pen

What to do

1. Roll a pipe cleaner into a ball to represent the cell body.
2. Attach another pipe cleaner to the cell body by pushing it through the ball so that there are two halves sticking out. Twist the two halves together into a single long axon.
3. Push another pipe cleaner through the cell body on the side opposite the axon to make a dendrite. This can be shorter than the axon and you can twist more pipe cleaners to make more dendrites.
4. Wrap a pipe cleaner along the length of the axon to form the myelin sheath.
5. Wrap another pipe cleaner on the end of the axon to make the synaptic terminal.
6. Tape your finished pipe cleaner neuron onto a piece of A3 or A4 paper and label the parts.
7. Mark the path of the nerve impulse, from start to finish, along the neuron.

Questions

1. Describe the role of a neuron.
2. Describe the role of the myelin sheath.
3. Explain how the message moves from one neuron to another via the synapse.

3.3A Testing reflexes

CHALLENGE

What to do

1. Look at the pupils (the black spots in the middle of the eyes) in the eyes of a classmate. Note the size of the pupils.
2. As a class, dim the lights in the room. After a few minutes, look at your classmate's eyes and note the size of the pupils.
   - How big are the pupils?
3. Turn the lights back on. Check the size of your classmate's pupils again.
   - How big are the pupils this time?

Questions

1. Describe how the pupils of the eyes changed when:
   a. the room was dimmed
   b. the lights were turned back on.
2. Describe the role of the pupil in the eye.
3. Describe an advantage of the change in pupil size when moving in and out of dark space.
4. With a partner, design an experiment to test another reflex. Write an aim and a reproducible method for your experiment.

Figure 1 Which pupil is in low light and which is in bright light?

3.3B How fast is the nervous system?

CHALLENGE

What you need

- Metre ruler
- Blindfold

What to do

1. Work in pairs. Student 1 holds the ruler between their thumb and forefinger so that the ruler hangs with the zero mark at the bottom. Student 2 waits with their thumb and forefinger at the bottom of the ruler, level with the zero mark.
2. Student 1 drops the ruler without warning. Student 2 catches the ruler as fast as they can between their thumb and forefinger.
3. Record the number of centimetres the ruler has dropped, by looking at the location of Student 2's thumb and forefinger on the ruler (Figure 1).
4. Repeat until you have 10 results for each student.
5. Work out the average reaction distance for each student.
6. Measure the approximate distance the messages must have travelled if they travelled from your eye to your brain to your fingers.
7. Try the experiment using touch only. Blindfold Student 2. When Student 1 drops the ruler, they tap Student 2 on the head. Does this make a difference to the reaction distance?
8. Try the experiment using hearing only. Blindfold Student 2. When Student 1 drops the ruler, they say 'now'. Does this make a difference to the reaction distance?

Questions

1. Contrast the results of the three experiments (no blindfold, blindfold and tap, blindfold and voice) to determine which experiment had the fastest results.
2. Evaluate the reliability of your results (by describing whether all the variables were controlled, explaining possible errors that need to be improved, and deciding whether anyone who repeated the experiment would obtain the same results).

Figure 1 Testing responses **a** using sight **b** using hearing

3.4 Sheep brain dissection

SKILLS LAB

CAUTION! Wear your lab coat, safety glasses and plastic gloves. Be careful with the scalpel because it is likely to be very sharp. Cut away from your hands and other people.

Aim

To explore the structure of a sheep's brain.

Materials

- Sheep's brain
- Dissecting board
- Scalpel
- Dissecting scissors
- Coloured pins
- Microscope, slide and cover slip (optional)
- Forceps

Method

1. Examine the outside of the brain. Set the brain down so that the flatter side, with the white spinal cord at one end, rests on the board (Figure 1). Using the different-coloured pins, identify the two hemispheres, the four lobes of the brain, the spinal cord, the cerebellum and the cerebrum. Draw a diagram (in pencil) or take a photo that displays the different sections of the brain. Check this with your teacher before continuing.

Figure 1 Step 1

2. Remove the pins and turn the brain over (Figure 2). Identify the medulla and the pons. Draw a diagram or take a photo that displays these parts of the brain.

Figure 2 Step 2

3. Place the brain with the curved top side of the cerebrum facing up. Use a scalpel to slice through the brain along the centre line, starting at the cerebrum and going down through the cerebellum, spinal cord, medulla and pons (Figure 3). Separate the two hemispheres of the brain (Figure 4). Draw a diagram or take a photo that displays these parts of the brain.

Figure 3 Step 3: Slice along the brain.

Figure 4 Step 3: separate the two hemispheres.

4. Cut one of the hemispheres in half lengthwise. Record what you see.
5. If a microscope is available, slice a very thin section of the cerebrum and put it on a slide, covering it with a drop of water and a cover slip. Draw a diagram of what you observe at low and high magnifications. Follow the same procedure with a section of the cerebellum, and then compare the two sections of the brain.

Discussion

1. Describe the texture of the brain (smooth, rough, slippery, waxy, tacky, flimsy, chalky, hard, soft, granular, rubbery).
2. Compare (the similarities and differences between) the structure of the sheep's brain and what you know about a human brain.
3. Contrast the cognitive functions (ability to think and reason) of a sheep and a human. Describe how these differences could be reflected in the structure of the brain.

3.6 Glands and organs of the endocrine system

CHALLENGE

What you need

> Large sheet of butcher's paper
> Felt-tipped pen
> Sticky tape

What to do

1 Working in pairs, draw an outline of your partner's body on the paper.
2 With your partner, draw in the glands and organs of the endocrine system. Using the information in Table 1 (page 60), annotate each gland with a brief description, in your own words, of what it is responsible for.
3 Use colour coding and arrows to show the path of the hormone(s) produced by each gland to its target organ.

Questions

Choose one gland or organ to research.

1 Identify the main hormone the gland secretes.
2 Describe how the hormone affects the target cells in the target organ.
3 Describe one disorder that results from a malfunction of this organ or gland.

3.7 Experiencing homeostasis

EXPERIMENT

Aim

To demonstrate how homeostasis maintains control of the heart rate during and after exercise.

Materials

> Stopwatch
> Heart rate monitors (optional)

Method

1 While sitting down, find your pulse and count the number of times your heart beats in 15 seconds.
2 Multiply this number by 4 to determine the number of beats every minute.
3 Measure your respiration rate by counting the number of breaths you take in 1 minute.
4 Do repeated step-ups or star jumps for 2 minutes. (Make sure you are wearing appropriate shoes.)
5 Measure your heart rate and respiration rate immediately after stopping exercise.
6 Measure your heart and respiration rate every 2 minutes for 10 minutes.

Results

1 Record the data in a table.
2 Draw a line graph showing how your heart rate varied after exercise.
3 Draw a line graph showing how your respiration rate varied after exercise.

Discussion

1 Describe how your breathing rate changed during and in the 10 minutes after exercise.
2 Explain why your heart rate increased during exercise.
3 Describe what happened to your heart rate during the 10 minutes after exercise.
4 Use the concept of homeostasis to explain why your heart rate was different before, during and after exercise.

Conclusion

Describe how homeostasis ensures that our muscles get enough nutrients and remove wastes during exercise.

Figure 1 Heart rate monitor on a smart watch

3.9A Investigating pathogens

CHALLENGE

Pathogens are organisms that cause disease.

What you need

> A selection of research resources, such as books, medical dictionaries, journals and computers

What to do

1 Working in small teams, brainstorm for 3 minutes and prepare a list of as many pathogen-caused diseases as you can.
2 You now have 2 minutes to predict the type of organism that causes each of the diseases in your list. Next to each disease, write one of the following words as your prediction: worm, fungus, protozoan, bacterium, virus.
3 Spend a minute discussing how your team can use your resources to confirm or refute your prediction. You must use at least two different types of valid reliable resources.
4 You now have 10 minutes to research the list of diseases to confirm which group of organisms causes each disease.

Questions

1 Describe the types of resources that you used in your research. Describe two types of resources that you avoided and why you avoided them.
2 Draw a bar graph showing the number of diseases you listed for each type of organism.
3 Identify the organism that occurred most frequently (the mode) on your list. Describe why you might be more familiar with the causes of some types of disease.

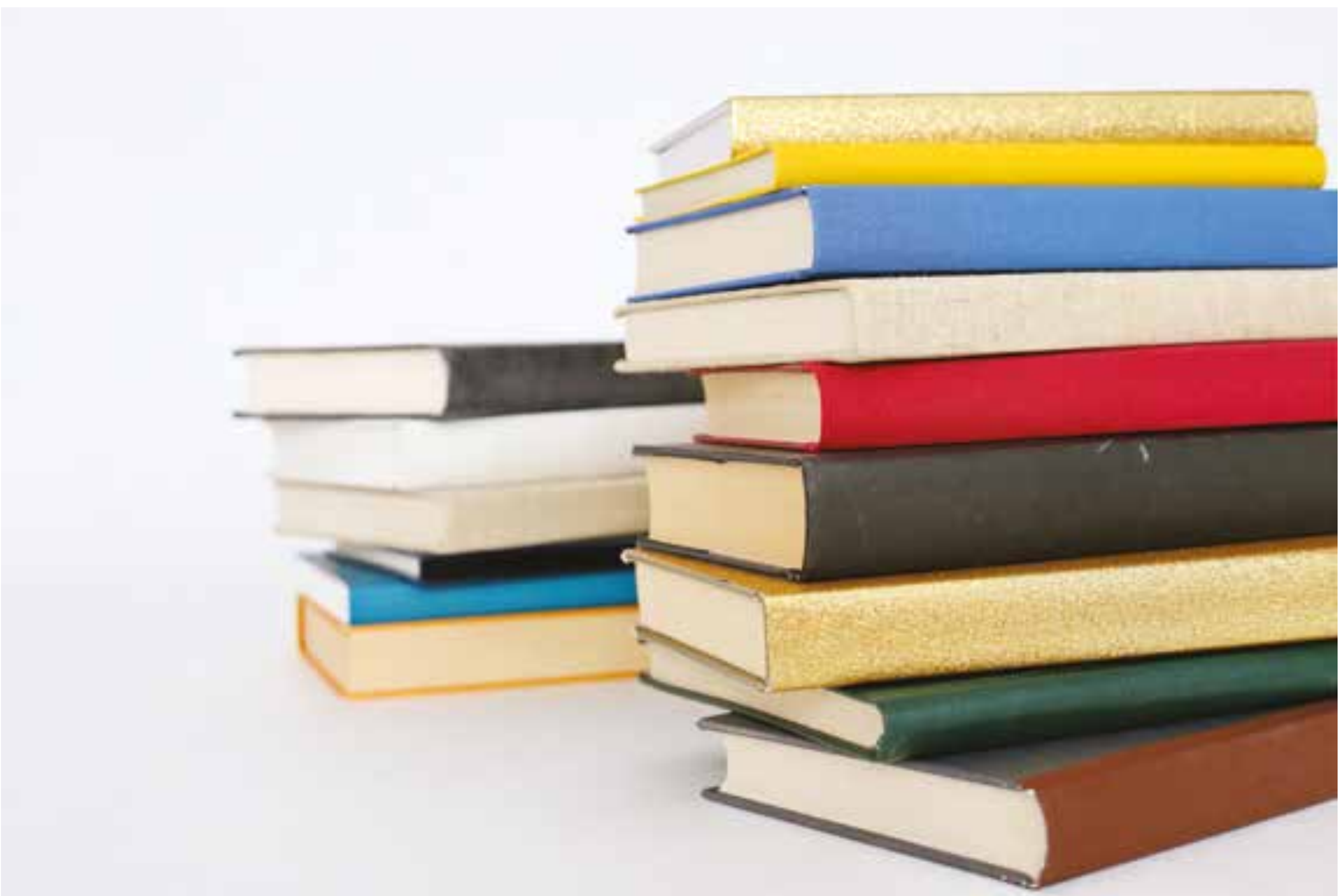


Figure 1 Books can be used to conduct research on disease.

3.9B Investigating germ theory

EXPERIMENT

CAUTION! Do not open the tape seals.

Aim

To determine what factors affect the growth of airborne microbes.

Materials

- Agar plates
- Various disinfectants
- Incubator
- Sticky tape or paraffin film
- Permanent marker
- Timer

Method

1. Open the lid of one agar plate and leave it sitting on the bench for 15 minutes.
2. Place the lid on the top and seal the agar plate with sticky tape. Write the label 'Open bench' around the edges underneath the plate, so that it does not obstruct the view of the agar.
3. Leave another agar plate unopened. Seal it with sticky tape. Label the plate 'Control'.
4. Incubate the agar plates at 35–37°C for approximately 3 days.
5. Do not open the plates! Examine the closed plates for any growth.

Inquiry

What if the first agar plate was sprayed with a disinfectant before being incubated?

Answer the following questions with regard to your inquiry question.

- Write a hypothesis (If … then … because …) for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables you will need to control to ensure a valid test. Describe how you will control these variables.
- Identify the materials you will need for your experiment.
- Write down the method you will use to complete your investigation in your logbook.
- Draw up a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Record all your results. You could take photos showing the microbe growth on the agar plates.

Discussion

1. Define the term 'bacterial colony'.
2. Describe how a bacterial colony forms on an agar plate.
3. Explain why colonies are different colours and sizes.
4. Compare the colour and size (diameter) of the different colonies that grew on each plate.
5. Explain why you left one agar plate unopened.
6. Evaluate whether your results support germ theory (by explaining germ theory, comparing your results to germ theory, and deciding whether your results support germ theory).
7. Evaluate whether your results support your hypothesis (by describing your results in 1–2 sentences, comparing your results to your hypothesis, and deciding whether your hypothesis was supported).

Conclusion

Describe the factors that affect the growth of microbes.

3.10 Modelling infection and vaccination

CHALLENGE

What you need

> 1 M sodium hydroxide
> 0.1 M hydrochloric acid
> Water
> Phenolphthalein indicator
> Plastic cups
> Pipette
> Felt-tipped pen

What to do

1 Half-fill a plastic cup with water and label it with your name.
2 All students place their cups on one table.
3 Students turn their back while the teacher adds 2 mL of sodium hydroxide to one cup. This represents a student having an infection.
4 Students then collect their cups and use the pipettes to exchange 3 mL of water with three other students. This is equivalent to shaking hands. Record who you 'shook hands' with in a table like the one below.

Person 1	Person 2	Person 3

5 Add a few drops of phenolphthalein indicator to each cup, to determine who caught the disease.
6 Use the information recorded in the table to determine who the original source of the infection was.
7 Repeat steps 1–5, this time choosing whether or not to become 'vaccinated'. Vaccination is done by adding 2 mL of hydrochloric acid to your cup of water. Redraw the table to record who you shook hands with after some people were vaccinated.
8 Repeat this activity, increasing the number of people vaccinated.

Questions

1 Identify the number of people who became infected when no one had been vaccinated.
2 Identify the number of people who became infected when a few people had been vaccinated.
3 Identify the number of people who became infected when more people had been vaccinated.
4 Explain why vaccination affected the number of people who became infected.
5 Describe a real-life example of how vaccination can protect vulnerable members of the community.

4.1A Reconstructing Pangaea

CHALLENGE

What you need

> Photocopy of a map of the world
> Scissors
> Glue

What to do

1 Roughly cut out the continents of the world and fit them back together in the shape of Pangaea.
2 Remember to cut off India from Asia, because it was once separated.
3 When you are happy with your supercontinent, glue the pieces into your science book.
4 You may like to add to your supercontinent what you know about the locations of the fossil and glacier evidence.

Questions

1 Explain why fossil twigs, roots and pollen found in Antarctica are almost identical to those found in Tasmania.
2 Identify one other country that may have fossils similar to those found in Australia.
3 Explain how this activity provides evidence of tectonic plate movement.

Figure 1 Fossil ferns in a rock

4.1B Milo convection currents

CHALLENGE

CAUTION! Do not eat in the laboratory. If the Milo will be consumed, this experiment should be done in a canteen/cafe.

This is a whole-class demonstration.

What you need

- 1 small container of Milo (Nesquik will dissolve too easily)
- 1 L of milk
- Saucepan
- Hotplate

What to do

1. Pour the milk into the saucepan and add a very thick layer of Milo over the surface.
2. Place the saucepan on the hotplate and heat slowly without stirring.
3. Record your observations of how the Milo cracks and moves as a result of the hot milk rising to the surface.

Questions

1. Describe how the heat from the hotplate moved into the milk. Identify which part of the milk was first heated.
2. Explain why heated milk rose to the surface.
3. Explain why the Milo moved the way it did when the heated milk rose to the surface.
4. Compare the movement of milk and Milo in this experiment to the breaking up of Pangaea into smaller pieces.

Figure 1 The Milo on the surface will move as heat is transferred to cooler areas of the cup.

4.2A Cooling and layers

EXPERIMENT

Aim

To investigate whether cooling of a substance causes layers to form.

Materials

- 250 mL beaker
- Copper sulfate (solid)
- Spatula
- Glass stirring rod
- Bunsen burner
- Heatproof mat
- Tripod
- Gauze mat
- Matches
- Water

Method

1 Set up the heating equipment and boil 50 mL of water in the beaker (Figure 1).

Figure 1 Heat the water

2 When the water is boiling, turn off the gas. Add the copper sulfate to the boiled water a little at a time, using the spatula and stirring constantly to make it dissolve (Figure 2). Stop when no more copper sulfate will dissolve.

Figure 2 Add copper sulfate

3 Allow the beaker of saturated copper sulfate solution to cool undisturbed for about 20 minutes, then carefully place it in the fridge. Examine it after an hour if possible (or the next day).

4 When the beaker has cooled, without moving the beaker, examine its contents and observe where any solid copper sulfate might be located.

Figure 3 Examine the cooled contents

Results

Describe what happened as the beaker cooled, and record where any solid copper sulfate is located.

Discussion

1 Contrast (the differences between) the density of solid copper sulfate and liquid water.

2 Compare (the similarities and differences between) the formation of solid copper sulfate from a solution, to the formation of solid tectonic plates formed from a molten mass.

Conclusion

Explain why layers are formed when a substance cools.

4.2B Modelling the parts of the Earth

CHALLENGE

CAUTION! Some students might have egg allergy.

What you need

> Hard-boiled egg
> Teaspoon

What to do

1 Gently crack the shell of the hard-boiled egg. The egg can be seen as a tiny model of the Earth. The thin shell can represent the Earth's crust, and within the shell can represent the Earth's mantle.
2 Move the pieces of the shell around. These pieces can represent the Earth's tectonic plates. Notice how the pieces of shell collide in some places and reveal pieces of the 'mantle' in others. This also happens on the Earth, resulting in volcanoes, earthquakes and the formation of mountain ranges.
3 Break the egg completely open. The yolk represents the core of the Earth.

Questions

1 In your model, the shell represents the Earth's crust. Describe what happened when you pushed two pieces of shell towards each other.
2 Describe an example of how this can happen with the Earth's crust.
3 Identify which parts of the egg should be liquid in a more accurate model of the Earth.

Figure 1 The egg's shell represents the Earth's crust, and within represents the mantle and the core.

4.3 Modelling plates

CHALLENGE

What you need

> Play dough
> Spatula

What to do

1 Wash your hands before starting this activity.
2 Use a clean spatula to cut the play dough in half lengthways. Flatten each half into a flat, thick rectangle, and place the two 'plates' beside each other.
3 To illustrate a transform boundary, gently push the 'plates' so that their sides are in firm contact with each other, then slide one half of the play dough forwards and the other backwards. Describe your observations.
4 To illustrate the force of compression associated with mountain building when continental plates collide, push on both sides of the play dough to squeeze it together. Describe your observations.

Questions

1 Describe the vertical movement of the top of the play dough when you modelled a transforming boundary.
2 Describe what happened to the top of the play dough when you modelled a converging boundary.
3 Describe how you would model a diverging boundary.
4 Explain how the play dough would change in your model of a diverging boundary.
5 Test your prediction. Compare your observations to your prediction.

Figure 1 Play dough can be used to model plate boundaries.

4.4 Volcanic bubbles

CHALLENGE

What you need

- Powdered chalk
- Vinegar
- Red food dye with dropper
- Bottle of lemonade
- 100 mL beaker
- Teaspoon

What to do

1 In a 100 mL beaker mix a small amount of powdered chalk with one teaspoon of vinegar and a few drops of food dye. The reaction produces carbon dioxide bubbles and the food dye makes the froth look like lava.

2 Tiny gas bubbles form as the pressure in a bottle of lemonade is released. As the pressure is released more, bigger bubbles form. This can be seen by slightly twisting the screw top of a bottle of soft drink, such as lemonade. The more you twist the lid, and the more pressure that is released, the bigger the bubbles. This is like the cooling of magma inside a volcano.

Questions

1 Compare (the similarities and differences between) the formation of carbon dioxide in step 1 with the gases formed in lava.

2 Compare the pressure in the lemonade bottle to the pressure in a volcano.

3 Step 1 described the formation of gases, while step 2 described how the size of the bubbles increased as pressure was released. Use this information to describe the formation of pumice (Figure 1) during a volcanic eruption.

Figure 1 Gas bubbles formed the holes in this piece of pumice rock.

5.1 What is the ratio of atoms in a compound?

CHALLENGE

What you need

- 2 marbles (representing hydrogen)
- 2 golf balls (representing oxygen)
- 50 g weight (representing carbon)
- Scales
- Paper bags

What to do

1 Place two marbles and one golf ball in a paper bag.

2 Use the scales to weigh the bag.

3 Add one 50 g weight and two golf balls to a different paper bag.

4 Use the scales to weigh the bag.

5 Your teacher will prepare a mystery bag of items in a combination that matches step 1 or step 3. Without opening the bag, use the scale to determine its weight. Prepare a hypothesis of what items are in the bag. Provide evidence from your previous results to support your hypothesis.

6 Open the bag to determine the accuracy of your hypothesis.

Questions

1 Identify the molecule that was formed in step 1.

2 Identify the molecule that was formed in step 3.

3 Evaluate the accuracy of your hypothesis (by describing the data you gathered about the mystery bag, comparing this data evidence to your hypothesis, and deciding whether your hypothesis was accurate).

4 Describe how you could use this process to determine what atoms were in a completely new compound ($C_6H_{12}O_6$).

5.2A How can you tell what is inside?

CHALLENGE

This kind of investigation uses 'indirect evidence'. It has been used by many scientists when trying to work out what is inside the atom.

What you need

- Ball
- Soft-drink can
- 2 nails
- Wooden block
- 3 small boxes
- Scales

What to do

1 Form two teams (A and B) of three students to work with each other.
2 Team A places one item in each of the small boxes. The boxes are then closed.
3 Team B plans a way of determining what is inside each of the boxes without opening or touching them. They can use any equipment that is available in the science laboratory. The team writes the steps of the method in their logbooks.
4 Team B then follows the method to touch and examine the boxes, still without opening them.
5 Repeat the process, with Team B preparing a box and Team A determining what is inside the box.

Questions

1 Contrast 'direct evidence' and 'indirect evidence'.
2 Describe the senses that team B used to identify what was inside the box.
3 Describe how scientists might have used indirect evidence to model what is inside an atom.
4 Identify at least one other field of scientific investigation in which scientists would have to use indirect evidence to develop their theories.

Figure 1 How can you determine what is in the box?

5.2B Rutherford model of the atom

CHALLENGE

CAUTION! Do not eat the popcorn used in the experiment.

What you need

- Hula hoop
- String
- Empty matchbox
- Popcorn
- Scissors

What to do

1 Tie the string securely around the matchbox and suspend it in the middle of the hula hoop.
2 One person holds the hula hoop so that it and the matchbox are hanging vertically, facing a second person.
3 The second person stands 1–2 m away and throws one piece of popcorn at a time at the hula hoop. Repeat 10 times.
4 Record how many kernels of popcorn go through the hoop and how many bounce off the matchbox.

Questions

1 The hula hoop represents a gold atom in Rutherford's experiment. Identify what the matchbox represents.
2 Identify the number of popcorn pieces that bounced off the matchbox.
3 Explain how your model of Rutherford's experiment provides supporting evidence for the Rutherford model of the atom.

Figure 1 What does popcorn represent in this experiment?

5.4 Flame tests

EXPERIMENT

CAUTION! Wear safety goggles and a lab coat. Ensure hair is tied back and loose clothing is removed or tucked away. Wire loops and flames are hot. Be careful not to burn yourself. 1 M hydrochloric acid can give a small chemical burn. If contact occurs, wash skin with tap water immediately.

Aim

To observe the coloured light emitted when certain substances are heated in a flame.

Materials

- Solid samples of sodium carbonate, copper carbonate, potassium carbonate and strontium carbonate
- 1 M hydrochloric acid
- Bunsen burner
- Heatproof mat
- Matches
- Wire loops

Method

1. Set up your Bunsen burner, observing safety instructions, and light the Bunsen burner on the safety flame.
2. Adjust the Bunsen burner to the blue flame. Take a wire loop and dip it in a small beaker of 1 M hydrochloric acid. Flame the loop. This will clean the loop, ready for your solid sample. Avoid getting too close to the flame. Stand back a little.
3. Take a loop of solid chemical and place it in the flame. Observe the colour of the flame. Try not to lose the solid down the Bunsen burner barrel. This could block the burner and contaminate the flame, changing the colour.
4. Once you have finished your observation, dip the loop in the 1 M hydrochloric acid again and re-flame it. This will clean the loop for the next sample.
5. Repeat steps 3 and 4 for the other samples.

Results

Record your results in an appropriate table.

Discussion

1. Explain why the loop was treated with hydrochloric acid before any carbonates were tested.
2. Explain why the flame colour changed in the different chemicals.
3. Evaluate whether the colour change is a chemical change or a physical change (by defining chemical change, defining physical change, comparing the change in the chemicals to these definitions and deciding the type of change).
4. Explain why the electrons in different elements produce different colours.
5. Identify whether the colour change is caused by the metal or the carbonate part of the powder. Justify your answer (by describing the differences between the chemicals tested and describing how these differences caused the colour changes).

Conclusion

Describe what you know about the different coloured flames produced by different elements.

Figure 1 Flames can change colour depending on what substances are heated.

5.6 Calculating relative atomic mass

CHALLENGE

Your bag contains a sample of a new element called 'legumium' (symbol Lg). The atomic number of legumium is 4. There are three isotopes of this element. The smallest isotope is ^{4}Lg. The next in size is ^{5}Lg, which has an atomic mass of 5. The largest of the isotopes is ^{6}Lg, which has an atomic mass of 6. Your role is to determine the relative atomic mass of the element and its isotopes.

What you need

- 1 bag of 'isotope sample' containing 8 large dried lima beans, 11 baby lima beans and 15 black-eyed peas
- Scales

What to do

1. Record the total number of isotopes in your sample.
2. Record the number of each of the isotopes in your sample.
3. Weigh each legumium isotope and record the mass in an appropriate table.
4. Use the equation below to determine the relative atomic mass of legumium.

$$\text{Average atomic mass Lg} = \frac{(\text{number of } ^{4}\text{Lg} \times \text{mass } ^{4}\text{Lg}) + (\text{number of } ^{5}\text{Lg} \times \text{mass } ^{5}\text{Lg}) + (\text{number of } ^{6}\text{Lg} \times \text{mass } ^{6}\text{Lg})}{\text{total number of isotopes}}$$

Questions

1. For each legumium isotope, show its mass, atomic number and symbol.
2. Identify the number of protons, neutrons and electrons in each isotope.
3. According to your sample, explain which legumium isotope is most common in nature.

5.7 Modelling radioactive decay

CHALLENGE

This activity illustrates the idea of exponential decay and half-life. Counters represent the nuclei.

What you need

- Counters (at least 30)
- A4 paper
- Disposable plastic cup
- Permanent marker

What to do

1. Draw up a table like the one below, to record your results.

Number of shakes	Number of undecayed 'atoms'		
	Trial 1	Trial 2	Trial 3
0 (start)			
1			
2			
…			

2. Draw an M on one side of each counter.
3. Count the total number of counters that you have, record this number and place them in the plastic cup.
4. Shake the cup and tip all the counters onto the paper.
5. Those that have the 'M' facing upwards represent atoms that have decayed. Move these to a 'discard' pile.
6. Count the remaining 'nuclei' and record this number.
7. Place the remaining nuclei back into the cup, shake them and tip them out again.
8. Move the decayed nuclei to the discard pile and count those remaining. Record the number.
9. Continue until you have three or fewer nuclei.
10. Repeat the whole process two more times.
11. Draw a set of axes with the number of atoms remaining (vertical axis) and the number of shakes (horizontal axis). Plot points and draw a line of best fit through the points for each of the three trials.

Questions

1. The atomic nuclei were represented by counters. Describe how the half-life of the decay process was represented.
2. Contrast the shapes of the curves drawn for each trial.
3. Explain how the overall shape of the curves would or would not change if you started with more atomic nuclei.
4. In this experiment, you would eventually end up with no 'undecayed' counters. Evaluate whether this would be the case with a real radionuclide (by describing how atoms randomly decay in real life, **comparing** this to the counter demonstration and **deciding** whether every atom of a real radionuclide would become stable).

6.1 Energy changes

EXPERIMENT

CAUTION! Wear your lab coat, safety goggles and plastic gloves. Check the safety data sheets to see how to handle the chemicals in this experiment safely.

Aim

To investigate an exothermic and an endothermic process.

Materials

- Sealed bottle containing potassium nitrate (KNO_3)
- Sealed bottle containing calcium chloride ($CaCl_2$)
- Measuring cylinder
- Water
- Stirring rod
- Thermometer (or temperature sensor)
- 2 foam cups
- 2 spatulas
- Stopwatch
- Wash bottle
- Residue bottle

This experiment may be carried out using a temperature probe and data logging equipment instead of a thermometer.

Method

1. Prepare a table to record the times and temperatures.
2. Measure 50 mL of water into a foam cup.
3. Measure the temperature of the water and record it.
4. Place three heaped spatulas of calcium chloride in the water and immediately commence stirring and timing.
5. Record the temperature every 15 seconds for 3 minutes.
6. Dispose of the solution into the container provided and carefully rinse the thermometer with the wash bottle, ensuring the rinse water is also added to the residue bottle. Dispose of the cup as directed by your teacher.
7. Repeat steps 2–6 using potassium nitrate.

Figure 1 This experiment requires a stopwatch.

Results

Draw a graph of temperature versus time, and plot your results from the two chemicals on the same graph. Make sure you label both axes and use the correct units.

Discussion

1. Identify the reaction that had products with less energy than the reactants.
2. Identify the reaction that had products with more energy than the reactants.
3. Identify which reaction was endothermic. Justify your answer (by defining the term 'endothermic' and comparing this definition to the changing temperatures of the matching experiment).
4. Identify which reaction was exothermic. Justify your answer.
5. Use the graphs to describe how quickly (the rate) the temperature rose or fell.
6. Explain why the temperature reached a steady value after some time.
7. Identify two variables that needed to be controlled in this experiment. Describe how they were controlled.
8. Describe one change that you would make to improve the reliability of the results.

Conclusion

Describe what you know about exothermic and endothermic reactions.

6.2A Testing with pH paper

CHALLENGE

What you need

- pH paper and pH colour chart or universal indicator
- White spotting tile
- Variety of laboratory acids and bases
- Vinegar
- Milk
- Toothpaste
- Lemon juice
- Water

What to do

1. Tear off about 1 cm of pH paper and place it on the white tile.
2. Place a drop of a laboratory acid on the paper.
3. Compare the colour of the wet spot on the pH paper with the pH colour chart.
4. Repeat for the laboratory bases.
5. Test each of the remaining substances on new sections of the pH paper. For each substance, record the pH colour and number and note whether the substance is an acid, a base or neutral.
6. Dilute some of the substances with water and measure the pH of the diluted solutions with more indicator paper.

Questions

1. Identify which substance was the most acidic solution that you tested (lowest pH).
2. Identify which substance was the most basic solution that you tested (highest pH).
3. Describe what happens to the pH of an acid when the acid is diluted in water.
4. Use your answer to question 3 to **describe** a way of treating a burn caused by acid.

Figure 1 pH paper and charts can determine whether a substance is acidic, basic or neutral.

6.2B What if plants were used to create an indicator?

EXPERIMENT

Aim

To make an indicator from red cabbage and demonstrate how it can be used to identify acids and bases

Materials

- 2 leaves from a fresh red cabbage (shredded)
- 0.1 M sodium hydroxide
- Water
- Stirring rod
- Spotting tile
- Plastic disposable pipettes
- Dropper
- 2 × 250 mL beakers
- Strainer
- 0.1 M hydrochloric acid
- Stick blender
- Test tubes and test-tube rack
- A variety of household products (e.g. shampoo, vinegar, baking soda)

Red cabbage contains a water-soluble pigment called flavin, which is also found in plums, poppies, grapes and apple skin. Very acidic solutions will turn flavin red, neutral solutions result in a purplish colour, and alkaline solutions appear greenish yellow if flavin is added to them.

Method

1. To make the indicator:
   a. Place the shredded red cabbage leaves in a beaker.
   b. Cover the cabbage leaves with water and blend the mixture until the water is purple.
   c. Strain the liquid into another beaker and save it, and then discard the cabbage leaves.
2. To test the indicator:
   a. Add a small amount of hydrochloric acid (using a pipette) to a test tube and then add a few drops of red cabbage indicator.
   b. Record any colour change in a table.
   c. Add a small amount of water (neutral solution) to a test tube and then add a few drops of red cabbage indicator.
   d. Record any colour change in your table.
   e. Add a small amount of sodium hydroxide (basic solution) to a test tube and then add a few drops of red cabbage indicator.
   f. Record any colour change in your table.
3. Test a variety of products, such as shampoo, vinegar and baking soda in water, by adding a few drops of red cabbage indicator solution to them.
4. Record the colour changes and determine which products are acids and which are bases.

Inquiry

What if another plant, flower or fruit was used to create an indicator?

Answer the following questions with regard to your inquiry question.

- Write a hypothesis (If … then … because …) for your inquiry.
- Identify the (independent) variable that you will change from the red cabbage method.
- Describe how you will measure whether the plant, flower or fruit (dependent variable) is an indicator. Predict the colour changes you might expect.
- Identify two variables that you will need to control to ensure a valid test. Describe how you will control these variables.
- Identify the materials you will need for your experiment.
- Write down the method you will use to complete your investigation in your logbook.
- Draw up a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Include your table of observations.

Discussion

1. Identify a colour change that can be used to determine the pH of a substance added to red cabbage.
2. Identify the colour that the extract from your plant becomes in:
   a. an acid
   b. a base
   c. water.
3. Describe any limitations of your experiment (by describing conditions where your extract will become inaccurate, describing the sensitivity of your extract or if it can determine the difference between pH 1 and pH 2, and how expensive your extract would be to produce for chemical laboratories or manufacturing chemicals).

Conclusion

Describe what you know about indicators and how they are produced.

Figure 1 Many plants, including red cabbbage, can be used to make an indicator.

6.3A Neutralisation reactions

EXPERIMENT

CAUTION! Ensure that you wear safety goggles at all times during this experiment. Avoid skin contact with the hydrochloric acid and sodium hydroxide solutions. 1 M hydrochloric acid can give a small chemical burn. If contact occurs, wash skin with tap water immediately.

Aim

To investigate neutralisation reactions.

Materials

- 1 M hydrochloric acid
- 1 M sodium hydroxide solution
- Universal indicator solution in a dropper bottle
- Dropping pipettes
- 10 mL measuring cylinder
- 100 mL beaker
- Petri dish
- Water

Method

1 Using the measuring cylinder, transfer 5.0 mL of hydrochloric acid into the beaker and then rinse out the measuring cylinder with water. Leave the test tubes in the test-tube rack throughout the experiment.
2 Add 2 drops of universal indicator solution to the acid.
3 Pour 10 mL of the sodium hydroxide solution into the measuring cylinder.
4 Using the dropping pipette, add drops of the sodium hydroxide from the measuring cylinder to the acid in the beaker. Carefully mix the solution between each drop.
5 Stop adding the sodium hydroxide when the acid has been neutralised. (The indicator will turn green at this point.)
6 Record how much sodium hydroxide you needed to add from the measuring cylinder.
7 Carefully empty and rinse out your glassware. Add 5.0 mL of hydrochloric acid to the beaker and the amount of sodium hydroxide that you recorded in step 6.
8 Pour the solution into a Petri dish and leave open in a safe place in the laboratory for a few hours. As the solution evaporates, record your observations.

Results

Present your results in a table.

Discussion

1 Identify the reactants and products in a neutralising reaction.
2 Explain why is it essential to rinse the measuring cylinder with water after it is used.
2 Explain why the experiment was repeated without the indicator.
3 Explain how you could produce the solid salt more quickly in the last step of the method.
4 Explain why you should not taste the product of this reaction to check whether salt has been produced.
5 Describe the shape of the salt crystals produced. Explain what this shape tells you about the arrangement of the particles inside the salt crystals.

Conclusion

Explain what you know about neutralising reactions.

6.3B Making sherbet

CHALLENGE

What you need

- 1 tablespoon icing sugar
- ¼ teaspoon sodium bicarbonate (baking soda)
- ¼ teaspoon citric acid
- 1 teaspoon flavoured jelly crystals
- Small zip-lock sandwich bag
- Measuring spoons
- Plastic spoon
- Marker pen

What to do

Do this experiment in a food preparation area so that the sherbet is safe to eat.

1 Make sure the utensils are clean and dry.
2 Mix all the ingredients in the sandwich bag and label the bag with your name.
3 Dip the plastic spoon into the mixture and put a small amount on your tongue.

Questions

1 Describe what happened to the sherbet when it mixed with the saliva in your mouth.
2 Identify the three substances that were formed.
3 Describe how the sherbet felt on your tongue. Describe the differences in tastes you observed.
4 Evaluate whether carbonates and bicarbonates should be described as bases (by **defining** 'base', **comparing** carbonates and bicarbonates to this definition, and **deciding** whether they match the definition and should therefore be described as a base).

6.4 What if a metal was protected from an acid?

EXPERIMENT

CAUTION! Ensure that you wear safety goggles at all times during this activity. Avoid skin contact with the acid. 1 M hydrochloric acid can give a small chemical burn. If contact occurs, wash skin with tap water immediately.

Aim

To determine what factors protect a metal from acid rain.

Materials

- 1 M hydrochloric acid
- Test tubes and test-tube rack
- Small pieces of metals (e.g. aluminium, copper, iron, magnesium, tin and zinc) to fit into test tubes
- Matches
- A variety of materials that could be used as a barrier (e.g. petroleum jelly, candle wax, masking tape, sticky tape)

Method

Work collaboratively to complete this experiment.

1. Add a small piece of one metal to a test tube and pour in enough acid to cover it.
2. Gently place your thumb over the top of the test tube to allow any gas to accumulate.
3. After about 1 minute, there should be pressure on your thumb from the gas trying to escape. Another student should light a match (or use a lighter) and carefully bring it to the end of the test tube as you take your thumb away.
4. Observe what happens (e.g. bubbling, metal dissolving, colour change, test tube warming) and record your observations in a table.
5. Repeat steps 1–4 for each metal.

Inquiry

What if a metal was protected from the acid?

Answer the following questions with regard to your inquiry question.

- Write a hypothesis (If … then … because …) for your inquiry.
- Identify the (independent) variable that you will change from the first method to protect the metal.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a valid test. Describe how you will control these variables.
- Identify the materials that you will need for your experiment.
- Write down the method you will use to complete your investigation in your logbook.
- Draw up a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Describe your observations. Draw or take pictures of the metal before and after exposure to the acid.

Discussion

1. Describe (summarise) the observations you made about how the different metals reacted with the acid.
2. Identify the metal that was the most reactive with the acid. Justify your answer (by comparing the observations of the different metals, describing the strongest/fastest reaction, and identifying the metal that was responsible for this reaction).
3. Identify the metal that was the least reactive with the acid. Justify your answer.
4. Describe the success of your method of protecting the metal. Justify your answer (by comparing the observations of your protected metal to the unreacted metal and deciding whether the outcome matches your hypothesis).
5. Compare your results to those of the rest of your class, to identify the most successful method of protection.
6. Describe the limitations of your results (by describing situations where the methods of protection would not work in the real world).

Conclusion

Describe what you know about reactions between metals and acid, and how these can be prevented.

6.5 Combustion and candles

CHALLENGE

What you need

- Tealight candle
- Beaker large enough to fit over candle
- Matches

What to do

1 Light the tea candle with a match.
2 Place the beaker over the candle and observe what happens.

Questions

1 Identify the fuel for the chemical reaction occurring with the candle.
2 Explain why the candle goes out shortly after being covered with the beaker.
3 Describe the moisture on the inside of the beaker. Identify the source of this water.
4 Write a word equation for the combustion of the candle wax.

7.1A Demonstrating electrostatics

CHALLENGE

What you need

- Plastic comb
- Woollen cloth
- Rice Bubbles
- Large plastic bag with tie
- Plastic rod or pen
- Small pieces of paper
- Balloons
- Balloon pump
- Felt-tipped pens
- String
- Tape

What to do

Part A

1 Place some of the Rice Bubbles in the plastic bag. Blow air into the bag and seal it with the tie.
2 Rub the woollen cloth over both the plastic bag and the comb.
3 Bring the plastic bag and comb together.
4 Record what happens.
5 Explain your observations, **using** the idea of electrostatic charge.

Part B

1 On a piece of paper, draw four positive and four negative charges. Show what happens to these charges when the positively charged woollen cloth is brought close to them.
2 Explain why the paper is attracted to the plastic rod or pen by **discussing** the movement of charges.

Part C

1 Using the balloon pump, blow up a balloon and carefully draw a face on it.
2 Tie the balloon onto a string and suspend it from a doorway or ceiling using tape, so that it is level with your head.
3 Rub the balloon face with the woollen cloth and walk towards it.
4 Record what happens.
   - Identify the distance from the 'balloon face' you have to be before it is attracted to you.
   - Describe what happens if you put a piece of paper between you and the balloon.
5 Blow up another balloon and draw a face on it.
   - Describe what happens when you bring it close to your suspended balloon.

Questions

1 Describe your observations in Part A **using** the terms 'like charges', 'unlike charges' and 'neutral or no charge'.
2 Describe your observations in Part B **using** the terms 'like charges', 'unlike charges' and 'neutral or no charge'.
3 Describe your observations in Part C **using** the terms 'like charges', 'unlike charges' and 'neutral or no charge'.

Figure 1 Can you explain the attraction of the balloon?

7.1B Separating charges with a van de Graaff generator

CHALLENGE

What you need

- van de Graaff generator
- Smaller sphere connected to discharge wand
- Paper streamers
- Small pieces of paper
- Aluminium plates
- Paper cup with Rice Bubbles

What to do

1 Observe what happens to objects that have been charged by a van de Graaff generator. Record your observations in a table.

2 Your teacher may demonstrate any of the following:
   a a smaller sphere held near a larger sphere
   b paper streamers attached to the top
   c paper streamers held nearby
   d long dry hair nearby
   e small pieces of paper thrown on top
   f aluminium plates placed on top
   g paper cup with Rice Bubbles inside.

Questions

1 Describe the three rules of electrostatic charges.

2 Explain what happens in each example, using your knowledge of electrostatic charge.

Figure 1 What happens to paper streamers?

7.2A Making a simple torch circuit

CHALLENGE

What you need

- Pieces of insulated electrical wire with the ends stripped bare
- 1.5 V battery
- 1.2 V torch globe
- Hand lens

What to do

1 Try different arrangements of the wires, battery and torch globe to make the globe light up. Draw each arrangement that you tried.

2 Use circuit diagrams to record some of the arrangements that work and some that do not.

3 Use the hand lens to look carefully at the filament in the globe. The filament is the tiny wire inside the glass of the globe – the part that glows brightly when the globe lights up. Draw what you see.

4 Use the hand lens to look at how a globe holder (the base of a globe) is constructed.

Questions

1 Select one of the arrangements that did not allow the globe to light up. Explain why this arrangement did not allow electricity to pass through the circuit.

2 Describe how the filament in the light globe is able to transform electricity into light and heat.

3 Describe how the globe holder connects the light globe to the circuit.

Figure 1 How does a torch work?

7.2B Connecting circuits

CHALLENGE

What you need

- 1.5 V battery
- 1.2 V light globe
- 2 switches
- Connecting wires

What to do

1 Construct a simple circuit containing a battery, a light globe and a switch. It is a good idea to start at a particular part of the circuit (e.g. the positive terminal of the battery) and work your way sequentially around.
2 Draw the circuit diagram for the circuit.
3 Pull the circuit apart and reuse the components. Construct a different circuit with a battery, a globe and two switches so that the globe lights up only when both switches are closed.
4 Draw the circuit diagram for this circuit.
5 Pull the circuit apart and reuse the components. Connect up a different circuit with a battery, a globe and two switches so that the globe lights up if either one of the switches is closed.
6 Draw the circuit diagram for this circuit.
 - Where might a circuit like this be useful?

Figure 1 Where might a circuit with a globe and a switch be useful?

Questions

1 Define the term ‘series circuit’.
2 Describe where a series circuit with two light globes and a single switch might be useful.
3 Describe where a circuit with two switches and a single light globe might be useful.
4 Describe a situation where a series circuit would not be useful.

7.3A Making series and parallel circuits

CHALLENGE

Find out how many ways you can connect two globes in a circuit.

What you need

- 2 × 1.2 V globes and holders
- 1.5 V battery and holder
- 8 connecting wires (with banana plugs or alligator clips)
- Switch
- Ammeter or multimeter

What to do

1 Construct four circuits, placing the switch so that it controls:
 a both globes, with both either on or off at the same time
 b one globe only, with the other on all the time
 c the other globe only, with the first globe on all the time
 d both globes, with one globe on when the other is off and vice-versa.

 Follow step 2 before you disconnect each circuit.
2 Draw the circuit diagram to show where the switch was placed in each circuit.
3 Connect an ammeter at different places in each circuit and measure the current at each point.

Questions

1 Describe the effect of changing the location of the switch in a simple circuit.
2 Define the term ‘current’.
3 Describe how an ammeter should be connected to measure the current in a circuit.
4 Describe how the current did or did not change when the ammeter’s location was changed.

Figure 1 How many ways can you connect multiple globes in a circuit?

7.3B Short-circuiting an electric current

CHALLENGE

What you need

- 1.5 V battery
- Switch
- Connecting wires
- 1.2 V lamp

What to do

1 Set up the circuit shown in Figure 1.
 - What do you think will happen if the switch is closed?

2 Close the switch.

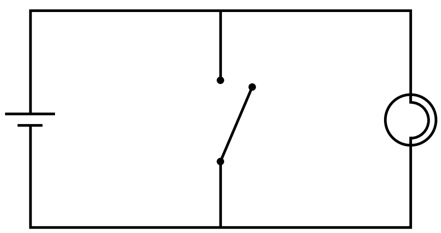


Figure 1 Circuit set-up

Questions

1 Describe the flow of electricity when the switch was left open.

2 Describe the flow of electricity when the switch was closed.

3 Use the term 'short circuit' to **explain** your observation.

7.4A Using Ohm's law to find resistance

SKILLS LAB

Example

Find the value of a resistor that has a voltage drop of 6 V across it when a current of 50 mA flows through it.

1 Check the units: 6 V is in volts and so can be used unchanged. You will need to convert 50 mA (milliamps) to amps. The prefix 'milli' means 0.001 (or $\times 10^{-3}$), so 50 mA = 50 × 0.001 or 0.05 A.

2 Use the Ohm's law triangle to find the correct formula. You want to find resistance, so use your fingertip to cover the R – the other two letters show you the formula to use (see Figure 1).
The V is over the I, so use:

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

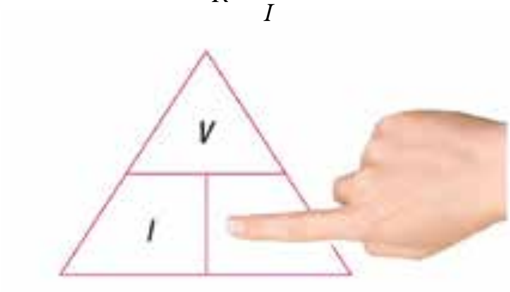


Figure 1 Using the Ohm's law triangle

3 Substitute the numbers for V and I:

$$R = \frac{6}{0.05}$$

4 Do the calculation: 6 ÷ 0.05 = 120 Ω.

Your turn

This law can also be used to work out the voltage or the current.

1 Calculate the voltage drop across a resistor with a value of 180 Ω and a current of 50 mA. (Remember to cover V in the Ohm's law triangle to get the correct formula for R and I. If the letters are next to each other, multiply them.)

2 If a 12 V battery is placed in a circuit with a 470 Ω resistor, **calculate** the current that will flow through the circuit.

3 If the current of a circuit with a 12 V battery is 0.004 A, **calculate** the resistance of the circuit.

7.4B Understanding resistor colour codes

SKILLS LAB

Carbon resistors typically have four colour-coded bands on their case (Figure 1). These bands are part of a code that allows you to work out their approximate value and tolerance. The fourth band is the tolerance band, which indicates the amount that the resistance may vary by (the relative accuracy of the resistor). Gold means 5 per cent tolerance, silver means 10 per cent tolerance, and no fourth band means 20 per cent tolerance. The lower the percentage tolerance, the more accurate (or closer to the true value) the resistor is.

Figure 1 A resistor with colour-coded bands

To read the three other bands, put the tolerance band on the right and start at the other end. The first two bands form a two-digit number according to their colour (see Table 1). The third band tells you how many zeros to put after the number.

Table 1 Resistor colour codes

Colour	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

Look at the resistor in Figure 2. What does its code mean?

1 The tolerance band is gold, so the resistor has 5 per cent tolerance.
2 The first band is blue, so it has a value of 6.
3 The second band is red, so it has a value of 2. The number is now 62.
4 The third band is also red, so this means 2 zeros need to be added to the number. The number is now 6200.
5 Resistor values are always coded in ohms, so the value of this resistor is 6200 ohms or 6.2 kilo-ohms.

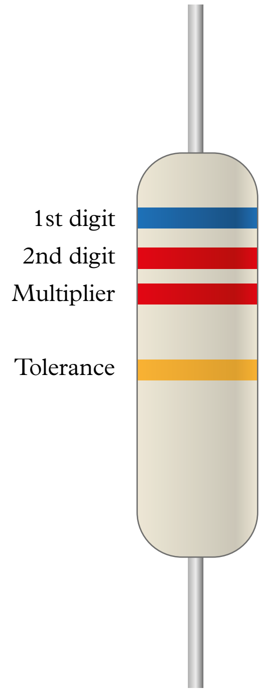


Figure 2 Calculate the value of this resistor.

Discussion

1 Define the electrical term ‘resistance’.
2 Explain why different resistors may need to be used in different circuits.
3 Explain what is meant by the term ‘tolerance’.

7.4C Investigating Ohm's law

EXPERIMENT

Aim

To investigate the voltage drop across and the current flow through a resistor, and to calculate an average value of the resistance.

Materials

- 2–12 V power supply
- Ammeter
- Voltmeter
- 10 Ω resistor
- 3 other resistors with masking tape over their coloured bands
- Connecting wires

Method

1 Identify the 10 Ω resistor. It should be colour-coded brown, black, black.

2 Connect the circuit as shown in Figure 1. Use the DC terminals of the power supply and start with the dial on 2 V.

3 Switch on the power supply, take the readings on the ammeter and voltmeter, and switch the power off again straight away (so you don't overheat the resistor).

4 Change the dial on the power supply to 4 V and repeat step 3. Then change the dial to 6 V and repeat.

Figure 1 Circuit set-up

5 Record your results in Table 1.

Table 1 Experiment results

Resistor	Voltage (V)	Current (mA)	Volts ÷ amps

6 Repeat the experiment for the other three resistors, without reading their coloured bands.

7 Complete the results table for each of the three masked resistors and calculate their resistance.

8 Remove the masking tape and determine the resistance values from the coloured bands of the resistors.

Results

Include your results table.

Discussion

1 From your results table, identify what the values in the last column calculate.

2 For the three masked resistors, compare the accuracy of the values you obtained to the values indicated by their coloured bands.

3 Use the formula below to calculate the difference (error) between the two values as a percentage of the marked value.

$$\%\ \text{error} = \frac{\text{marked value} - \text{average calculated value}}{\text{marked value}} \times 100$$

4 Identify which value – the one obtained by reading the coloured bands or the one obtained from your calculations – provides the most useful measure of a resistor's resistance. Justify your answer (by explaining how each value is obtained, describing which value is most relevant to use in a circuit and deciding which value provides the most useful measure).

Conclusion

Describe what you know about Ohm's law.

7.5A Investigating with a remote control

CHALLENGE

What you need

- Wireless remote device with a working remote control
- Mirror
- Smart phone

What to do

1. Most remote-control devices use infrared LEDs to send their signal. This colour of light is outside the visible spectrum. You can test whether a remote control is working by using the camera function on your smart phone. Open the camera app on your phone and switch it to the front-facing camera. Point the remote at the camera and press any button on the remote.
   - Describe what you see in the camera picture.
2. Make sure the device that the remote belongs to is turned off. With your back to the device, angle the mirror so that you can see the device. Point the remote control towards the mirror and push the 'on' button. Can you activate the device?

Questions

1. Define the term 'LED'.
2. Explain how the device is able to detect the signal from the LED.
3. Explain how you were able to use the mirror to switch on the device.

7.5B Lighting up LEDs

CHALLENGE

What you need

- 2–12 V power supply
- Red LED
- 330 Ω resistor
- 1000 Ω resistor
- Connecting wires

What to do

1. Connect the power supply set on 8 V DC in series with the red LED and 330 Ω resistor (orange, orange, brown). If the LED doesn't light up, reverse its connection.
2. Try a larger resistor, such as the 1000 Ω (brown, black, red), in the circuit and observe what effect it has.
3. Draw a circuit diagram of your circuit when the LED lights up.

Questions

1. Identify which leg of the LED (one leg is longer than the other) needs to be connected to the positive side of the circuit for it to light up.
2. Explain why a resistor should be used in this circuit.
3. Explain the advantages of using an LED instead of a traditional light globe.

Figure 1 LED lights

7.5C Wiring a house

CHALLENGE

What you need

- Cardboard box
- 6 LEDs
- 4 resistors (330 Ω)
- 9 V battery
- Wires
- Paperclip
- Split pins
- Cardboard
- Optional: decorations for your house

What to do

1 Design a room in a house that needs lighting for at least three parts of the room and a power switch that needs to be turned on and off. It may be a bedroom with an overhead light, a computer or television and a bedside lamp. It may be a study with an overhead light, a desk light and a computer terminal. It may be a kitchen with an overhead light, an oven light and a fridge where the light turns on when the door is opened. You may choose to use several LEDs to make more complicated overhead lights (such as a chandelier).

- Draw your room design.
- Draw a circuit diagram for your room. Consider whether you need the devices connected in series or in parallel. Describe the reasons for each of your decisions.

2 Use the LEDs, wires, resistors, switch and other items as needed to complete your room design in the cardboard box.

Questions

1 Describe the advantages and disadvantages of devices being connected:
   a in series
   b in parallel.

2 Party lights often have groups of five LEDs connected in series. These groups are then connected in parallel with other groups of LEDs. Describe what will happen when one of the LEDs is damaged.

3 Explain why it is important that resistors be used when wiring LEDs.

4 Government codes require circuit switches (with electrical fuses) to be included in the electrical wiring of a house. Describe where you would put a circuit switch in your house to prevent damage in the event of a short circuit.

Figure 1 What is the best way to organise wiring in a house?

8.1 Creating magnetic fields

EXPERIMENT

Aim

To investigate the magnetic field around a single wire and a solenoid when connected to direct current (DC) and alternating current (AC).

Materials

- Different-shaped magnets
- Iron filings
- Sheet of A4 paper
- AC/DC 12 V power supply
- Long insulated wire
- Iron nail
- Connecting wires
- 2 plotting compasses
- Retort stand

Method

1. Arrange the magnets under the paper. Sprinkle the iron filings on the top of the paper. The iron filings will align with the magnetic field around the magnets. Draw the lines that are created. Include arrows showing the magnetic field moving from the north pole to the south pole of the magnets. Put the iron filings away before starting the next step.
2. Wrap the wire around the nail as many times as possible. Remove the nail to make a solenoid.
3. Sit the solenoid on the retort stand base.
4. Connect the solenoid to the power supply. Use the DC connections and turn the knob to 12 V. Before switching on the power, position the plotting compass under one of the connecting wires so that its needle is parallel to the wire.
5. Switch the power on and observe the compass needle. Move the compass above the connecting wire and observe. Test the other compass with the other connecting wire. Record your observations.
6. Insert the nail into the solenoid. What do you notice during this process? What happens to the temperature of the nail? Try to pull the nail out of the solenoid while the power is still on, and again after the power is off. Was there a difference? Move the solenoid off the stand base and again try to remove the nail while the power is on. Was there a difference?
7. Remove the nail and change the power to AC. Reinsert the nail. Is there any evidence that the magnetic field is vibrating? Does the nail get hot after a while?

Discussion

1. Explain why the magnetic field around the solenoid is stronger than around the wire.
2. Explain the difference in pulling the nail out of the solenoid with the power on and off.
3. Explain the effect of the stand on the ease or difficulty of removing the nail from the core.
4. Describe the effects of DC and AC on the nail.
5. Explain why the iron nail became hotter when the solenoid was switched on.

Conclusion

Describe the effects of an electric current on the magnetic field surrounding a wire and a solenoid.

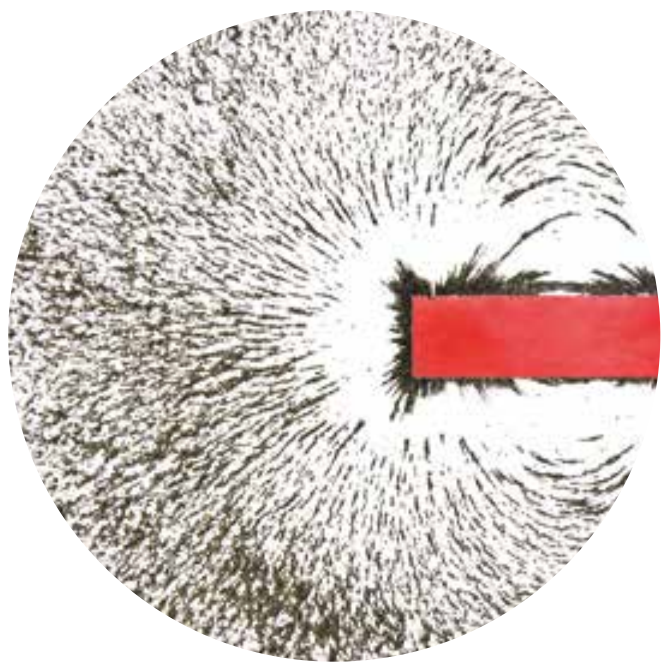


Figure 1 The pattern of iron filings shows the magnetic field.

8.2A Observing magnetic force

CHALLENGE

What you need

> 2–12 V power supply
> Strong horseshoe magnet
> Connecting wires

What to do

1 Set up the equipment as shown in Figure 1.
2 Turn on the power. The wire should 'jump' out of the magnetic field. Consider why this happened.
3 Predict what will happen if you change the positions of the wires and the magnet. Set up the equipment to match your prediction and observe what happens.
4 Set up the equipment so that the current is parallel to the magnetic field and observe what happens.

Questions

1 Use the right-hand slap rule to **explain** your observations.
2 Describe how the force is dependent on the angle between the current and the magnetic field.
3 Complete the following:
When the angle is 0°, the force is ____________________.
When the angle is 90°, the force is ____________________.

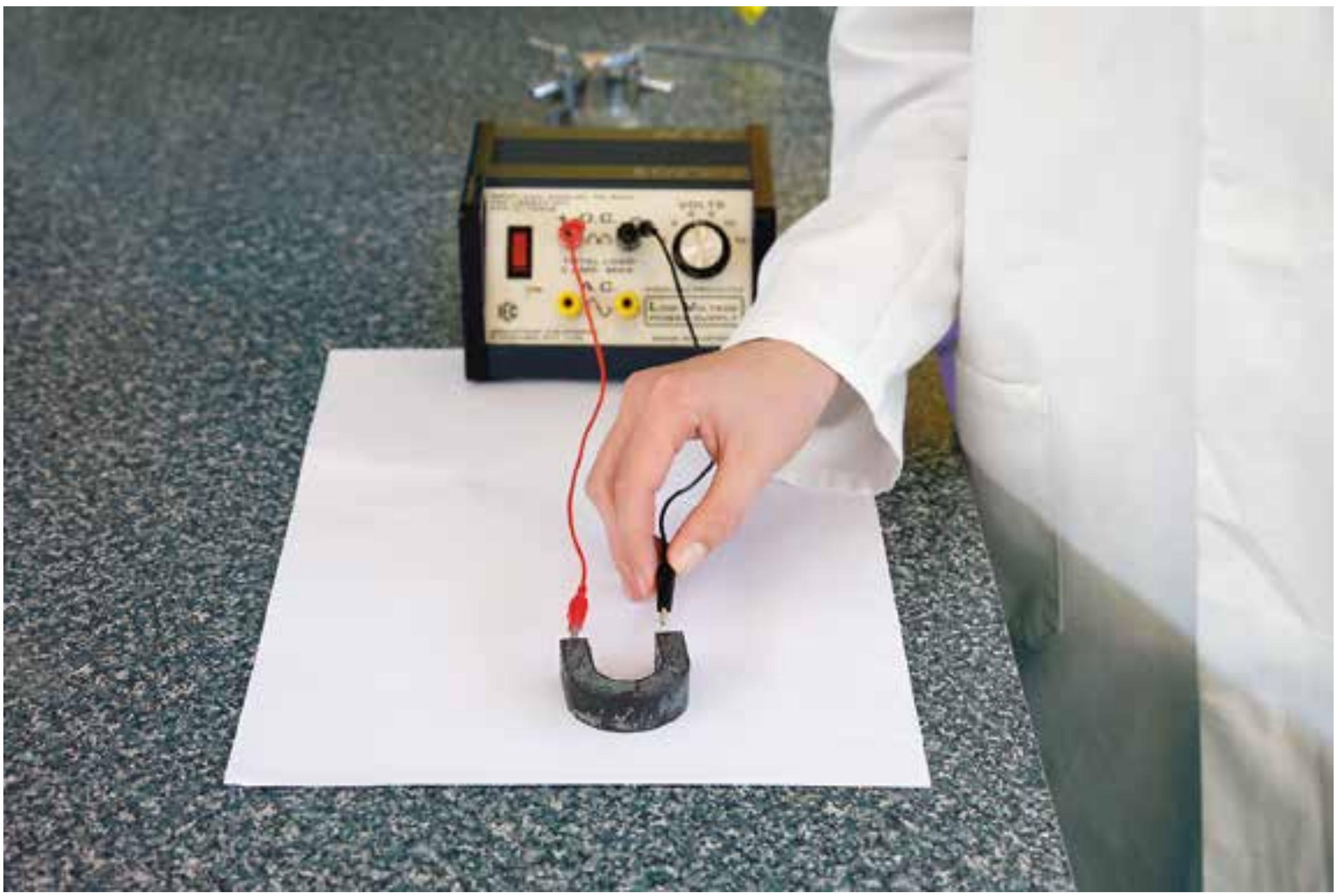


Figure 1 Equipment set-up

8.2B Building an electric motor

CHALLENGE

What you need

- 2 m of insulated copper wire
- 2 paperclips
- D battery
- Rubber band
- Blu-Tack
- 2 disc magnets
- Sticky tape
- Pliers

What to do

1. Use the pliers to strip the ends of the copper wire so that the metal is exposed.
2. Unwind the paperclips to create two roughly straight pieces with small loops in them.
3. Hold the straight parts of the two paperclips at either end of the battery and place the rubber band around them to hold them against the battery terminals.
4. Place the battery on the bench and secure it with a piece of Blu-Tack on either side. The paperclips should point straight up and the loops should be approximately level with each other.
5. Wind the copper wire into coils, leaving the ends sticking straight out. These ends will fit into the loops of the paperclips. When you are satisfied with your coil and you have checked that it sits easily in the paperclip loops, tape up the coil to hold it together. Sit it in the loops ready for the start-up.
6. To start the motor, bring the two disc magnets between the coiled wire and the battery. The coil may need a kickstart to get it running.

Questions

1. Describe how increasing the number of coils of wire could change the speed or force of your electric motor.
2. Describe how increasing the voltage of the battery would affect your motor.

Figure 1 Power cables

8.3 Producing electricity with a generator

CHALLENGE

What you need

- Model demonstration generator
- Lamp
- Galvanometer
- 2–12 V power supply
- Connecting wires

What to do

1. Inspect the demonstration generator.
2. Identify the coil of wire, the magnets, the brushes, the split ring commutator and the two slip rings of the generator.
3. Use the generator to light a lamp.

Questions

1. Draw a picture of the generator, labelling each section, including the coil of wire, the magnets, the brushes, the split ring commutator and the two slip rings of the generator.
2. Draw arrows to indicate the direction of the rotation and the letters N and S to indicate the poles of the magnet.
3. There are always three parts to any motor or electricity generator. Identify these three parts and **describe** how they interact with each other.

Figure 1 High-voltage transmission lines carry electricity from power stations to our homes.

[STEAM project 1]

How can we use sustainable farming practices so that no one goes hungry in the future?

Figure 1 Vertical farming allows people to grow more food in a smaller space.

The United Nations ranks food shortages and hunger among the most serious issues affecting humankind. It predicts that more than 840 million people will be hungry by 2030. Even in a high-income country such as Australia, 5 per cent of the population are unable to access enough nutritious food. The experience of having inadequate access to food, or having an inadequate supply of food, is known as food insecurity. Food insecurity is linked to poor general health, higher rates of some cancers and higher mortality.

Rapid climate change is increasing threats to Australia's and the world's food security. Changes in the amount of rainfall, longer droughts and an increase in the number of extreme weather events are expected to disrupt the amount and quality of food that Australia can produce. A hotter climate is expected to cause stress in livestock animals such as chickens, sheep and cattle, and to increase the amount of water needed for crop irrigation.

Figure 2 Drought impacts Australia's production of important crops, such as wheat.

Sustainable farming

Sustainable farming practices use methods that balance the needs of all members of the community. This means that new and old technologies are used to make sure that food production is:

- economically viable – if farmers cannot make enough money to survive, then the farming practice is not sustainable
- socially supportive – if the lifestyle of the farming community is not supported, then people will not want to live in the area
- ecologically sound – if the local environment is not supported, then the land will be unable to support food production. Sustainable farming also works to maintain the diversity of the local wildlife.

Sustainable farming uses technology to increase the production of fresh, nutritious food while minimising the impact on the local environment.

HUMANITIES

In Geography this year, you will learn about food security around the world and food production in Australia. You will investigate the factors that influence crop yield (such as soil moisture) and how food production can alter a biome. In Economics and Business, you will study the agricultural resources (such as wheat) that form a large part of Australia's trade economy.

To complete this task successfully, you will need to investigate the environmental constraints on agricultural production in Australia, such as climate and distribution of water resources. You will also need to understand the extent to which agricultural innovations have overcome these constraints.

You will find more information on this in Chapter 3 'Food security', Chapter 2 'Biomes' and Chapter 17 'Understanding the global economy' of *Oxford Humanities 9 Victorian Curriculum*.

MATHS

In Maths this year, you will build on your knowledge of measurement and geometry to determine areas and volumes of more complicated shapes. You will be introduced to Pythagoras' Theorem and trigonometry. You will also extend your skills in collecting, representing and investigating data.

To complete this task successfully, you will need to perform calculations involving angles, lengths and areas of two-dimensional and three-dimensional shapes. You will need to apply your understanding of scale factors to build a prototype of your designed product. To consider the situation at local, national and international scales, you will need skills in dealing with ratios and proportions. You may also find it helpful to use scientific notation for very large or very small numbers.

You will find help for applying these maths skills in Chapter 6 'Measurement and geometry', Chapter 7 'Pythagoras' Theorem and trigonometry', and section 2E 'Scientific notation' of *Oxford Maths 9 Victorian Curriculum*.

SCIENCE

In Science this year, you will learn about the biotic and abiotic factors that support and maintain ecosystems. You will consider the role of different nutrients and sunlight on plants and the effects each of these will have on the surrounding ecosystem.

To complete this task successfully, you will need to understand the factors required to keep a system, such as a vertical garden, alive. You may need to consider how these factors can be monitored and controlled automatically. You will also need to be familiar with the scientific method, and understand how to conduct a fair test.

You will find more information on this in Chapter 2 'Ecosystems' of *Oxford Science 9 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, those who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your vertical garden, you need to define the criteria that you will use to test the success of your vertical garden in achieving your goal.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide:

'How can we help (the group) to solve (the problem) so that (the reason)?'

Determine the criteria

1 What is the total area of the 100 m × 100 m plot of land? (Remember to use the correct units.)

2 If the plants are planted 25 cm apart in a 100 m row, and the rows are placed 1 m apart, how many plants could be planted in the plot of land? HINT: Draw the plot of land to make sure you reach maximum capacity.

3 What criteria will you use to measure the success of your solution or design? How will you measure how much the end-users have been helped?

Ideate

Once you know who you're designing for, and you know what the criteria are, it's time to get creative!

As a group, brainstorm ways the problem can be solved. Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Once you have many possible solutions, it is time to sort them by possibility. Select three to five ideas that are possible. Research whether these ideas have already been produced by someone else. If they are already on the market, can you make a better version?

Build

Draw your top two vertical garden designs. Label each part of the designs. Include the materials that will be used for their construction.

Include in the designs:

a the total surface area available for plant growth

b a description of how food production will be increased c a description of how the design (inputs and waste) will impact the local ecosystem

d a description of how the workers will access all areas of the design to tend the plants

e at least one advantage and disadvantage of each design.

Select one of the designs to take to the building and testing stage.

Build the prototype

You will need to build at least three versions of your vertical garden design prototype. The first prototype garden will be tested for effectiveness. The second prototype will be used to survey the group you are helping. The third prototype will be used for the presentation. The prototype may be full size, or it may be a scale model (10 cm represents 1 m). Use the following questions as a guideline for your prototype:

- What materials will you use?
- What material will you use to represent the plants?
- How will you represent the height, width and angle of the finished prototype?

Test

Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first vertical garden prototype. You will test the prototype more than once, to compare results, so you will need to control your variables between tests. What criteria will you use to determine the success of your prototype? Conduct your tests and record your results.

Prototype 2

If your prototype will be used to help market gardeners, then you will need to generate a survey to test whether the prototype is appropriate for their use. (How would they use it? Would they consider buying it?)

If your prototype will be used to help another group, or native plants and animals, you will need to consider how you could test the impact it will have. (Will the prototype affect normal behaviours? How will the prototype affect the soil or waterways?)

Prototype 3

Use the information you have obtained from testing the first two versions to adapt your last prototype to be more effective and usable for the group you are helping. You may want to use the first two prototypes to demonstrate how the design has been improved.

Communicate

Present your vertical garden design to the class as though you are trying to get your peers to invest in it. Describe the criteria and testing used to measure the effectiveness of your vertical garden design.

In your presentation, you will need to:

- explain why we need to be more efficient with food production
- describe the key features of your design and how they improve or solve the problem of food shortages
- show a labelled, to-scale diagram of your prototype
- describe how the ecosystem will be affected by the installation of the prototype
- explain the relevant scientific principles that support your designed solution (e.g. water cycle, photosynthesis, nitrogen/carbon cycle)
- quantify the increase in food production that your design allows; present calculations to justify your claim
- present a calculation for the estimated cost of producing a full-size model of your design
- explain the implications of your design at a state or national level, by comparing the benefits and costs.

Check your student obook pro for the following digital resources to help you with this STEAM project:

Student guidebook
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase of the design cycle.

How to manage a project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to pitch your idea
This 'how-to' video will help you with the 'Communicate' phase of your project.

[STEAM project 2]

How can we harness technology so that we can live healthier lives?

A disorder or disease is a condition that affects the normal functioning of the body. Different disorders and diseases can affect many parts of the body. They can be caused by infectious agents such as bacteria or viruses that spread from person to person. Some disorders or diseases are inherited. Environmental factors (such as pollution or diet) can also have an impact on the development of disorders or diseases.

Heart disease, a non-infectious disease, is the leading cause of death globally. Mental health disorders, such as depression, bipolar disorder and dementia, also affect many people around the world.

Disorders and disease affect both high-income and low-income countries, but there are large differences in the ability of different healthcare systems to provide adequate care for people. The need for low-cost health care has led many researchers to investigate how technology can be used to help people live healthier lives.

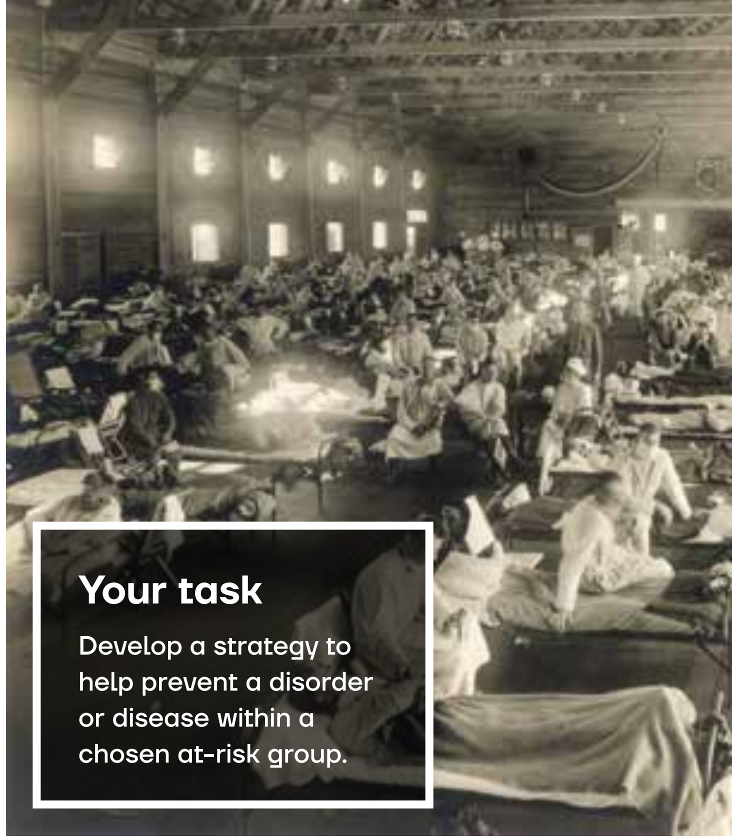


Figure 1 During the 1918 flu pandemic (sometimes called the Spanish flu), an estimated 500 million people, or a third of the world's population, were infected with the virus.

Prevention of disorders and disease

There are many disorders and diseases that can be prevented through simple, low-cost interventions. Below are a few examples.

- Wearing a helmet or a seat belt has been shown to decrease the risk of brain injury from a road accident. In Vietnam, when wearing a helmet was made mandatory for motorcycle riders, it resulted in a 16 per cent decrease in head injuries.
- The use of mosquito nets can help to prevent malaria, a disease that can lead to life-long neurological impairment, such as epilepsy in children if they have a severe infection.

Figure 2 Healthcare workers wear personal protective equipment (PPE) to prevent the spread of infectious disease.

- Providing vaccinations for viruses such as polio and meningitis can also prevent neurological conditions.
- Promoting a healthy lifestyle and educating the population about the importance of diet can reduce the prevalence of stroke. In Japan, campaigns and treatment for high blood

pressure have reduced the rate of strokes by 70 per cent.

- Personal protective equipment (PPE) is used to protect people from catching infectious diseases, such as Covid-19.

HUMANITIES

In Economics and Business this year, you will learn about different economic systems, and how health services are provided in Australia. In Geography, you will study how people are interconnected through travel, technology and trade. These connections affect where and how people access the services they need. In History, you will examine the experiences of different groups during the Industrial Revolution, and the reforms made to improve living standards.

To complete this task successfully, you will need to research the demographics of your local area, and the location and accessibility of health services. You should also consider the economic performance of your area to determine what type of preventative strategy would be most successful for your at-risk group.

You will find more information on this in Chapter 17 'Understanding the global economy', Chapter 4 'An interconnected world' and Chapter 8 'The Industrial Revolution' of *Oxford Humanities 9 Victorian Curriculum*.

MATHS

In Maths this year, you will extend your skills in representing and interpreting data. You will consider media reports that use statistics and collect secondary data to investigate social issues. You will relate real-world data to probabilities of events, and compare data sets using summary statistics and different graphical displays. You will evaluate and represent data, both with and without digital technology.

To complete this task successfully, you will need to find data to quantify the problem, work out how much your strategy will cost, and calculate a quantitative, evidence-based estimate of the possible benefits of your strategy. You will need skills in dealing with ratios, proportions and percentages to consider the situation at local, national and international scales.

You will find help for applying these maths skills in sections 1A 'Calculator skills' and Chapter 8 'Statistics' of *Oxford Maths 9 Victorian Curriculum*.

SCIENCE

In Science this year, you will learn about how the body coordinates and regulates its internal systems so that it can respond to changes. When things change in the environment (such as the emergence of a disease-causing agent), or a part of the body fails, the normal functioning of the body is interrupted. The body needs to respond and attempt to return to a normal homeostatic state before permanent damage is caused.

To complete this task successfully, you will need to identify how the body's systems work together to maintain a functioning body. You should consider the type of disorder or disease that you will be fighting, and how it may cause changes in the body's normal function and response mechanisms.

You will find more information on this in Chapter 3 'Control and regulation' of *Oxford Science 9 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for? Is it the people directly affected by the disorder or disease, or do their families and carers need support too?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems? What words would you use to describe these feelings?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your solution to the problem, you need to define the parameters you are working towards.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide.

'How can we help (the group) to solve (the problem) so that (the reason)?'

Determine the criteria

1 Describe the type of life that the people you are helping lived before their lives were affected by the disorder or disease.
2 Describe how the people affected by the disease have needed to change their lives to cope with the effects of the disorder or disease.
3 Describe how you will know that you have made their lives better as a result of your prototype strategy.

Ideate

Once you know who you're designing for, and you know what the criteria are, it's time to get creative!

Outline the criteria or requirements your design must fulfil (i.e. usability, accessibility, cost).

Brainstorm at least one idea per person that fulfils the criteria.

Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Build

Each group member should draw an individually designed solution. Label each part of the design. Include the material that will be used for its construction.

Include in the individual designs:

a a detailed diagram of the design
b a description of why it is needed by the individual or group

c a description of any similar designs that are already available to buy

d an outline of why your idea or design is better than others that can be purchased.

Present your design to your group.

Build the prototype

Choose one design and build two or three prototypes.

Use the following questions as a guideline for your prototype.

- What materials or technology will you need to build or represent your prototype design?
- What skills will you need to construct your prototype design?
- How will you make sure your prototype design is able to be used by the people who need it?
- How will you describe the way the prototype design will work?

Test

Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first prototype. You will test the prototype more than once, to compare results, so you will need to control your variables between tests.

What criteria will you use to determine the success of your prototype?

Conduct your tests and record your results in an appropriate table.

Prototype 2

If your prototype will be used to help individuals with the disorder or disease, then you will need to generate a survey to test whether the prototype is appropriate for their use. (How would they use it? Would it make their life easier or harder? Would they consider buying it? How much would they be willing to pay to access the design?)

Prototype 3

Your last prototype should be adapted using the information gathered from testing the first two versions to make it more effective and usable for the group you are helping. You may want to use the first two prototypes as a demonstration of how the design has been improved over time.

Communicate

Present your design to the class as though you are trying to get your peers to invest in your design.

In your presentation, you will need to:

- outline the relevant disorder or disease and how it affects individuals, as well as society as a whole
- create a working model, or a detailed series of diagrams, with a description of how it will be used by an individual and group
- explain how you changed your design as a result of testing or feedback
- describe how the design will improve the life of an individual or group
- describe how many people need or will use the design
- describe how individuals will be able to access the design (will they need to purchase it or will it be publicly funded?)
- describe how the design will improve an individual's ability to contribute to society as a whole.

Check your Student obook pro for the following digital resources to help you with this STEAM project:

Student guidebook
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase of the design cycle.

How to manage a project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to pitch your idea
This 'how-to' video will help you with the 'Communicate' phase of your project.

GLOSSARY

A

abiotic
all the non-living components of an ecosystem; for example, light, temperature, water

accuracy
how carefully, correctly and consistently data has been measured or processed; in science, how close a measured value is to the true value

aerobic respiration
the second step in the breakdown of glucose to carbon dioxide and water; occurs in the mitochondria when oxygen is present and produces 34 ATP molecules

alkali
a base that dissolves in water

alkaline solution
a solution that consists of a base dissolved in water

allergy
an overreaction by the immune system in response to pollen, dust or other non-pathogens

alpha particle
a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

alternating current (AC)
electrical current that flows first in one direction, then in the opposite direction, then back in the first direction and so on; electrical energy is usually generated in this form in a power station

alternator
a generator that produces alternating current (AC) through the use of slip rings

anaphylaxis
a life-threatening overreaction by the immune system to a normally harmless substance

anion
a negatively charged ion formed when an atom gains electrons

antibody
a molecule produced by B cells that binds to a specific pathogen

armature
coils of current-carrying wire in a motor or generator

atomic theory
the theory that all matter is made up of atoms

autonomic nervous system
the part of the nervous system that controls involuntary actions such as heartbeat, breathing and digestion

axon
the part of a neuron (nerve cell) that carries an electrical message away from the cell body to the synapse

B

B cell
an immune system cell that produces antibodies in response to pathogens

beta particle
a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

biological control
a method of controlling a population by releasing a living organism (a parasite or consumer) into an ecosystem

biosphere
a layer around the Earth's surface that supports life; consists of the atmosphere, hydrosphere and lithosphere

biotic
relating to the living organisms in an ecosystem

Bohr model
a model of the atom in which electrons orbit the nucleus in a series of defined orbits known as shells

brushes
a pair of contacts that bring current into an armature (motor) or take current out of an armature (generator)

C

capture–recapture
a method of estimating the number of organisms in an ecosystem by capturing, marking and releasing a sample of the organisms

carbon dating
a method of estimating the age of organic material, by comparing the amount of carbon-14 in the material with the amount in the atmosphere, knowing the rate at which carbon-14 decays over time

carrying capacity
the maximum number of organisms in a population that can be sustained by an ecosystem

cation
a positively charged ion that results from an atom losing electrons

cell body
the main part of a cell that contains the nucleus/genetic material

central nervous system
the brain and spinal cord

chlorophyll
a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

circuit diagram
a diagrammatic way to represent an electric circuit

collaboration
a relationship between organisms of the same species working together to ensure their survival

combustion reaction
an exothermic reaction between a fuel and oxygen that produces heat, carbon dioxide and water

commensalism
a type of relationship between two organisms of different species, in which one organism benefits and the other is not affected

community
different populations living in the same place at the same time

competition
a type of relationship between organisms using the same limited resources in an ecosystem

continental drift
the continuous movement of the continents over time

continental shelf
a flat area under shallow ocean water at the edge of a continent

convection
the transfer of thermal energy by the movement of molecules in air or liquid from one place to another

convection current
the current or flow of air or liquid that results from the transfer of thermal energy by convection

converging boundary
the boundary between two tectonic plates that are moving together

core
the centre of the Earth

correlated
when results in an experiment show that independent and dependent variables are related

corrosion
the gradual destruction of materials by a chemical reaction with their environment

crust
the lithosphere, or outer layer of the Earth

D

decomposer
an organism that gains nutrients by breaking down dead organisms into simpler nutrients

dendrite
the part of a neuron (nerve cell) that receives a message and sends it to the cell body

dependent variable
a variable in an experiment that may change as a result of changes to the independent variable

derived units
units of measurement that are calculated using a combination of SI (international system) base units, e.g. cm^3 for volume (base unit is cm), m^2 for area (base unit is m)

direct current (DC)
the type of current that flows in one direction only; electrical energy is produced in this form by a battery or a generator

disease
a disorder or condition that interrupts the normal functioning of an organism

disease vector
a living organism that can transmit infectious disease between humans, or from animals to humans

diverging boundary
the boundary between two tectonic plates that are moving apart

dry cell
an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

dynamo
a generator that produces direct current (DC) through the use of a split ring commutator

E

ecosystem
a community of living organisms (biotic) and non-living (abiotic) factors

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

electric current
the flow of electrical charge through a circuit

electrical conductor
a material through which charged particles are able to move

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

electrical insulator
a material that does not allow the movement of charged particles

electromagnetic induction
the production of voltage (and hence a current) in a circuit, by the magnetic field through the circuit or by the relative movement of the magnetic field and the circuit; all dynamos and generators use this principle

electron
a negatively charged particle in the nucleus of an atom

electron shell
a defined area of space in which electrons move around an atom's nucleus

electronic configuration
a numerical way of showing the number of electrons in each electron shell around a particular atomic nucleus

electrostatic charge
an electrical charge that is trapped in an object such as a balloon

emigration
when an organism leaves an ecosystem

emission spectrum
the pattern of wavelengths (or frequencies) that appear as coloured lines in a spectroscope; it is unique to each element

endocrine system
a collection of glands that make and release hormones

endothermic reaction
a chemical reaction that absorbs energy in the form of heat

enhanced greenhouse effect
an increase in carbon dioxide and other heat-capturing gases in the atmosphere, resulting in increased warming of the Earth

epicormic bud
a small growth beneath the bark of a plant that allows regeneration after a fire

evaporation
a change in state from liquid to gas; also a technique used to separate dissolved solids from water

exothermic reaction
a chemical reaction that releases energy in the form of heat or light

F

fault
a fracture in rock where the tectonic plates have moved

fuel
a substance that undergoes a chemical reaction producing large amounts of energy

fuse
a wire of high resistance; it will melt if too much current flows in the circuit

G

gamma rays
high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

generator
a machine that uses the electromagnetic effect to separate charges and produce electricity

glycolysis
the first part of cell respiration in which glucose is broken down to produce energy

group
a vertical list of elements in the periodic table that have characteristics in common

H

habitat
the place where a population of organisms live

half-life
the time it takes the radioactivity in a substance to decrease by half

hibernation
a state of inactivity of an organism, usually as a result of low environmental temperature

homeostasis
the process by which the body detects and responds to stimuli to ensure a stable internal state is maintained

hormone
a chemical messenger that travels through blood vessels to target cells

hydrocarbon
a molecule that contains only carbon and hydrogen atoms

I

immune
able to fight an infection as a result of prior exposure

immune system
a system of organs and structures that protect an organism against disease

independent variable
a variable (factor) that is changed in an experiment

indicator
a substance that changes colour in the presence of an acid or a base

insulator
a substance that prevents the movement of thermal or electrical energy

interneuron
a nerve cell that links sensory and motor neurons; also known as a connector neuron

ion
an atom that is charged because it has an unequal number of electrons and protons

isotope
an atom of a particular element that has more or fewer neutrons in its nucleus than another atom of the same element

L

light-dependent resistor (LDR)
a resistor that changes its resistance according to the amount of light it is exposed to

light-emitting diode (LED)
a type of diode that emits light of a particular colour

lignotuber
a small growth in the root of a plant that allows regeneration after a fire

litmus paper
a paper containing an indicator that turns red when exposed to an acid and blue when exposed to a base

M

magma
semiliquid rock beneath the Earth's surface

mantle
the layer of molten rock beneath the Earth's crust

mass number
a number that represents the total number of protons and neutrons in the centre of an atom

mating
the pairing of a male and female of a species to produce offspring (babies)

matter
anything that has space and volume; matter is made up of atoms

memory cell
an immune system cell produced in response to an infection; retains the memory of how to fight the pathogen

metal oxide
a molecule containing a metal and oxygen

mid-ocean ridge
a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

migration
the movement of a single organism or a population from one ecosystem to another

mitochondrion
an organelle of a cell, where energy is produced (plural: mitochondria)

motor neuron
a nerve cell that carries a message from the central nervous system to a muscle cell

mutualism
a type of relationship between two organisms of different species in which both organisms benefit

myelin sheath
a fatty layer that covers the axon of a nerve cell

N

negative feedback mechanism
a regulatory loop in which the stimulus causes a response that acts in the opposite direction to whatever is being regulated

negative terminal
the point in the circuit where electrons flow out from

neuron
a nerve cell

neurotransmitter
a chemical messenger that crosses the synapse between the axon of one neuron and the dendrite of another neuron

neutral
having a pH of 7, so neither an acid nor a base; an example is water

neutralisation
a reaction in which an acid and a base combine to produce a metal salt and water

neutron
a neutral (no charge) subatomic particle in the nucleus of an atom

non-metal oxide
the product of a reaction between a non-metal and oxygen

nucleus
1. in biology: a membrane-bound structure in cells that contains most of the cell's genetic material; 2. in chemistry: the centre of an atom, containing protons (positive charge) and neutrons (no charge)

O

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

outlier
a data value that is outside the normal range of all the other results

P

parallax error
an error, or inaccurate reading, that occurs as a result of reading a scale from an angle

parallel
a way of connecting loads (e.g. lights) in an electric circuit so they are all connected to the battery separately; they are in parallel to each other

parasitism
a relationship in which one organism (parasite) lives in or on the body of the other organism (host) and benefits while the host is harmed

pathogen
a microbe that can potentially cause disease

period
(in chemistry) a horizontal list of elements in the periodic table

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to similar properties

peripheral nervous system
all the neurons (nerve cells) that function outside the brain and spinal cord

pH scale
a scale that represents the acidity or alkalinity of a solution; $pH < 7$ indicates an acid, $pH > 7$ indicates a base, pH 7 indicates a neutral solution

phagocyte
an immune system cell that surrounds, absorbs and destroys pathogens

photoconductivity
a property of light-dependent resistors, where the amount of electricity passing through the resistor is dependent on the amount of light it is exposed to

photosynthesis
a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

plate tectonics
the theory that the surface of the Earth consists of pieces, known as plates, that are continually moving

population
a group of individuals of the same species living in the same place at the same time

positive terminal
the point in the circuit where electrons flow into

precipitation
1. in meteorology: the process in which water vapour in the upper atmosphere becomes liquid water in the form of rain, snow or sleet and falls to the ground; 2. in chemistry: the process of forming a precipitate

predator
an animal that hunts and feeds on another (prey) for food

prey
an animal that is hunted and killed by another (predator) for food

proton
a positively charged subatomic particle in the nucleus of an atom

Q

quadrat
a randomly selected square plot used to estimate the number of organisms

R

radioactive decay
the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide
a radioactive isotope

reading error
an error that occurs when markings on a scale are not read correctly

receptor
a structure that detects a stimulus or change in the normal functioning of the body

rectifier
a device that coverts AC to DC, commonly composed of diodes

reflex
an involuntary movement in response to a stimulus

relative atomic mass
the average mass of an element, including the mass and prevalence of its different isotopes

resistance
a measure of how difficult it is for the charged particles in an electric circuit to move

rheumatoid arthritis
an autoimmune disease in which the immune system attacks the joints of the body

rift valley
a deep valley that forms as a result of tectonic plates moving apart on land

right-hand grip rule
a rule used to predict the magnetic field direction around a current-carrying wire or the magnetic field of a solenoid; the right thumb indicates the current direction and the curled fingers give the magnetic field direction; also known as the right-hand curl rule

right-hand slap rule
a rule used to predict the force on a current-carrying wire in a magnetic field; the right thumb indicates the current direction, the outstretched fingers follow the magnetic field direction and the palm of the hand pushes in the direction of the force

rounding off
reducing the number of significant figures by increasing or decreasing to the nearest significant figure; for example, 7.6 cm is rounded up to 8 cm, 7.2 cm is rounded down to 7 cm

S

salt
a compound that contains a metal cation and a non-metal anion

sample size
the number of subjects being tested or used in an experiment

sea-floor spreading
the theory that the middle of the ocean is spreading apart, forming new oceanic crust

semiconductor
a material that conducts electricity more than an insulator and less than a conductor; its conductivity can be changed by adding other substances to it

sensory neuron
a nerve cell that carries a message from a receptor to the central nervous system

series
describes an electric circuit that is arranged with the loads (e.g. lights) connected in a row, so the electrical energy passes through one load at a time

shell diagram
a diagram that shows the number of electrons in each electron shell around a particular atomic nucleus

short circuit
when electrical current flows along a different path from the one that was intended

SI system
an international system of measurement based on the metric system, with units such as kilogram, metre, kilometre

significant figures
the number of digits that contribute to the overall value of a number

solenoid
a coil of wire that can carry an electric current; an iron core can be added to make an electromagnet

solution
a mixture of a solute dissolved in a solvent

somatic nervous system
the part of the nervous system that controls the muscles attached to the skeletal system

split ring commutator
a device in a DC motor or a DC generator that reverses the current flow in an armature every half turn to maintain rotation (motor), or that converts the AC generated in the armature to a DC output (generator); most consist of two shells or half-rings that rub against the brushes

starch
a complex form of sugar that is found in certain foods (e.g. bread, potato and rice)

stimulus
any information that the body receives that causes it to respond

stomata
small holes in a plant leaf surrounded by guard cells that control their opening and closing (singular: stoma)

subatomic particles
particles that are smaller than atoms

subduction
the movement of one tectonic plate under another tectonic plate

symbiosis
a close physical relationship between two organisms of different species

synapse
a small gap between two neurons that must be crossed by neurotransmitters

T

T cell
an immune system cell that recognises and kills pathogens

target cell
a cell that has a receptor that matches a specific hormone

tectonic plate
a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

temperature-dependent resistor
a resistor that varies the flow of current according to the temperature it is exposed to

thermistor
a temperature-dependent resistor that varies the flow of current according to the temperature it is exposed to; commonly used for temperature control

Thomson plum pudding model
an early model of the atom in which the positively charged nucleus has negatively charged electrons scattered through it, like a plum pudding

transformer
a device that changes the voltage at which energy is transmitted by an alternating current; usually consists of two coils of wire (primary and secondary), an iron core and an AC power source

transforming boundary
the boundary between two tectonic plates that are sliding past each other

transpiration
the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

tsunami
a series of large waves that result from an underwater earthquake

type 1 diabetes
an autoimmune disease in which the immune system attacks the insulin-producing cells in the pancreas

U

universal indicator
a solution that is used to determine the pH (amount of acid or base) of a solution

V

vaccination
an injection of an inactive or artificial pathogen that results in the individual becoming immune to a particular disease

valence shell
the outermost electron shell in an atom that contains electrons

van de Graaff generator
a machine that produces an electrostatic charge

variable
something that can affect the outcome or results of an experiment

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

W

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

white blood cell
an immune system cell that destroys pathogens

Z

zero error
an error that occurs when an instrument has not been adjusted to zero before the measurement is taken

INDEX

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Notes

Australia is one of the most biologically diverse countries on Earth. It is home to more than one million species of plants and animals, many of which are found nowhere else in the world. This image shows researchers using a special type of net, known as a fyke net, to study a platypus. Studying platypuses helps us understand their health and diet, as well as the overall health of the ecosystems in which they live. The scientific name for the platypus is *Ornithorhynchus anatinus*.

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