OXFORD SCIENCE 9

AUSTRALIAN CURRICULUM

* EACH OF THESE OPTICAL DETECTORS WILL BE POSITIONED IN ARCTIC ICE AT A DEPTH OF UP TO 2400 M AND WILL DETECT CHARGED PARTICLES GENERATED WHEN NEUTRINOS FROM SPACE COLLIDE WITH THE ICE. ZEUTHEN, GERMANY

HELEN SILVESTER

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HELEN SILVESTER

OXFORD UNIVERSITY PRESS
AUSTRALIA & NEW ZEALAND

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SCIENCE 9

1 Science toolkit

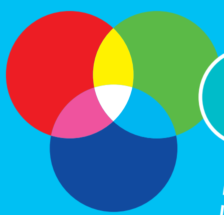
Scientists work collaboratively and individually to design experiments. They control variables and use accurate measurement techniques to collect data. They consider ethics and safety. They analyse data, identify trends and relationships, and reveal inconsistencies in results. They analyse and evaluate 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

Multi-cellular 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.

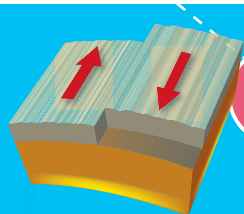


4 Sound and light

Sound and light are forms of energy that are transferred in waves. Sound is caused by the vibration of particles moving in a wavelike motion called a longitudinal wave. There are many different types of light, with a very wide range of wavelengths. Light waves are transverse waves.

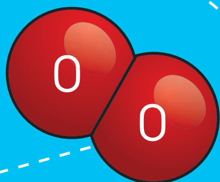
5 Heat and electricity

Thermal energy is the energy of vibrating particles. Thermal energy transfers from a hotter substance to a cooler substance in a process called heating. Heat transfer can occur when one substance passes its kinetic energy on to another (conduction) or when the hot, highly kinetic particles themselves move (convection). Radiation of thermal energy involves the transfer of energy across space. Electricity is a general term related to the presence and flow of electric charge.



6 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.



7 Matter

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

8 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.

CONTENTS

Using Oxford Science

Oxford Science is a series developed to meet the requirements of the Australian Curriculum: Science across Years 7 to 10. Taking a concept development approach, each double-page spread of Oxford Science represents **one concept** and **one lesson**.

What if?

Student-directed inquiry is encouraged throughout this series using a simple questioning technique. As the series progresses, students discover that their own *What if* questions are actually testable '*if and then*' hypotheses. For example, 'What if *the bubble is touched with a finger*' becomes 'If *the bubble is touched with a finger,* then *it will pop*'.

Concept development

Students are given access to the chapter concepts at the start of every chapter. Each double-page spread of this series represents **one concept**. Students explore concepts one-by-one, encouraging incremental learning and, by the end of the chapter, complete understanding.

The unit heading introduces the concept.

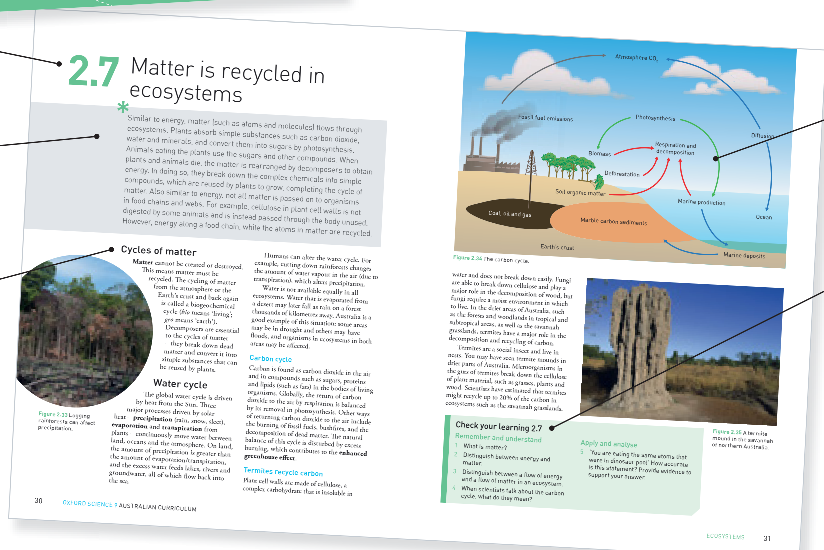
Each unit begins with a short summary of the concept.

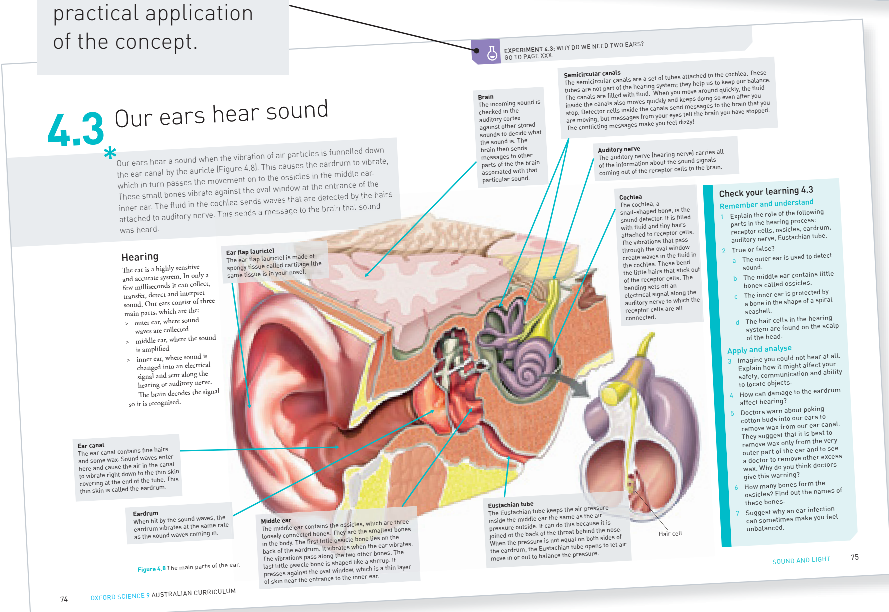
Body text elaborates on the concept in clear and accessible language.

Every spread is linked to one or more experiment, challenge or skills task as a practical application of the concept.

Diagrams and photos are used to illustrate the concept and engage students.

Every double-page spread ends with **Check your learning** questions, allowing students to consolidate their understanding. Questions are graded according to Bloom's Taxonomy – catering for a range of abilities and learning styles.





Accessibility and engagement

Oxford Science has been engineered to be accessible to all science students. We believe that science students are served best when they are free to focus on learning the knowledge and skills of science in simple accessible language, crafted into short sentences. Students will be engaged by the inclusion of stunning photography throughout.

Science as a human endeavour

Concepts are linked to real-world applications in the highly engaging **Science as a human endeavour** spreads. The **Extend your understanding** questions on these spreads are designed to be used flexibly as either homework tasks or an extended project.

Experiments

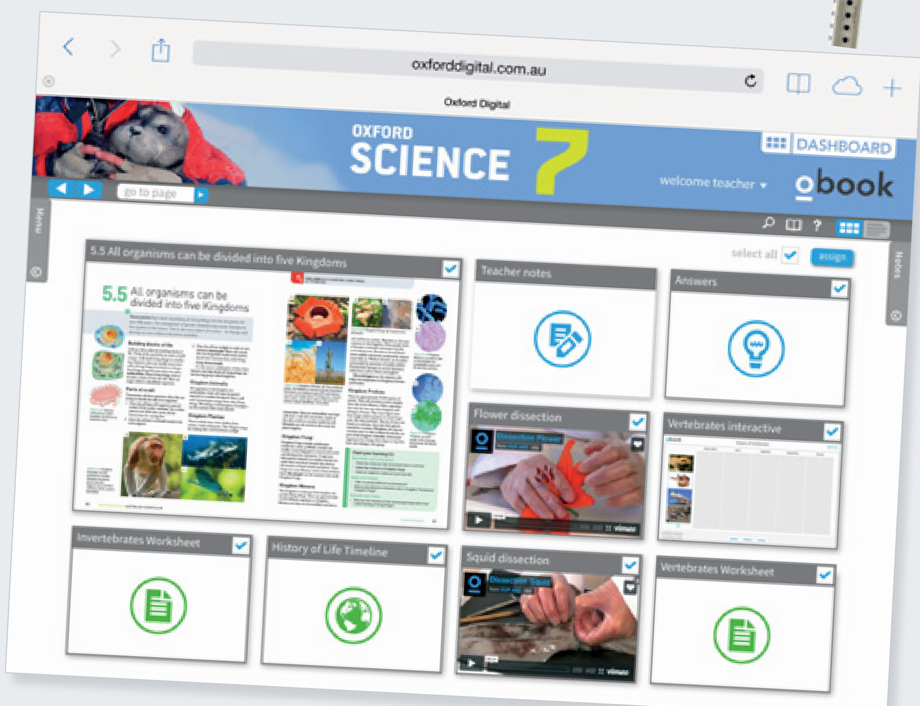
Uniquely, experiments are organised at the end of the book in an extended experiments chapter, rather than being confined to each double-page spread. There is a link on most double-page spreads to an experiment, challenge or inquiry task to ensure that practical activites remain aligned to the content.

Integrated teaching and learning support

obook **assess**

obook assess provides an interactive electronic version of the student book in an easy-to-read format. It features multimedia links, interactive learning objects, videos, note-taking, highlighting and bookmarking tools, and live question blocks. **obook** is compatible with laptops, iPads, tablets and IWBs, and also offers page view (in flipbook format) that can be used offline. **assess** provides 24/7 online assessment designed to support student progression and understanding.

DASHBOARD



Oxford Science is supported by teaching strategies, lesson ideas, planning tips, assessment advice and answers to all activities. **obook assess** allows teachers to manage their classes by assigning work, tracking progress and planning assessment. Teacher Dashboard is your online lesson control centre, which allows you to instantly preview or assign related teacher resources to deliver incredibly engaging digital learning experiences. Students can also toggle from their **obook** to the Dashboard to interact with student resources for each topic.

Australian Curriculum: Science 9 scope and sequence

SCIENCE 9 LEVEL DESCRIPTION (ABBREVIATED)

In Year 9, students consider the operation of systems at a range of scales. They explore ways in which the human body as a system responds to its external environment and the interdependencies between biotic and abiotic components of ecosystems. They are introduced to the notion of the atom as a system of protons, electrons and neutrons, and 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. They are introduced to the concept of the conservation of matter and begin to develop a more sophisticated view of energy transfer. They begin to apply their understanding of energy and forces to global systems such as continental movement.

SCIENCE CONTENT DESCRIPTIONS	
Chapter 3	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175)
Chapter 2	Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176)
Chapter 7	All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (ACSSU177)
Chapter 7, Chapter 8	Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed (ACSSU178)
Chapter 8	Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (ACSSU179)
Chapter 6	The theory of plate tectonics explains global patterns of geological activity and continental movement (ACSSU180)
Chapter 4, Chapter 5	Energy transfer through different mediums can be explained using wave and particle models (ACSSU182)

SCIENCE AS A HUMAN ENDEAVOUR (YEARS 9 –10)	
Nature and development of science	
All chapters	Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community (ACSHE157)
All chapters	Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE158)
Use and influence of science	
All chapters	People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions (ACSHE160)
All chapters	Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities (ACSHE161)
All chapters	The values and needs of contemporary society can influence the focus of scientific research (ACSHE228)

SCIENCE INQUIRY SKILLS (YEARS 9 –10)	
Questioning and predicting	
All chapters	Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)

SCIENCE INQUIRY SKILLS (YEARS 9 –10)	
Planning and conducting	
All chapters	Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)
All chapters	Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166)
Processing and analysing data and information	
All chapters	Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS169)
All chapters	Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)
Evaluating	
All chapters	Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS171)
All chapters	Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems (ACSIS172)
Communicating	
All chapters	Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

YEAR 9 ACHIEVEMENT STANDARD

By the end of Year 9, students explain chemical processes and natural radioactivity in terms of atoms and energy transfers and describe examples of important chemical reactions. They describe models of energy transfer and apply these to explain phenomena. They explain global features and events in terms of geological processes and timescales. They analyse how biological systems function and respond to external changes with reference to interdependencies, energy transfers and flows of matter. They describe social and technological factors that have influenced scientific developments and predict how future applications of science and technology may affect people's lives. Students design questions that can be investigated using a range of inquiry skills. They design methods that include the control and accurate measurement of variables and systematic collection of data and describe how they considered ethics and safety. They analyse trends in data, identify relationships between variables and reveal inconsistencies in results. They analyse their methods and the quality of their data, and explain specific actions to improve the quality of their evidence. They evaluate others' methods and explanations from a scientific perspective and use appropriate language and representations when communicating their findings and ideas to specific audiences.

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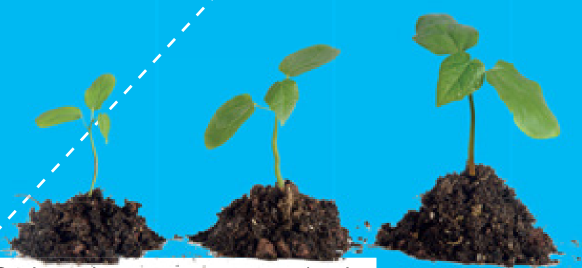
SCIENCE TOOLKIT 1

1.1 Scientists can test manufacturers' claims

1.2 Scientists must be aware of experimental errors

1.3 Scientists prepare material safety data sheets



1.4 Scientists present their data accurately

1.5 Scientists investigate consumer products

What if?

Staples

What you need:

10 sheets of A4 paper, a variety of staplers with staples

What to do:

1 Fold an A4 sheet of paper in two.
2 Staple the two sheets of paper together with one of the staplers.
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 same stapler.
5 Repeat steps 3 and 4 until the staple 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

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 is a branch of science that involves applying the scientific method to the claims made by manufacturers.

Consumer science case study

Several years ago, two New Zealand science students, Jenny Suo and Anna Devathasan, exposed a startling fact about the fruit juice drink Ribena while performing 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 performed 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*.

Figure 1.1 Ribena was found to contain less vitamin C than its competition, despite the manufacturer's claims.

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 theory or hypothesis that arises as a result of a 'what if' question. For Jenny and Anna, this question was:

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

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

'*If* the vitamin C content of Ribena was compared with other fruit drinks, *then* Ribena will have more vitamin C/mL.'

Figure 1.2 Anna Devathasan and Jenny Suo.

EXPERIMENT 1.1: WHAT IF THE ABSORBENCY OF DIFFERENT PAPER TOWELS WAS COMPARED?
GO TO PAGE 178.

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

Variables

A hypothesis should be tested in an objective way. For example, for a fair comparison of the fruit juices, 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 juices tested, the age and temperature of the fruit juices and the quality of the chemicals used in the testing.

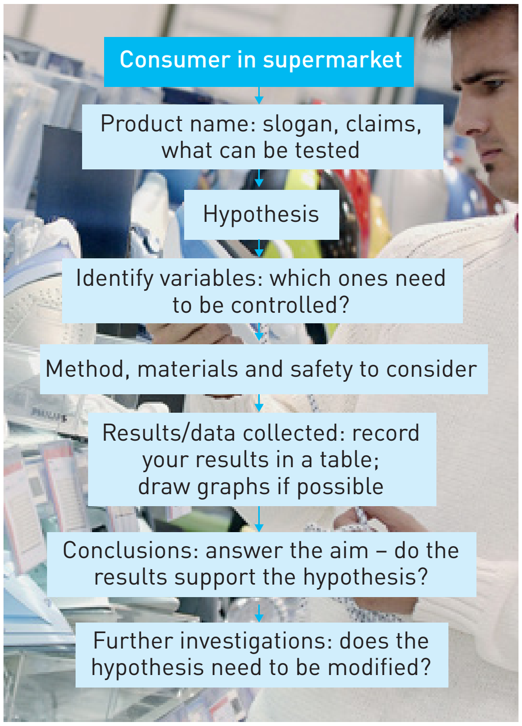


Figure 1.3 Using the scientific method to test manufacturers' claims.

To test the hypothesis, all of 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 being tested. The variable being measured is the **dependent variable**, such as amount of vitamin C in a fruit juice.

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 greater the number of 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, or data, that you make 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.

Conclusion

A conclusion should answer the initial question asked about the experiment. It should provide evidence that supports or refutes the hypothesis. Any further investigations that may need to be done can be outlined here.

Check your learning 1.1

Remember and understand

1 What is a hypothesis? Give one example.

2 Why should an experiment have a clear and detailed method?

3 Does an increased sample size give greater validity to an experiment? Give reasons for your answer.

4 If your hypothesis is shown to be wrong, was your experiment still useful? Justify your answer.

5 Often scientists have to present their findings to the public in order to get action taken. Sometimes this is very difficult, so they need to be quite sure that their findings are reliable. Explain how the scientific method ensures that the findings are reliable.

1.2 Scientists must be aware of experimental errors

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

Figure 1.4 A burette is a laboratory instrument used to accurately measure the volumes of liquids.

Choosing the right device

Choosing the right instrument is the first step in achieving accuracy. For example, if you need to accurately measure the volume of a liquid, then you would use a burette or a measuring cylinder, and certainly not a beaker. A burette has a more accurate scale than a measuring cylinder. A beaker has no scale.

Errors and accuracy

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

A **reading error** can result when guesswork is involved when taking a reading. For example, when a reading lies between the divisions on scale, a guess of the actual reading will result in a reading error (Figure 1.5).

A **parallax error** occurs when the eye is not placed directly opposite the scale when the reading is being taken. You can avoid parallax errors by ensuring that your eye is placed 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 1.6).

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 empty containers. For example, scales must be set to zero correctly before making a weight measurement of substances (Figure 1.7).

Scientists will often repeat measurements and then find an average measurement to improve their accuracy.

Mathematical accuracy

When conducting a scientific investigation, mathematical accuracy is very important. Not only must your equipment be appropriate and precise to avoid errors, but your calculations must also be mathematically accurate. When taking a reading, you should quote the maximum allowed number of **significant figures**. This can represent the accuracy of a measurement or reading. When results are recorded, it is important to know the number of significant figures the instrument allows. The final answer can only be quoted correct to the number of significant figures present in the least accurate result. For example, if one measuring device measures to 0.22 and a second device measures to 0.345, the final answer should only have two figures after the decimal point. This might require a **rounding off** procedure.

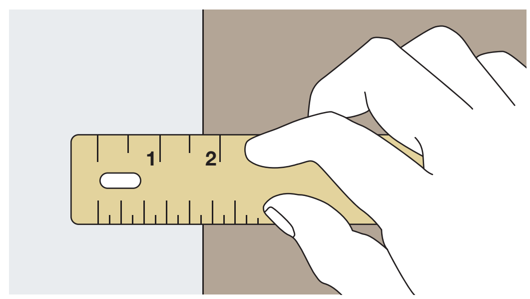


Figure 1.5 Guessing the measurement between units of measurement (for example, between 1.5 and 2) can produce a reading error.

Measurements and units

Scientists measure fundamental quantities, such as mass, time and length, in a standard unit that has been agreed upon by scientists

CHALLENGE 1.2: AVOIDING ERRORS AND IMPROVING ACCURACY
GO TO PAGE 179.

across the world. The international system of units, known as the **SI system** of units, is based on the metric system. Table 1.1 shows some SI units. Other measurements, such as volume, are calculated from those basic units and so are termed **derived units**.

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 zeroes in it. For example, masses of 0.000 000 007 43 kg or 850 000 000 kg are very inconvenient to write. So, scientists and mathematicians choose a unit that requires as few zeroes as possible. They denote this by using a system of prefixes before the basic measurement unit, shown in Table 1.2.

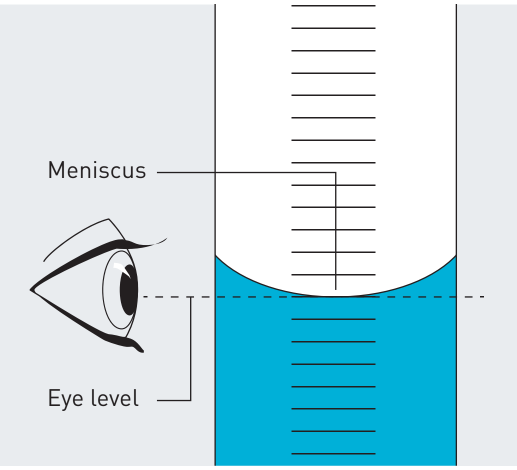


Figure 1.6 To avoid parallax error, make sure your eye is correctly lined up with the bottom of the meniscus.

Table 1.1 SI units

PHYSICAL QUANTITY	SI UNIT	ABBREVIATION OR SYMBOL
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A

Figure 1.7 Scales must be zeroed correctly before weighing yourself.

Notice that when the number is larger than the basic measurement, the prefix is a capital letter. When it is only a fraction of the basic measurement, the prefix is a small (i.e. lower case) letter. 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. Kilograms is an exception to this general rule. A kilogram is 100 grams and its symbol is kg.

Table 1.2 Standard prefixes and meanings

NAME	SYMBOL	VALUE	MEANING
peta	P	10^{15}	One thousand million million
tera	T	10^{12}	One thousand million
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

Check your learning 1.2

Remember and understand

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

2 How can these errors be reduced to improve accuracy?

3 Why do scientists often repeat experiments and then take an average?

4 What symbol would you write for:
  a millionths of a gram?
  b billions of litres?
  c thousandths of an ampere?
  d thousands of metres?

Apply and analyse

5 State 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 for an experiment:
5.6 volts, 2.97 amperes, 3000 seconds
To how many significant figures should the final answer be stated? Justify your answer.

1.3 Scientists prepare material safety data sheets

A Material Safety Data Sheet (MSDS) is an important tool for maintaining safety in a science laboratory. It contains information about a chemical such as its various names, the dangers involved in its use and the precautions scientists should take when handling the chemical. MSDSs should be prepared for all the reactants used and the products produced during science experiments.

MATERIAL 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 1.8 Example of an MSDS 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 Material Safety Data Sheet (MSDS) provides scientists and emergency personnel with information on how to use a particular substance. An MSDS also helps scientists understand more about how the chemical is used during the experiment.

Figure 1.9 Emergency workers in sealed positive pressure protective suits communicating with each other.

MATERIAL SAFETY DATA SHEETS

The information on a Material Safety Data Sheet includes the following.

- **The various names of the chemical**, including 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 or Sudafed.
- **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 on the right.
- **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.
- **Protective measures**
  The MSDS 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 chemical**
  Everyone in a laboratory should be able to easily identify the chemical. The MSDS should include the colour, smell, pH, flammability, solubility, melting and boiling points of the chemical.

Figure 1.10 MSDSs are used in many industries, including the mining industry.

- **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 whether 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 safety for both 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 MSDS was last reviewed**

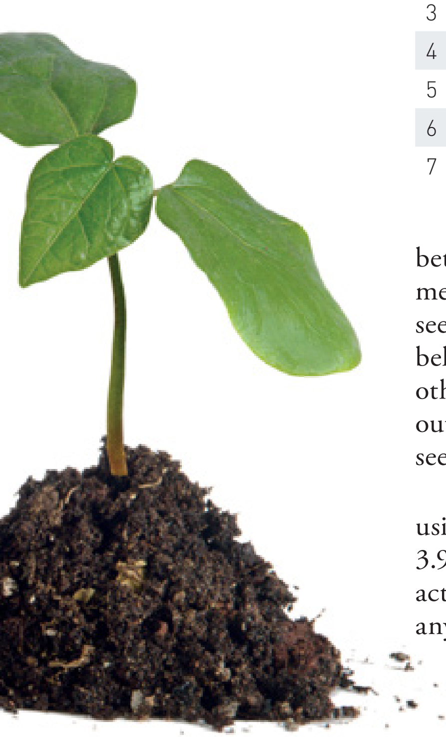
Check your learning 1.3

Remember and understand

1. What does MSDS stand for?
2. Why is it important to prepare an MSDS before starting an experiment?
3. Why is it important to have all the various names of a chemical on the MSDS?
4. What type of personal protective equipment do you have in your laboratory?
5. What is the phone number of the Office of Chemical Safety in your state?

1.4 Scientists present their data accurately

*The results section is often the most important part of an experiment report. It must present an accurate picture of the findings. 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) or the mode (most common result) is less affected by outliers. Positive correlation of data does not mean one event caused another event.



Outliers

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.

Table 1.3 Seeding 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 3.3 cm. This average is well below the growth of any of the seedlings other than seedling 5. This shows how one outlier can present an artificial result of the seedling growth.

If the average is determined without using 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?

Are the results 'pure' if some are left out? For this reason, an outlier is only excluded if it is explained how the results are modified and the reason for doing so. For example, the discussion might include the statement that 'Seedling 5 was excluded from the analysis due to a fungal infection that affected its growth.'

Median

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

$$0.1,\ 3.5,\ 3.6,\ \underset{\uparrow \atop \text{Median}}{4.0},\ 4.0,\ 4.1,\ 4.3$$

The median amount the seedling 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.

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 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.

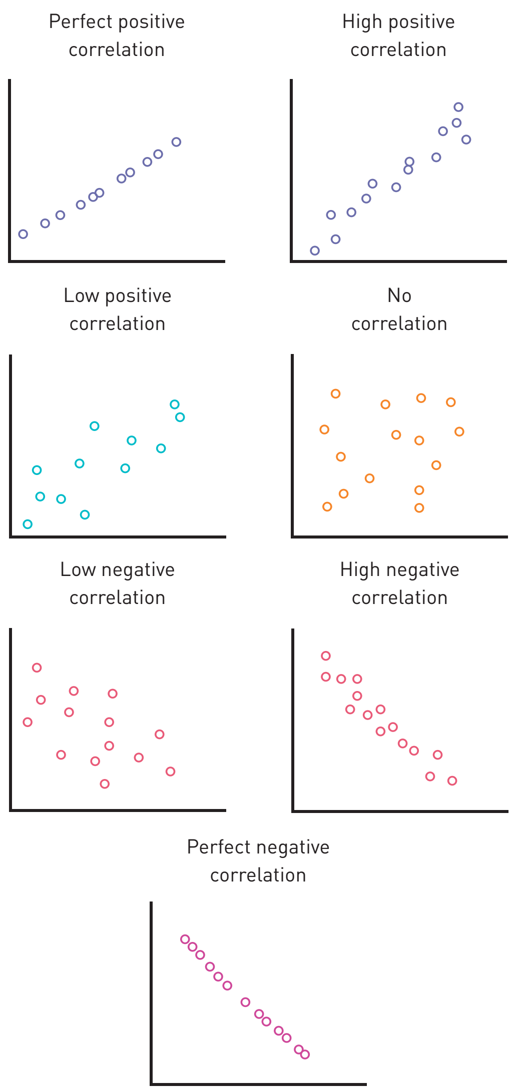


Figure 1.11 Correlation of data.

Check your learning 1.4

Remember and understand

1 Why is it best to present your data in table form?

2 What is an outlier? Should an outlier be included? Give reasons for your answer.

3 What is meant by the:

a mean?

b median?

c mode?

Apply and analyse

4 Draw a graph of the following set of data.

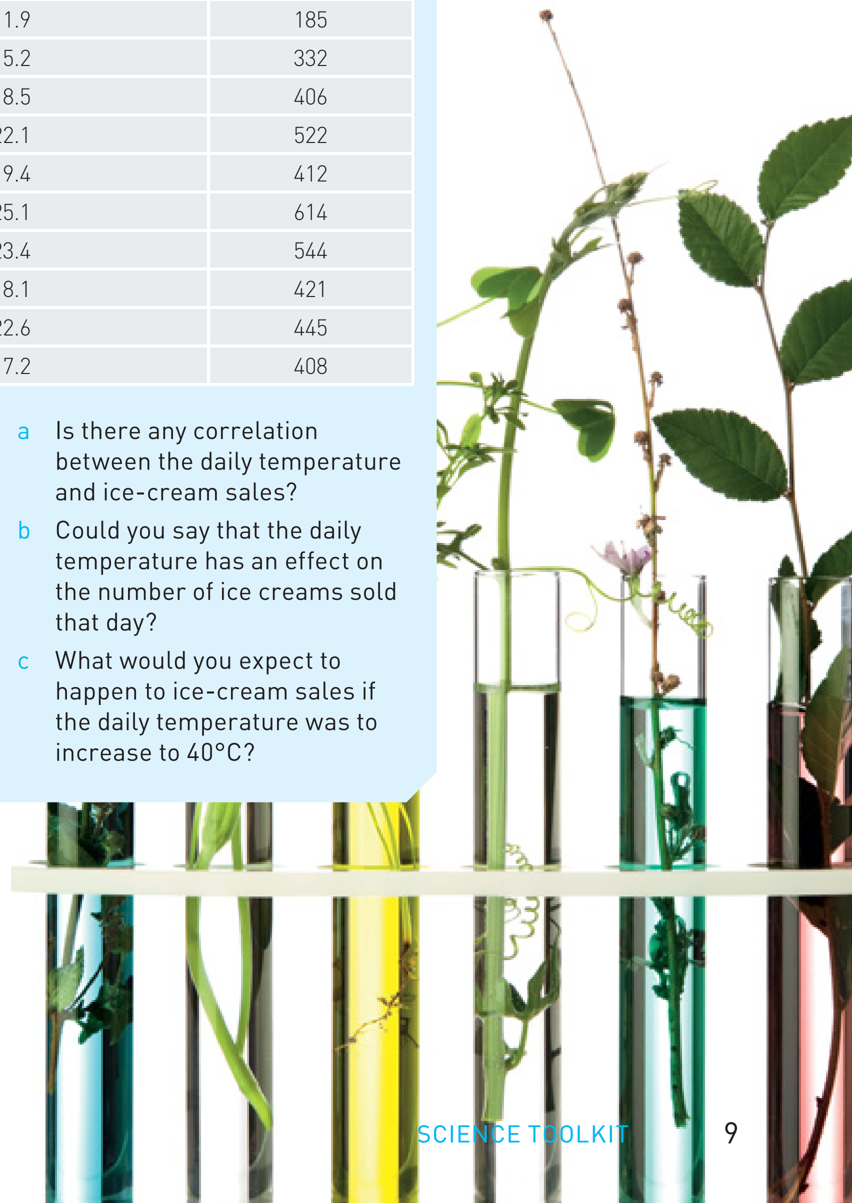
Ice-cream sales vs temperature

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

a Is there any correlation between the daily temperature and ice-cream sales?

b Could you say that the daily temperature has an effect on the number of ice creams sold that day?

c What would you expect to happen to ice-cream sales if the daily temperature was to increase to 40°C?



//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 will be to practise using the scientific method. You will need to ensure that you follow the scientific method.

Think

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 an 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 prices and packaging of different brands, as well as searching the Internet, journals, books and encyclopaedias to identify the science behind your product.

Ideas

Here are some ideas for your investigation.

> Do all brands of bubble gum make the same size 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/types of markers produce the same result?
> Do consumers prefer bleached paper products or natural coloured paper products? Why?
> Is laundry detergent as effective if you use less than the recommended amount? What if you used more than the recommended amount?
> Is bottled water more pure 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.

> Does the design follow the scientific method?
> 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 challenge, you will need to think about reducing your errors and improving your 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 with 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? Does this imply causation?

You will also need to complete a presentation about your investigation. This could be done as a web page, a PowerPoint 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

Remember and understand

1 List the main steps used when conducting an experimental investigation by the scientific method.

2 What is a variable?

3 Why are consumer scientists interested in what can be observed and tested rather than in the slogans and claims of manufacturers?

4 How do scientists find out about the safety risks involved in an experiment they are planning?

5 Suppose you are conducting a fair experiment in which you have identified six variables. How can you be sure of the effect of one particular variable?

6 Why aren't beakers used to measure volumes?

7 What is the difference between instrumental error and parallax error?

8 What is an SI unit?

9 State the SI unit for:

- a time
- b mass
- c length.

10 What do the following prefixes for a quantity mean?

- a mega
- b micro
- c kilo

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

Apply and analyse

12 A consumer scientist wanted to test the effect of a lotion for treating acne. At first she tested the lotion on a group of 20 teenagers, all aged 15, but then she decided to conduct some more tests. So she then tested 100 teenagers, all aged 15.

- a Is this an example of experimental repetition or increasing the sample size?
- b Which result is likely to lead to the most reliable conclusion? Justify your answer.

13 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. How might the scientist test a fabric for durability in a fair and objective way? Why is this important?

14 State the number of significant figures in each of the following measurements.

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

15 Determine the mean, median and mode of the following set of data:

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

16 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. Identify the variables you will be considering. What measurements will you take and how will you ensure that they are accurate?

17 For the experiment you designed in question 16, outline the results you would expect to obtain if your stated hypothesis was correct.

Evaluate and create

18 For the experiment you designed in question 16, assess how accurate your results may be, and suggest what further investigation you could take to improve the reliability of your conclusion.

19 For the experiment you designed in question 16, if you found that the manufacturer's claim was correct, create a scientifically accurate slogan or advertisement for the lipstick based on your findings.

20 One source of information for consumers is *Choice* magazine. The magazine reports the results of testing a variety of brands of consumer products. If a consumer scientist was reading a report on the safety of children's pyjamas, what evidence might they look for to see if the report was fair and objective? If they conclude that it is, how might the public be convinced to read such reports before purchasing children's pyjamas?

Research

21 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.

> **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 to include the outcomes or conclusions reached in any of these studies.

> **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. What scientific tests are performed to check that the claims are correct and what results have been obtained? After researching and comparing a range of evidence, what is your conclusion? Should we drink bottled water here in Australia and not tap water? Or does this depend on where you live?

> **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. What is the meaning of the term 'antipodal evidence'? Are there warnings based on anecdotal evidence or scientific evidence? Can anecdotal evidence be of value to scientists? Discuss.

*KEY WORDS

1

dependent variable
the variable being tested in an experiment

derived units
units of measurement that are calculated from the international system of units; for example, volume (cm^3) and area (cm^2)

independent variable
the variable that is deliberately changed or tested during an experiment

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

parallax error
an error that occurs when the reader's eye is not placed directly above a mark

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

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

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

SI system
international system of units based on the metric system; for example, kilogram, metre, kilometre

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

variable
anything that can change the outcome or result of an experiment

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

ECOSYSTEMS

2

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

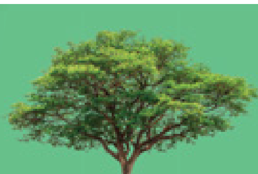
2.2 Relationships between organisms may be beneficial or detrimental

2.3 Population size depends on abiotic and biotic factors

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

2.5 Energy enters the ecosystem through photosynthesis

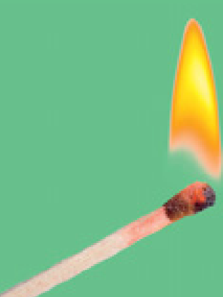
2.6 Energy flows through an ecosystem



2.7 Matter is recycled in ecosystems

2.8 Natural events can disrupt an ecosystem

2.9 Human activity can disrupt an ecosystem



2.10 Human management of ecosystems continues to change

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 and 1 spatula of sugar to the test tube.
2. Add 5 mL of warm water to the test tube.
3. Measure the temperature of the water.
4. 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.
5. Measure the height of the culture every minute for 15 minutes.
6. 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

An ecosystem is a community of living organisms (biotic) and their non-living surroundings (abiotic). It is the basic unit of ecology. Ecology is the study of the interrelationships of organisms with other organisms and with their non-living environment. Groups of organisms live together in communities. Many different species may live in a community. They share the same environment because they find their requirements there. A group of organisms of the same species in the environment is called a population.

Figure 2.1 Wetlands such as those in Kakadu National Park in the Northern Territory are an example of an ecosystem.

The biosphere – a home for our ecosystems

The **biosphere** describes the living world. It is where all of the plants, insects and animals live. The biosphere extends to any place that life, of any kind, can exist on the Earth. The biosphere can be thought of as the intersection between the atmosphere (gases), the hydrosphere (water) and the lithosphere (land). Since the biosphere is large, and its relationships are so 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 lives. 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 better habitat or will die out.

Benefits of an ecosystem

Humans depend on ecosystems for survival. Ecosystems provide a number of benefits to ensure our continual existence.

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 during a process called photosynthesis. Animals, including humans, use the oxygen in cellular respiration and release carbon dioxide into the air.

CHALLENGE 2.1: MAKING A BIOSPHERE
GO TO PAGE 179.

EXPERIMENT 2.1: PURIFICATION OF WATER
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Figure 2.2 Dolphins come to the surface of the water to breathe in air and release carbon dioxide through an air hole.

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 not only helps wild plants, it is also important for crop plants. Over 70% 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 not only prevent dead organisms from piling up, they also take the nutrients from the dead body to use when building their own bodies. The nutrients will then be 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.

Figure 2.4 Fungi are important decomposers. These fungi are feeding off a rotting log.

Figure 2.3 The forested water catchment areas around Melbourne are vital for keeping its water supply clean.

Wetlands and forests clean water

If you poured dirty water through a filter, you would expect cleaner water to come out. A similar situation 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.

Figure 2.5 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.

Check your learning 2.1

Remember and understand

1. What three systems interact to form a biosphere?
2. What is the scientific word for non-living components of an ecosystem? Give three examples of these components.
3. What is the difference between a population and a community?
4. Give some examples of the benefits that ecosystems provide.

Apply and analyse

5. Why does Melbourne have such good drinking water? Figure 2.3 may help to answer this.

Evaluate and create

6. Imagine someone walked up to you and asked 'Why is the environment so important?' Draft a reply, taking into account the key concepts covered here.

2.2 Relationships between organisms may be beneficial or detrimental

All organisms interact with each other in a community. 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 with each other. This type of relationship is called symbiosis. Symbiotic relationships include mutualism, commensalism and parasitism. Both organisms benefit in mutualism; only one organism benefits in commensalism; and one organism benefits and the other is harmed in a parasitic relationship.

Relationships within a species

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

1 **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.
2 **Mating** between members of the same species produces offspring, thus ensuring the survival of the species.

3 **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.

EXPERIMENT 2.2: WHAT IF MORE SEEDS WERE PLANTED IN A POT?
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Figure 2.6 Mutualism. A lichen is 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.

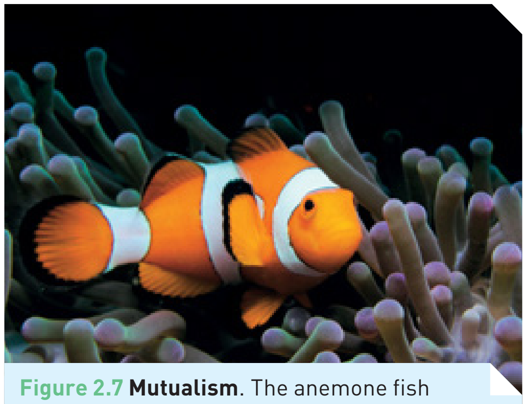


Figure 2.7 Mutualism. The anemone fish hides within the tentacles of the sea anemone where it is camouflaged from its predators. The sea anemone is cleaned of algae by the fish.

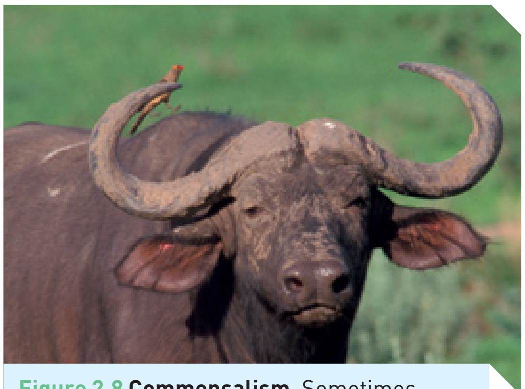


Figure 2.8 Commensalism. Sometimes herbivorous animals such as cattle and water buffalo flush insects out of the grass as they wander through. Birds such as cattle egrets feast on the insects.

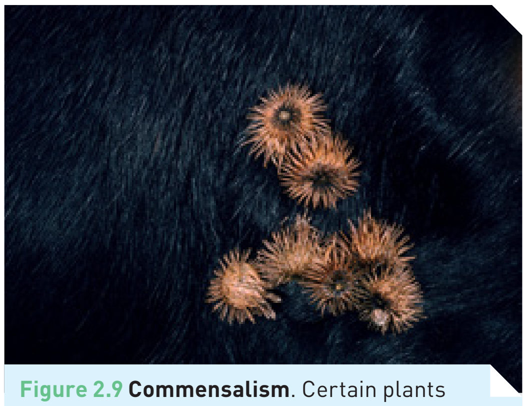


Figure 2.9 Commensalism. Certain plants rely on passing animals to disperse their seeds. The seeds have tiny hooks that attach to animal fur and they will usually fall off a distance from their parent plant.

Figure 2.10 Parasitism. Ticks attach to the skin of animals and slowly drink their blood. Bacteria from the digestive system of the tick can infect the animals.

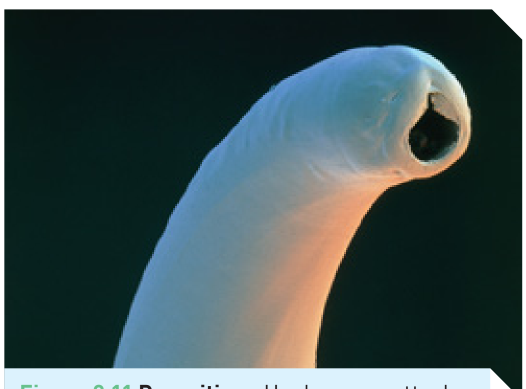
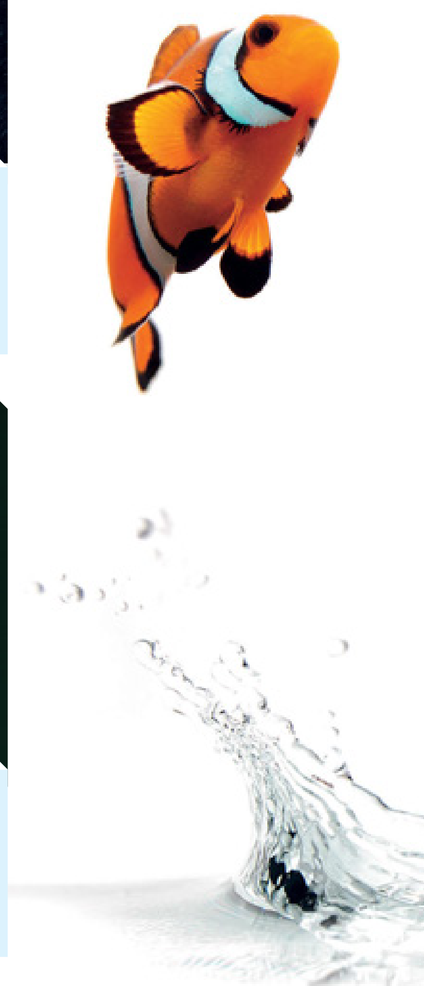


Figure 2.11 Parasitism. Hookworms attach themselves to the inner lining of the human intestine, feeding on nutrients as they pass by. If the host doesn't eat enough, the worm has been known to burrow out of the intestines and travel to other organs, where significant damage can be done.



Non-symbiotic relationships

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 has the opportunity. Predators and their prey have a balanced relationship with each other. If all the prey are eaten, then the predator will starve. A graph of predator–prey numbers (Figure 2.12) shows a typical pattern.

Competition may also exist between members of different species that share a resource such as food (Figure 2.13).

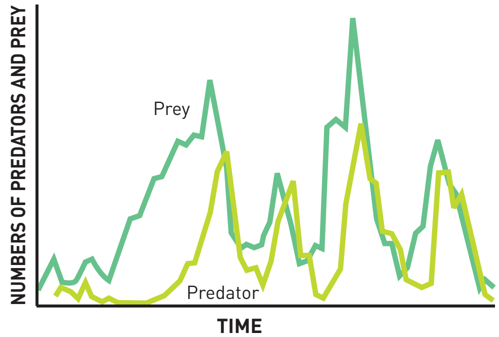


Figure 2.12 A predator–prey graph. The scales aren't shown but the prey numbers are mostly greater than those of the predators. Notice that the increase and decrease in prey numbers usually comes before the increase and decrease in predator numbers.

Figure 2.13 A black periwinkle (*Nerita*) competes for food with the limpet (*Cellana*) on a rock platform – both feed on algae growing on the rocks. The periwinkle moves faster but feeds less efficiently than the limpet, 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.

Inhibition is a particular type of competition that occurs when one organism produces a chemical that directly inhibits or hinders the growth and development of another (Figures 2.14 and 2.15).

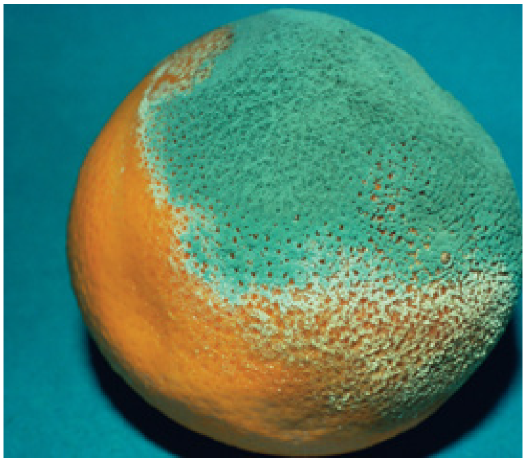


Figure 2.14 *Penicillium* mould (fungus, seen here growing on an orange,) produces an antibiotic called penicillin that inhibits the growth of many species of bacteria.

Figure 2.15 The *Lantana* plant was introduced into Australia and has become a weed. It releases a chemical in the soil that inhibits the growth of native plant species.

Check your learning 2.2

Remember and understand

1 State one similarity and one difference between a predator–prey relationship and parasitism.

2 How can a large plant that produces a lot of shade prevent smaller plants from growing?

Apply and analyse

3 Give an example of the following relationships.

   a Predator–prey

   b Mutualism

   c Commensalism

   d Parasite–host

4 Some eucalyptus trees have mistletoe plants living on them. Mistletoe has very similar leaves to eucalyptus leaves. Mistletoe can make their own food but their stems send suckers into the eucalypt to obtain water and minerals. If too much water and minerals are removed, the eucalypt can die. What type of relationship is this? Give a reason.

5 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. What type of relationship is this? Why?

2.3 Population size depends on abiotic and biotic factors

The number of organisms in a population can be affected by many different 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. An ecosystem needs to be able to maintain a balance 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).

Consider the food web for an ecosystem shown in Figure 2.16. If the number of frogs decreased in this ecosystem, consequences could include:

> increase in grasshopper numbers and thus depletion of grass
> initial increase in praying mantis numbers because of more grasshoppers
> decrease in lizard numbers
> diversion of birds towards a diet of praying mantises rather than frogs and lizards
> consequent decrease in praying mantis numbers
> further increase in grasshopper numbers and intensified depletion 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 will decrease so that all species will return to balance with reduced population sizes. A positive effect is that it might enable the frog population to recover.

Ecosystem balance is a type of dynamic equilibrium. Changes may upset the equilibrium, but 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 (for example, seasonal changes), disasters (floods, droughts, earthquakes) and human intervention occur regularly.

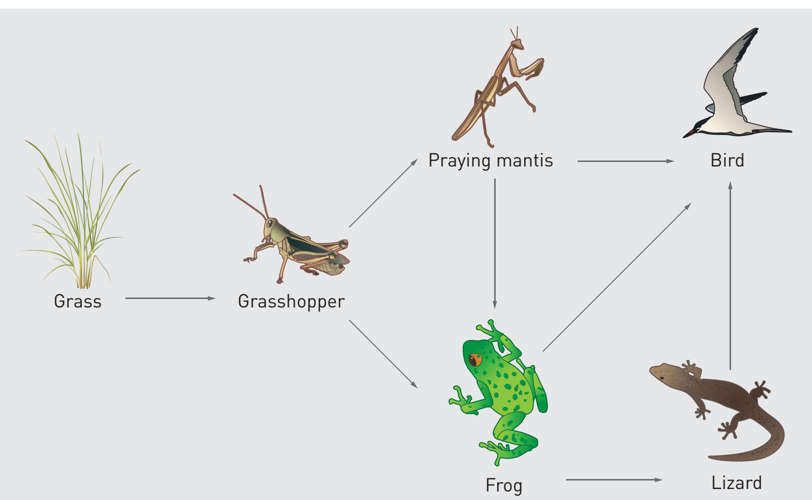


Figure 2.16 A food web for an ecosystem.

Population dynamics

Population dynamics is the study of the changes in population numbers within ecosystems. Scientists can make predictions and take certain precautions to conserve species if they have an approximate idea of how many of each species are in a certain location. Regular sampling provides information about

CHALLENGE 2.3: DELICIOUS COUNTING
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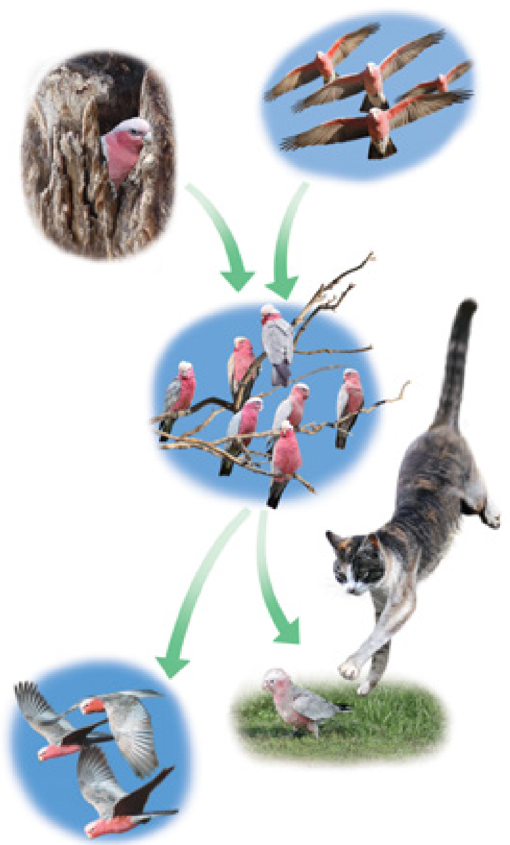

Figure 2.17 The size of a galah population in a particular area depends on the food available and the number of births and deaths.

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 is to count all the organisms, but in practice this is rarely possible. Estimates are more easily achieved by counting from helicopters or 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. 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 mobile, **capture–recapture** is a popular method. Animals are captured in traps and marked with tags, liquid paper 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:

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

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

Figure 2.18 Using a quadrat.

Figure 2.19 Marking a captured animal.

Check your learning 2.3

Remember and understand

1 Describe suitable methods for estimating the size of populations of:
  a plants and stationary animals
  b other animals.
2 What are the advantages and disadvantages 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 eight animals on the first night and marked white dots on their tails. Then they released them. On the second night, they captured 10 animals, of which four were marked.
  a What is the estimation of the population size of *A. stuartii* in this ecosystem?
  b How could the students increase the accuracy of this experiment?
4 Is growth in population size always desirable? Discuss.
5 Ecosystems are said to be in a state of equilibrium or balance. It appears that nothing is changing. But is there change?
6 Explain how predator–prey relationships achieve a state of balance. Why is this balance essential for the:
  a prey?
  b predator?

//SCIENCE AS A HUMAN ENDEAVOUR//

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

Introducing or removing a species from an environment can have devastating effects on other populations in an ecosystem. 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. Ecosystems must establish a balance between all organisms in the community.

Figure 2.21 Rabbits bite tusks of grasses very close to the ground. Combined with digging extensive burrows, this makes the soil more prone to erosion.

Introducing rabbits

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

Rabbits breed very quickly. A single female rabbit can have up to 14 babies every 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 2.20).

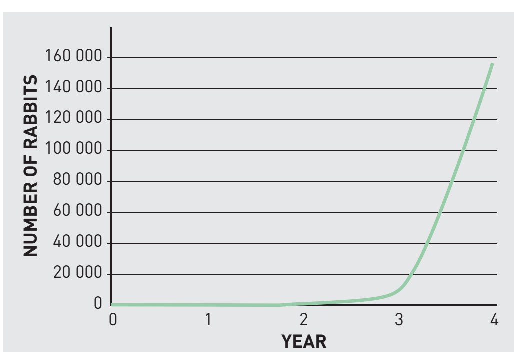

Figure 2.20 The growth of a rabbit population over four years from a single female rabbit (assuming unlimited food and no predators).

Rabbits for sport

In 1859, farmer Thomas Austin requested 24 wild rabbits be sent 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 conditions slowed the growth of rabbit populations. 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 for the rabbits. Over the next 40 years, the rabbits spread as far as Queensland, Western Australia and the Northern Territory.

Controlling 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 even a rabbit-proof fence across large sections of Western Australia was trialled.

CHALLENGE 2.4: RABBIT AND FOX CHASEY
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The increase in 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. Predators of the rabbits (such as dingos and eagles) grew in numbers due to the increase in food. Unfortunately, these increased numbers of predators also ate the local marsupials, causing their populations to decline. All these factors contributed to the permanent loss of several species of native plants and animals.

Macquarie Island rabbits

In 1985, scientists on Macquarie Island (halfway between Australia and Antarctica) devised a plan to remove all the non-native cats that had been introduced to the island since the early 19th century. It was thought this would increase the native burrowing bird populations on the island. However, when the cats were removed, the island rabbit population increased dramatically, destroying native plants and affecting many other organisms native to the island. Scientists needed to find a way to control the rabbits.

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 fevers and swellings around the head of the rabbits. Death occurs within 14 days. *Myxoma* was eventually released in the wild and quickly killed almost all of the rabbits that caught the infection. This increased Australia's wool and meat production within two years. A small percentage of rabbits were unaffected by the disease. These rabbits survived and were able to breed a new population of rabbits that were **immune** to the disease. New viruses, such as the caliciviruses, have been tried with similar results.

Before any species is introduced or removed from a population, scientists must ensure they are aware of all the possible implications for the ecosystem.

Figure 2.22 In 1907, a rabbit-proof fence was built between Cape Keraudren and Esperance in Western Australia.

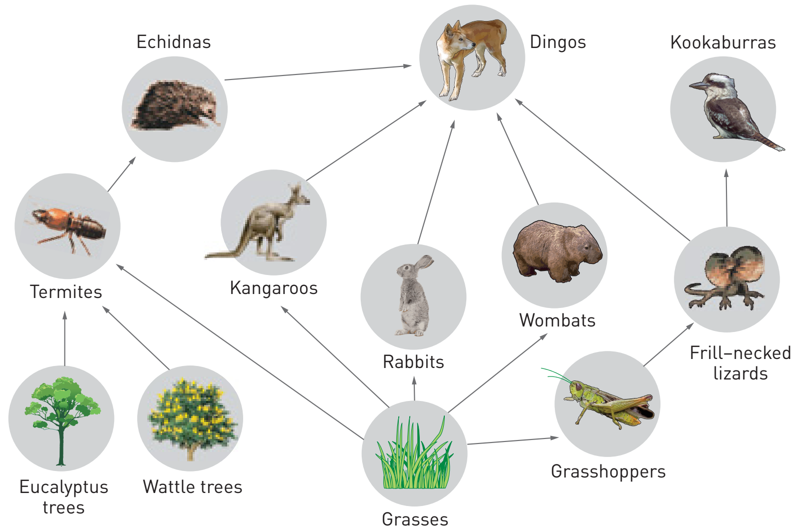

Figure 2.23 Rabbits compete with grasshoppers, wombats and kangaroos for grass.

Figure 2.24
(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 non-native cats were eradicated.

Extend your understanding 2.4

1. Why are rabbits referred to as an introduced animal in Australia?
2. Suggest two reasons why the rabbit population was able to increase so quickly when first introduced to Australia.
3. Use the food web in Figure 2.23 to suggest two populations that will increase as a result of the introduction of rabbits.
4. What effect does a high rabbit population have on the ecosystem in Figure 2.23?
5. What is a biological control?
6. Why is *Myxoma* no longer effective in controlling rabbit populations?

CHALLENGE 2.5: PHOTOSYNTHESIS ROLE PLAY
GO TO PAGE 184.

2.5 Energy enters the ecosystem through photosynthesis

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 the chemosynthetic bacteria on the ocean floor and craters of volcanoes, which 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 is converted into glucose (a sugar) and oxygen. The overall equation for photosynthesis is:

$$\begin{array}{ccccccccc} \text{carbon dioxide} & + & \text{water} & \rightarrow & \text{glucose} & + & \text{oxygen} & + & \text{water} \\ 6CO_2 & + & 12H_2O & \rightarrow & C_6H_{12}O_6 & + & 6O_2 & + & 6H_2O \end{array}$$

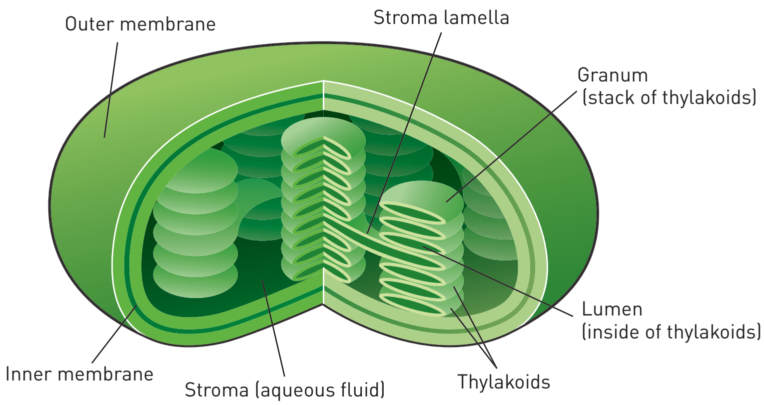

Figure 2.25 The structure of a chloroplast.

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 traps it in the chemical bonds of glucose.

Because plants cannot breathe like we do, they must take in carbon dioxide through microscopic pores called stomata (singular 'stoma') in the leaves. The water needed for photosynthesis enters through the roots and travels to the leaves through xylem vessels.

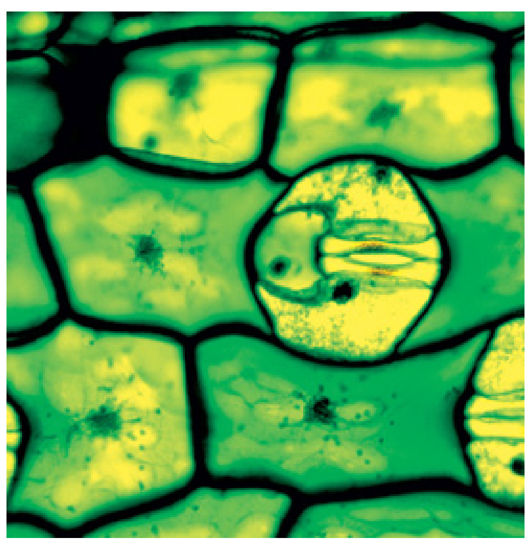

Figure 2.26 Guard cells open and close the stomata of a plant.

EXPERIMENT 2.5A: INPUTS AND OUTPUTS OF PHOTOSYNTHESIS
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EXPERIMENT 2.5B: EFFECT OF CARBON DIOXIDE ON STARCH PRODUCTION
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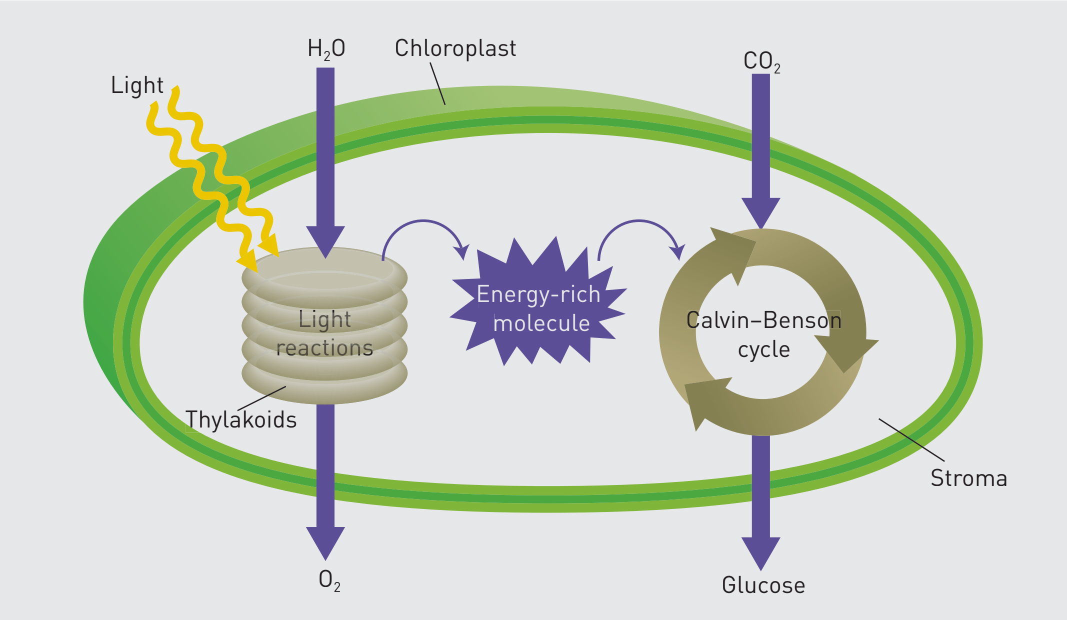


Figure 2.27 The light and dark reactions occur inside chloroplasts.

A closer look at photosynthesis

Although the overall equation for photosynthesis is shown as one reaction, it is really two.

1. The light reaction needs sunlight and takes place in the grana in chloroplasts. Sunlight causes charged particles (electrons) to become excited, and the bonds within water molecules are broken, releasing oxygen and forming energy-rich molecules.
2. The dark reaction does not require sunlight and takes place in the stroma of chloroplasts. The energy-rich molecules formed in the light reaction, together with carbon dioxide, are used to make carbohydrate molecules, such as glucose. This process is called the Calvin–Benson cycle, or carbon fixation.

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 repair damage. During daylight, more glucose is made than can be used directly by plants, so excess glucose is stored in the form of starch and other carbohydrates in the roots, the stems or the leaves. Starch is stored in underground storage organs, such as roots and tubers (for example, potatoes, carrots and parsnips) all store starch in this way.

Figure 2.28 Starch is stored in roots and tubers. 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 the night.

Check your learning 2.5

Remember and understand

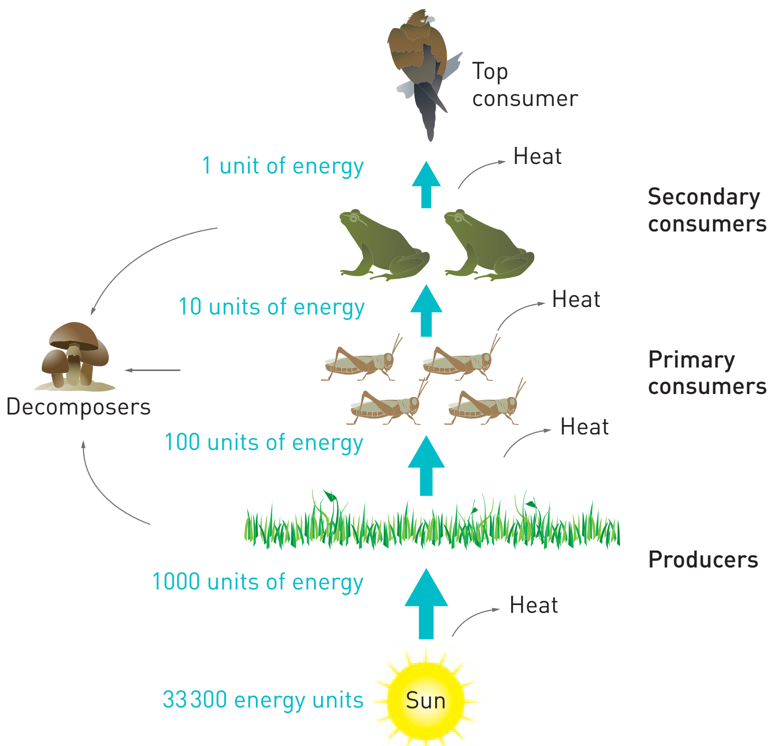
1. Where does photosynthesis occur?
2. What is essential for photosynthesis?
3. What are the raw materials needed for photosynthesis? How do they enter a plant?

Apply and analyse

4. Explain why it is fair to say that photosynthesis is the most important metabolic process on the Earth.
5. Draw a flow diagram showing the inputs and outputs of photosynthesis.
6. Name some plant foods that we eat because they are stores of starch.

2.6 Energy flows through an ecosystem

Sugars contain energy locked in the bonds of their molecules, but this energy cannot be used directly by organisms. They must convert it into other forms in a process called cellular respiration. This transformation process is not efficient. Only 10% of the energy is passed on to the next level in a food chain. Waste energy in the form of heat is produced.



Living systems continuously take in energy from the Sun. When one organism eats another, it takes the energy that was stored in the cells and tissues. Of this energy, 90% is transformed into movement, or stored again as the organism grows and repairs its own cells. Only 10% of the energy gets passed from one organism to the next in a food chain. Energy in an ecosystem flows in only one direction.

Energy for work

Many energy transformations keep a living organism alive and carry out metabolic processes (chemical reactions that keep cells working). 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 2.1.

Figure 2.29 The movement of energy along a food chain can be represented by an energy pyramid. The size of each level represents the amount of energy being passed on to the next level in the food chain.

Table 2.1 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 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.

CHALLENGE 2.6: FOOD FOR THOUGHT
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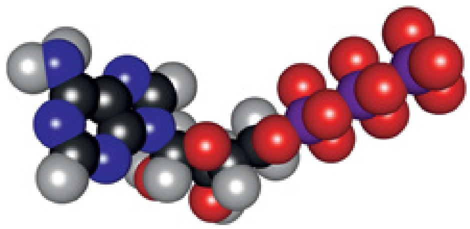


Figure 2.30 ATP (adenosine triphosphate) is the energy currency of organisms.

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 into the bonds in 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 cells.

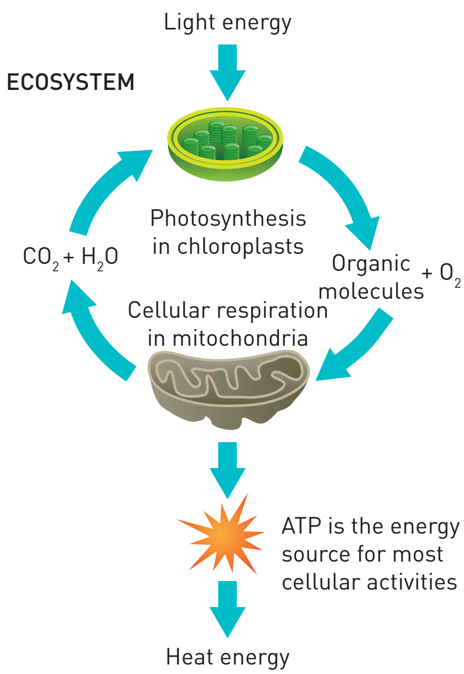


Figure 2.31 Energy flows into an ecosystem as sunlight and it leaves as heat. Matter is recycled.

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:

glucose	+ oxygen	→ carbon dioxide	+ water	+ energy
$C_6H_{12}O_6$	+ $6O_2$	→ $6CO_2$	+ $6H_2O$	+ 36ATP

The breakdown of glucose to carbon dioxide and water requires 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 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 2.32 The fermentation of yeast is used to produce beer.

Photosynthesis and respiration

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

Check your learning 2.6

Remember and understand

1 Explain why cellular respiration is constantly occurring in cells.
2 Draw a diagram that illustrates the water cycle.
3 Living systems continuously take in energy from the sun. How is this different from the flow of matter in an ecosystem?
4 Where does cellular respiration take place in cells?

Apply and analyse

5 How are cellular respiration and photosynthesis related?
6 Do plants undergo aerobic respiration? Explain your answer.
7 If a plant is able to convert 50 joules of energy through photosynthesis, how much energy will a herbivore obtain when it eats the plant?

2.7 Matter is recycled in ecosystems

Similar to energy, matter (such as atoms and molecules) flows through ecosystems. Plants absorb simple substances such as carbon dioxide, water and minerals, and convert them into sugars by photosynthesis. Animals eating the plants use the sugars and other compounds. When plants and animals die, the matter is rearranged by decomposers to obtain energy. In doing so, they break down the complex chemicals into simple compounds, which are reused by plants to grow, completing the cycle of matter. Also similar to energy, not all matter is passed on to organisms in food chains and webs. For example, cellulose in plant cell walls is not digested by some animals and is instead passed through the body unused. However, energy along a food chain, while the atoms in matter are recycled.

Cycles of matter

Figure 2.33 Logging rainforests can affect precipitation.

Matter 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'). Decomposers are essential to the cycles of matter – they break down dead matter and convert it into simple substances that can be reused by plants.

Water cycle

The global water cycle is driven by heat from the Sun. Three major processes driven by solar heat – **precipitation** (rain, snow, sleet), **evaporation** and **transpiration** from plants – 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.

Water is not available equally in all ecosystems. Water that is evaporated from a desert may later fall as rain on a forest thousands of kilometres away. Australia is a good 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.

Carbon cycle

Carbon is 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**.

Termites recycle carbon

Plant cell walls are made of cellulose, a complex carbohydrate that is insoluble in

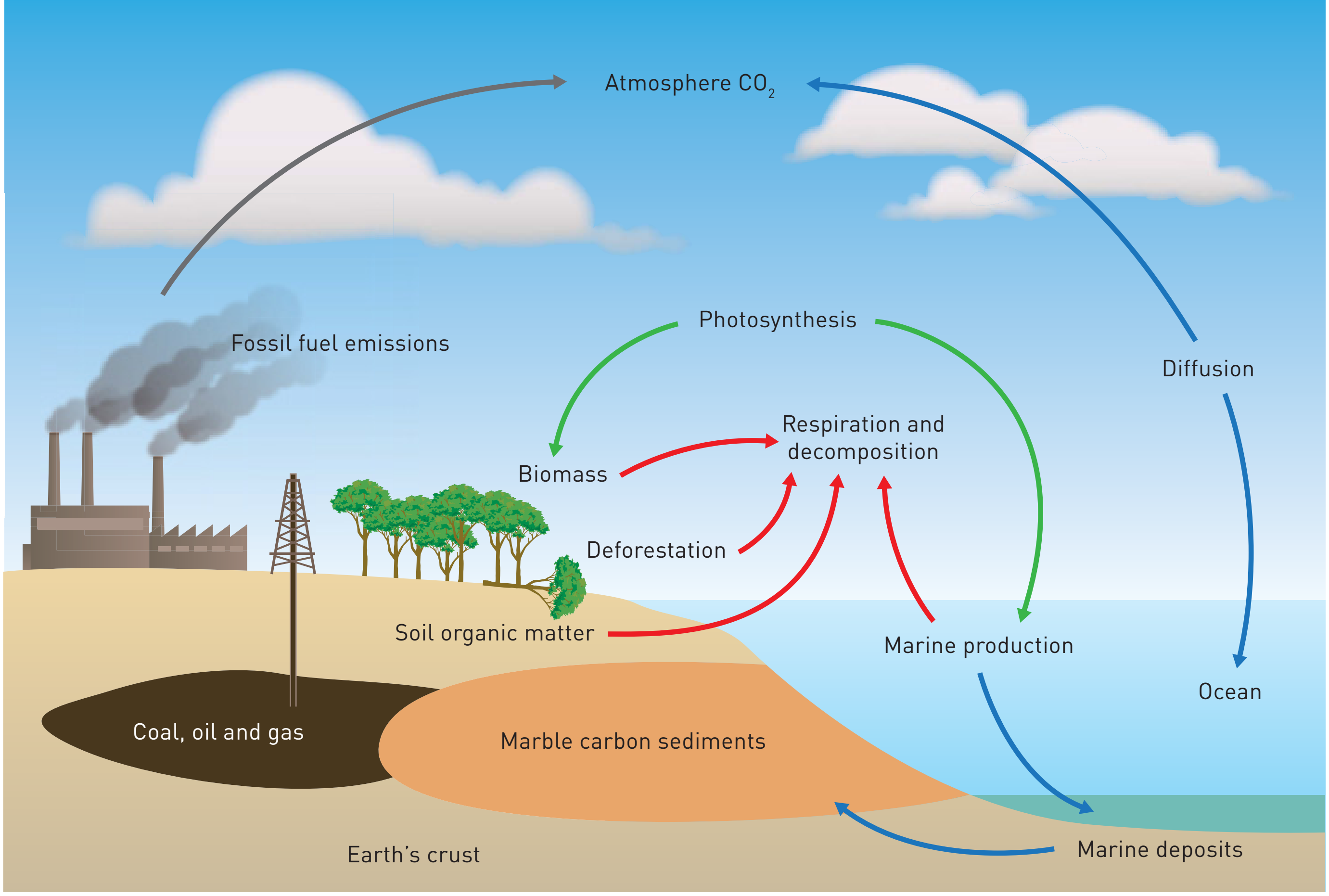


Figure 2.34 The carbon cycle.

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 fungi require a moist environment in which to live. In the drier areas of Australia, such as the forests and woodlands in tropical and subtropical areas, as well as the savannah grasslands, termites have a major role in the decomposition and recycling of carbon.

Termites are a social insect and live in nests. You may have seen termite mounds in drier parts of Australia. Microorganisms in the guts of termites break down the cellulose of plant material, such as grasses, plants and wood. Scientists have estimated that termites might recycle up to 20% of the carbon in ecosystems such as the savannah grasslands.

Figure 2.35 A termite mound in the savannah of northern Australia.

Check your learning 2.7

Remember and understand

1 What is matter?
2 Distinguish between energy and matter.
3 Distinguish between a flow of energy and a flow of matter in an ecosystem.
4 When scientists talk about the carbon cycle, what do they mean?

Apply and analyse

5 'You are eating the same atoms that were in dinosaur poo!' How accurate is this statement? Provide evidence to support your answer.

2.8 Natural events can disrupt an ecosystem

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 of the organisms will all affect population numbers. Natural disasters such as drought, floods and bushfires will also cause changes throughout the whole ecosystem. Some plants and animals have adapted to cope with these.

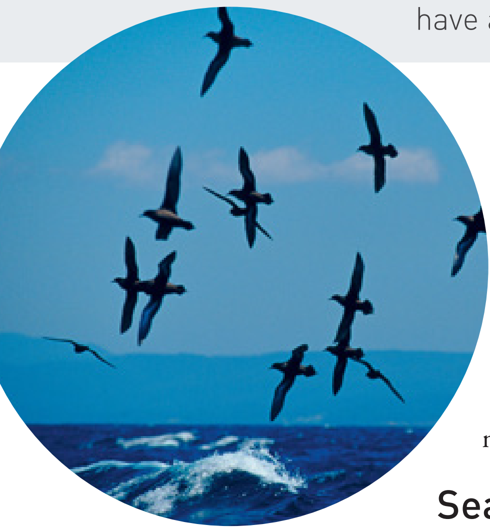


Figure 2.36 Short-tailed shearwaters leave their burrows on Montague Island on the southern coast of New South Wales and fly to feeding grounds in the area of the Bering Sea during the northern summer. They return for breeding in late September.

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. Some organisms will either die or emigrate (leave) and the population will stabilise (reach its maximum size).

Seasonal changes

When the weather becomes colder, many animals migrate to areas with warmer temperatures. As a result, their populations decrease in one environment and increase in another. During the breeding season, usually spring, numbers of animals will increase. Flowering plants will be pollinated and form seeds that spread throughout the environment, and later germinate.

Natural disasters

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

Figure 2.38 The Black Saturday bushfires in Victoria in 2009 devastated entire communities.

Figure 2.37 Flooding in Queensland in 2011.

CHALLENGE 2.8: NATURAL DISASTERS IN AUSTRALIA
GO TO PAGE 186.

Figure 2.39 Drought poses a great threat to life.

Figure 2.40 Lack of foliage indicates a lack of food and places to hide and shelter.

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 became 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.

Droughts pose an even greater challenge than floods. During droughts, 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 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 have adapted for fire resistance and tolerance, and they may actually rely on fires to complete their life cycles. These adaptations include:

- thick bark that insulates and protects the growing and transporting tissue inside the trunk (stem)
- **epicormic buds** beneath the bark that can regenerate the branches when the fire has passed
- **lignotubers** within the roots that can grow into new shoots after fire.

Most *Eucalyptus* species have epicormic buds and lignotubers.

Animal populations in fire-prone areas are, in general, tolerant of fire. Some 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. The migration of animals will change the composition of the ecosystem in the fire area. Animals may not return to the area for a long time. The change in the vegetation and the soil conditions alters their food supply and sheltering options. The loss of shelter will increase the risk of predation in some cases.

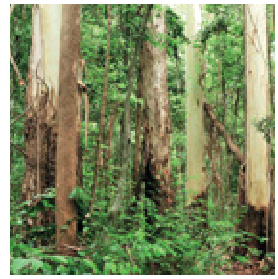


Figure 2.41 Native Australian trees have thick bark to protect them from fire.

Figure 2.42 Epicormic buds beneath bark can regenerate branches when fire has passed.

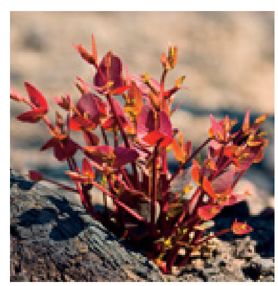


Figure 2.43 Lignotubers within roots grow into new shoots after fire.

Check your learning 2.8

Remember and understand

1. What does the carrying capacity of an ecosystem mean?
2. In relation to resources, what does 'limiting' mean? How does this differ from 'limited'?
3. Other than birds, what animals migrate due to seasons?

Apply and analyse

4. List some long-term effects on plants after a drought, bushfire or flood.
5. How might an animal survive a drought, bushfire or flood?

2.9 Human activity can disrupt an ecosystem

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 enhancing global warming.

Figure 2.44 Numbers of Murray cod, and other native fish, have decreased significantly due to irrigation. Some fish have now been declared rare or endangered.

Competition for resources

In 2014, the world human population was approximately seven billion and it is predicted to rise to about nine 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. Water is used to irrigate the farms that produce our 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.

Permanent removal of trees and other plants by humans can affect the animals that used them for food or shelter. These animals must migrate or perish. Removing even a few plants from an ecosystem may reduce pollination of similar species in the area.

Pollution

Human activity has introduced many unwanted chemicals into ecosystems. Certain 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 they can release into the environment.

Figure 2.45 When James Cook sailed into Botany Bay near Sydney in 1776, it was a natural ecosystem. Today it is an urban ecosystem because of the many human-induced changes that have taken place.

CHALLENGE 2.9: FIELD TRIP
GO TO PAGE 187.

Figure 2.46 Phosphates in detergents and fertilisers 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

Increasing numbers of humans, increasing wealth and more sophisticated technology have resulted in the use of large amounts of fossil fuels for transport, industry, agriculture and electricity. The burning of these fuels is contributing to increases in atmospheric temperatures and a warming climate. This is called the enhanced greenhouse effect.

Ecological effects of climate change

Although many humans welcome the thought of warmer weather, small increases in average temperatures can have devastating effects on ecosystems (Table 2.2). In mountainous areas, plants and animals that need cooler environments to survive are losing their habitats as the snowline retreats higher up the slopes. One such animal is the mountain pygmy possum, which needs a snow depth of at least one metre to provide enough insulation for **hibernation**. Less snow means the cycle of hibernation and breeding is disrupted.

Table 2.2 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	Genetic changes as species adapt to new climatic conditions
Changes in the composition of 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	Increased coral bleaching and destruction of and/or changes to coral reefs
Changes in river flows, sediment formation and nutrient cycles	Flow-on effects, such as eutrophication and algal blooms
Drying of ecosystems	Decrease in coastal mountain rainforests

Check your learning 2.9

Remember and understand

1. List two ways humans compete with plants and animals for resources.
2. What does eutrophication mean?

Apply and analyse

3. Currawongs are 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. Could it be said that the impact of currawongs on the populations of small birds is a human impact? Discuss.
4. What is the enhanced greenhouse effect?
5. Suggest two ways your local ecosystem will be affected by the enhanced greenhouse effect.
6. The green sea turtle lays its eggs in the warm sands of northern Australia. If the sand at is 29°C, half the turtles will develop into males and the other half will be female. Below 27°C, most of the turtles will be male. Above 31°C, most of the turtles will be female. What effect will enhanced global warming have on the green sea turtle population?

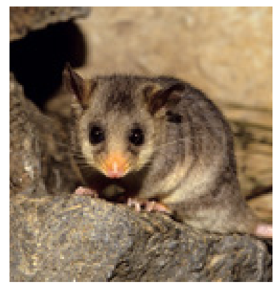


Figure 2.47 The mountain pygmy possum is listed as an endangered species.

Figure 2.48 Increased carbon dioxide levels in the atmosphere causes the ocean to become acidic. As a result, the polyps in the coral die, causing bleaching.

//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 growing population needs food to support it. Maximising food production while maintaining resources such as soil and nutrients can be difficult. An ability to see an ecosystem from another's perspective can be useful.

Historical use of ecosystems

People first came to Australia at least 40 000 years ago. It is presumed they came from South-East Asia.

They were hunter–gatherers who respected the land because it provided them with the resources for life – food, water, shelter and medicine. The land was, and is, central to their spirituality.

Indigenous people were (and in many cases, still are) aware of the seasonal nature of plant and animal life 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. These nomadic practices enabled vegetation to recover and animal populations to survive.

In some areas, Indigenous people used fires to maintain ecosystems. Australian soils are poor in nitrogen and phosphorus. Controlled burns produced ash, which provided nutrients for dormant seeds. Hence, the diversity of plants increased after fire as many new seedlings appear following germination. Burning also flushed out animals upon which native populations depended for food.

Land management methods of Indigenous people contrasts with European land management. Indigenous people disrupt natural ecosystems to a minimal extent while obtaining their resources. Their land management is based on shared ownership and a deep respect. As a former Indigenous Person of the Year, Bob Randall said, 'We do not own the land. The land owns us'.

Figure 2.49 The grass tree had many uses in traditional Indigenous communities.

European systems are based on individual ownership. Its practices involve clearing the land of native vegetation, planting crops, and introducing domestic animals. European systems introduced agricultural and urban ecosystems to Australia whereas land management of Indigenous people left ecosystems very close to their natural state.

Indigenous people were experts at using the resources of local ecosystems for numerous purposes. A good example is the varied uses for the grass tree (*Xanthorrhoea*). They used:

- the shaft as a spear
- resin from the plant for sticking things together
- nectar from the flowers for food
- leaf bases for food
- insects that feed on the flowers for food.

Modern needs

We need food for survival. When food is in short supply, people will fight for it. In Australia, we currently have plenty of food thanks to a strong agricultural community. Irrigation of large areas ensures that the large crops are able to survive. However, a major drought, a natural disaster or a war can suddenly plunge a community into famine.

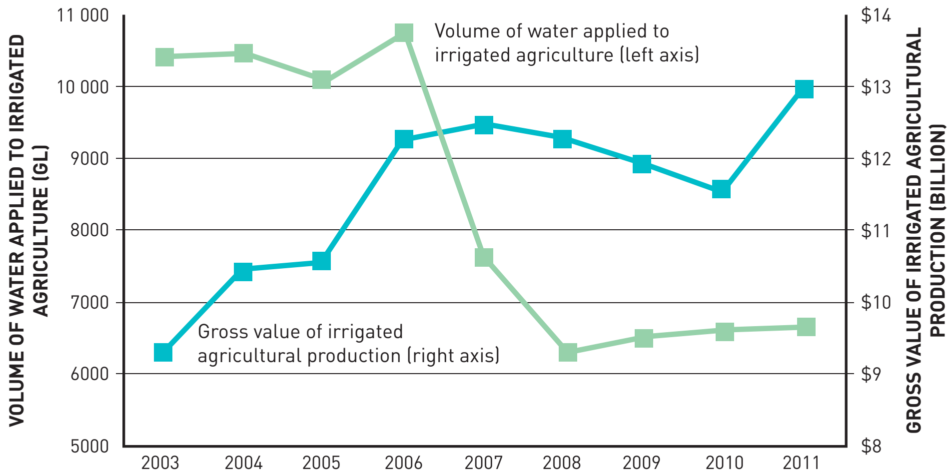


Figure 2.50 Modern farming involves using water more wisely.

Tropical Cyclone Larry in 2006 wiped out large numbers of banana plantations, causing a countrywide shortage. Enhanced global warming may 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 impact 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.

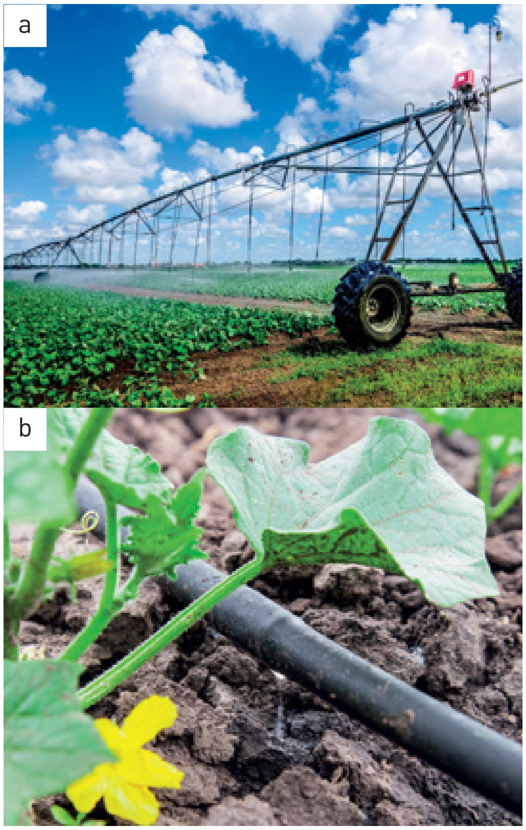


Figure 2.51 Scientists are developing ways to use water more efficiently. (a) Traditional irrigation (b) Modern micro-irrigation system.

Extend your understanding 2.10

1. 'Indigenous people manipulate the environment to their advantage without changing it significantly'. Discuss this statement in terms of:
   a. nomadic existence over the centuries
   b. use of fire.
2. Compare traditional land management systems of the Indigenous people with those of modern Australians.
3. Would these traditional land management methods be vulnerable to the increased intensity of storms caused by enhanced global warming?
4. Prepare three arguments for and against the statement: 'Traditional land management of Indigenous people is better than modern methods of farming'.
5. Some park rangers carry out controlled burns to remove old-growth plants. Explain how this will encourage new plants to grow.

*REVIEW

2

Remember and understand

1 State two ways of defining an ecosystem.

2 What do mutualism, parasitism and commensalism have in common? How are they different?

3 What is photosynthesis?

4 What products of photosynthesis are essential for cellular respiration?

5 Can competition occur between members of the same species and members of different species? Explain using examples.

6 If only 10% of the energy is transferred along a food chain (such as Figure 2.29 on page 28), where is the rest of the energy?

7 Respiration in your cells provides the energy for all your metabolic processes. Make a list of six different cellular processes that require energy from respiration.

8 Find some examples of how humans, especially since European settlement, have changed ecosystems because of introduced species.

9 What makes environmental conditions in Australian ecosystems so challenging for populations of living organisms?

10 Describe the adaptations to fire of many Australian plants.

11 The Queensland floods of 2011 caused enormous destruction and some deaths. Explain some ways these floods affected the ecosystems in coastal and inland Queensland.

Apply and analyse

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

13 Observe your school ground or your home garden for one week. Keep a journal listing any examples of interrelationships between organisms.

Evaluate and create

14 Explain how a small seed is able to grow and form a huge log of wood that we can burn or use to make furniture.

15 Analyse the marine Antarctic food web in Figure 2.52.

- a What is the relationship between:
  - i orca whales and seals?
  - ii penguins and seals?
- b If overfishing rapidly decreases deep sea fish numbers, what pressures could this place on the:
  - i seal population?
  - ii sperm whale population?

16 The human population was fairly stable until approximately 1 CE. In the past century, it has almost quadrupled. What are the likely effects of population increase on world ecosystems?

17 Find out the conditions that cause an animal or plant species to be classified as endangered. List some examples of endangered species in Australia. Evaluate whether measures to protect them are adequate.

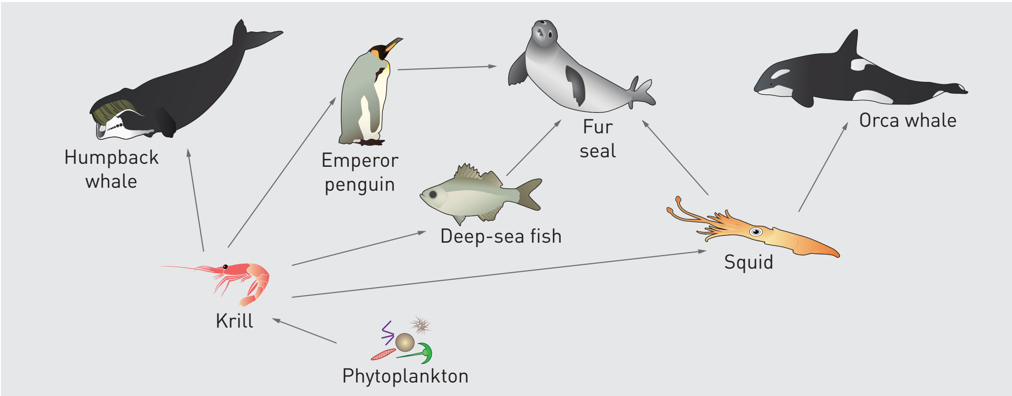


Figure 2.52 A marine Antarctic food web.

18 Seed banks are an important way of preserving plant species that are at risk of decreasing populations or extinction. Research the establishment and maintenance of seed banks. How might a seed bank contribute to sustainable ecosystems and to biodiversity?

19 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 2.53).

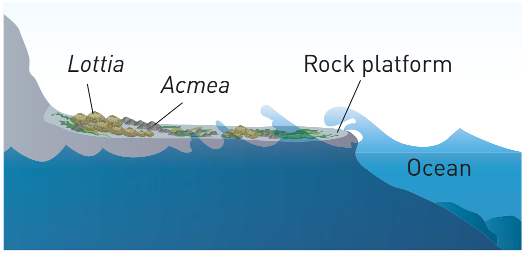


Figure 2.53 *Lottia* and *Acmea* on a rock platform.

a Suggest one possible hypothesis (reason) for this situation.

b Describe an experiment you might set up to test if your hypothesis is correct.

Ethical behaviour

20 In terms of resource use, many would argue that one person cannot make a difference. Do you agree?

Critical and creative thinking

21 Imagine it is your job to find out if soil is 'consumed' as plants grow. Design an investigation to test this idea. How will you tell if the plant(s) have actually 'consumed' the soil? What evidence do you need to collect? What variables do you need to control? How will you control these variables? What is your hypothesis?

22 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 plus some of the disadvantages.

Research

23 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. Some native species have also faced new predators. 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 story of the floods in the Bible, 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 is proposed to decrease the amount of carbon dioxide that we are adding to the atmosphere is to capture and store carbon dioxide. What does this mean? How will it work? Explain some of the options being considered for storing carbon dioxide.

*KEYWORDS

2

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

aerobic respiration
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

biological control
releasing a living organism (a parasite or consumer) into an ecosystem in order to control a population

biosphere
the intersection between the atmosphere, hydrosphere and lithosphere

biotic
all the living organisms in an ecosystem

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

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

commensalism
a relationship between two organisms from different species; one organism benefits; the other organism is not affected

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

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

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

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

ecosystem
a community of living organisms (biotic) together with their non-living (abiotic) factors

emigration
when an organism leaves an ecosystem

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

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

evaporation
the process of liquid water gaining thermal energy and changing into gas

habitat
the place where a population of organisms live

hibernation
when an organism becomes inactive, usually as a result of low temperatures

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

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

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

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

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

parasitism
a relationship in which one organism (parasite) benefits and the other organism (host) is harmed

photosynthesis
the process in plants in which glucose is made from water and carbon dioxide

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

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

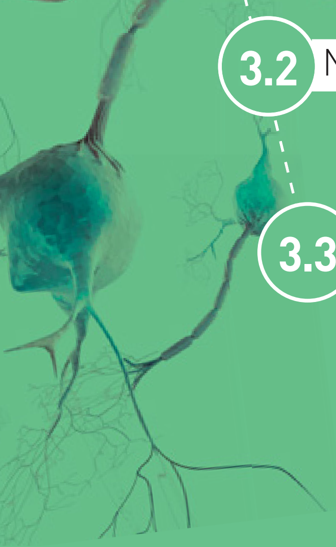
quadrat
a randomly selected square plot used to estimate the number of organisms

symbiosis
a close physical relationship between two members of different species

transpiration
the process of water evaporating from plants

CONTROL AND REGULATION

3



3.1 Receptors detect stimuli

3.2 Nerve cells are called neurons

3.3 The nervous system provides fast control of the body

3.4 The central nervous system receives information from the peripheral nervous system

3.5 Things can go wrong with the nervous system

3.6 The endocrine system is slower but more sensitive to change

3.7 Homeostasis regulates through negative feedback

3.8 Hormones are used in sport

3.9 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:

blindfold

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 a blindfold?

» What if you blocked your nose?

» What if you were barefoot?

3.1 Receptors detect stimuli

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. The easiest stimuli to identify are those that we respond to physically.

Responding to change

Within our bodies, we regularly respond to changes without consciously acknowledging a **stimulus** and response. What makes you know 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 would the source of these stimuli be?

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 microorganisms.

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**.

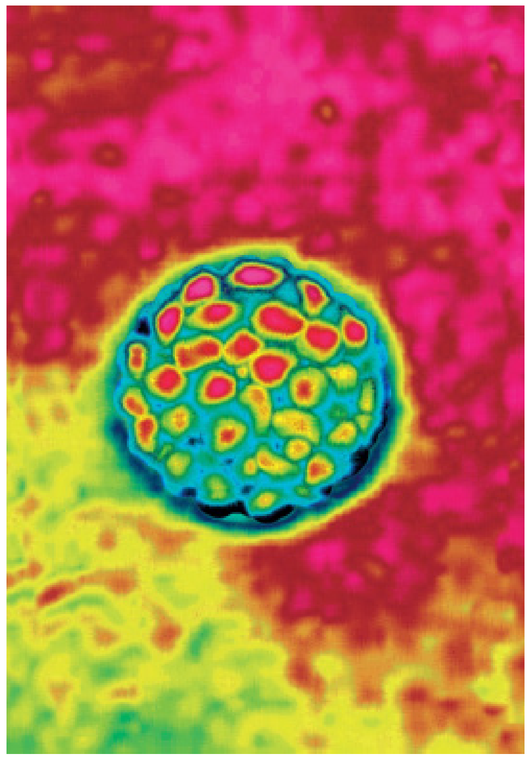


Figure 3.2 The papilloma virus (seen here under a microscope) stimulates an immune response in the human body.

The sense organs

We have five main senses: sight, hearing, taste, smell 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.

Figure 3.1 We often respond to hot weather by drinking more.

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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 photoreceptor cells at the back of the eye transform the light into nerve signals for the brain. It is not your eyes that allow you to see, but your brain! The information from your eyes is transferred to your brain, which then tells you what you are seeing.

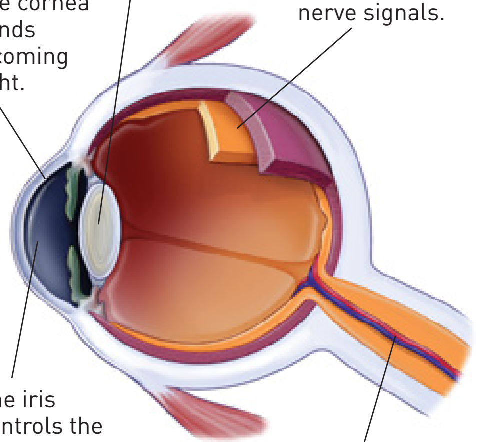


Figure 3.3 Photoreceptors in the human eye transform light into nerve signals.

Figure 3.4 A crocodile's eye has an elliptical (oval-shaped) pupil, which helps to protect its sensitive retina from the bright light of day.

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

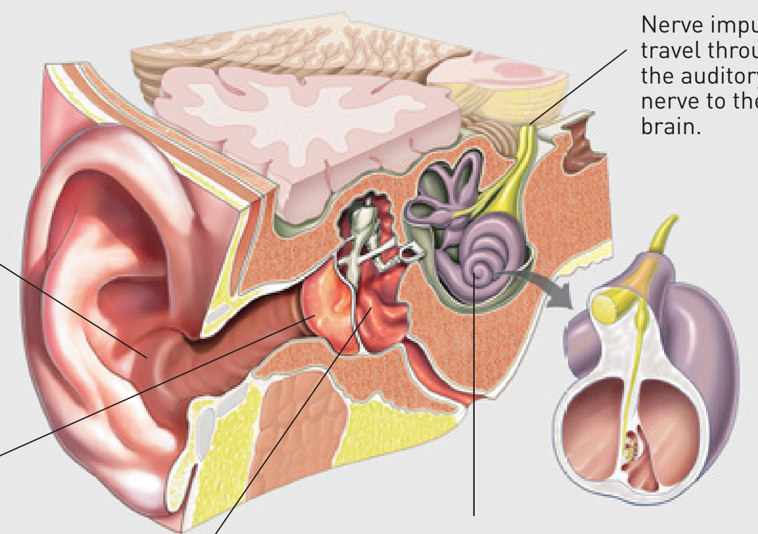


Figure 3.5 The human ear transfers vibrations to the middle ear. These become nerve impulses.

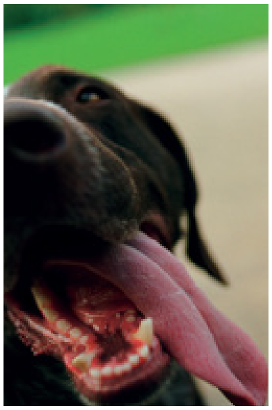


Figure 3.7 A dog uses its tongue for many things, including taste and temperature control. Panting moves cool air over the tongue and lungs, allowing heat loss.

Taste

Your tongue is covered with thousands of tiny taste buds. You can see this in a mirror. Taste buds contain special receptor cells that react to chemicals in foods. Taste buds can recognise basic kinds of taste: sweet, salty, sour and bitter. When you eat or drink, the information from the taste receptor cells is sent to the brain through nerves. This tells you what flavours you are tasting.

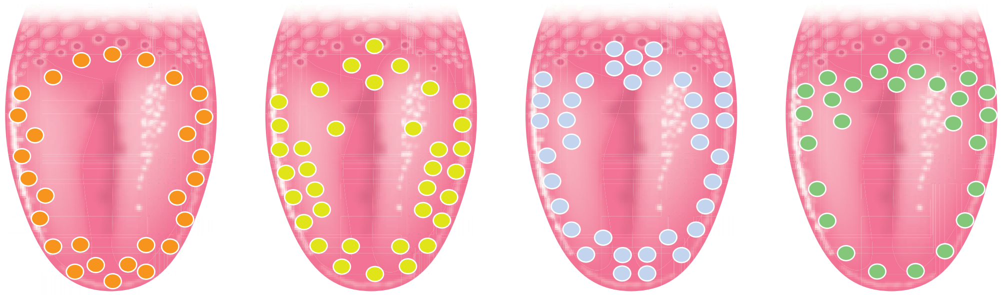


Figure 3.8 The human tongue can perceive all tastes equally well everywhere on the tongue.

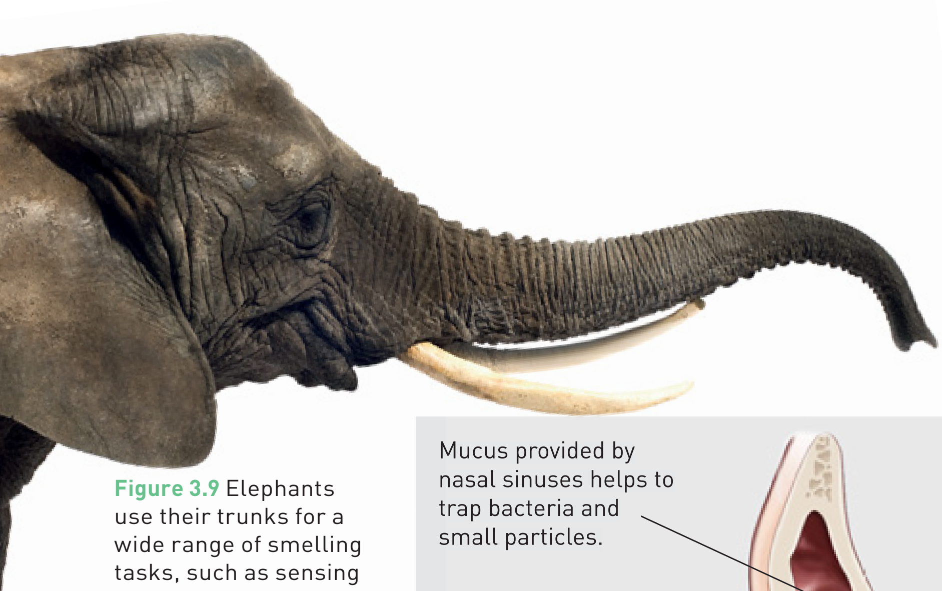


Figure 3.9 Elephants use their trunks for a wide range of smelling tasks, such as sensing danger.

Smell

Our perception of smell depends on chemical receptors that are found in each of our nostrils. These receptors detect chemicals in the air and then send messages to the brain, which interprets the message 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.

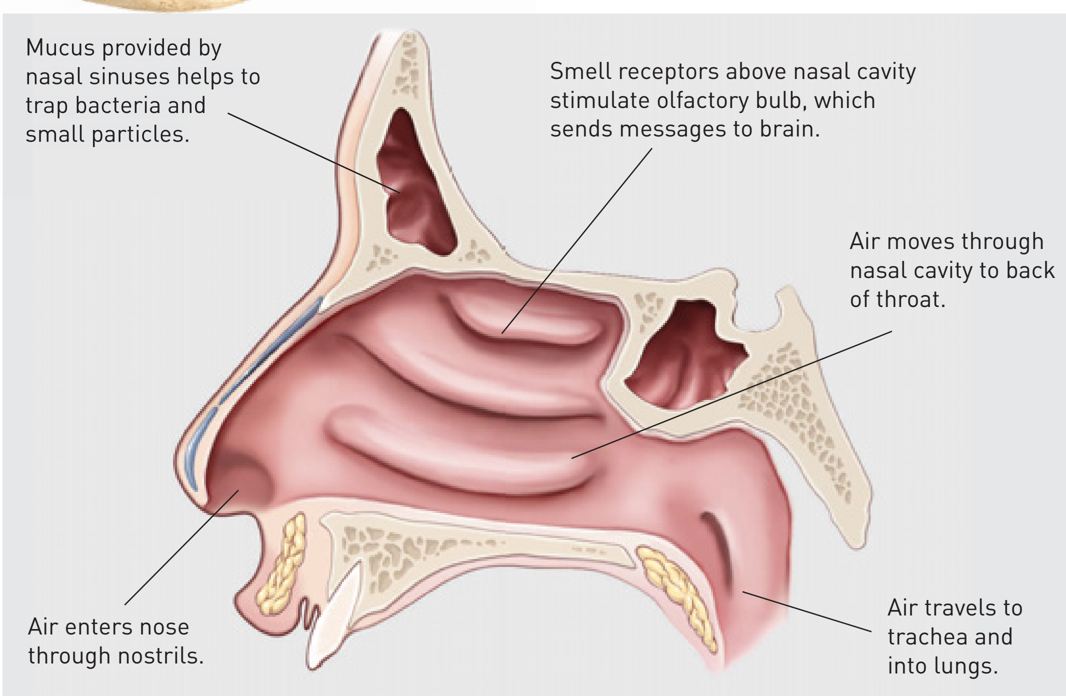


Figure 3.10 Smell receptors in human nostrils detect chemicals and send messages to the brain.

Touch

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

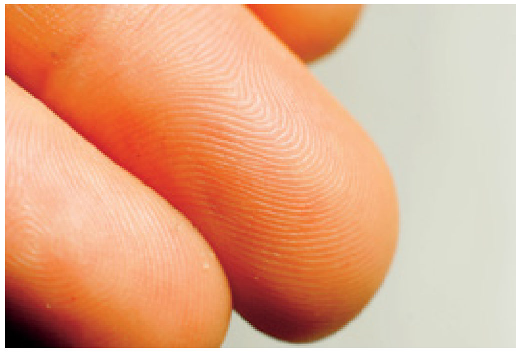


Figure 3.11 The skin of a human's fingertip has about 100 touch receptors.

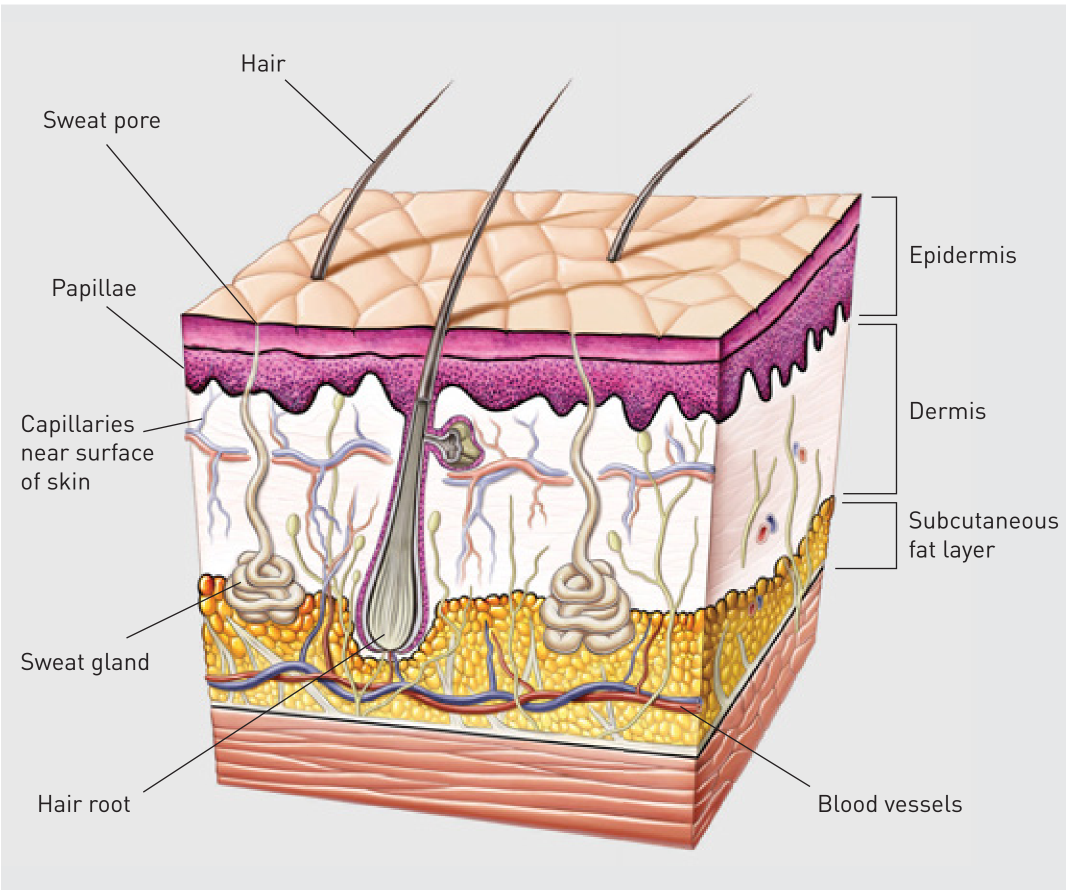


Figure 3.12 A cross-section of human skin.

Check your learning 3.1

Remember and understand

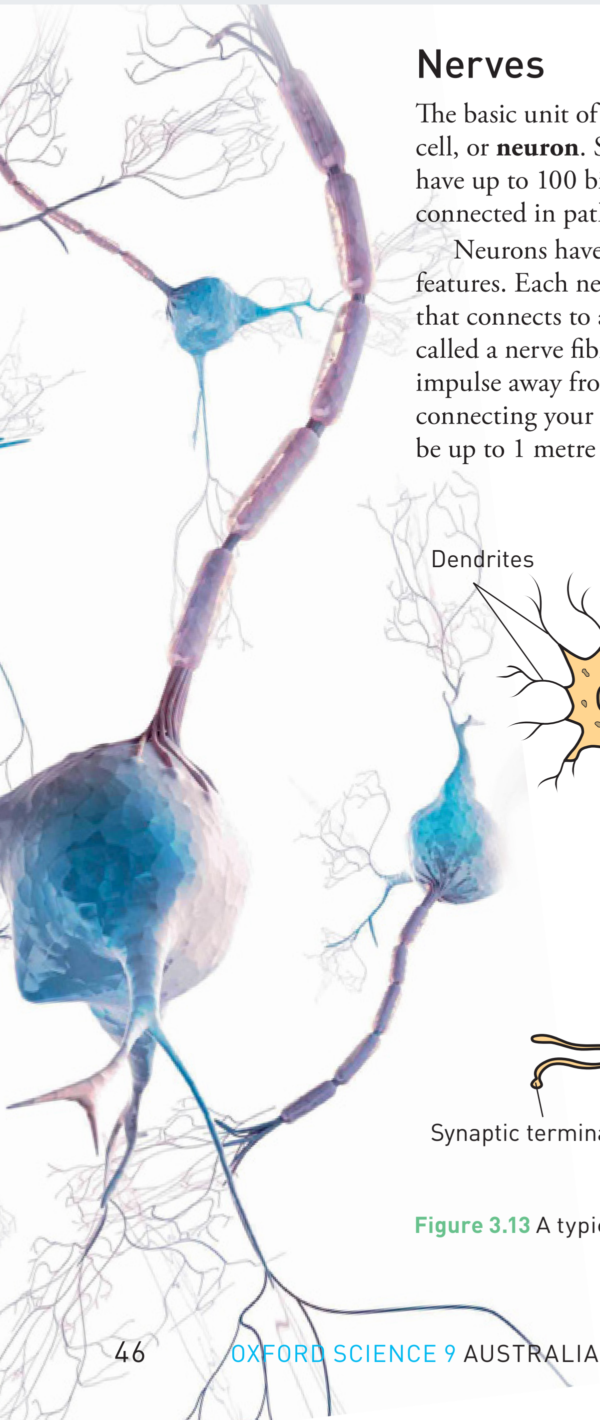
1. Define the term 'stimulus'.
2. Stimuli can be changes in our immediate environment or changes within our bodies. Give two examples of each.
3. What are the five sense organs?

Apply and analyse

4. Describe five situations in which each sense organ would need to respond.
5. Is it possible to survive without one or more of your sense organs? Explain.

3.2 Nerve cells are called neurons

Neurons are cells in our body that enable us to pass messages quickly. A change or stimuli 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. A myelin sheath protects parts of the neuron and prevents the message becoming lost.



Nerves

The basic unit of the nervous system is a 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**, which is also called a nerve fibre. An axon carries the nerve impulse away from the cell body. The axons connecting your spinal cord to your foot can be up to 1 metre long.

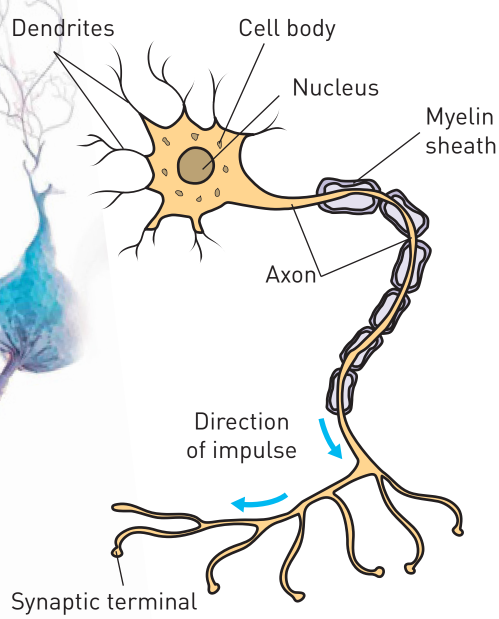


Figure 3.13 A typical neuron.

At the end of the axon is a small bulb called the synaptic terminal. Here, messages are passed to the next neuron.

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 able to escape along the length of the axon. This causes movement and sensory problems.

Dendrites are nerve endings that branch out of the cell body. These highly sensitive, thin branches receive information and form contacts with the axons of other neurons, allowing nerve impulses to be transmitted.

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 neuron, chemicals called **neurotransmitters** drift out of the synaptic terminal of an axon and across the gap 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

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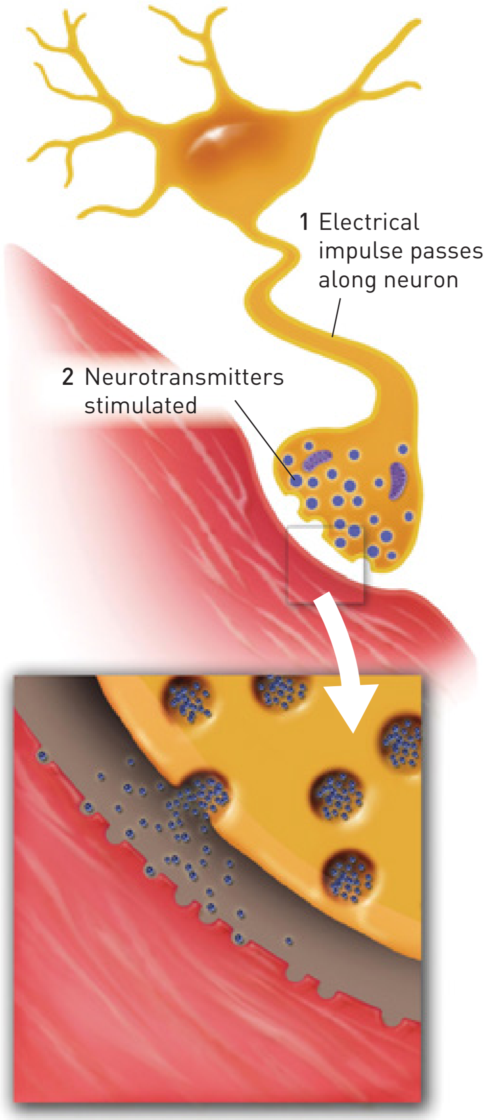

Figure 3.14 Electrical messages are converted to chemical messages (neurotransmitters) to cross a synapse.

neurons send the information they have collected to the central nervous system for processing.

> **Motor neurons** (or efferent neurons) carry messages from the central nervous system to muscle cells throughout the body, which then carry out the response.
> **Interneurons** (or connector neurons) link sensory and motor neurons, as well as other interneurons. Interneurons are the most common neuron in your body. They only make connections with other neurons.

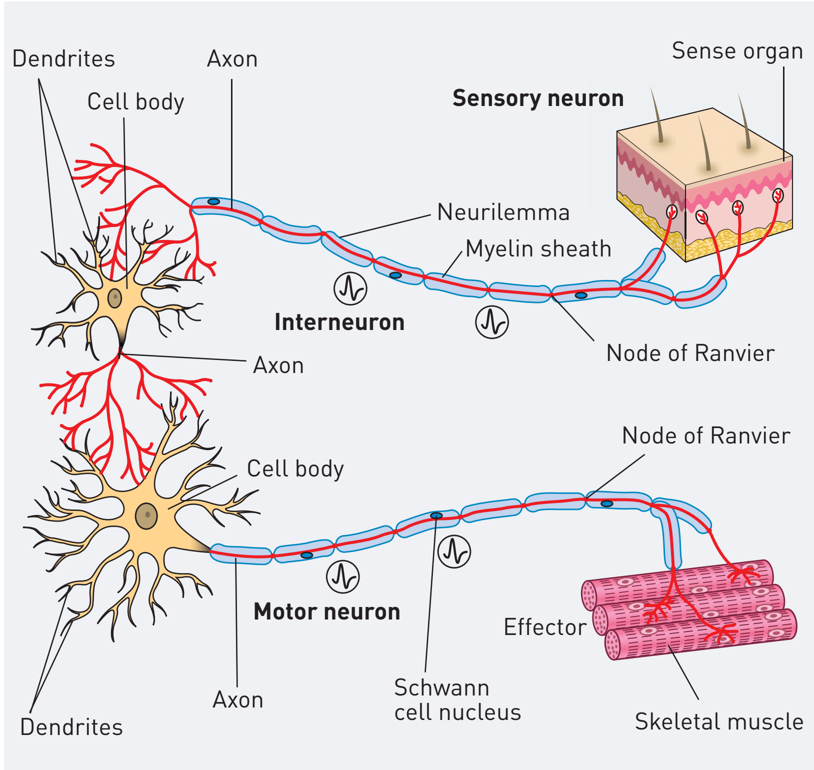

Figure 3.15 Messages get passed from the sensory neuron to interneurons. The interneuron passes the message to the motor neuron. This causes the muscles to respond to stimuli.

Check your learning 3.2

Remember and understand

1 With a partner, think of a way to remember the difference between sensory neurons, motor neurons and interneurons. Be creative! Share your memory trick with the class.
2 Name and describe the features of a neuron that enable it to carry messages.
3 Where are sensory neurons that detect:
   a smells?
   b tastes?
   c sounds?
   d touch?
   e sights?
4 What is the role of the myelin sheath?

Apply and analyse

5 Using a diagram, explain the problems that may result from damage to the myelin sheath.

3.3 The nervous system provides fast control of the body

To survive immediate danger, you respond quickly to stimuli. Receptors in the nervous system detect the stimulus and pass it on to control centres. The control centres initiate a message to the effectors, which cause a response. Reflexes are special pathways that allow a response to occur before the brain has time to think.

Stimulus response model

Stimuli can be in many different forms. It may be pressure or heat on the skin, a puff of air or strong light in your eye. These stimuli are detected by the receptors and the message gets sent to the spinal cord and the brain via the sensory neurons. The spinal cord and brain form the control centre of the nervous system. The interneurons in this control centre pass the message on to other interneurons as your brain thinks about how you should respond to the stimuli. 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.

Stimulus → Receptor → (Via sensory neuron) → Control centre → Effector → (Via motor neuron) → Response

Reflexes

If you ever accidentally touched something very hot, you will remember how quickly you snatched your hand away. In fact, it was so quick that you know 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 that the object was hot. This make reflexes even faster than usual responses.

Most reflexes help us in survival situations. Can you think of the advantages to these reflexes?

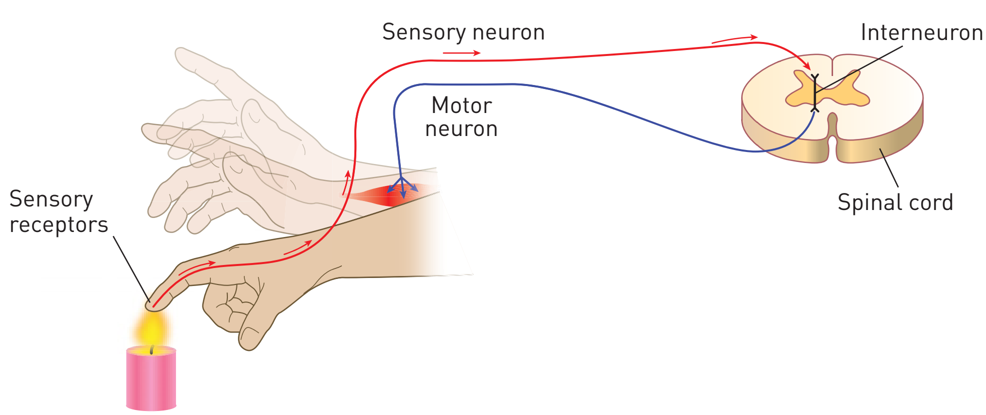

Figure 3.16 A reflex action ensures that a fraction of a second after you pull your hand away from a hot flame, you feel the pain in your hand.

CHALLENGE 3.3A: HOW FAST IS THE NERVOUS SYSTEM?
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Figure 3.17 Grasp reflex: when an object is placed on a baby's palm, their fingers curl over and grasp it.

Figure 3.18 Sneezing reflex: when small particles land on receptors in the back of your nose, the muscles in your diaphragm force air out rapidly.

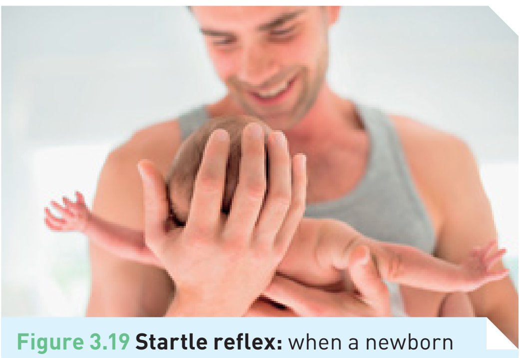

Figure 3.19 Startle reflex: when a newborn baby is startled, they will fling their arms out wide and grab onto anything they touch.

Figure 3.20 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.

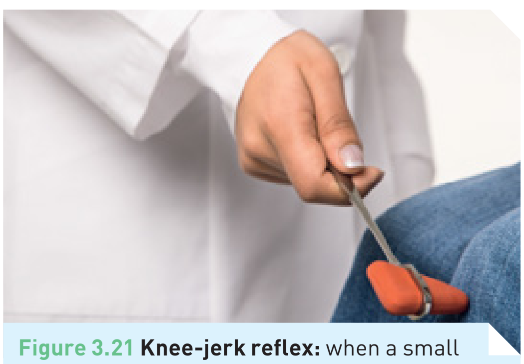

Figure 3.21 Knee-jerk reflex: when a small section below the kneecap (the tendon that connects the muscle to the bone) is stimulated with a tap, the foot will kick out.

Check your learning 3.3

Remember and understand

1. Define the following terms.
   a. Stimulus
   b. Receptor
   c. Effector
   d. Response
2. What is the stimulus response model of regulation?

Apply and analyse

3. Is the brain involved in a reflex reaction? Explain.
4. What is the advantage of a baby having the startle reflex?
5. If a person has a damaged spinal cord so that they cannot feel their toes, will they still have a knee-jerk reaction? Explain your answer.

3.4 The central nervous system receives information from the peripheral nervous system

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

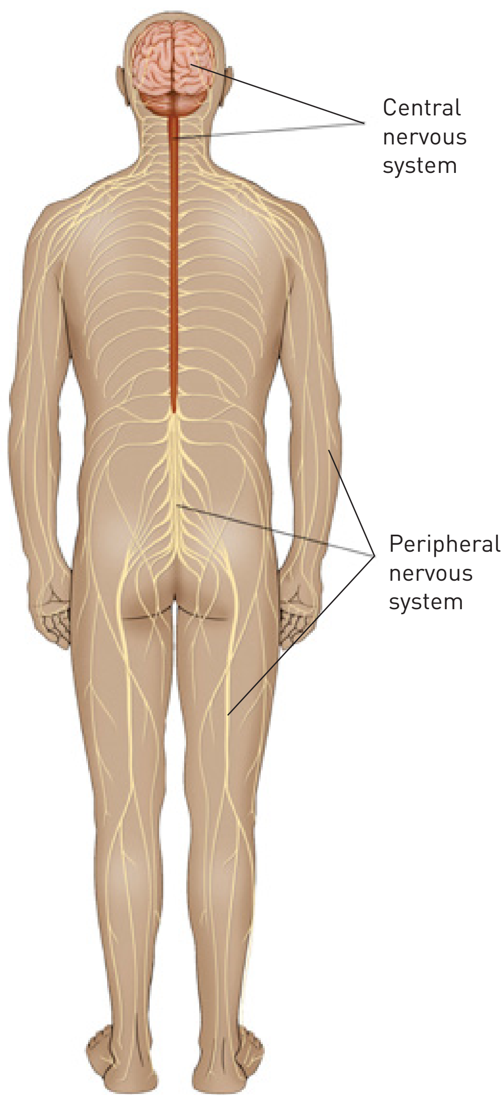

Figure 3.22 The nervous system of the body is made up of the central nervous system and the peripheral nervous system.

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 the central nervous system. The two main features 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 our survival. The brain is a soft, heavy organ that is surrounded by a tough skull. The brain gathers information about what is going on inside and outside the body. It then makes decisions about things such as internal changes and movements. It is also home to your memories, personality and thought processes.

Lobes of the brain

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

> The frontal lobe is located 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.

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> The temporal lobe is located in the region near your ears. It deals with the recognition of sounds and smells.
> The occipital lobe is at the very back of the brain. It is responsible for various aspects of vision.

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.

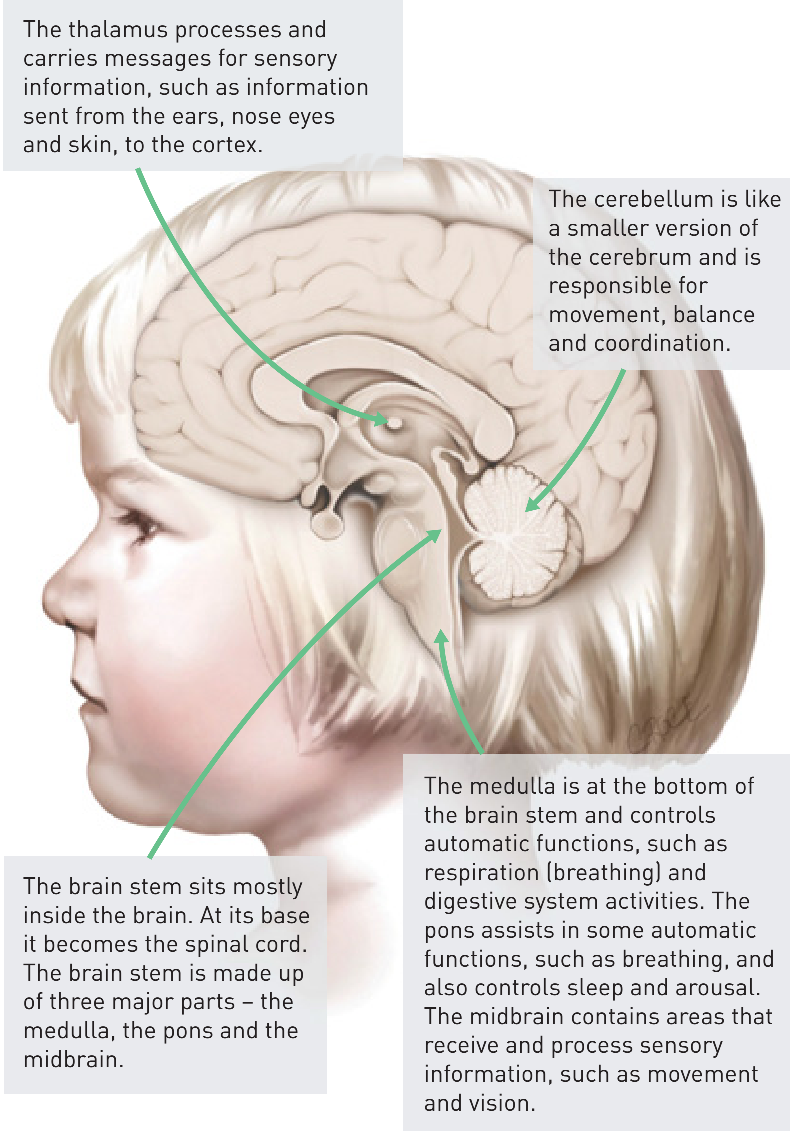

Figure 3.23 Structure of the human brain.

Check your learning 3.4

Remember and understand

1 Which two parts make up the central nervous system?
2 What is the peripheral nervous system made up of?

Apply and analyse

3 Draw a scientific diagram of the brain that shows the four lobes. In each of the lobes:
   a write what functions are carried out in that lobe
   b draw something to remind you of the functions carried out in that lobe.
4 How do the peripheral nervous system and 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 What is the difference between the somatic nervous system and the autonomic nervous system?

//SCIENCE AS A HUMAN ENDEAVOUR//

3.5 Things can go wrong with the nervous system

The nervous system plays a very important role in coordinating and regulating our body. When things press on the nerves in the spinal cord (slipped disc), the myelin sheath becomes damaged (multiple sclerosis), the motor neurons fail (motor neurone disease) or interneurons are lost (Alzheimer's disease), and then people's lives are affected.

Figure 3.24 Paraplegia is spinal damage that affects the lower part of the body.

Spinal damage

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

When the spine is damaged, messages from below the level of injury to the brain or above the level of injury from the brain are blocked. How much of the body is able to move after a spinal injury depends on where the injury is in the spine. 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 will be able to work as they normally would.

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

Slipped disc

Your backbone consists of 26 bones or vertebrae that surround the nerves that make up your spinal cord. Between each vertebra is a sac filled with a thick fluid or gel called a disc. Occasionally, the disc will become weak and put pressure on the nerves entering or leaving the spinal cord. This causes you to feel 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.

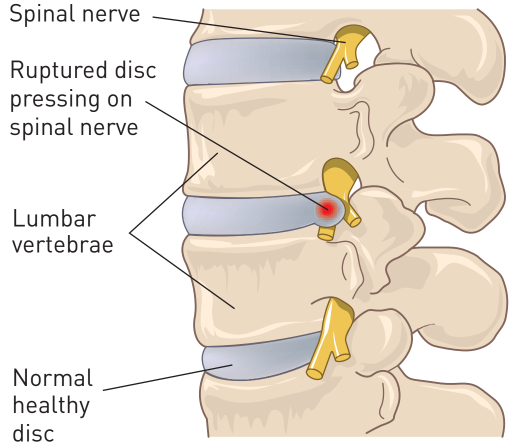

Figure 3.25 The bones of the vertebrae are separated by a fluid-filled disc. Rupturing of this disc can put pressure on the spinal nerves.

Multiple sclerosis

The myelin sheath plays a very important role in ensuring the electrical message passes along the axon of a neuron. When the myelin sheath becomes damaged, the electric signal can become 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 recognises the myelin sheath cells as dangerous, and attacks and destroys them. This means the messages to and from the senses (including the eyes, skin and bladder) and the muscles become lost. Muscles can become weak, the sufferer can be dizzy or tired or have difficulty seeing properly. Most commonly, the symptoms will appear for a short time, before disappearing completely. This is called a relapsing-remitting cycle.

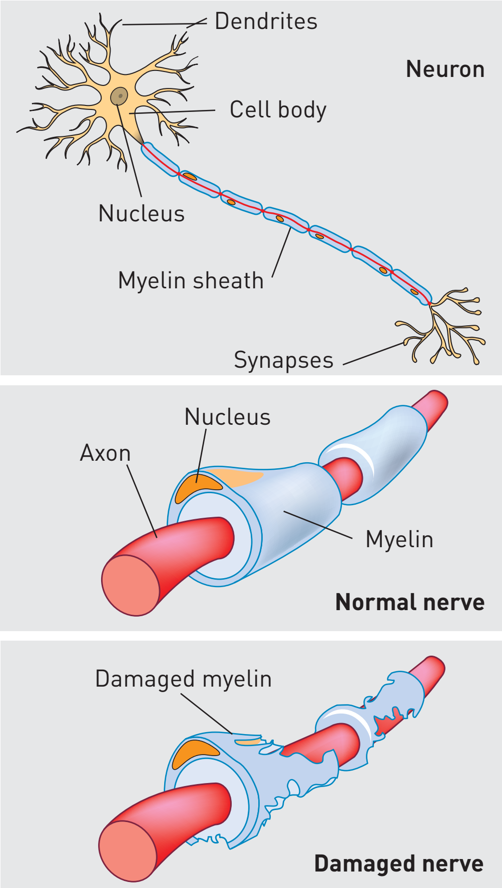

Figure 3.26 The myelin sheath surrounds the axon and helps the electrical message to move along the nerve. Damage to the myelin sheath (in motor neuron diseases) prevents the nerves from passing on messages.

Motor neurone disease

Also known as amyotrophic lateral sclerosis (ALS), this disease causes the neurons that send message to the muscles to become weaker and eventually lose function. As the muscles become weaker, they can get spasms, and become stiff. This usually starts in the muscles in legs and arms, before progressing to the face and chest. This can affect the ability to talk and eventually 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 still continuing.

Figure 3.27 Physicist Stephen Hawking developed motor neurone disease at the age of 21.

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. 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 is not known. It is thought that chemical changes in the neurons may be caused by genetic, environmental and health factors.

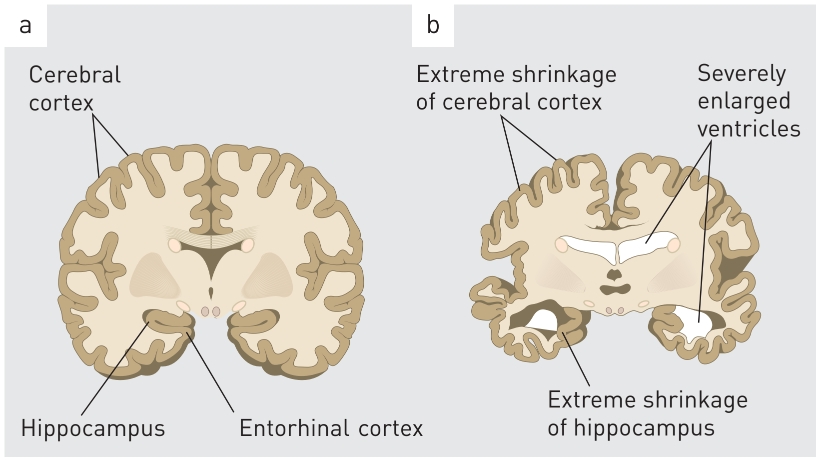

Figure 3.28 Damage to the neurons in Alzheimer's disease can cause the brain to shrink. (a) Normal brain; (b) Brain of patient with Alzheimer's disease.

Extend your understanding 3.5

1. Name the individual bones that make up the spine.
2. Explain the difference between quadriplegia and paraplegia.
3. What is the role of a disc in the spinal column?
4. What causes the myelin sheath to be destroyed in multiple sclerosis?
5. What is another name for motor neurone disease? What role do motor neurons usually play in a healthy nervous system?
6. Think about where you were and what you were doing 1 hour ago. What would you experience if you could not remember this?

3.6 The endocrine system is slower but more sensitive to change

The endocrine system is much slower than the nervous system. It uses chemical messengers called hormones to maintain control and to regulate growth. These chemical messengers act more slowly than the nerve impulses sent around by the nervous system, but their effects often last for a lot longer.

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 to cause a change in the target cell.

The glands and organs of the endocrine system are spread throughout the body (Table 3.1).

Table 3.1 Some organs and hormones of the endocrine system

ORGAN	HORMONE	TARGET TISSUE	MAIN EFFECTS
Hypothalamus	Wide range of neurohormones	Pituitary gland	Links nervous system to endocrine system via pituitary gland to control many homeostatic functions such as body temperature, hunger, thirst and sleep patterns
Ovaries	Progesterone	Uterus	Thickens wall of uterus
	Oestrogen	Body cells	Development of female sexual characteristics; aspects of pregnancy and foetal development
Testes	Testosterone, progesterone and oestrogen	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
	Calcitonin	Blood	Decreases the amount of calcium in the blood
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
	Progesterone	Body cells	Important for calcium in bones
	Oestrogen	Body cells	Development of certain sexual characteristics
Pineal gland	Melatonin	Skin cells	Whitening of skin; involved in daily biological rhythms

CHALLENGE 3.6: GLANDS AND ORGANS OF THE ENDOCRINE SYSTEM
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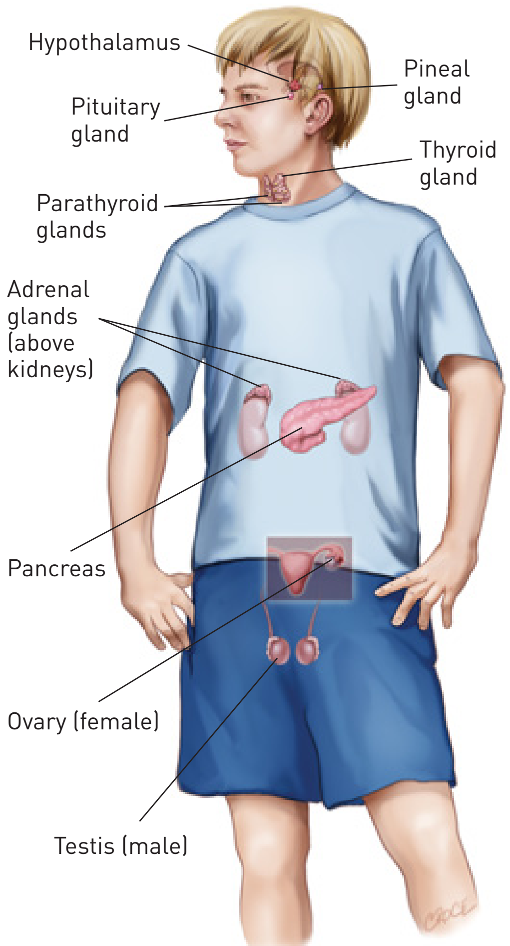


Figure 3.29 The human endocrine system.

Fight or flight?

If you are ever in a dangerous or frightening situation, you may experience a 'fight or flight' 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 the symptoms are triggered by the release of the hormone adrenalin (also called epinephrine). Adrenalin is constantly produced by the adrenal glands in small doses. The adrenal glands are located above the kidneys. The usual function of this hormone is stimulating heart rate and enlarging blood vessels. However, when you are in danger, adrenalin takes on another role. It floods into 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) or run away (flight).

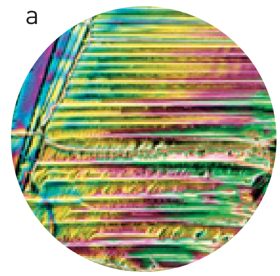
Figure 3.30 Adrenalin is responsible for the fight or flight response in mammals.

Types of hormone

Hormones are classified into two types on the basis of their chemical structure: peptide hormones and steroid hormones. Most hormones are peptides. Peptide hormones are made from proteins and produced by the anterior pituitary, parathyroid gland, placenta, thyroid gland and pancreas. Peptides travel through the bloodstream until they find and interact with specific receptors on the surface of their target cells. This causes the target cells to respond.

Steroid hormones include those hormones secreted by the adrenal glands and the ovaries (women) and testes (men). Steroid hormones are produced from cholesterol.

a



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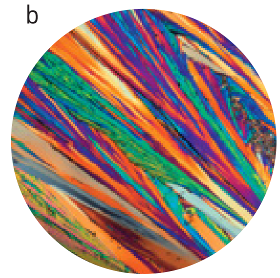

Figure 3.31 Crystal structures (as seen under a microscope) of (a) the peptide hormone calcitonin and (b) the steroid hormone testosterone.

Check your learning 3.6

Remember and understand

1. What is the name of the system in your body responsible for hormones?
2. What is meant by the phrase 'fight or flight' and how does it relate to hormones?
3. Describe the two different types of hormone.
4. Why is the endocrine system referred to as a communications system?

Apply and analyse

5. How is a hormonal response different to a nervous response? Name one advantage for each system.

3.7 Homeostasis regulates through negative feedback

Your body works to maintain constant levels of important nutrients and water and temperature in order 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.

Figure 3.32 Homeostasis is your body's ability to regulate and maintain a stable condition inside your body, regardless of changes to the external environment.

So far, scientists have been unable to discover another planet that humans could inhabit. The reality is that humans can only survive in very specific environments. Our bodies are quite fussy and need to have access to 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 cells working efficiently. This 'business as usual' that is maintained by your body is called **homeostasis**.

Homeostasis

To maintain homeostasis, your body uses a mechanism a bit like a thermostat on a heater. When temperature receptors on your skin and in the hypothalamus of your brain detect cooling down (stimulus), then a message gets sent to a variety of effectors around your body. This may include muscles to make you shiver (to warm up) or blood vessels to redirect the warm blood flow to the important organs in your body (your 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. This causes your body to respond by the blood carrying heat to your skin so that sweat evaporates and cools you. This a negative feedback mechanism system – the effectors respond by removing 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.

Figure 3.33 When your body is stimulated by heat, homeostasis ensures you cool down by sweating.

Hormones at work

The rate of hormone production and secretion is often regulated by the negative feedback mechanism. This means that if a stimulus is received that indicates something in the body is happening 'too much', the response would be to produce a hormone to remove it.

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 the 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

EXPERIMENT 3.7: EXPERIENCING HOMEOSTASIS
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of glucose in your blood is too high (stimulus), then receptors in the pancreas will detect it. They will then release the hormone insulin into the blood. Insulin will travel throughout the body to the insulin receptors on muscle and liver cells. These cells will then act as effectors and remove the glucose from the blood. This causes the blood glucose to decrease, removing the original stimuli. This is an example of negative feedback.

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

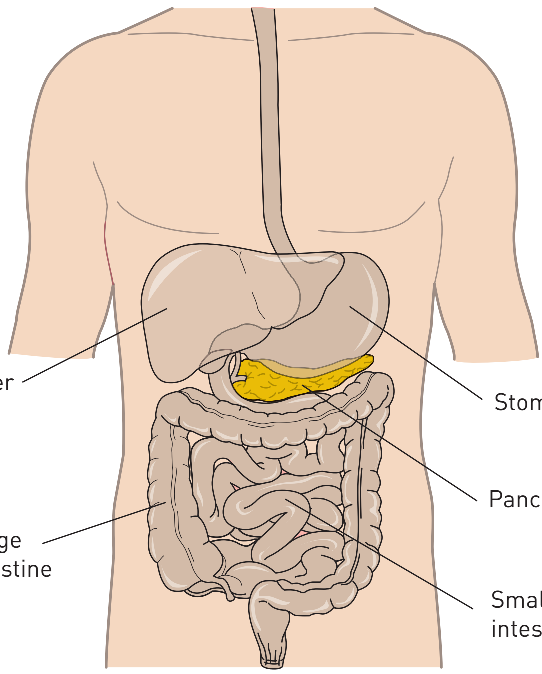


Figure 3.34 The pancreas is the endocrine organ responsible for the regulation of blood glucose levels.

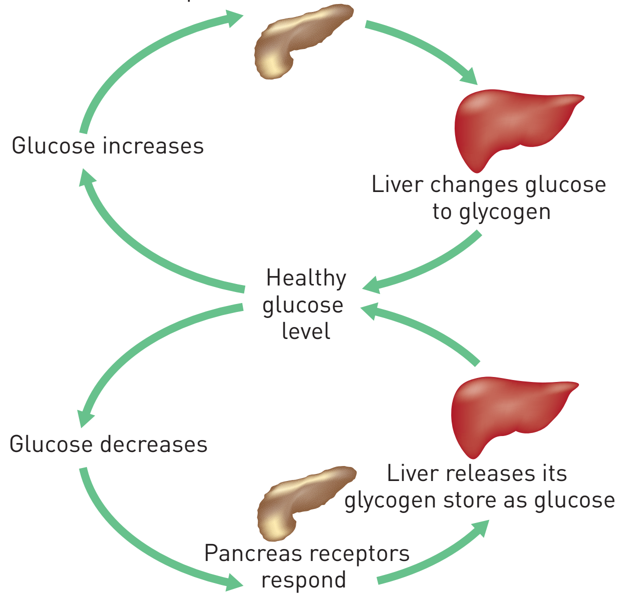


Figure 3.35 The pancreas and the liver work together to maintain healthy glucose levels in the body.

Check your learning 3.7

Remember and understand

1 What is homeostasis?

2 How does your body respond to cold weather?

3 What happens to your blood sugar levels when you eat?

4 How does your body respond to low blood sugar levels?

Apply and analyse

5 How is the stimulus response model similar to or different from the negative feedback mechanism?

6 If a negative feedback loop reduces the effect of a hormone, what would a positive feedback loop do?

Evaluate and create

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

Figure 3.36 After eating, 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.

//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 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% 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.

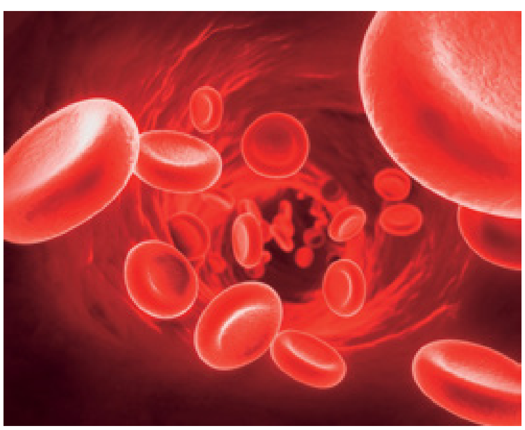


Figure 3.38 Erythropoietin increases the production of red blood cells.

Figure 3.37 Training at high altitude can increase an athlete's performance.

Exercising at 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 start being noticeable. When the athlete returns to compete at sea level, 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 high altitude uses the negative feedback mechanism to the athlete's advantage.

Some athletes bypass the 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 stroke.

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 suffering kidney disease will also have low red blood cell levels. This is called anaemia. Symptoms of anaemia are a pale appearance and feeling tired when doing exercise. Regular injections of erythropoietin will increase the production of the red blood cells and improve the person's health.

Drug testing

Erythropoietin started being 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, USA, the first athlete was identified as having a version of erythropoietin in their urine and blood.

Figure 3.39 In 2013 Lance Armstrong admitted to injecting erythropoietin to help him win world cycling events.

Extend your understanding 3.8

1 Is erythropoietin part of the nervous system or endocrine system? Explain your answer.
2 What symptoms will an athlete have when they first start training at high altitude?
3 List the stimulus, location of the receptor, effector and response in the negative feedback mechanism of erythropoietin.
4 What are the symptoms of anaemia?
5 'The only way to create a level playing field in sport is for all athletes to be able to use performance enhancing drugs.' Do you agree or disagree? Provide at least three forms of evidence to support your view.

Figure 3.40 Testing for erythropoietin is part of the routine tests that professional athletes undergo.

3.9 Pathogens cause disease

Our understanding of how infectious pathogens disrupt the normal functioning of our body and cause disease has developed over many centuries. Scientists use Koch's postulates to provide evidence that a pathogen causes a disease. There are many different types of pathogens including bacteria, fungi, protozoans and non-living viruses. Penicillin and other antibiotics can be used to kill bacteria, but not viruses or other pathogens.

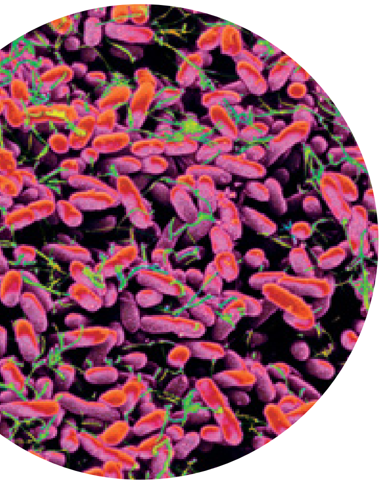


Figure 3.41 Some bacteria keep us healthy. Other bacteria are pathogens and interfere with the natural functioning of our body.

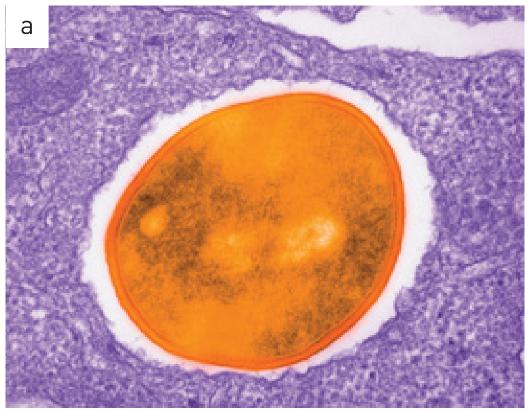
One of the first people in Western medicine to question the accepted idea of supernatural causes of diseases was Hippocrates (460–377 BCE). He concluded that something in the air, soil, water and food causes diseases in humans and animals. His work was followed up by Claudius Galen (131–201 CE), who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

Girolamo Francastor (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 microorganisms. These microorganisms are called **pathogens**. Germ theory was confirmed by Louis Pasteur and Robert Koch.

Robert Koch went on to develop Koch's postulates.

1 The microorganism or other pathogen must be 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 must cause the disease when inoculated into a healthy susceptible laboratory animal.
4 The pathogen must be re-isolated from the new host and shown to be the same as the originally inoculated pathogen.



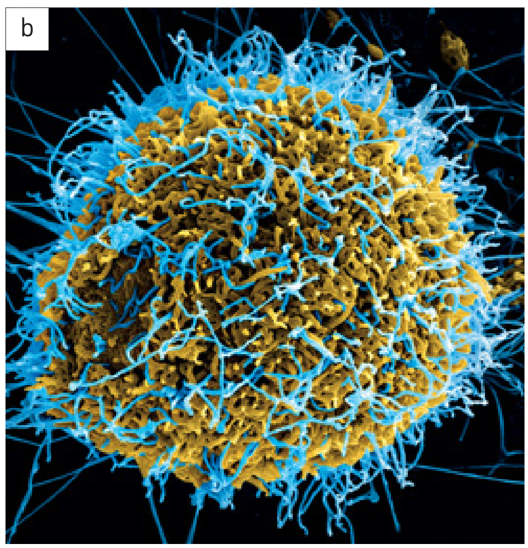


Figure 3.42 Most infections are caused by microscopic pathogens such as bacteria or viruses. (a) Bacteria are very small cells that are able to reproduce by themselves. They can release toxins that affect the normal functioning of our body. (b) Viruses are unable to reproduce by themselves. Instead they invade our cells and use the organelles to make new copies of themselves. This stops our cells from functioning properly.

CHALLENGE 3.9: INVESTIGATING PATHOGENS
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EXPERIMENT 3.9: INVESTIGATING GERM THEORY
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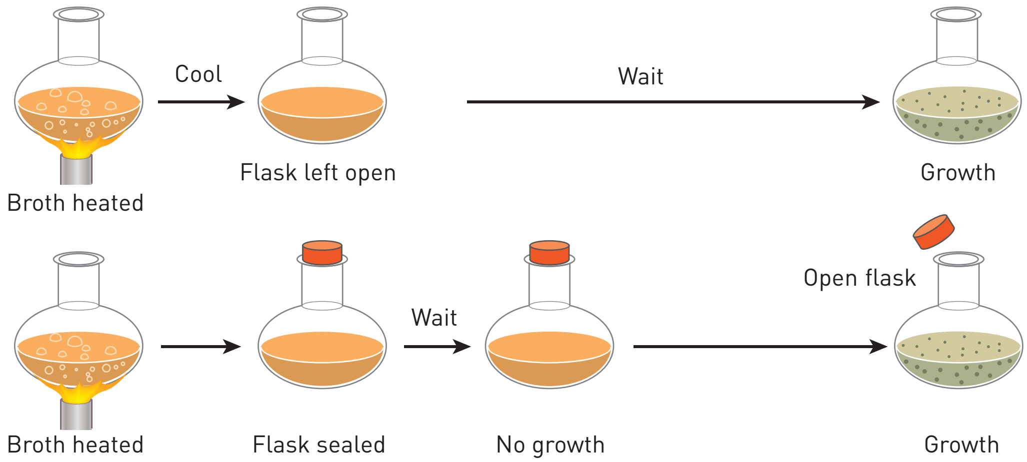

Figure 3.43 Louis Pasteur's experiments found that microorganisms in milk were killed by heat. This process is called pasteurisation and is still in use today.

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 bacteria could survive in the acidic environment of the stomach. Marshall and Warren isolated the bacteria and injected it to cause the disease in mice. Unfortunately, many doctors still did not believe the research, so Barry Marshall swallowed a culture of the bacteria to cause the disease in himself. 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 the thorn on a rose bush could become infected and kill you.

In 1928, Alexander Fleming was trying to grow bacteria in his laboratory. When he returned from holidays he discovered some Petri dishes he had left open on the bench were growing a mould similar to that found growing 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 men 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 or the common cold.

Most viruses cannot be treated by any readily available medicines.

Figure 3.44 Robin Warren (left) and Barry Marshall (right).

Check your learning 3.9

Remember and understand

1. What is the difference between a virus and bacteria?
2. What is the germ theory?
3. What are Koch's postulates?
4. Identify how Warren and Marshall used each of Koch's postulates to find the cause of stomach ulcers.
5. Name an infection that you or someone you know had, that needed antibiotics to cure.
6. How is Louis Pasteur's discovery still in use today?

3.10 The immune system protects our body in an organised way

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

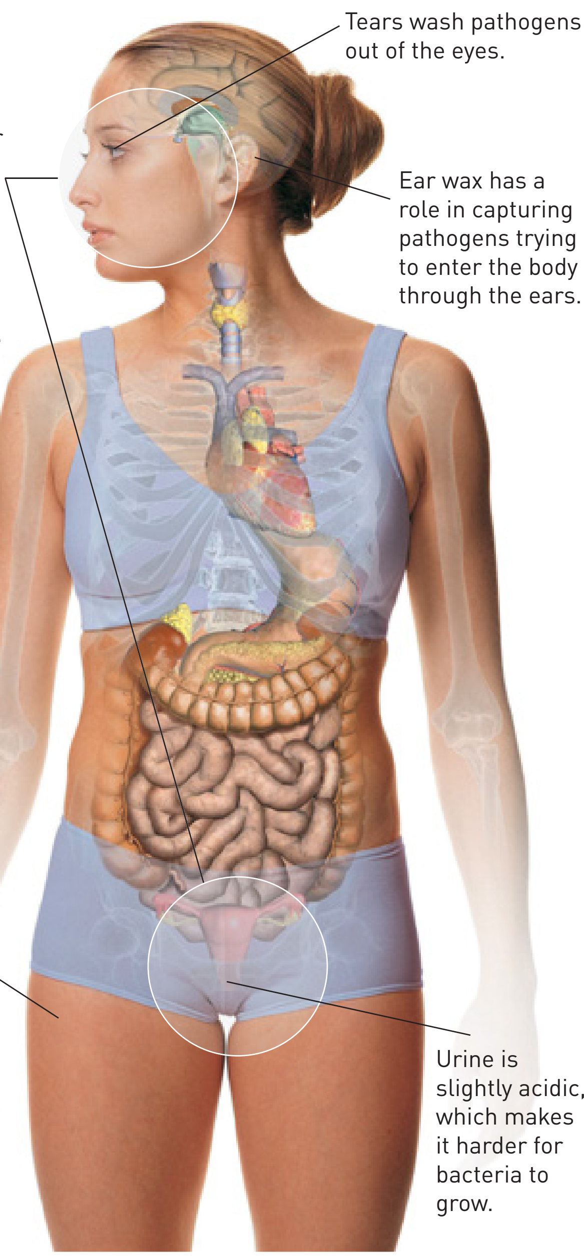

Figure 3.45 The skin and mucous membranes are the first line of defence against pathogens.

First line of defence

The first line of defence is to stop the pathogens from getting inside your body (Figure 3.40). It consists of the skin and mucous membranes.

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

CHALLENGE 3.10: MODELLING INFECTION AND VACCINATION
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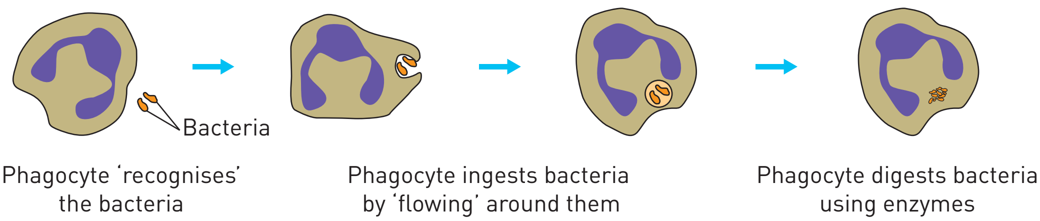


Figure 3.46 The process of phagocytosis.

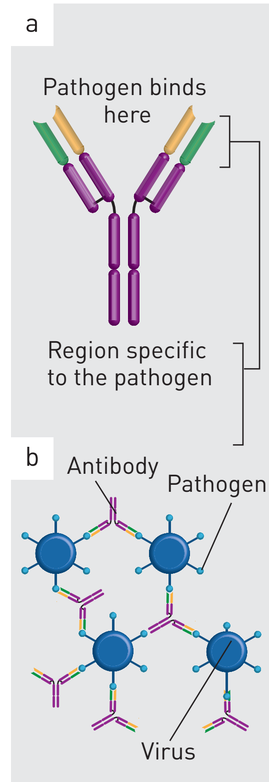


Figure 3.47 (a) Antibodies have regions that are specific to pathogens. (b) Antibodies cause pathogens to clump together.

Third line of defence

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

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. Each antibody will fit only one section of the pathogen. This will cause the pathogens to become locked together and stop 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 the B and T cells will 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 does damage a second time. Your body will be protected from re-infection in the future. You are now **immune**.

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

One other 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:

> the dead pathogen
> a living but non-virulent (weakened) form of the pathogen
> parts of the broken up pathogen.

Through vaccination, a person makes antibodies, 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. For example, a tetanus vaccination may be given after a tetanus-prone injury, such as an open wound caused by a rusty or dirty object, because tetanus can be fatal.

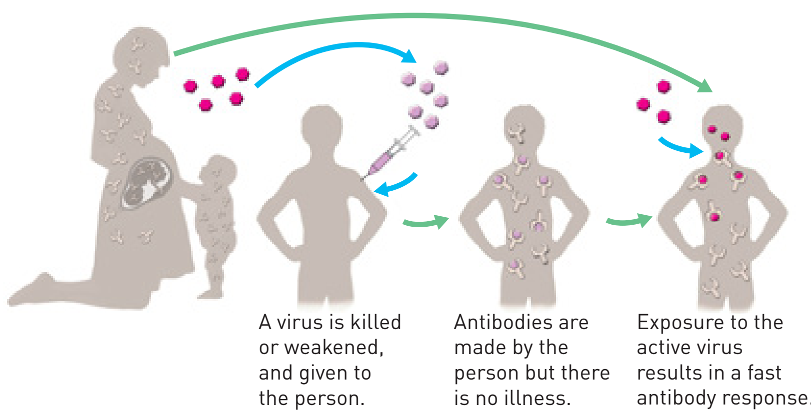


Figure 3.48 A person can become protected or immune through active vaccination or antibodies passively being passed on from their mother.

Check your learning 3.10

Remember and understand

1 What is the body's major first line of defence?
2 In what other ways can the body prevent pathogens from entering?
3 Describe in your own words how the non-specific immune response works.
4 What are the different types of immunity?
5 What is the difference between a vaccination and a vaccine?

Apply and analyse

6 What might a vaccine contain?

//SCIENCE AS
A HUMAN ENDEAVOUR//

3.11 Things can go wrong with the immune system

The immune system coordinates attacks on pathogens that are trying to disrupt the body. The immune system can be disrupted. 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 the T cells, resulting in an acquired immunodeficiency syndrome (AIDS).

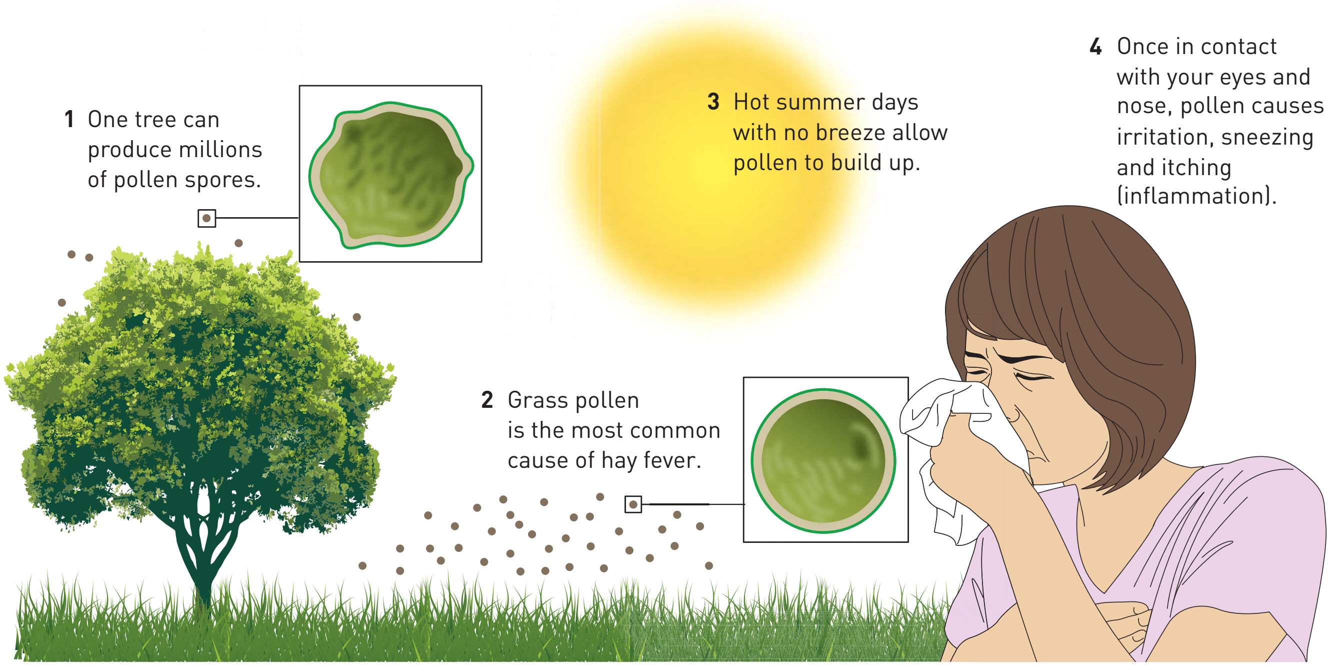


Figure 3.49
How a hay fever attack happens.

Hay fever and other allergies

Allergies result when your immune system mistakes a harmless substance for a pathogen. The most common example is plant pollen, mainly from grass but also from trees. 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 trying 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 whole of your throat will swell shut, making it difficult to breathe. The large amount of fluid leaking from your blood vessels can also cause your blood vessels to collapse. This life-threatening response is called **anaphylaxis**.

Figure 3.50 Epipens deliver adrenaline 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 and destroy the synovial membrane that lines the joint. This causes the joint to swell up with fluid. This causes heat and pain for the sufferer.

Figure 3.51 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 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.

HIV causes AIDS

Human immunodeficiency virus (HIV) is a virus that infects a special type of T cells in the immune system. This affects the whole immune system and makes it 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 easily destroy. For example, simple fungal infections, viral eye infections and diarrhoea (loose bowel motions) can make a person with a HIV infection very sick. Collectively these symptoms are called acquired immunodeficiency syndrome (AIDS).

Figure 3.52 Opportunistic pathogens such as yeast will make the most of an ineffective immune system to grow out of control.

Extend your understanding 3.11

1 Why does hay fever cause a runny nose and watery eyes?
2 With hay fever, why is it always worse the second time you are exposed to pollen?
3 Why are the finger joints swollen in a person with rheumatoid arthritis?
4 Explain why people with type 1 diabetes are unable to produce their own insulin.
5 What is the difference between HIV and AIDS?
6 How can eating a small amount of peanuts cause death in some people?

*REVIEW

3

Remember and understand

1 Write a definition of:

  a stimulus

  b homeostasis

  c pathogen.

2 Describe three different ways the human body can receive a stimulus from the environment.

3 Name two glands in humans that produce hormones.

4 Explain why the nervous system and the endocrine system are both communication systems.

5 How are hormones transported in the body?

6 What are the major features of the body's first line of defence?

7 Give an example of an infectious disease.

8 What is an antibody?

9 Why do you think it is important to have certain vaccinations before travelling overseas? Give two examples of diseases you may need to be vaccinated against.

10 How does the specific immune system remember pathogens for the next time you are infected by them?

Apply and analyse

11 Explain what a feedback mechanism is and give an example.

12 Complete this sentence by inserting the missing words.
A person with diabetes has a problem with the hormone ____________, which is secreted by the ____________.

13 Transmission of pathogens can cause mass outbreaks of disease that affect large numbers of people. Examples are HIV and AIDS, the SARS virus and swine flu, and the outbreak of cholera in Zimbabwe. Choose one disease and explain how it can spread so quickly. What can be done to prevent the spread of such diseases?

14 Given that people have usually caught a cold before, why is it that we continue to catch colds?

Evaluate and create

15 Why might holding your nose help you to swallow something that tastes awful?

16 Predatory animals have their eyes on the front of their face, while their prey generally have eyes on the sides of their heads. Why might this be the case?

17 In 2006, a woman in Canada fought off a polar bear with her bare hands when it attacked her daughter. She literally wrestled with the bear and won. Give arguments for and against this reaction being attributed to the hormone adrenalin.

18 Compare viruses, bacteria and protozoa, which are all pathogens. How are they similar? How are they different?

19 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 lies with their parents or guardians. Find out which vaccinations are available and present the arguments for and against them.

20 Imagine that you wake up one day and one of your sense organs has stopped working. Write a creative story outlining this day in your life.

21 Your body is constantly monitoring and controlling the numbers of pathogens in and on your body. What can you do to assist your body in controlling pathogens? What can a doctor help you with?

22 Draw a cartoon strip with at least five squares, illustrating a person receiving a stimulus and then responding.

23 Explain how the endocrine system assists your body to 'respond to the world'? Why couldn't the endocrine system handle this big job on its own?

24 Prepare a visual presentation on the role of the different types of white blood cell in attacking pathogens.

Research

25 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, so, to date, damage to the spinal cord is permanent. Scientists have been researching the use of stem cells in the treatment of spinal cord injury. What are stem cells? What type of stem cells are used? What sorts of advances have been made in this field of research? What issues have affected such research?

> **Type 2 diabetes**

Type 2 diabetes is increasing in our society. Why is this? What is the cause of it? What complications can result from diabetes? What can you do to prevent diabetes?

> **Artificial skin**

Investigate the work of Australian scientists Dr Fiona Wood and Dr Marie Stoner on skin regeneration, including spray-on skin. Why is their area of research so important? How was it related to the treatment of the Bali bombing victims?

* KEY WORDS

3

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

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

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 the electrical message away from the cell body to the synapse

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

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

central nervous system
the brain and spinal cord

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

endocrine system
a collection of glands that make and release hormones

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

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

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

memory cell
an immune system cell that is produced in response to an infection, and retains the memory of how to fight the pathogen

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

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

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

pathogen
anything that causes disease

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

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

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

reflex
an involuntary movement in response to a stimulus

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

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

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

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

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

T cell
an immune system cell that recognises and kills pathogens

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

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

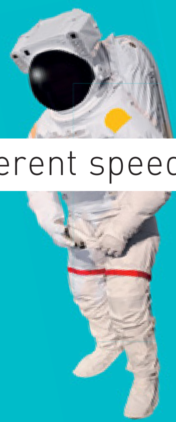
vaccination
an injection of an inactive or artificial pathogen that results in the individual becoming immune to the disease

white blood cell
an immune system cell that destroys pathogens

SOUND AND LIGHT

4

4.1 Vibrating particles pass on sound



4.2 Sound can travel at different speeds

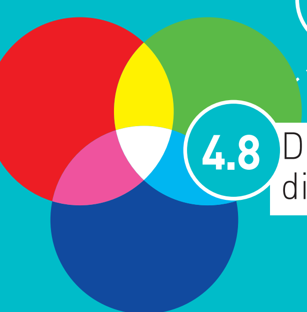
4.3 Our ears hear sound

4.4 Things can go wrong with our hearing

4.5 Visible light is a small part of the electromagnetic spectrum

4.6 Light reflects off a mirror

4.7 Light refracts when moving in and out of substances



4.8 Different wavelengths of light are different colours

4.9 The electromagnetic spectrum has many uses

4.10 Our eyes detect light

4.11 Things can go wrong with our eyes

What if?

String phones

What you need:

2 foam cups, 3 metres of string, scissors

What to do:

1. Place a small hole in the bottom of each foam cup.
2. Poke the end of the string through the end of each cup and tie it off. The two cups should now be connected.
3. Pull the string taut between two people.
4. One person should speak quietly into the cup at one end while the second person listens in the other cup.

What if?

» What if the string was shorter? (Would the sound be louder or softer?)

» What if the string was longer?

» What if you used different types of string between the two cups?

4.1 Vibrating particles pass on sound

Sound is caused by the vibration of particles moving in a wavelike motion. The vibration of a guitar string causes the particles in the air to compress together (compression) and then move apart (rarefaction) in a longitudinal wave. The distance the air particle moves is called the amplitude. The length between the start of one compression and the next is the wavelength, and the number of waves passing a point each second is the frequency of the wave.

Modelling sound waves

We know that sound energy travels because we can often hear it a long way from its source. Consider the example of a drum being played. The drum skin vibrates (moves up and down) when it is hit. The vibrations push the surrounding air particles closer together in one place and force them further apart in another. In this way, the air around the drum is made to vibrate too. This causes the particles further away to vibrate, and so on, until the air close to your ears eventually vibrates and causes your eardrum to vibrate too. And that's when you hear the sound.

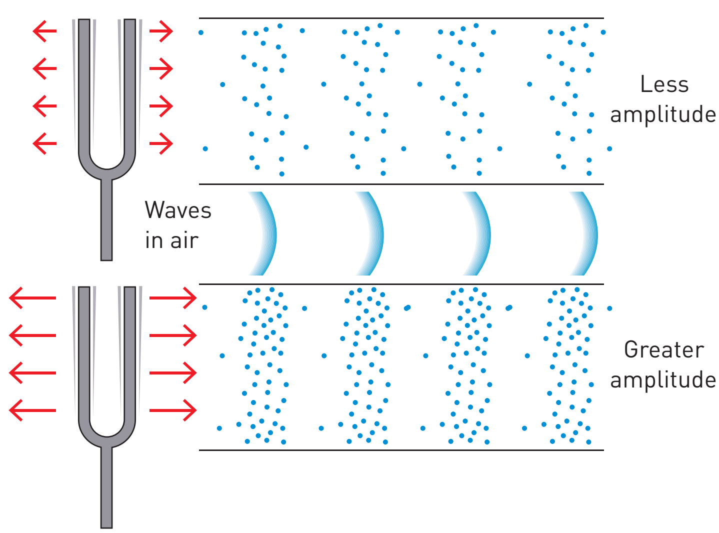


Figure 4.1 Red arrows indicate how far a particle in a sound wave moves.

The region with the particles forced close together is called a **compression**, and the less dense region is called a **rarefaction**. Sound waves travel as a **longitudinal wave**. The air particles move back and forth in the same direction as the wave as the vibration passes through the air. The distance a particle of air moves is called the **amplitude** of the wave. Sound waves with a large amplitude mean the air particles move with greater energy. This makes the sound appear louder to our ears. An example of this is when musicians use amplifiers to increase the loudness of their music. Amplifiers increase the distance air particles move during compression and rarefaction.

A sound wave moves out in all directions from the place where the vibration began (Figure 4.2).

Describing sound

You can sing high. You can sing low. You can talk in a funny voice if you want to because you can alter the number of vibrations coming from your vocal cords every second.

Compression waves can be close together or far apart. The distance between the start of one compression wave and the start of the next is called the **wavelength**. Short wavelengths mean more vibrations hit your eardrum each second.

When the waves travel close together, then they are considered more frequent. The number of waves that pass a point each second is called

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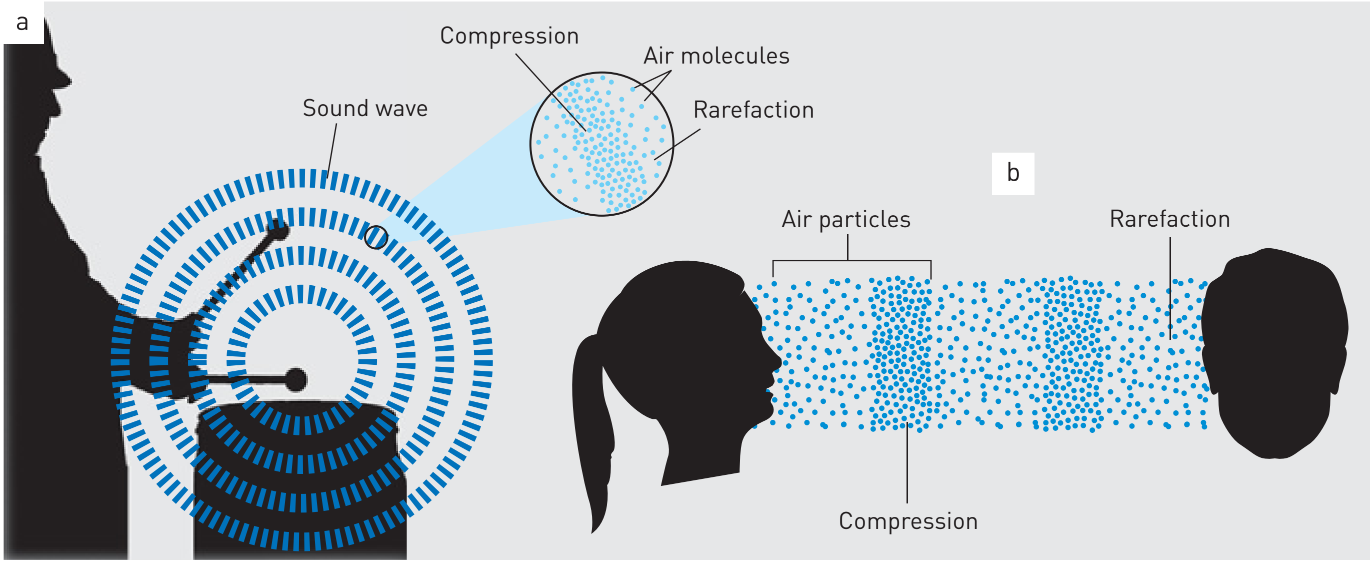

Figure 4.2 (a) When a drummer hits a drum skin, (b) a sound wave is produced.

the **frequency** of the wave. This is measured in the unit **hertz** (symbol Hz). We hear different frequencies as different pitches. For example, a soprano singer sings the high notes in an opera. These notes are high pitched. The sound waves for these notes have very short wavelengths and therefore high frequency. A deep bass singer is able to sing very low-pitched notes. These notes have long wavelengths and few of them can pass a point each second. Therefore, they have a low frequency.

As the waves move further away from their source, they lose energy and eventually fade out. As neighbours will confirm, the closer you live to a drummer, the louder they seem!

Figure 4.3 Middle C (shown in red) played on a piano has a wavelength of 1.33 metres and creates vibrations at a frequency of 256 vibrations every second or 256 Hz.

Check your learning 4.1

Remember and understand

1. How are particles in air arranged in a:
   a. compression?
   b. rarefaction?
2. Work with a partner. Explain to your partner how the sound waves created by hitting a cymbal reach your ears. Use the following terms: compression, rarefaction, sound wave, spread out, air particles and ear.
3. Of the two springs shown in Figure 4.4, which demonstrates a:
   a. lower frequency?
   b. smaller wavelength?

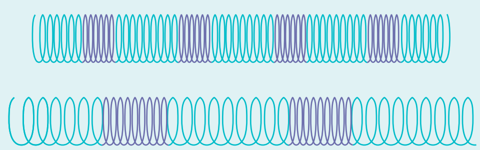

Figure 4.4

Apply and analyse

4. Imagine you have three tuning forks of frequencies 250, 500 and 1000 Hz. Which one would:
   a. sound the lowest?
   b. have the highest pitch?
5. Research the speed of sound in air.

4.2 Sound can travel at different speeds

Sound travels at 340 m/s at sea level at 20°C. The speed of sound varies according to the temperature and material through which it travels. At higher temperatures, particles have more kinetic energy, so they can compress more easily. Therefore, sound travels faster at higher temperatures. The more closely packed the particles, the faster the sound wave travels.

Figure 4.5 In outer space, there are so few particles of gas, and they are so far apart, that they cannot be compressed. As a result, outer space is silent.

Sounds of silence

If you are a drummer, you have probably been told more than once to 'keep the noise down!' But is there somewhere you could play your drum kit as hard and as loud as possible with absolutely no sound being heard? The answer is 'yes', but it is not a place you can get to easily.

A famous sci-fi movie was advertised with the tagline 'In space, no one can hear you scream.' The moviemakers were right. In outer space, you can play your drum kit without anyone hearing a sound – but you wouldn't hear it either. You could even see an explosion without hearing a thing. This is because sound needs something to travel through; it needs a substance (or medium) that contains particles that can be compressed to create the sound waves. The medium could be a solid, a liquid or a gas.

Speed of sound

The speed of sound is affected by the closeness of the particles in a material, and how far they can move. For example, the particles in water are much closer together than in air but they can still compress against each other. This means a compression sound wave can travel very easily through water. The particles in a solid are packed even closer together. Therefore, sound will travel even faster in most solids.

The speed of sound also depends on the temperature of the material it is travelling through. Particles at higher temperatures have more kinetic energy. Since the particles are already vibrating fast, they can move more easily in a compression wave.

Table 4.1 Speed of sound in different materials and at different temperatures

MATERIAL	SPEED (m/s)
Air at 0°C	331
Air at 20°C	343
Water at 20°C	1482
Lead	1960
Glass	5640
Steel	5960

CHALLENGE 4.2A: THE SPEED OF SOUND
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CHALLENGE 4.2B: RACING DOMINOES
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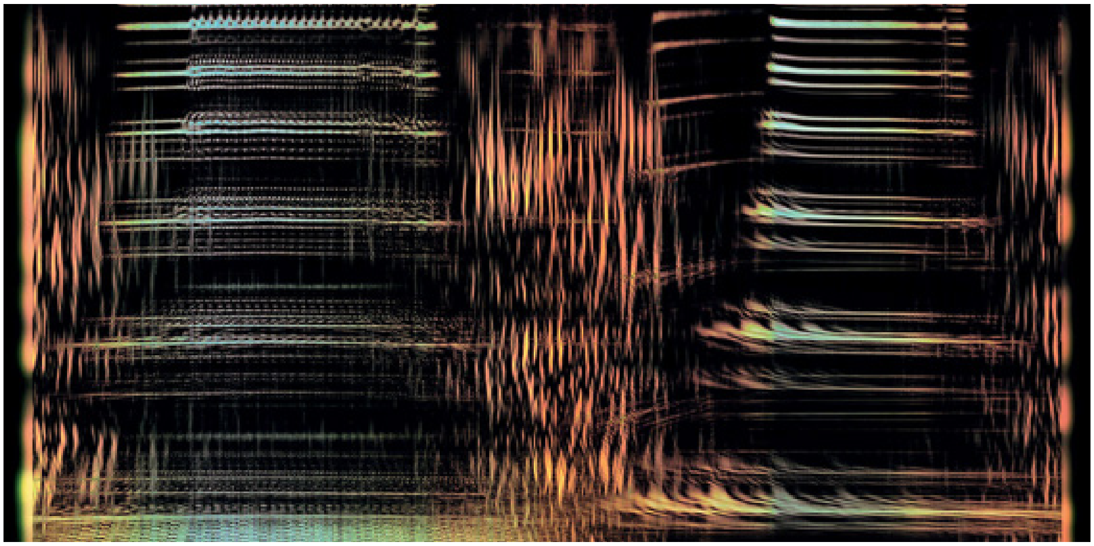

Figure 4.6 The speed of sound travels five times faster in water than in air. Blue whales sing to each other in a series of moans, and pulses (shown) that can travel thousands of kilometres underwater.

Sonar

In all wars since World War I, reflected waves have been used to detect enemy submarines under water. In a similar way to radar (radio waves), sonar sends out sound waves and records how long the sound takes to reflect or echo back after striking an object. The longer the sound takes to return, the further away the object is. An exact location can be calculated by knowing how fast sound travels in water. This information, along with the time taken for the sound to return, allows the exact location of a submarine to be determined.

Sonar is widely used today and can help map the ocean floor, check the depth of water and locate schools of fish.

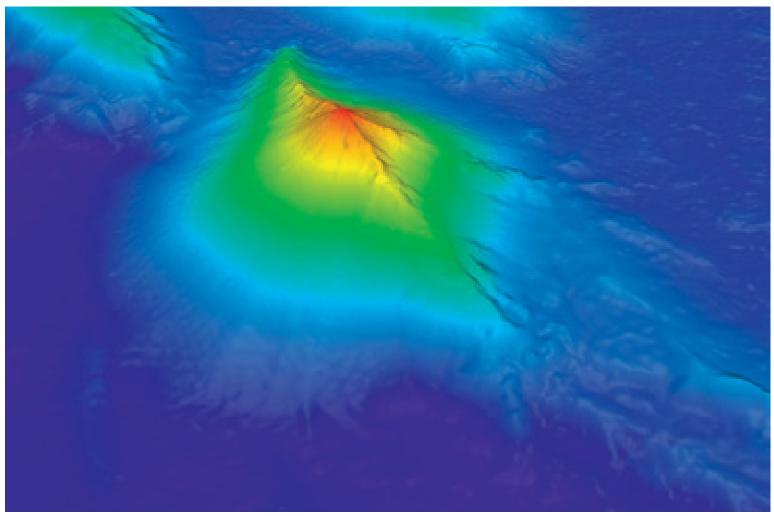

Figure 4.7 Sonar is used to map volcanoes on the ocean floor.

Check your learning 4.2

Remember and understand

1 Which of the following materials will allow sound to travel the fastest?
   a Water
   b Lead
   c Air
   d Glass

Apply and analyse

2 How is sonar similar to light striking a mirror?

3 Which of the following is most likely to produce a loud echo? Explain your answer.
   A Talking in a furnished, carpeted room
   B Singing in a tiled shower
   C Yelling across an open field

4 If a nearby star were to explode, why wouldn't we hear the noise of the explosion here on Earth?

5 Many movies show people tapping SOS on water pipes to get help. Why is tapping on water pipes a quicker way of passing on a message than yelling?

4.3 Our ears hear sound

Our ears hear a sound when the vibration of air particles is funnelled down the ear canal by the auricle (Figure 4.8). This causes the eardrum to vibrate, which in turn passes the movement on to the ossicles in the middle ear. These small bones vibrate against the oval window at the entrance of the inner ear. The fluid in the cochlea sends waves that are detected by the hairs attached to auditory nerve. This sends a message to the brain that sound was heard.

Hearing

The ear is a highly sensitive and accurate system. In only a few milliseconds it can collect, transfer, detect and interpret sound. Our ears consist of three main parts, which are the:

> outer ear, where sound waves are collected

> middle ear, where the sound is amplified

> inner ear, where sound is changed into an electrical signal and sent along the hearing or auditory nerve.

The brain decodes the signal so it is recognised.

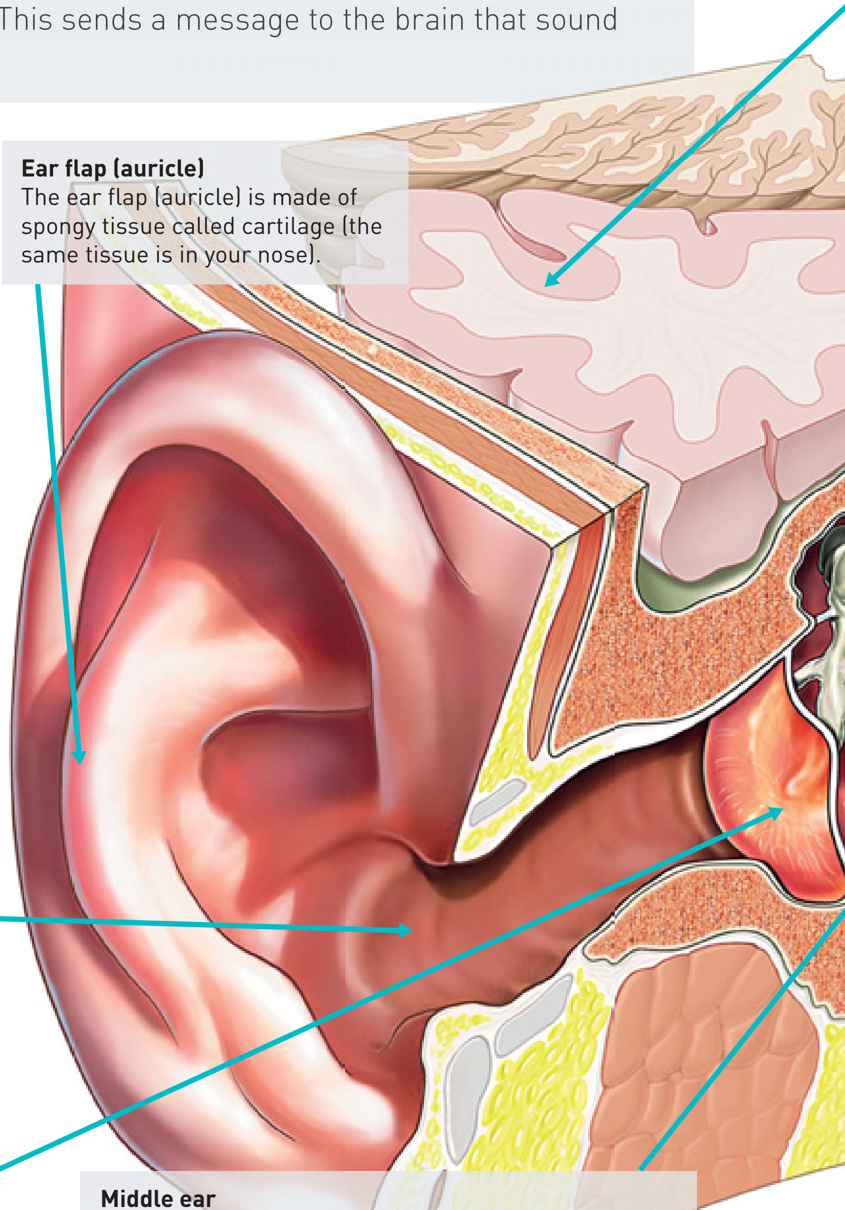

Figure 4.8 The main parts of the ear.

EXPERIMENT 4.3: WHY DO WE NEED TWO EARS?
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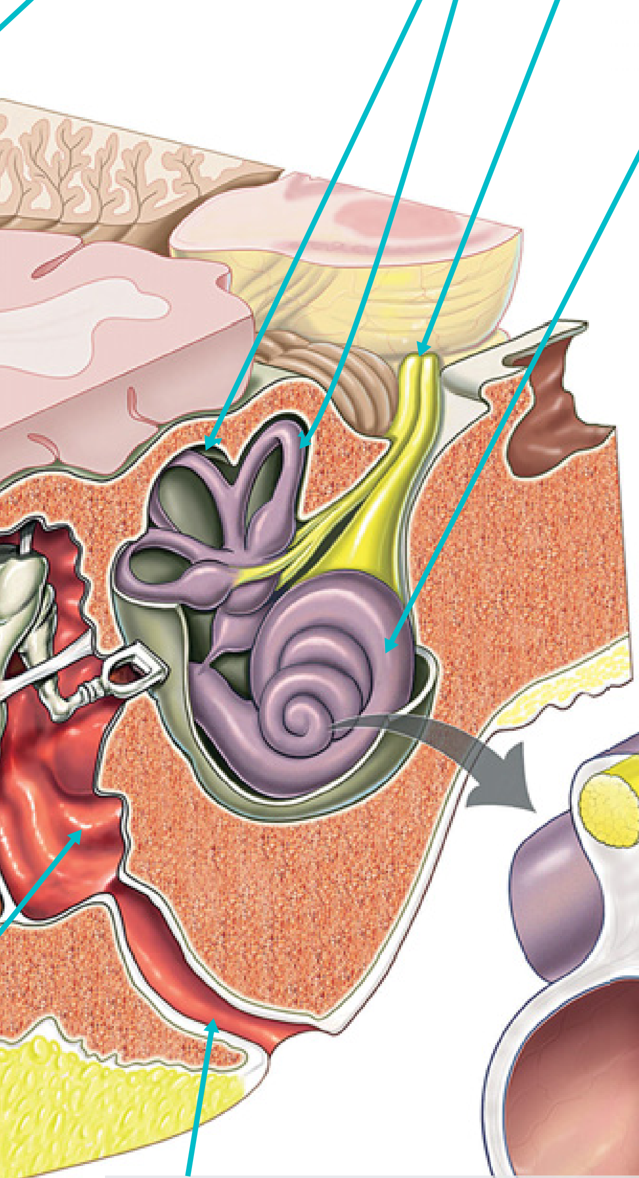
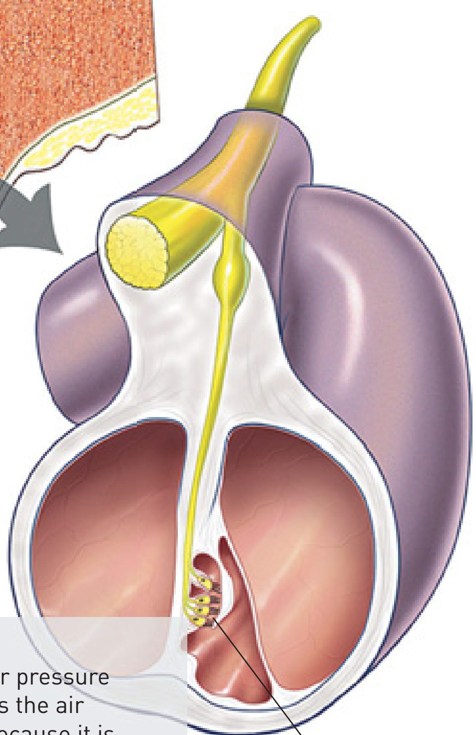
Semicircular canals
The semicircular canals are a set of tubes attached to the cochlea. These tubes are not part of the hearing system; they help us to keep our balance. The canals are filled with fluid. When you move around quickly, the fluid inside the canals also moves quickly and keeps doing so even after you stop. Detector cells inside the canals send messages to the brain that you are moving, but messages from your eyes tell the brain you have stopped. The conflicting messages make you feel dizzy!

Brain
The incoming sound is checked in the auditory cortex against other stored sounds to decide what the sound is. The brain then sends messages to other parts of the the brain associated with that particular sound.

Auditory nerve
The auditory nerve (hearing nerve) carries all of the information about the sound signals coming out of the receptor cells to the brain.

Cochlea
The cochlea, a snail-shaped bone, is the sound detector. It is filled with fluid and tiny hairs attached to receptor cells. The vibrations that pass through the oval window create waves in the fluid in the cochlea. These bend the little hairs that stick out of the receptor cells. The bending sets off an electrical signal along the auditory nerve to which the receptor cells are all connected.





Eustachian tube
The Eustachian tube keeps the air pressure inside the middle ear the same as the air pressure outside. It can do this because it is joined ot the back of the throat behind the nose. When the pressure is not equal on both sides of the eardrum, the Eustachian tube opens to let air move in or out to balance the pressure.

Check your learning 4.3

Remember and understand

1 Explain the role of the following parts in the hearing process: receptor cells, ossicles, eardrum, auditory nerve, Eustachian tube.

2 True or false?

  a The outer ear is used to detect sound.

  b The middle ear contains little bones called ossicles.

  c The inner ear is protected by a bone in the shape of a spiral seashell.

  d The hair cells in the hearing system are found on the scalp of the head.

Apply and analyse

3 Imagine you could not hear at all. Explain how it might affect your safety, communication and ability to locate objects.

4 How can damage to the eardrum affect hearing?

5 Doctors warn about poking cotton buds into our ears to remove wax from our ear canal. They suggest that it is best to remove wax only from the very outer part of the ear and to see a doctor to remove other excess wax. Why do you think doctors give this warning?

6 How many bones form the ossicles? Find out the names of these bones.

7 Suggest why an ear infection can sometimes make you feel unbalanced.

//SCIENCE AS A HUMAN ENDEAVOUR//

4.4 Things can go wrong with our hearing

Your hearing relies on very thin layers of skin in the eardrum, small bones in the middle ear, and fine hairs in the cochlea. These delicate mechanisms can become damaged by loud noises, infections or age.

Sound level meter

The loudness of a sound can seem different to different people. It can seem different depending on the frequency or pitch of the sound. To measure it scientifically, we use a sound level meter. Sound level is measured in **decibels** (dB). Decibels were named after Alexander Graham Bell, the inventor of the telephone.

Figure 4.9 A sound level meter.

Tinnitus

Tinnitus is usually described as a constant ringing in the ears. It can be low or high pitched and can be caused by loud noises, infections or drugs. It is occasionally the first sign of hearing loss as a result of age. Exposure to constant loud noise can damage the small hairs in the cochlea. This damage can send confusing messages through the aural nerves, which the brain interprets as the constant noise that characterises tinnitus.

Figure 4.10 Professor Graeme Clark, who led the development of the cochlea implant.

Hearing aid

A hearing aid is designed to increase the amplitude of sound waves as they move into the middle ear. This makes sounds louder so that the person is more likely to hear them.

Cochlea implant

Until the 1970s, everyone believed that nothing could be done to restore the hearing of people with profound deafness due to nerve damage. With the invention of the silicon chip and advances in electronics, several scientists began researching how to make a tiny electronic replacement for a damaged cochlea that could do the job of healthy receptor cells.

Professor Graeme Clark and his team at the University of Melbourne took 8 years to develop a prototype, and it was a further 7 years before a commercial cochlea implant – a 'bionic ear' – was available to people with profound nerve deafness.

A cochlea implant has two sections: the internal and the external parts. The internal part of the implant consists of 22 tiny wire electrodes that are surgically inserted inside the cochlea.

The external part of the cochlea implant consists of a tiny computer (the speech processor). The speech processor sits in a

CHALLENGE 4.4: IS SCHOOL BAD FOR YOUR HEALTH?
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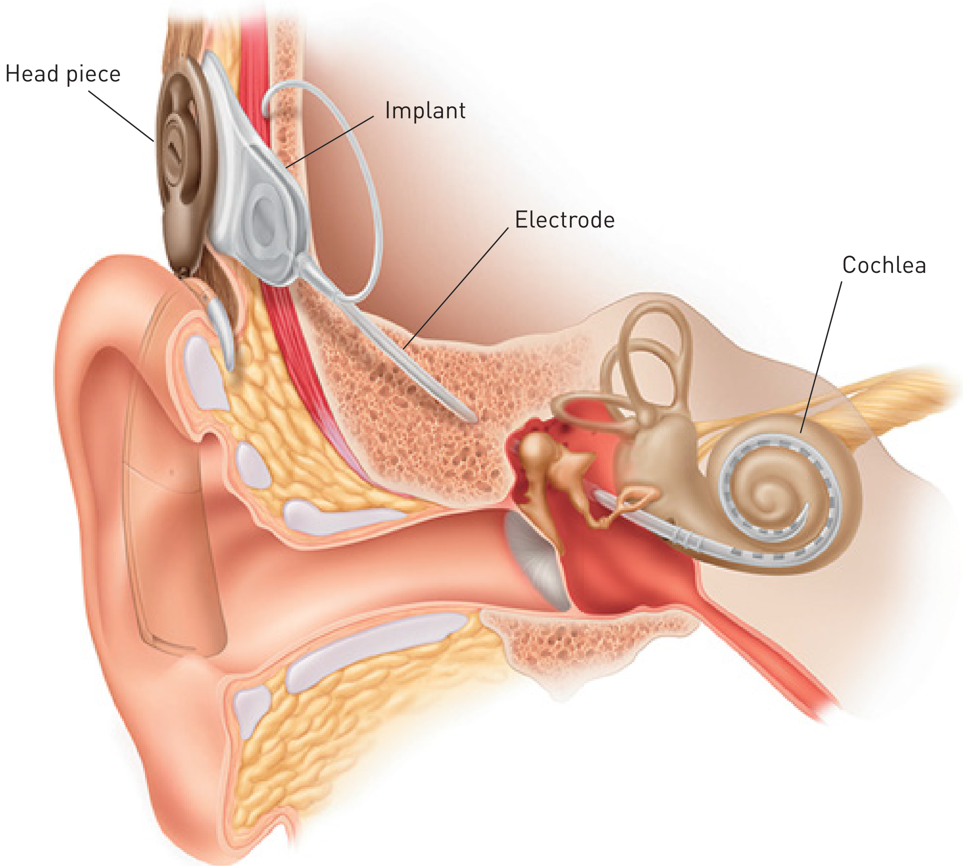
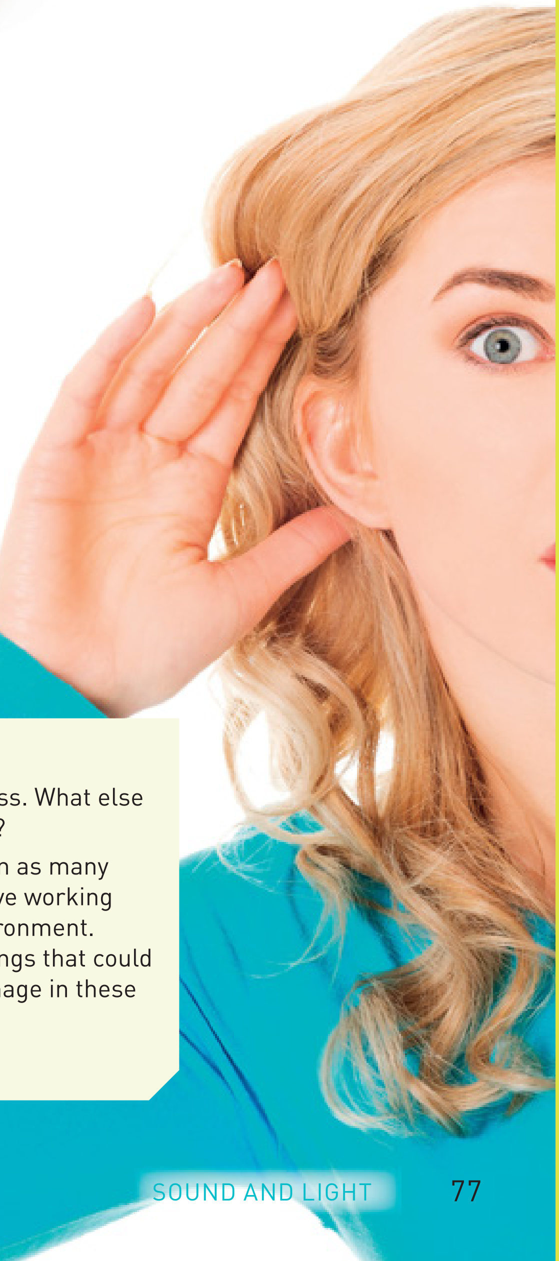


Figure 4.11 A cochlea implant.

small case behind the ear, looking similar to other hearing aids. It has a powerful built-in microphone. The sound of speech is processed by the computer and converted to electrical signals, which are sent by radio waves through the skin into the internal part of the cochlea implant. The electrical signals activate the hearing nerve inside the cochlea and send a message to the brain to indicate that sound has been detected, just as healthy receptor cells would.

Researchers at Swinburne University of Technology in Victoria are now investigating a similar approach to restoring sight. They are looking for a non-contact method of stimulating nerves and are exploring the use of laser light, perhaps as a tiny laser device fitted in a pair of spectacles.



Extend your understanding 4.4

1. What causes tinnitus?
2. Why do people have difficulty hearing when they have a middle ear infection?
3. How are hearing aids different from cochlea implants?
4. What does the unit dB stand for? Who is it named after?
5. In an experiment, an opera singer sang at a particular frequency at 130 dB for 3 seconds to smash a glass. What else has a loudness of 130 dB?
6. With a partner, write down as many jobs as you can that involve working in an extremely loud environment. Suggest at least three things that could help prevent hearing damage in these jobs.

4.5 Visible light is a small part of the electromagnetic spectrum

*

The electromagnetic spectrum is a way of describing all the different forms of light, including the light we see. All forms of light travel at the same speed through a vacuum and behave similarly to a transverse wave. Light also behaves like a particle called a photon.

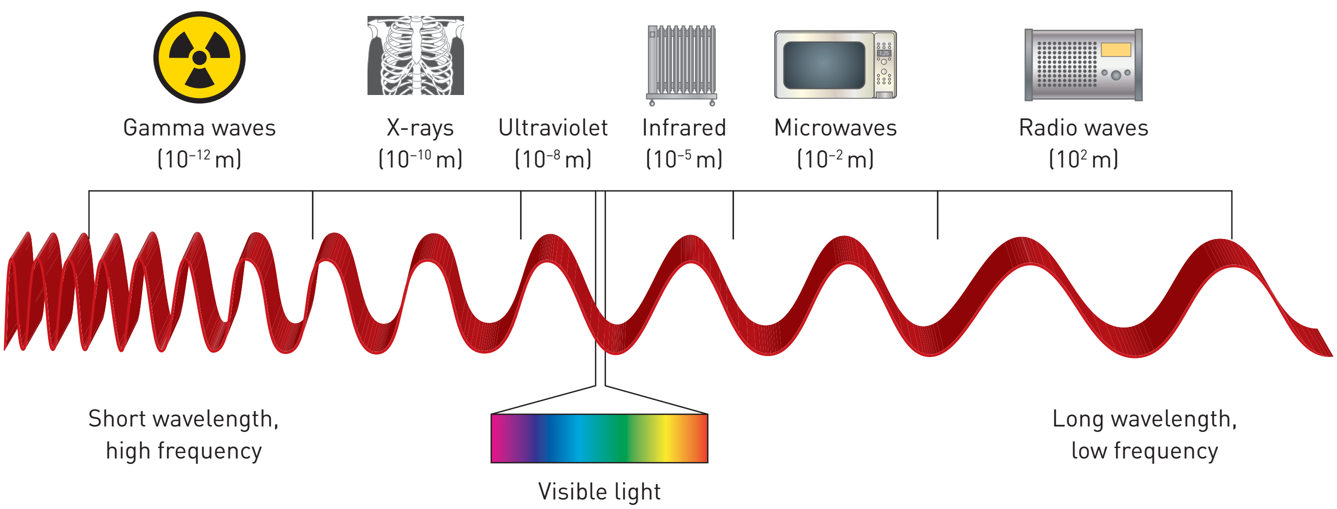


Figure 4.12 The electromagnetic spectrum.

Ancient civilisations believed that light was emitted from the eye and this enabled us to see. We now know that we see by light entering our eyes. Like sound, light is a form of energy, which can behave like a wave. There are many different types of light, with a very wide range of wavelengths. Together, these forms of light are called the electromagnetic spectrum.

Electromagnetic spectrum

The electromagnetic spectrum includes the energy that provides music on your radio, the picture on your television, and the heat to cook popcorn in your microwave.

We only see a small amount of this light energy. All these different types of light have common features. They all travel at the same speed, the speed of light, but they have an obvious difference. They have different wavelengths and therefore different frequencies.

Transverse waves

Light waves are different from sound waves. Sound waves exist as longitudinal waves – the vibrations of the air particles are in the same direction as the direction of travel of the wave. In light waves, the vibrations are at right angles to the direction of travel of the wave. We call these waves **transverse waves**.

The distance between two neighbouring peaks (rises) on a transverse wave is called the wavelength. It is the same as the distance between two consecutive troughs (dips) or between any two consecutive matching points on the wave. At a different wavelength the nature of the light wave changes. In the region of visible light, this change of wavelength is seen as different colours.

Because light waves have different wavelengths, they also have different

CHALLENGE 4.5: MODELLING LIGHT WAVES
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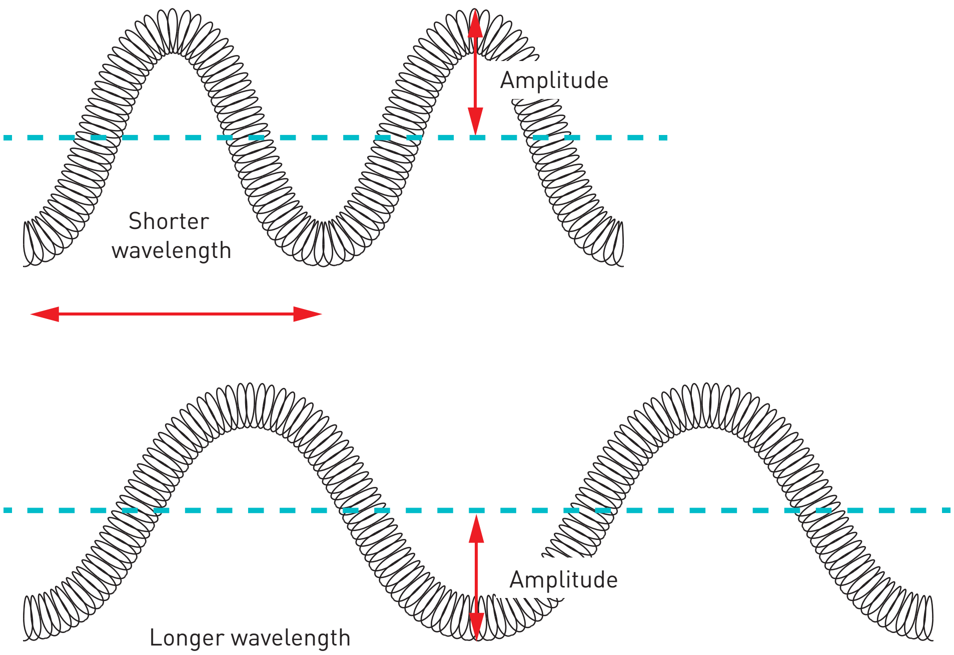


Figure 4.13 The wavelength of a wave is measured from any point on the wave (usually a peak or trough) to the next corresponding point.

frequencies. As with sound waves, the frequency of a light wave is a measure of the number of waves that pass a point each second (unit Hz). Amplitude is a measure of how far a particle moves from its place of rest.

Speed of light

Light waves travel extremely fast: 300 000 km/s in a vacuum. This value is known as the speed of light. Light waves can travel through other mediums too such as air, water and glass, where they slow down slightly. Unlike sound waves, light waves don't need a medium (solid, liquid or gas) in which to travel, due to their electromagnetic nature. They don't pass their energy from atom to atom like sound waves do. This means the different forms of light can travel through space to reach us on Earth.

Particle or wave?

Experiments by early scientists provided two forms of evidence about how light behaves. In some experiments, light behaved as if it were a wave. Other experiments indicated that light was a particle. Scientists now agree that light consists of a particle called a photon, which can move in a wavelike fashion. Just like a wave of water, it can bounce or reflect off surfaces and slow down if it travels through a thicker, denser material. Just like a separate particle, it can move by itself through space. This is how the light from the Sun can reach the Earth.

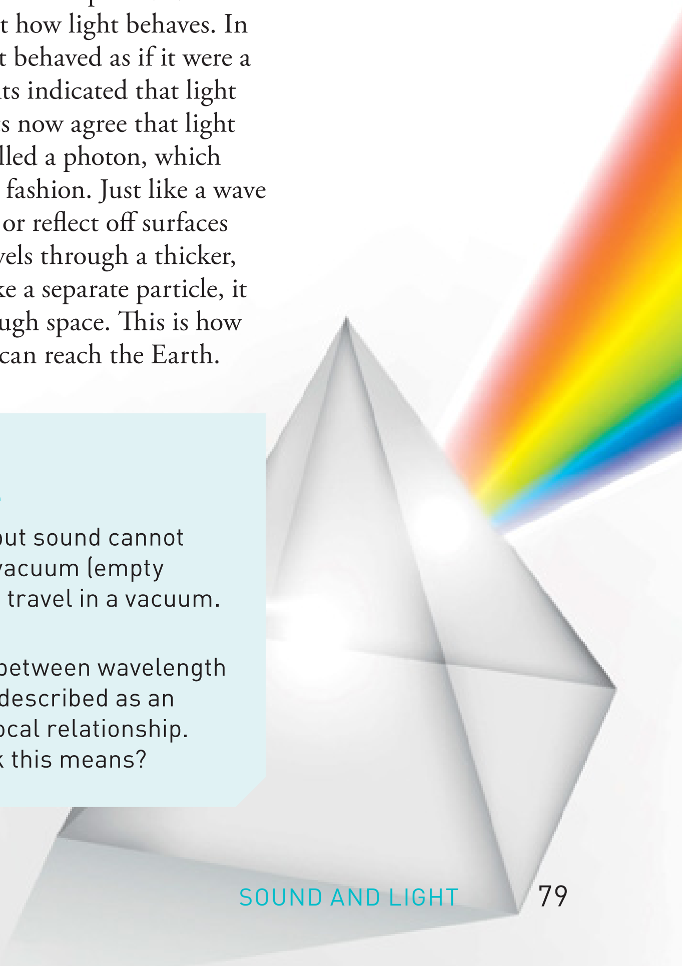
Check your learning 4.5

Apply and understand

1. What unit is used to measure wavelength?
2. The frequency of a wave is measured in units called hertz (Hz). How is this unit related to the unit of time, the second (s)?
3. What is the speed of light in a vacuum?

Apply and analyse

4. Sound is a wave but sound cannot travel through a vacuum (empty space)? Light can travel in a vacuum. Why is this?
5. The relationship between wavelength and frequency is described as an inverse or reciprocal relationship. What do you think this means?



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EXPERIMENT 4.6: REFLECTION FROM PLANE MIRRORS
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4.6 Light reflects off a mirror

* Light can travel through transparent objects and is blocked by opaque objects. Translucent objects allow some light energy through.

Light can reflect off a glass window but most of the light is transmitted and passes through. This is because the glass in the window is **transparent**. Some types of frosted glass prevent us seeing through them clearly. They are **translucent**. If an **opaque** material is shiny enough or has a shiny coating, it will reflect the light and allow us to see the clear **image**. The best example of this is a **mirror**.

The reflection of light from a mirror is shown in Figure 4.14. Light always follows particular rules when it reflects from a surface, no matter how rough or how smooth the surface is. The **normal** is an imaginary line that can be drawn at 90° (or perpendicular) to the mirror's surface. It is usually drawn as a dotted line.

The incident ray represents the incoming light and strikes the mirror at the base of the normal. The **angle of incidence** is the angle between the incident ray and the normal. The reflected ray leaves the mirror from the base of the normal at the same angle as the incidence ray. The **angle of reflection** is the angle between the reflected ray and the normal. An arrow is always used to indicate which line is the incident ray and which is the reflected ray. The law of reflection states that the angle of incidence (symbol i) equals the angle of reflection (symbol r).

When we look in a plane mirror we see a picture, or image, of ourselves. In the case of a plane mirror (a flat mirror), the image is always a **virtual image**. This means it cannot be captured on a piece of paper or on a screen as a movie projector does. The image always forms where the light rays cross. The image we see in a plane mirror is also laterally inverted, or turned sideways.

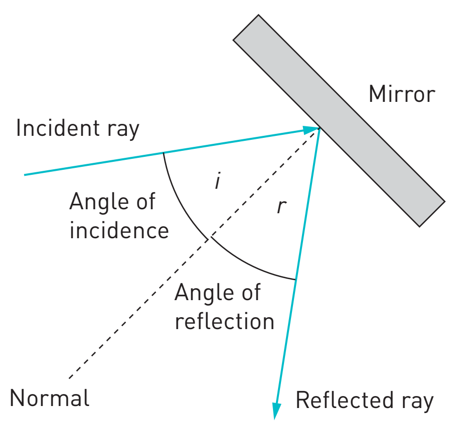

Figure 4.14 The angle of incidence (i) and the angle of reflection (r) are the same when light reflects off a mirror.

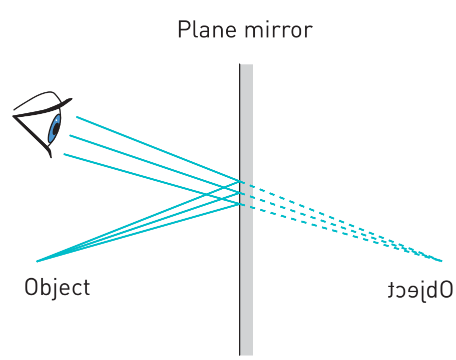

Figure 4.15 The image in a plane mirror is virtual, laterally inverted, the same size as the object and the same distance from the mirror.

CHALLENGE 4.6A: MIRROR WRITING
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CHALLENGE 4.6B: USING CURVED MIRRORS
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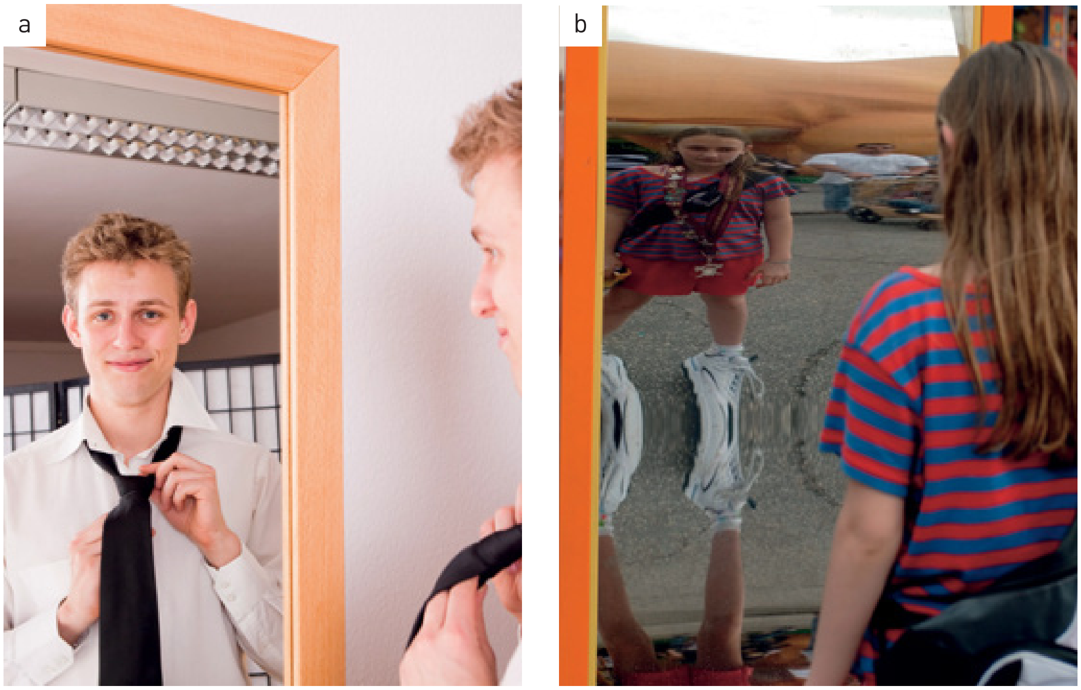

Figure 4.16 (a) A mirror shows the lateral inversion of what we look like. (b) Curved mirrors can change the way we look.

If we raise our left hand in front of a mirror, our image looks as if it is raising its right hand. The image is also the same distance behind the mirror as the object is in front of it.

Curved mirrors are not as predictable as plane mirrors. They can change the size and nature of the object's image. Curved mirrors can be **convex**, where the centre sticks out, or **concave**, where the centre goes in, like a cave.

Concave mirrors cause the reflected light to bend towards a central point. They are used in reflecting telescopes. Convex mirrors scatter the light of an object. They are typically used in passenger side mirrors.

Check your learning 4.6

Remember and understand

1. Summarise the meanings of 'transparent', 'translucent' and 'opaque' and give two material examples of each.
2. Light fittings are often translucent. Why is this so?

Apply and analyse

3. Draw up a table that explains the meaning of the normal, incident ray, angle of incidence, reflected ray and angle of reflection.
4. Can you think of some uses of convex and concave mirrors?
5. What do concave and convex mirrors have in common?
6. What do plane mirrors and a convex mirror have in common?

4.7 Light refracts when moving in and out of substances

Refraction is the bending of light as it enters or leaves a denser material at an angle. Reflection occurs from shiny surfaces but when light strikes a transparent material it enters the material and may change direction.

Figure 4.17 Water refracts light and distorts images.

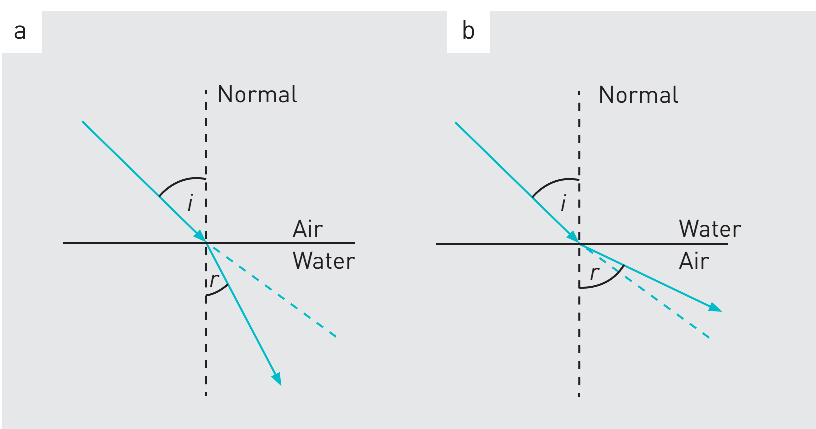

Figure 4.18 (a) Light entering a denser medium bends towards the normal. (b) Light entering a less dense medium bends away from the normal.

Refraction is the bending of light as it passes at an angle from one transparent **medium** (i.e. substance or material) into another. Often when light is refracted, our view is distorted. You might be familiar with this effect when looking through water.

The amount light bends depends on the optical density or **refractive index** of the material and has the symbol n. The bent ray is called the **refracted ray** and its angle with the normal is the **angle of refraction**, r. When a light ray enters a denser medium, such as from air into water, it slows down and consequently bends closer to the normal.

When the light ray leaves the denser medium and moves into a less dense medium, it is able to speed up. When this happens, the light ray bends away from the normal.

Generally, dense liquids have a higher refractive index than less dense gases. Dense solids have a higher refractive index than less dense liquids. Light bends because it changes speed. The lower the refractive index, the faster the light travels in the medium.

The only time that light does not refract is when it enters a new medium along the normal (90° to the surface). It still changes speed, but there is no bending of the light.

Refraction in everyday life

Refraction explains a lot of everyday phenomena (Figures 4.19 – 4.21).

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EXPERIMENT 4.7B: CREATING IMAGES WITH CONVEX LENSES
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Figure 4.19 Swimming pools and the ocean look shallower than they really are. The depth we see is the apparent depth. This person looks shorter in the water because the apparent depth is less.

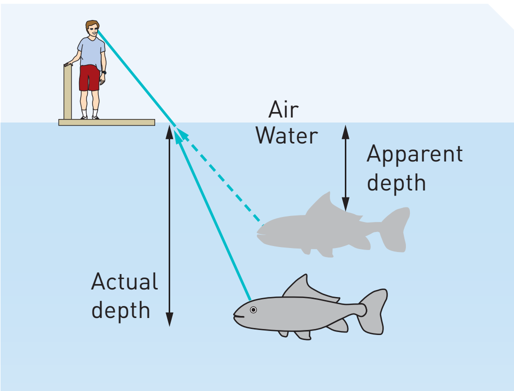


Figure 4.20 Refraction makes underwater objects appear closer to the surface than they really are. The fish looks closer than it really is because the light has left a denser medium.

Figure 4.21 Refraction makes straight objects appear disconnected. This pencil looks bent because its apparent position is different from its real position

Lenses

A **lens** is usually a curved piece of transparent material, such as glass or plastic. Convex lenses are thicker in the centre than at the edges and concave lenses are thinner in the centre than at the edges. They work in a similar way to convex and concave mirrors.

Convex lenses cause light rays to **converge**, or focus. The **focus** (or focal point) is the point where the rays cross and the **focal length** is the distance from the focus to the middle of the lens.

Concave lenses cause light rays to **diverge**, or spread out. The focus is on the other side of the lens and to find it the diverging rays are extended back until they cross at the apparent source. The focus can therefore be described as a **virtual focus** because the light rays do not really come from this point.

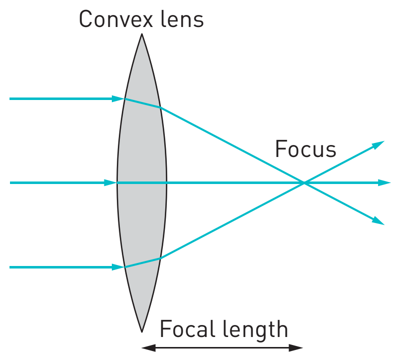


Figure 4.22 Parallel rays converge to a focal point with convex lenses.

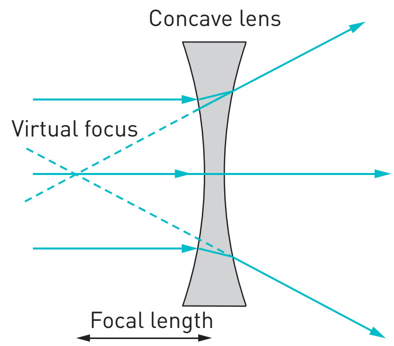


Figure 4.23 Parallel rays diverge from a focus through with concave lenses.

Check your learning 4.7

Remember and understand

1 Make a list of the similarities and differences between reflection and refraction.

Apply and analyse

2 The refractive index of water is 1.33 and that of diamond is 2.42. Draw a diagram to show how a light ray bends when it travels from water into diamond.

3 The refractive index of glass is 1.52 and that of air is 1.00. Draw a diagram to show how a light ray bends when it travels from glass into air.

4 What are some uses of convex and concave lenses?

5 What do convex and concave lenses have in common?

4.8 Different wavelengths of light are different colours

Visible light can be separated (dispersed) into the colours of the visible spectrum – red, orange, yellow, green, blue and violet. Each colour has a different wavelength and will refract different amounts to produce a rainbow. An object appears coloured when some colours are absorbed, and others are reflected into our eyes.

White light can be separated into an infinite range of different colours and shades, but there are generally considered to be six (or seven) basic colours – red, orange, yellow, green, blue and violet. Sir Isaac Newton discovered this concept and popular belief has it that he included a seventh colour for good luck, called indigo, between blue and violet. This makes the colour sequence easy to remember as 'ROY-G-BIV'. This range of colours is called the **visible spectrum**. The process used to produce these colours is called **dispersion**.

Each colour of the visible spectrum has a different wavelength (the length of one complete cycle of a wave) and is refracted by a different amount when moving through mediums of different densities. This produces the separation of colours. A rainbow is an example of dispersion (and total internal reflection). Three of the six basic colours are called **primary colours of light**. These are red, green and blue. This is because these three alone can be mixed to produce white light. When two of the primary colours are mixed, they form **secondary colours of light**. Red light and blue light make a red-blue light called magenta. Blue light and green light make an aqua or turquoise light called cyan. Green light and red light make yellow light. These rules are different for paints, so if you are an art student, you will need to think differently when considering mixtures of light compared to mixtures of paint!

If cyan light and red light are mixed, the result is white. When only two colours are needed to make white light, they are called complementary colours of light.

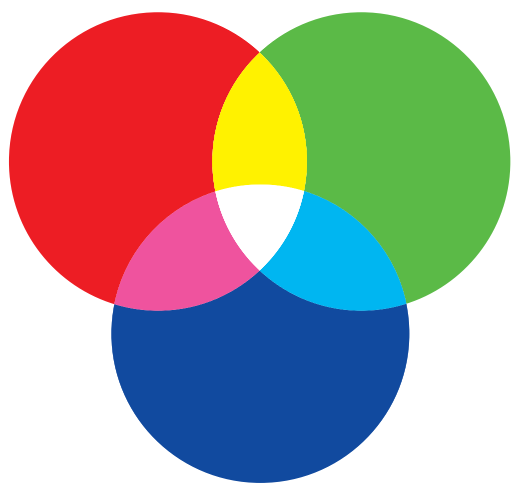


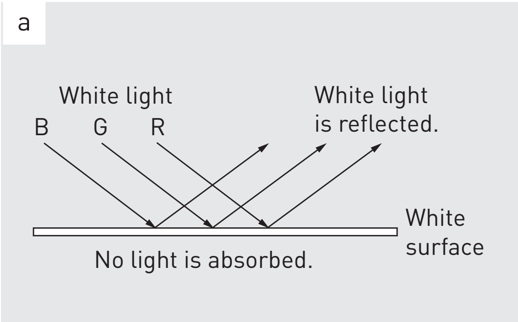
Figure 4.24 Where the red, green and blue lights overlap, white light is produced. The secondary colours are formed by the overlap of two of the primary colours.

This is because the cyan light already contains blue and green, so if we add red light, we effectively have the three primary colours, which we already know make white.

Colour of opaque objects

So, why do coloured objects appear coloured? When white light (or sunlight) falls on an opaque object, some colours may be reflected while others are absorbed (or soaked up or subtracted from the white light). The colour the object appears to be depends on the mix of colours that reflect into our eyes. In most cases, it is easier to consider white light as just made up of red, green and blue light.

If some colours are absorbed and some are reflected, the object will appear to be the colour of the mix it reflects. This rule is the same for objects illuminated by coloured light. So, a red top appears red because red light is reflected from the red surface to our eye. Grass is green because the red and blue wavelengths are absorbed and the green wavelength is reflected back to our eyes.



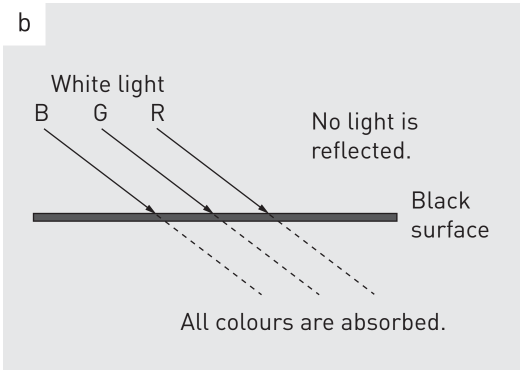


Figure 4.25 (a) A white surface reflects all colours and so looks white. (b) A black surface absorbs all colours and so looks black. No colours are reflected.

Colour of transparent objects

Transparent objects, such as the coloured **filters** in the Hodson light box kits, or coloured cellophane, **transmit** (allow to pass) and absorb colours in the same general way that blue objects appear blue to us. If the blue colour is transmitted while the red and green colours are absorbed, then the filter appears to be blue. For example, a red filter appears red because the blue light and green light are absorbed and red passes through. Therefore we see the red light from the filter.

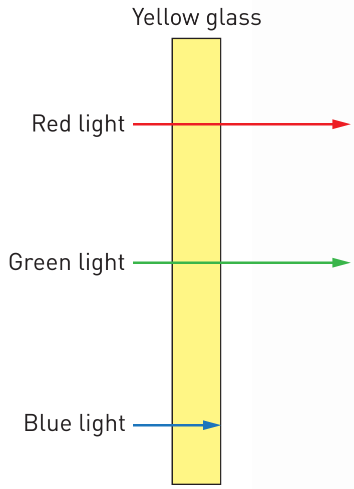


Figure 4.26 A filter that transmits red and green light and absorbs blue light will appear yellow.

Check your learning 4.8

Remember and understand

1. What is the result when magenta and yellow lights are mixed? Hence, what are these two colours called?
2. How does a green surface appear in red light? Explain your answer.

Apply and analyse

3. What would you see if you looked at white light through a yellow filter? Explain your answer.
4. What is the difference between primary and secondary colours of light?
5. If white light is a mixture of all the primary colours of light, what is black?

//SCIENCE AS A HUMAN ENDEAVOUR//

4.9 The electromagnetic spectrum has many uses

When a light ray passes into a less dense medium at a particularly large angle, it can be reflected back into the dense medium. This is called total internal reflection. This characteristic of light is used in optic fibres. Other forms of the electromagnetic spectrum, such as microwaves, are used in everything from communication to cooking food.

Total internal reflection

Many optical instruments, such as cameras, microscopes and some telescopes, use lenses but several use prisms to reflect light. A prism is usually a triangular block of glass. When light passes from one medium to a less dense medium, it is refracted away from the normal. As the angle of incidence increases, the refracted ray may be refracted so much that it travels along the surface between the two mediums, known as the interface, at an angle of 90° to the normal. The angle of incidence at which this occurs is called the **critical angle** (symbol i_c). If the angle of incidence is increased further, the light has nowhere to go and is reflected back into the dense

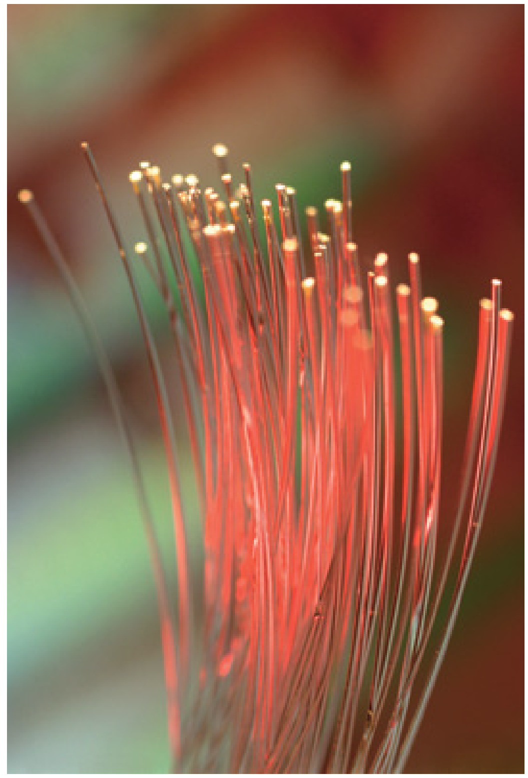


Figure 4.28 Optic fibres are used to carry digital light signals and they have various applications.

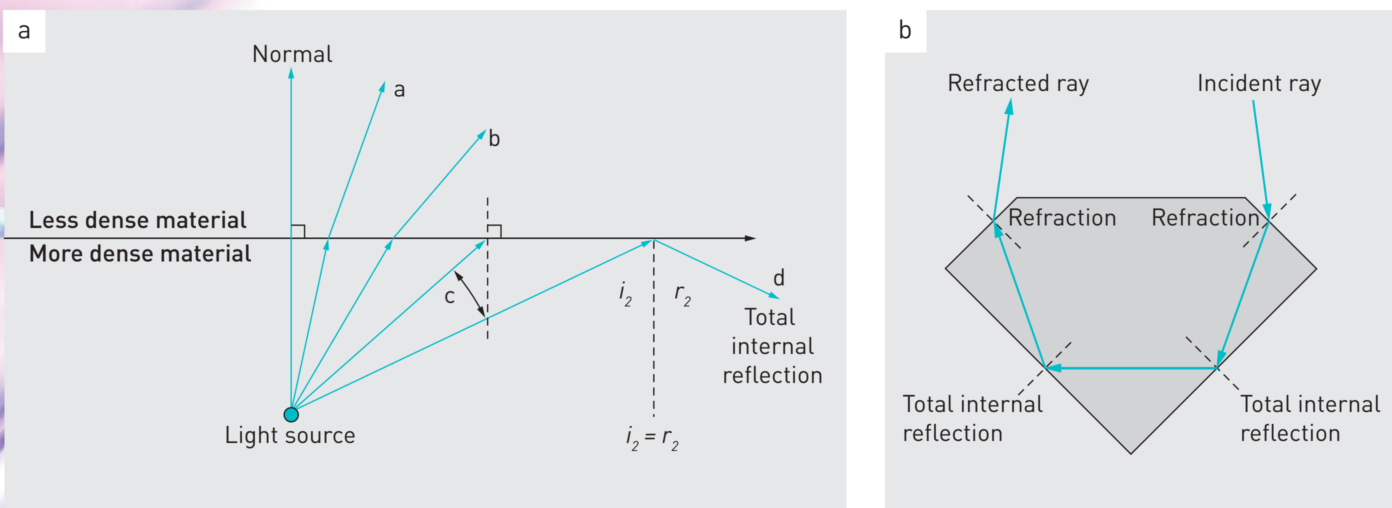


Figure 4.27 (a) Rays a and b are refracted because the angle of incidence is less than the critical angle. Ray c occurs when the critical angle is reached. Ray d is reflected when the angle of incidence is greater than the critical angle. (b) Total internal reflection.

EXPERIMENT 4.9: WHAT IS THE WAVELENGTH OF A MICROWAVE?
GO TO PAGE 202.

medium. This phenomenon is known as **total internal reflection**. It only occurs when light attempts to travel from a more dense medium into a less dense medium and only for angles greater than the critical angle.

Using total internal reflection

Optic fibres have revolutionised communications systems. Instead of relying on copper wires to carry electrical signals, we now use bundles of optic fibres to carry light signals for landline telephone calls, the Internet and networking of computers. An **optic fibre** is a very thin fibre of glass or plastic that carries light. By sending the information as controlled pulses of light, a single fibre less than a millimetre wide can carry thousands of landline telephone calls.

The advantages of optic fibres over copper wire are less signal loss, greater carrying capacity and immunity to electromagnetic interference. Hence, long distances can be covered with fewer repeater (or booster) stations. A single optic fibre carries much more data than a copper cable, so optic fibres save space, and crossed messages (a form of interference) cannot happen. Optic fibres do not generate heat like the current in a copper wire and are non-electrical, so they don't pose a fire risk and can be used around high voltages.

The National Broadband Network of fibre optic cables is currently under construction. The federal government says it will be available to 93% of Australian homes, schools and businesses, providing broadband speeds up to 100 times faster than many people in Australia use today.

Microwaves

Microwaves are one small part of the electromagnetic spectrum. The wavelengths of microwaves are usually 1 mm to 1 m in length. Microwaves have many uses from communication (mobile phones) to cooking, from global positional systems (GPS) to radar. Microwaves can be focused into narrower beams than radio waves. This allows them to be used for person-to-person communication on Earth or even between Earth and the space station.

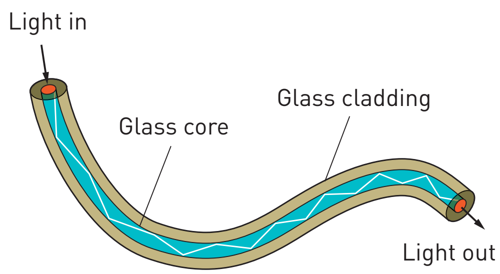


Figure 4.29 Light zigzags along inside an optic fibre at the boundary of the core and the cladding.

Microwave ovens

The electromagnetic waves in a microwave oven provide energy to make the water molecules in food move. The increased movement of the water molecules causes friction between the other molecules in the food. This friction between all the molecules causes the food to heat up.

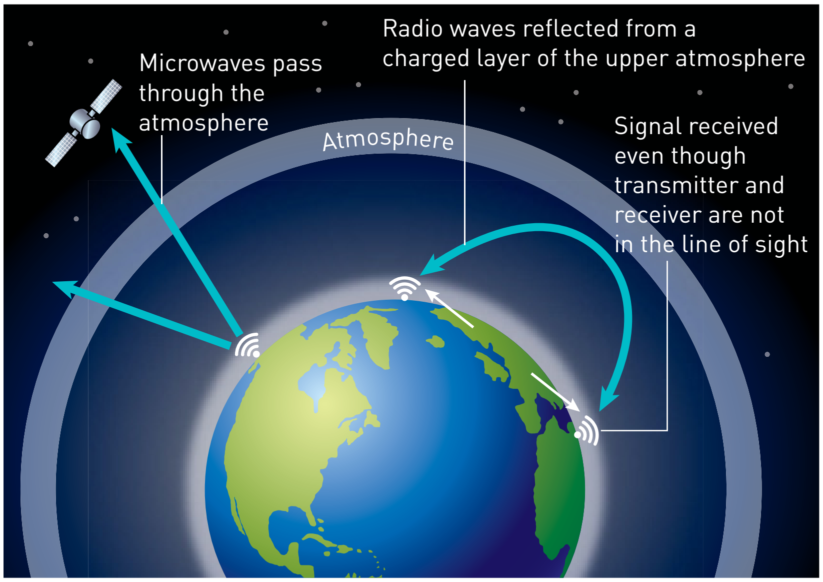


Figure 4.30 Electromagnetic waves with different wavelengths behave differently in the Earth's atmosphere.

Extend your understanding 4.9

1 List the ways total internal reflection is similar to and different from reflection from a plane mirror.
2 Why can't total internal reflection occur for light passing from a less dense material into a denser material?
3 What is the advantage of using optic fibres instead of copper wire for telecommunications?
4 Why is the amount of water in a food important when cooking in a microwave?
5 Research three other uses for other forms of electromagnetic waves.

4.10 Our eyes detect light

Our eyes are amazing organs. They automatically control how much light enters, enabling us to see in both dim and bright conditions. A lens focuses the light onto the back of the eye. The light receptors detect light and send a message to the brain, which then forms a picture.

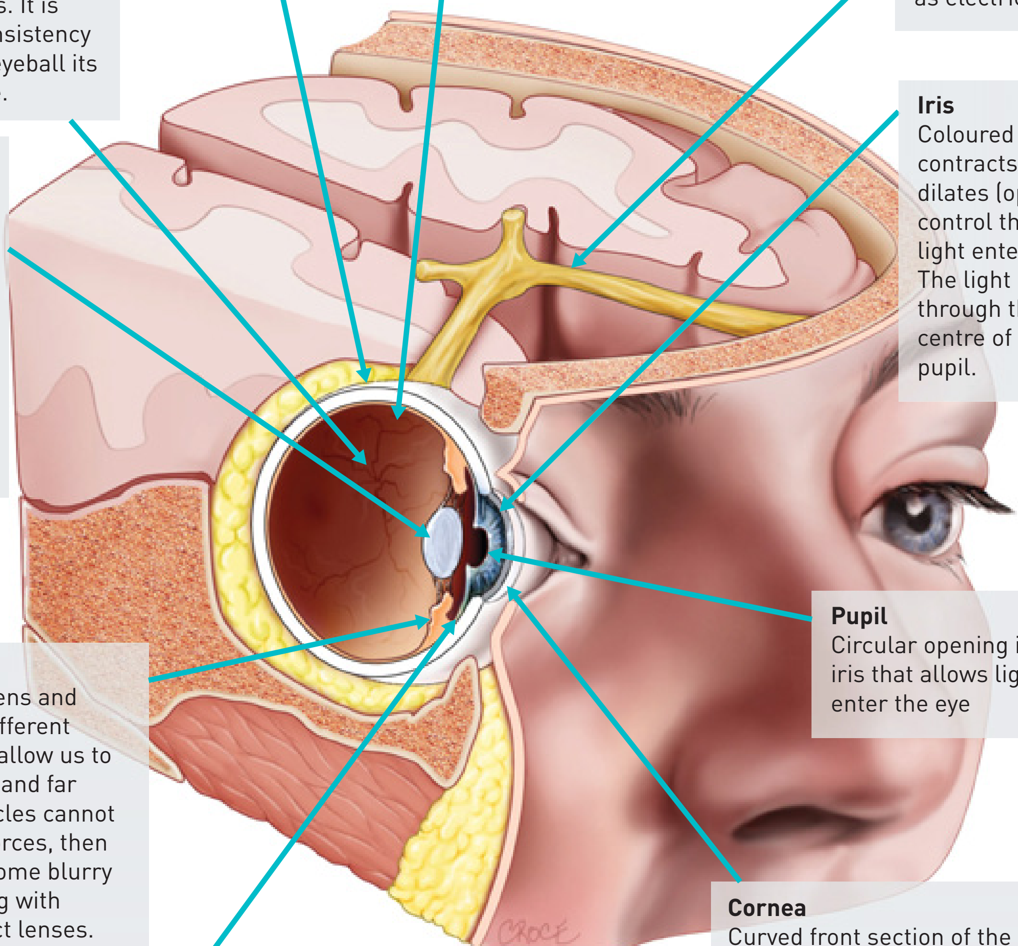


Figure 4.31 The human eye.

CHALLENGE 4.10: VISION TESTS
GO TO PAGE 203.

EXPERIMENT 4.10: EYE DISSECTION
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The amount of light entering the eye is controlled by the iris. The **iris** is the coloured part of the eye and consists of a ring of muscular tissue that expands and contracts, effectively controlling the size of the hole in its centre, the **pupil**.

This automatic response can easily be tested by shining a bright light into a person's eyes to see if their pupils automatically constrict (shrink). If they don't, the person may have a head injury or an altered state of consciousness.

As light enters the eye, it is bent, or refracted, first by the **cornea** at the front of the eye and then by the **lens**. Both of these structures are transparent and curved so they bend the light rays towards each other. Muscles attached to the lens allow it to change shape and adjust the focus of the light from near and far objects. The image produced on the back of the eye, the **retina**, is upside down (inverted) and smaller than the object (diminished).

The retina contains light-sensitive cells called rods (sensitive to dim light) and cones (sensitive to colour). These cells detect light and convert it into an electrical signal, which is carried to the brain by the **optic nerve**. The brain then interprets the signals, turning them the right way and resizing them.

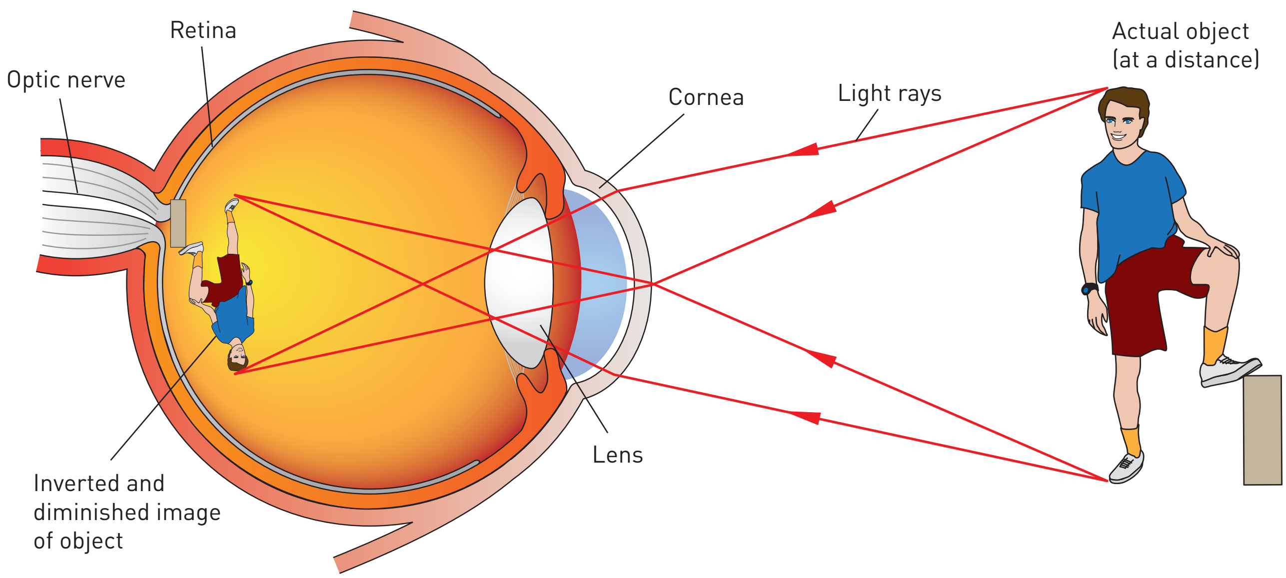


Figure 4.32 The image produced on the retina is upside down.

Check your learning 4.10

Remember and understand

1 List, in order, the parts of the eye that a ray of light passes through, starting with the cornea and ending with the retina.

2 The lens of the eye can change shape, becoming thicker or thinner in the centre. What is the effect of each of these two changes on the focal length of the lens?

Apply and analyse

3 Which shape of the lens in question 2 is needed for our eye to focus on close objects? Explain your answer.

4 What are the similarities and differences between the aqueous humour and the vitreous humour?

//SCIENCE AS A HUMAN ENDEAVOUR//

4.11 Things can go wrong with our eyes

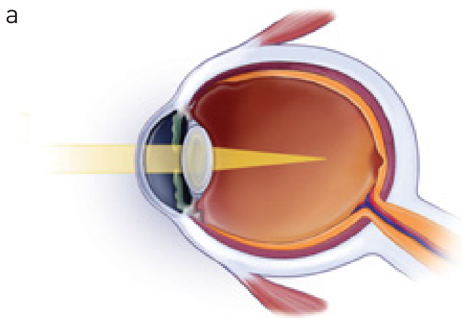
Some people find it difficult to focus their vision on close (hyperopia) or distant objects (myopia). Other people may have an eyeball shaped like an Australian Rules football (astigmatism). These problems can be fixed with the correct lens. Other conditions may require surgery.

Myopia

A person who can focus on near objects, such as a book or newspaper, but cannot focus on distant objects is described as **short-sighted**. The scientific term for this condition is **myopia**. In this case, the eyeball is too long and the lens focuses the image in front of the retina.

The light rays need to be spread apart (diverged) to refocus the image on the retina. This defect is corrected by using glasses with concave lenses.

a



b

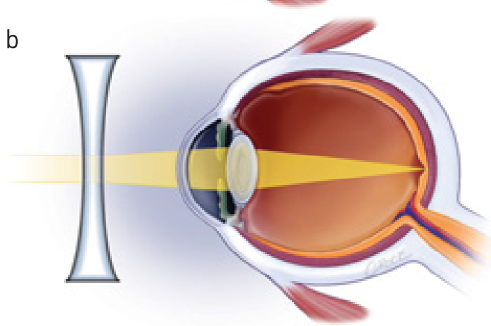
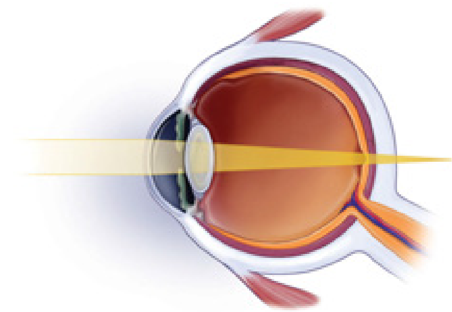


Figure 4.33 (a) In myopia, the distance vision is blurred because the light rays focus in front of the retina. (b) This is corrected by a concave lens.

a



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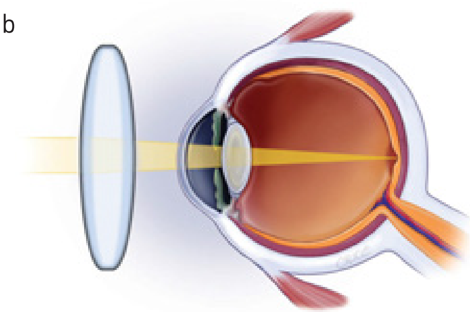


Figure 4.34 (a) In hyperopia, the close vision is blurred because the light rays focus behind the retina. (b) This is corrected by a convex lens.

Hyperopia

If a person can see distant objects but close objects are blurry, they are **long-sighted**. This is called **hyperopia**. It is caused by the eyeball being too short and the lens focusing the image behind the retina.

The light rays need to be drawn in closer together (converged) to refocus the image on the retina. This defect is corrected by using glasses with convex lenses.

Colour-blindness

Another interesting problem is **colour-blindness**. This doesn't mean a person sees in black and white. If the cone cells (that detect colour) do not function correctly, a person may not be able to tell the difference between certain colours. Red-green colour-blindness is an inherited condition and is more common in males than females.

CHALLENGE 4.11: MAKE A JELLY LENS FOR YOUR SMARTPHONE
GO TO PAGE 205.

Cataracts

As you get older, the lens in the eye can start to become cloudy to the extent that is can eventually frost over, like frosted glass. This is called a **cataract** and leads to total blindness. The cataract lens can be removed in eye surgery and replaced with a plastic multifocal lens.

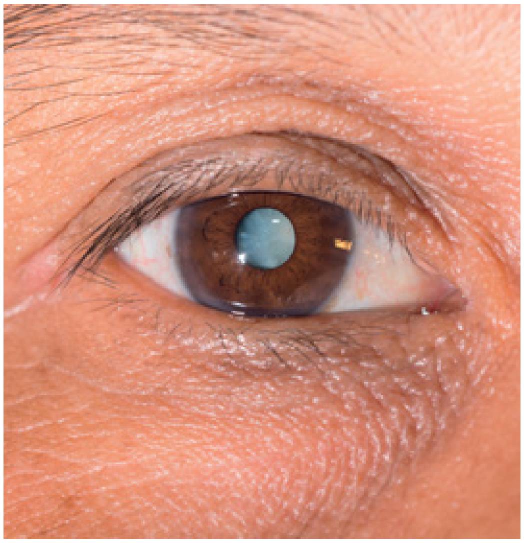


Figure 4.35 The white film of a cataract prevents light from entering the eye.

Astigmatism

Most people's corneas are curved in the shape of a soccer ball – curved evenly across and up and down. If a person suffers from astigmatism, their corneas are shaped more like an Australian Rules football. In this type of condition, the curvature is different across the cornea from the lengthways curve. This condition leads to an inability to focus correctly and, therefore, blurry vision. It can be corrected with prescription glasses.

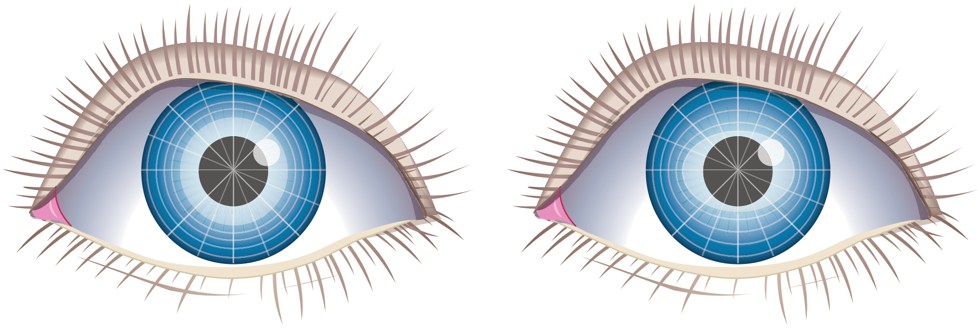


Figure 4.36 The cornea of a normal eye is round, whereas an astigmatic eye has a football-shaped cornea.

Extend your understanding 4.11

1. Use a table to compare short-sightedness and long-sightedness, listing the differences between these two problems and how they are corrected.
2. If a person has more than one vision problem, how could their vision be corrected? Explain your answer.
3. What advantages can you think of for wearing contact lenses compared to glasses? Are there any disadvantages?
4. Ask someone who wear glasses if you could examine them. Carefully try to detect which type of lenses they have. Try the glasses on. What do they do to your near and far vision? (If you already have glasses, try someone else's.)
5. Investigate what is involved in laser eye surgery and write a short report.

* REVIEW

4

Remember and understand

1 Complete this paragraph by inserting the missing words. The first letter of each missing word is given.

Sound is created by v________. The v________ create c________ and r________ due to the movement of the particles as the sound w________ passes through. The w______ travels through the substance and is known as a l________ wave. The greater the vibration, the higher the v________ of the sound, which means it sounds l________. Sound waves must have a m______ to pass through.

2 The semicircular canals are located in our ears but are not used for hearing. What do they do?

3 Print out and label the diagram of the ear shown in Figure 4.37.

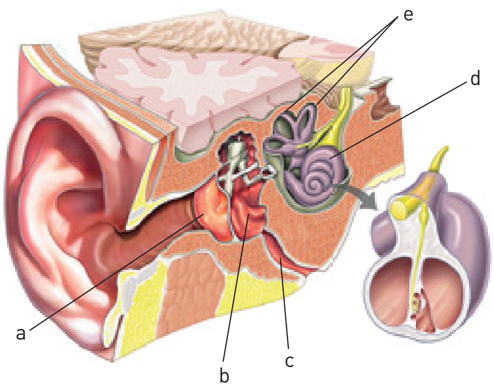


Figure 4.37

4 What does the 'frequency' of a sound describe? What is its unit?

5 Why does sound travel faster in solids than in air?

6 What is the difference between the primary colours of light and the primary colours of paint.

Apply and analyse

7 If radio communication between astronauts broke down on the Moon, would it help if they shouted at each other with their helmets touching? Why or why not?

8 Explain how pitch and frequency are related. Is there a difference between the two terms?

9 List the advantages of optic fibres over copper wires for communications.

10 Create a table on your computer, listing the parts of the human eye. In another column, explain each role.

11 Exposure to 85 dB or more of noise for 8 hours is illegal in Australian workplaces. Suggest a reason why even though this sound is not regarded as 'painful'.

13 Describe the appearance of the Australian flag when viewed in:

a blue light

b red light

c green light.

Evaluate and create

14 Bifocals are glasses that have two distinct sections. What might be the purpose of these two sections?

15 Butchers sometimes use red lights to illuminate their meat in the shop window. Why might they choose this colour?

16 Is black a colour? Explain your reasoning.

17 A grand piano can be played with the lid opened or closed. Most often, concert pianists will play with the lid open towards the audience. Why do you think they would choose to do this? What effect might this have on the sound produced by the piano?

18 The table shows the speed of sound at different temperatures.

AIR TEMPERATURE (°C)	SPEED OF SOUND (m/s)
0	330
10	336
20	342
30	348
40	354

a Using graph paper, draw a graph of the speed of sound (vertical axis) at various air temperatures (horizontal axis). Start the scale at 320 m/s on the vertical axis.

b What happens to the speed of sound as the temperature increases?

c Use your graph to determine the speed of sound at 5°C.

d Use your graph to work out the temperature of the air if the speed of sound is 351 m/s.

19 Research the differences and similarities between audible sound, ultrasound and infrasound. Display your answer using a Venn diagram.

20 Can you think of a device that works in a similar way to the retina–optic nerve–brain system? It does not have to produce visual images but should carry a signal from some sort of receiver to a processing unit. Explain how the device works and what similarities it has to the retina–optic nerve–brain system.

21 Interview someone who recently had their eyes tested, recently had laser eye surgery, wears contact lenses, is colour-blind or has a vision impairment. Prepare some appropriate questions for the person to answer. Present your findings to the class or in an appropriate and engaging format.

22 Astronauts in space can still see each other even if they cannot hear them.

a What does this say about the mechanism by which light travels compared to how sound travels?

b What can you infer about the ability of light energy to travel through outer space?

Research

23 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, but one component of your report must include a demonstration of sound (for example, if you make an instrument, it needs to be played). In a multimedia presentation, sound must be part of the presentation. If you interview someone as part of your research, you must present a tape of your interview with your report.

> **Supersonic planes**
>
> What does 'supersonic sound' mean? What is the difference between a supersonic jet and a normal jet aircraft? What are some of the problems with supersonic planes? Why was the Concorde removed from air travel service?

> **Hearing technologies**
>
> What would it be like to wear a bionic ear? What does 'sound' sound like with a bionic ear? What sound technologies are being developed right now? What other non-hearing technologies are being developed through our knowledge of sound energy?

> **Vision defects**
>
> Some people find it difficult to focus on near or distant objects. This type of defect is reasonably common. Find out what causes both types and how it can be corrected. What other vision defects are quite common and how are they treated?

> **Speed of light**
>
> What is the speed of light? Why can't objects travel faster than the speed of light? What if they could? How is it measured and how was it discovered? What applications does it have in science?

> **Night vision goggles**
>
> Night vision goggles allow soldiers to see at night and spot the enemy before they are spotted themselves. They give an army a tactical advantage, but how do they work? Will they work in a totally dark environment? Do they have any disadvantages to the soldiers operating them?

4 KEYWORDS

amplitude
the distance a particle moves from its position of rest

angle of incidence
the angle between the incident ray and the normal (the line drawn at right angles to a reflective surface)

angle of reflection
the angle between the reflected ray and the normal (the line drawn at right angles to a reflective surface)

angle of refraction
the angle between the refracted ray and the normal (the line drawn at right angles to a refractive surface)

compression
part of a sound wave where air particles are forced close together

concave
a lens or mirror in which the centre is thinner than the two ends

converge
when rays of light move towards a single point

convex
a lens or mirror in which the centre is thicker than the two ends

cornea
a transparent layer at the front of the eye

diverge
when rays of light move away from each other

focal length
the distance between the centre of the lens and the focus

focus
the point where rays of light cross

frequency
the number of waves that pass a point every second; measured in hertz

image
a likeness of an object that is produced as a result of light reflection or refraction

iris
the coloured part of the eye

lens
a curved piece of transparent material

longitudinal wave
a type of (sound) wave where the particles move in the direction of travel of the wave

medium
a substance or material through which light can move

normal
(light) an imaginary line that is drawn at right angles to the surface of a reflective or refractive material

opaque
a substance that does not allow light to pass through

optic fibre
a thin fibre of glass or plastic that carries information/data in the form of light

optic nerve
the nerve that carries information from the eyes to the brain

pupil
the dark opening in the centre of the eye that allows light to pass through

rarefaction
a part of a sound wave where air particles are forced apart

refracted ray
a ray of light that has bent as a result of light speeding up or slowing down

refraction
the bending of light as a result of light speeding up or slowing down

refractive index
a measure of the bending of light as it passes from one medium to another

retina
the layer of cells at the back of the eye

total internal reflection
when a light ray passes from a more dense material at a large angle, it can be reflected back into the dense medium

translucent
a substance that allows light through, but it diffuses so that objects cannot be seen clearly

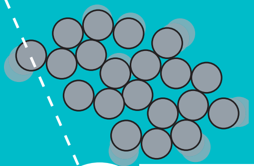
transparent
a substance that allows all light to pass through

transverse wave
a type of (light) wave where the vibrations are at right angles to the direction of the wave

wavelength
the distance between two crests or troughs of a wave

HEAT AND ELECTRICITY

5

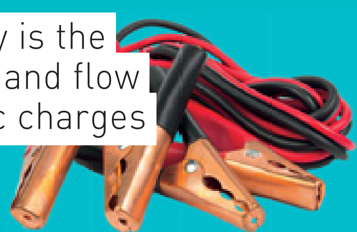


5.1 Thermal energy moves down the temperature gradient

5.2 Conduction transfers kinetic energy between particles. Convection causes the particles to move

5.3 Thermal energy can radiate through a vacuum

5.4 The ability to use energy efficiently is considered a benefit to society



5.5 Electricity is the presence and flow of electric charges

5.6 Electric current results from the movement of charges around a closed circuit

5.7 Current can flow through series and parallel circuits

5.8 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit

What if?

Knife races

What you need:

variety of knives of various sizes made from different materials, beaker, hot water, thermometer, butter, dried pea, permanent marker, ruler, timer

What to do:

1. Place a metal knife into a beaker.
2. Place a small amount of butter on the highest end of the knife.
3. Carefully place the dried pea on the butter so that it stays in position.
4. Use the permanent marker to draw a line 5 cm below the dried pea and butter. This is the finish line.
5. Add hot water to the beaker and time how long it takes for the butter to melt and the pea to slide down the knife to the finish line.

What if?

» What if cooler water was used?

» What if another knife was used?

» What if the starting and finishing points were closer to the water?

5.1 Thermal energy moves down the temperature gradient

Thermal energy is the energy of moving/vibrating particles. This is related to an object's temperature. Thermal energy can be transferred from hotter objects to cooler objects. This is called moving down the temperature gradient. This will continue to happen until both objects are the same temperature and thermal equilibrium is reached. Insulation slows the process of thermal energy transfer.

Whenever energy is changed from one form to another, some of the energy will be transformed to **thermal energy**. Energy is never lost or used up – when energy transfers from one form to another, the total amount of energy stays the same. This is one of the most important laws in science: energy is always conserved. So why is it that when we heat our homes, we seem to use up energy? Energy is quickly lost to the surroundings and seems to disappear. It is no longer available for our use and, to keep our house warm we have to keep supplying fuel. So even though the total amount of energy remains the same, the amount of useable energy has been reduced.

Thermal energy

Energy transfers usually involve a transformation to heat, which is thermal energy. Substances such as water and air are made of molecules. These molecules move around at different speeds, depending on the temperature. When air or water is hot, the molecules are moving faster than when they are cold.

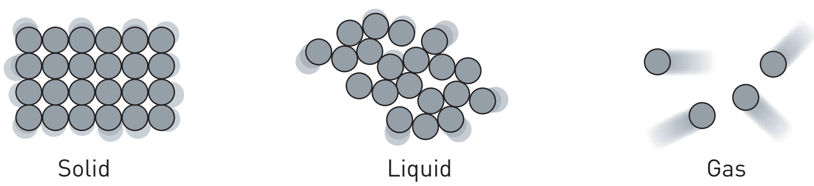


Figure 5.1 Particles move further apart and faster when they are heated. This can cause a change of state from solid to liquid to gas.

Because the molecules are moving faster, they collide with more energy and push each other further apart. When air is heated, the molecules move further apart to occupy more space or increase the pressure if the air is contained in a fixed volume. We say the air expands – the molecules don't get bigger, but the spaces between the molecules do.

Heating metals

Metals are not molecular substances. They are made of atoms lined up in rows and columns, with each atom close to its neighbours. The atoms are fixed in this arrangement, but they are able to vibrate. When a metal is hot, its atoms vibrate faster than when it is cold. When a metal is heated, it expands; this is because the vibrating atoms nudge one another further apart as they vibrate faster.

Insulation

If a substance were perfectly insulated from its surroundings, it would stay hot forever: the vibration of the atoms or the movement of the molecules would never stop. However, everything hot eventually transfers some its thermal energy to its surroundings and cools down. The only way to avoid this is to constantly transfer more thermal energy from somewhere else to replace the lost thermal energy.

EXPERIMENT 5.1: THERMAL ENERGY VERSUS TEMPERATURE
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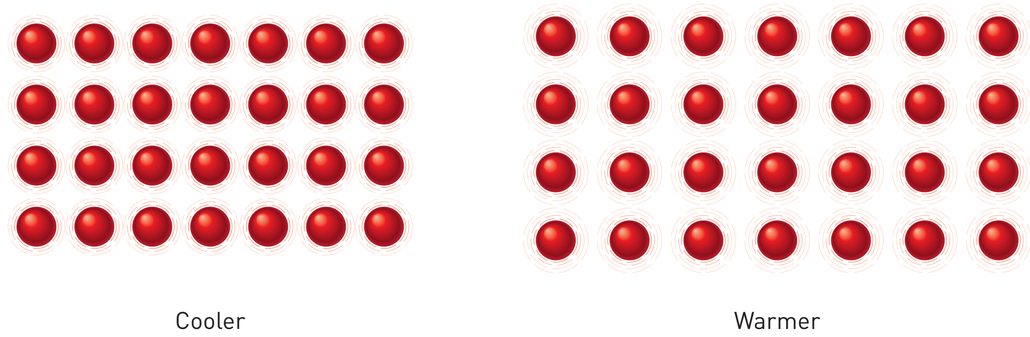

Figure 5.2 Atoms of a metal vibrate faster when they are heated.

Thermal equilibrium

If you put a hot brick into a bucket of cold water, the thermal energy will transfer from the brick, which is at a higher temperature, to the water, which is at a lower temperature (Figure 5.3). This difference in temperature between the hot brick and the cooler water is called the **temperature gradient**. The thermal energy of the brick will be transferred down the temperature gradient to the water. This means the brick will become cooler and the water will become hotter. Eventually, both objects will reach the same temperature, and the transfer of energy will stop.

When thermal energy is balanced with its surroundings, **thermal equilibrium** has been achieved.

Figure 5.3 Some of the energy of the hot brick is transferred to the cooler water.

When we use a thermometer to measure temperature, such as that of the air in a room, the thermometer is actually measuring its own temperature. When the thermometer is in thermal equilibrium with the air around it, the temperature that it measures will be the temperature of the surrounding air. To get an accurate measurement, you have to allow time for the thermometer to reach thermal equilibrium with the object being measured. You are waiting for the transfer of thermal energy from the hotter object: either the thermometer or the object it is measuring.

Check your learning 5.1

Remember and understand

1. What happens to molecules when they are heated?
2. Which has the higher temperature: a cup of water at 70°C or a bucket of water at 70°C? Which has more thermal energy?
3. Describe what happens to a hot cup of tea as it reaches thermal equilibrium.

Apply and analyse

4. Think of something you can do at home that uses two objects at different temperatures and creates thermal equilibrium.
5. Some ice at 0°C is added to a bucket of water at 20°C. The resulting combination reaches an equilibrium temperature of 19°C. Why didn't it reach 10°C?

5.2 Conduction transfers kinetic energy between particles. Convection causes the particles to move

Thermal energy moves spontaneously from a hotter substance to a cooler substance. This energy transfer is called heating, even though one substance is being cooled. Heat transfer can occur when one substance passes its kinetic energy on to another (conduction) or when the hot, highly kinetic particles themselves move (convection).

Heating by conduction

Heat transfer by **conduction** is the transfer of thermal energy from matter that is warmer to matter that is cooler. This happens spontaneously when two solid objects make direct contact with each other and reach thermal equilibrium.

Consider what happens when we heat a saucepan of water on a gas burner.

1. When the gas burns, thermal energy is released.
2. The hot molecules in the gas flame move quickly and occasionally bump into atoms of the relatively cold metal of the saucepan.
3. Energy passes to the slowly vibrating atoms in the saucepan so that they vibrate faster.
4. The quickly vibrating atoms in the saucepan bump into other nearby metal atoms, transferring energy to them. This heats the saucepan.
5. When the saucepan heats up, energy is transferred to the water inside it.

Although the energy moves through the metal of the saucepan and into the water, the atoms in the metal do not change their positions – metal atoms do not move into the water.

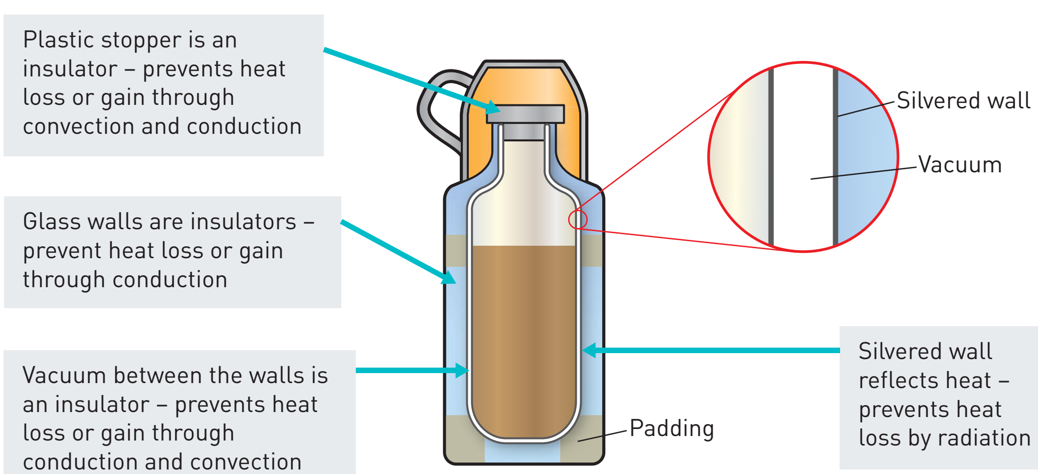

Figure 5.4 The structure of a vacuum flask. Vacuum flasks are designed to keep hot substances hot and cold substances cold. To do this they must prevent the contents from losing or gaining heat – conduction, convection and radiation must be minimised. Careful choice of materials and clever design make this possible.

EXPERIMENT 5.2: INVESTIGATING HEATING BY CONVECTION
GO TO PAGE 206.

Conductors and insulators

A thermal conductor is any material that allows thermal energy to flow easily through it. All metals are conductors, although some are better conductors than others. Thermal insulators are materials that slow down the transfer of thermal energy because the molecules don't allow the energy to flow very easily. Insulators such as socks, jumpers and blankets keep us warm in cold weather. They make it difficult for our 'body heat' to escape, insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and loss during summer and winter. So insulation can hold heat in or keep it out.

Heating by convection

In liquids and gases, thermal energy moves by **convection**. Tiny currents, called **convection currents**, carry the thermal energy. A convection current is a movement within a liquid or gas.

When we heat a saucepan of water on a gas flame the following occur.

1 Energy transfers by conduction from the hot saucepan to the water molecules that are touching the metal.
2 The water molecules in contact with the metal move faster than the molecules in the water above. Because they are moving faster, they take up more space. They are less dense.
3 As a result, the heated water molecules near the bottom of the saucepan begin to rise, leaving room for the cooler water molecules to take their place.
4 The heated water molecules take thermal energy with them as they move.

We heat liquids from below because most of the energy transfer in liquids (and gases) takes place by convection. This process happens in the air. The Sun heats the ground and the warmed ground then heats the air next to it by conduction. The warmed air, being less dense than the cooler air above, rises, taking the thermal energy with it. This distributes the energy through a much deeper layer of air than could occur just by conduction from the ground. This process of convection in the air is what drives the weather on Earth.

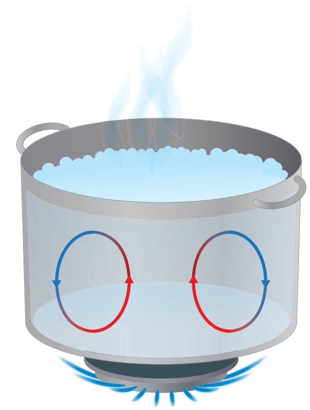

Figure 5.5 Convection currents are created in a saucepan of water when it is heated. The heated water molecules (shown in red) rise while the cooler ones (shown in blue) sink.

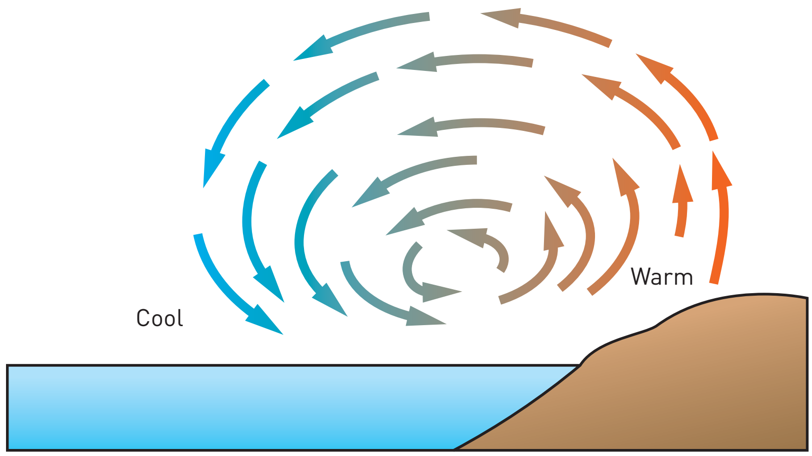

Figure 5.6 The circulation of air in a sea breeze.

Check your learning 5.2

Remember and understand

1 Think of a situation where you can see expansion due to heating of a solid, liquid or gas. Explain what the molecules or atoms are doing to cause the expansion.
2 Give two examples of situations where thermal energy is transferred by:
   a conduction
   b convection.
3 Give some examples of where good thermal insulators and conductors are needed in everyday life. Which materials are used in each situation?
4 Explain why scientists are happy to refer to thermal energy transfer as heating, even though in every case something is being cooled.

Apply and analyse

5 Modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. Why is each of these materials used for a particular part of each saucepan?

5.3 Thermal energy can radiate through a vacuum

Radiation of thermal energy involves the transfer of energy across space or through another substance without heating it. This energy is a form of electromagnetic radiation. Radiant heat is one of the biggest killers during bushfires and the best protection is distance or insulating barriers.

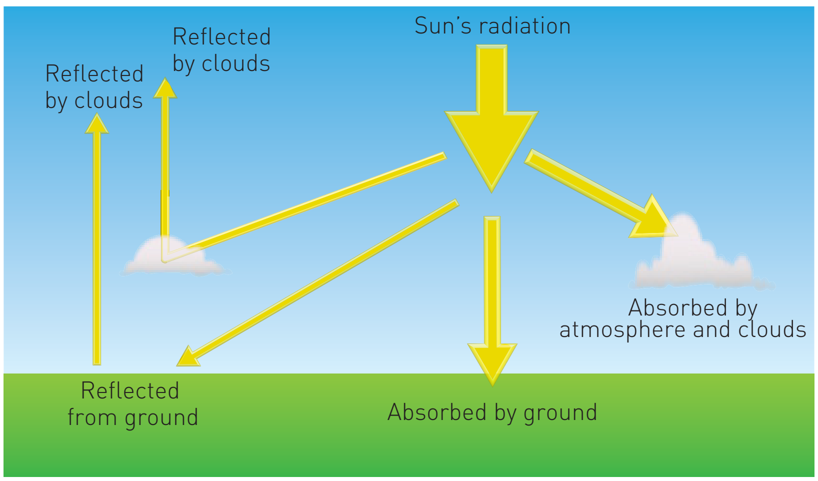

Figure 5.7 Radiation from the Sun passes on energy differently, depending on the weather conditions.

Figure 5.8 In a household radiator, energy from the movement of particles becomes infrared radiation.

When you go outside on a sunny day, you experience a particular kind of heating process. Energy transfers from the hot Sun, at a temperature of about 6000°C, to you at a temperature of 37°C. This is a different kind of heating process from conduction and convection. Conduction and convection both need the presence of a substance to transfer the energy and, in the process, the substance heats up. But the energy from the Sun travels across many millions of kilometres of space to reach the Earth. It then passes through the Earth's atmosphere, hardly heating the air in the atmosphere on the way through at all.

Radiation is the transfer of energy (via photons) across empty space or through another substance without heating it. Any object above –273°C will give off radiation. The hotter the object, the more radiation it gives off. The radiation can be in the form of visible or ultraviolet light, radio waves or microwaves, as well as infrared radiation that you sense as 'heat'.

Radiation moves through space in a way that is similar to a disturbance, or wave, moving across the surface of water. However, these waves do not disturb a substance in the way a water wave does. They are electromagnetic in origin and are often called **electromagnetic radiation** (see Chapter 4). Radiation is not necessarily absorbed when it meets a substance – it may be reflected or transmitted. For example, radiation from the Sun is transmitted through the atmosphere, absorbed by the ground and reflected from the tops of clouds.

Any object radiates energy in one or more forms, depending on the temperature. An electric radiator radiates energy in the form of mainly infrared radiations at about 500°C.

An incandescent globe radiates some visible light as well as infrared radiation at about 1200°C. The Sun radiates energy at about 6000°C, mainly in the form of ultraviolet radiation. The gases that are found between the galaxies of our universe are at a temperature of about –270°C and radiate microwaves or radio waves.

Radiation can be produced in ways other than by heating an object. For example, radio waves can be produced by a transmitter, and light can be produced in a fluorescent tube. The different forms of radiation have one thing in common – they can all be produced just by heating an object to the right temperature.

CHALLENGE 5.3: PROTECTION FROM HEAT RADIATION
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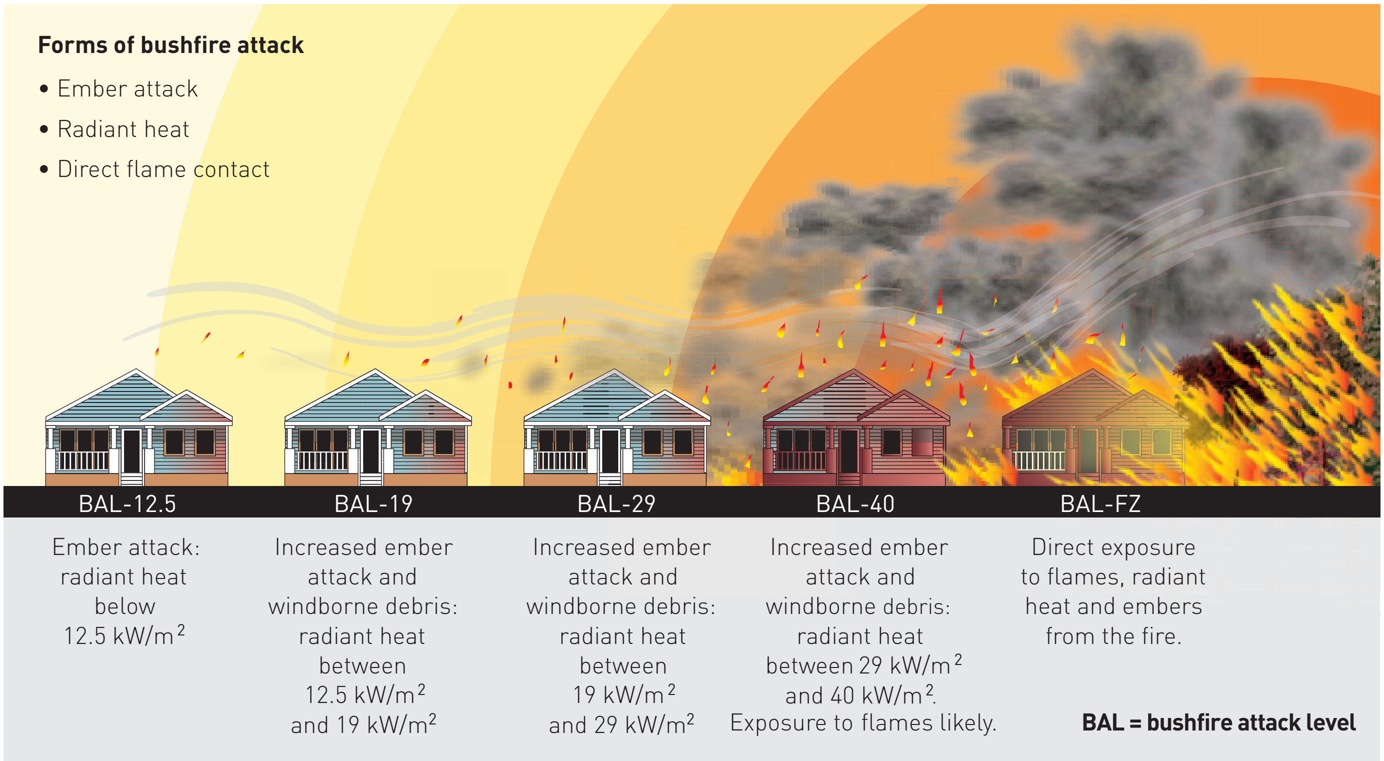

Figure 5.9 The radiant heat of a bushfire can kill living things before the flame reaches them.

Deadly radiant heat

Being outdoors during a bushfire means you can be exposed to large amounts of radiant heat even if the air around you is cold. The closer you are to the source of the fire, the more radiant heat you are exposed to and the hotter you feel. This heat travels in straight lines out from the bushfire. It can heat up objects so much that they spontaneously burst into flames before the fire has even reached the location.

Radiant heat can kill very quickly. Your body cannot absorb large amounts of radiation for very long, and the body's cooling regulation system cannot cope with the large amounts of heat that are generated.

The best protection is to put a barrier between you and the source of the radiant heat (the bushfire). Concrete walls and buildings can absorb the radiant heat with little damage, unlike windows, which will shatter, or rubber, which will melt. Cover all your skin, and wear sturdy boots, gloves and a hat. Cover your face with a mask or towel, and protect your eyes with goggles.

Figure 5.10 Firefighters wear special clothing to protect themselves from the radiant heat of fires.

Check your learning 5.3

Remember and understand

1 How is radiation different from conduction and convection?
2 List some examples of familiar devices that work using light, infrared radiation, microwaves or radio waves.
3 List some examples of familiar devices in which light, radio waves or infrared radiation are absorbed. What effect(s) does this absorption produce?
4 Describe three possible pathways for radiation from the Sun.
5 What precautions should you take if you are fighting a bushfire? Explain the reason behind these precautions.

//SCIENCE AS
A HUMAN ENDEAVOUR//

5.4 The ability to use energy efficiently is considered a benefit to society

One of our most valuable skills is our ability to make wise choices about claims or explanations made by manufacturers. The ability to use energy efficiently is considered a benefit to society. How efficiently do you use your energy? How efficient are the devices you use in your home?

Energy efficiency

Energy efficiency is a measure of how much energy is transformed into the desired energy type, compared to the amount that might be lost as heat, sound or other types. It is impossible to get more energy output from a device than the energy input but scientists strive to design the best devices possible with the highest efficiency ratings. Many appliances now come with efficiency star ratings (Figure 5.11).

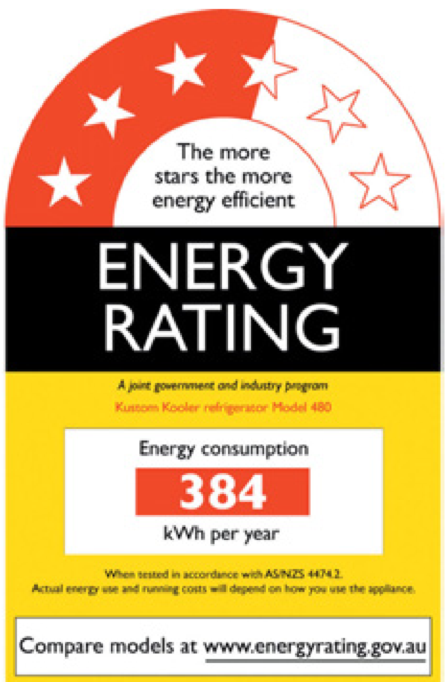

Figure 5.11 More stars mean an appliance is more energy efficient.

Kilowatt-hours

Electrical energy used in the home is measured in kilowatt-hours (kWh). The cost to a householder of each kWh varies around Australia and between different companies, but it is approximately 20 cents.

To find out how many kilowatt-hours you use in your house, you will need to examine your electricity meter.

This activity takes a minimum of 3 days to complete and should be done with the help of a parent or guardian. You could take photographs throughout the investigation to use in your final report.

CHALLENGE 5.4: WHICH IS THE MORE ENERGY EFFICIENT?
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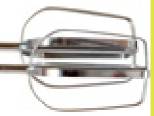


Extend your understanding 5.4

1 Record the reading on your electricity meter at a time you are able to repeat the next day (for example, 7.00 pm).

2 Record the reading on the meter at exactly the same time the next day.

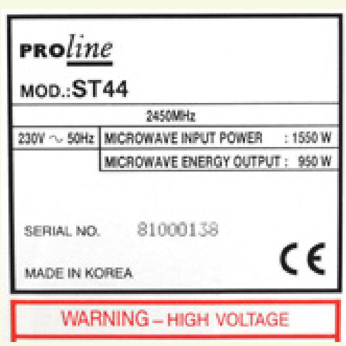
3 Calculate the number of kilowatt-hours your family used in that 24-hour period (subtract the second reading from the first).

4 Calculate the approximate cost of this electricity, assuming that each kWh costs 20 cents.

5 Write a list of the electrical appliances that were used during this time (this includes electric hot water, refrigerator, reverse-cycle air-conditioning, computers).

6 Choose four appliances in the house and read their electricity label. It might be on the back of the appliance or on the base. This should give details of the power an appliance uses.

For example, if a microwave oven has a 1000 W rating, then it uses 1 kW (1 kW = 1000 W). This means that if the microwave is used for 1 hour, it uses 1 kWh of energy.



7 Estimate how long each appliance is used for each week. Multiply the power rating of the appliance (in kW) by the estimate of the number of hours used per week (in hours).

For example, the microwave may be used for 2 hours per week total (5 minutes per use, used 24 times per week). The energy it uses would be:

Energy = power × time
= 1 kW × 2 h
= 2 kWh

8 Give the total amount of energy each of your four appliances uses each week and the amount that all four of them use together each week.

9 Estimate the cost of using these four appliances each week (remember to use 20 cents per kWh). You might like to adapt the table below.

10 How could you and your family reduce the amount of electricity used at home in time for the next bill?

11 Record the reading on the meter, then ask your household to do as many of these things as possible over the next 24 hours. Record these changes and check the meter again at the same time the next day.

12 Is there any difference in the amount of energy used by your household as a result of your changes? Show this by finding the amount of energy used for the 24 hours over which you implemented your energy-saving strategies.

13 Can you think of anything that your household could do that would reduce your electricity usage over a longer period of time?

14 Do you think the cost of electricity is reasonable considering the whole process of getting electricity to your home?

15 What have you and your family discovered during this challenge?

16 Combine all your data into a format of your choice for presentation to your class.

APPLIANCE	POWER (W)	POWER (kW)	TIME USED (h)	ENERGY (kW × h)	COST (c)	COST ($)
Microwave	1000	1	2	2	40	0.40
Fridge	67	0.067	168	11.27	225.4	2.25

Total cost per week =

5.5 Electricity is the presence and flow of electric charges

*

'Electricity' is a general term related to the presence and flow of electric charge. It is produced when negative electrons and positive protons are separated and reunite through a closed circuit. If the charges are unable to move, then it is called an electrostatic charge. A conductor allows the charges to flow easily. An insulator restricts the movement of the charges.

Electrostatic charge

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. Objects are normally uncharged – their atoms usually have equal numbers of positive protons and negative electrons. But when two objects are rubbed together, we may be able to transfer electrons 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 see examples of this when you rub a balloon against a woollen jumper, take off synthetic clothing or walk across synthetic carpet. In all of these cases, the positive or negative electric charge stays on the charged object without moving. This is called an **electrostatic charge**.

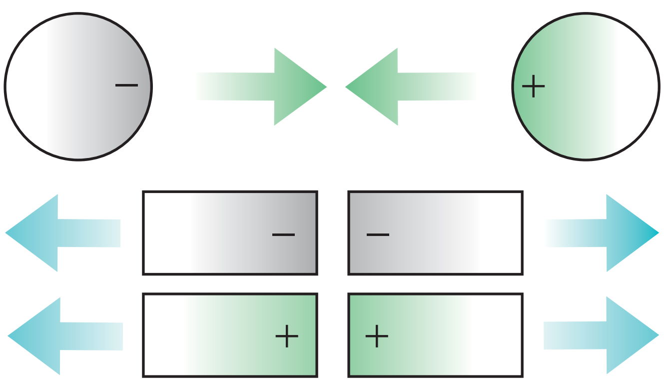


Figure 5.12 Like charges repel; unlike charges attract.

Important rules to learn about electrostatics are the following:

> Like charges repel.
> Unlike charges attract.
> Charged objects attract neutral objects.

The **van de Graaff generator** is a machine that produces an electrostatic charge by rubbing a belt (Figure 5.13). A van de Graaff generator 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 change 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** (for example, a torch battery) or a **wet cell** (for example, a car battery) uses a chemical reaction to continually separate charges and produce current electricity through wires.

CHALLENGE 5.5A: DEMONSTRATING ELECTROSTATICS
GO TO PAGE 208.

CHALLENGE 5.5B: SEPARATING CHARGES WITH A VAN DE GRAAFF GENERATOR
GO TO PAGE 209.

Figure 5.13 A van de Graaff generator produces an electrostatic charge by rubbing a belt together.

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 uses 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 5.14.

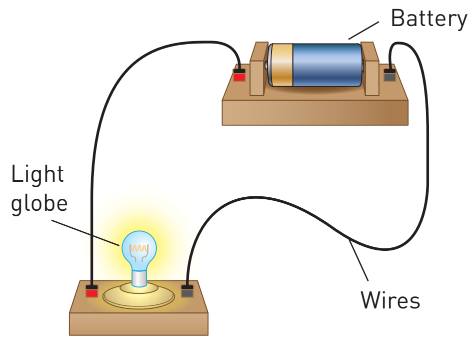


Figure 5.14 Electric charges move from the battery through the wires to the light globe.

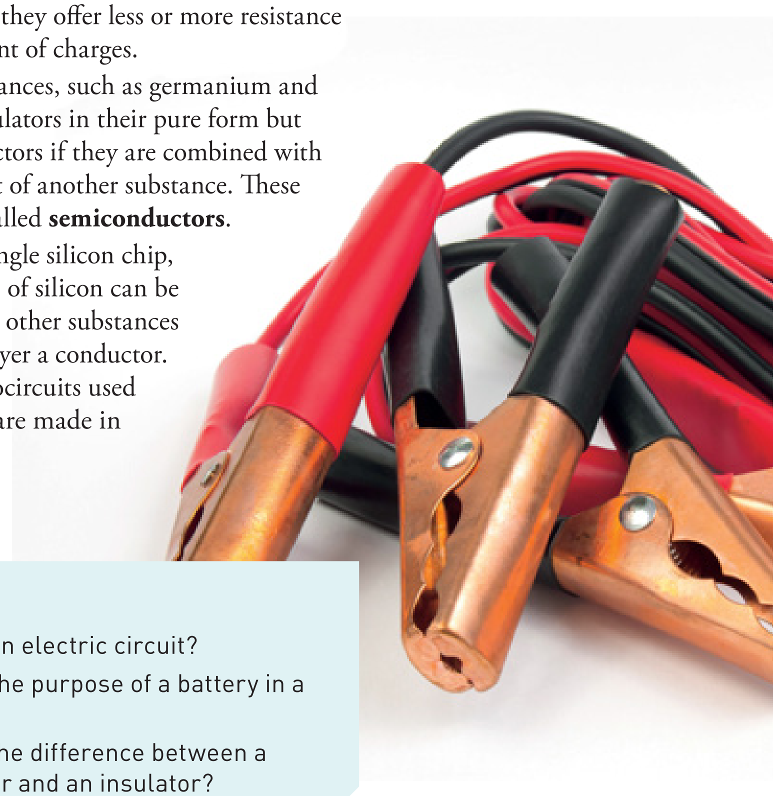
Electrical conductors and insulators

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 a copper metal with a plastic coating around the outside. Copper metal is an electrical conductor – electrons are able to move through it easily. However, plastic is an electrical insulator. The wires are coated in plastic to prevent the charge being 'lost' to the surroundings as it passes through the wires.

Some substances are better insulators or better conductors than others. This depends on how easily they allow electrons to move through them – that is, they offer less or more resistance to the movement of charges.

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.



Check your learning 5.5

Remember and understand

1. How can objects become electrostatically charged?
2. How can electrical energy be produced?
3. What is an electric circuit?
4. Explain the purpose of a battery in a circuit.
5. What is the difference between a conductor and an insulator?

5.6 Electric current results from the movement of charges around a closed circuit

*

An electric circuit contains an energy source (a battery), a pathway (usually wires) and a load, which transforms the electrical energy into other forms of energy. Current (measured in amperes) is a measure of the number of negative electrons that pass a point each second. The pathway of the charges can be represented by a circuit diagram.

Figure 5.15 A switch creates a 'gap' in the electric circuit to stop the flow of electricity.

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 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 around 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 flow of positive charges is referred to as a conventional current (Figure 5.16).

Circuit diagrams

Circuits are represented by **circuit diagrams**. Each component of a circuit is represented by a symbol (Figure 5.17). The circuit illustrated in Figure 5.18a 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 5.18b. Connecting wires are usually shown as straight lines, and when they meet at junctions they are often (but not always) joined at right angles. The longer line on the battery represents the positive terminal and the shorter line represents the negative 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 no breaks in the circuit.

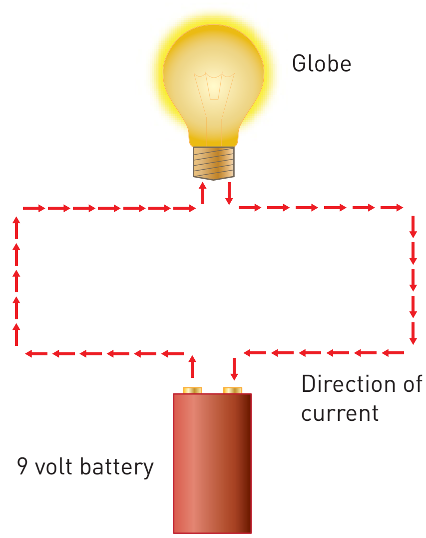


Figure 5.16 Conventional current in an electric circuit.

CHALLENGE 5.6A: MAKING A SIMPLE TORCH CIRCUIT
GO TO PAGE 209.

CHALLENGE 5.6B: CONNECTING CIRCUITS
GO TO PAGE 210.

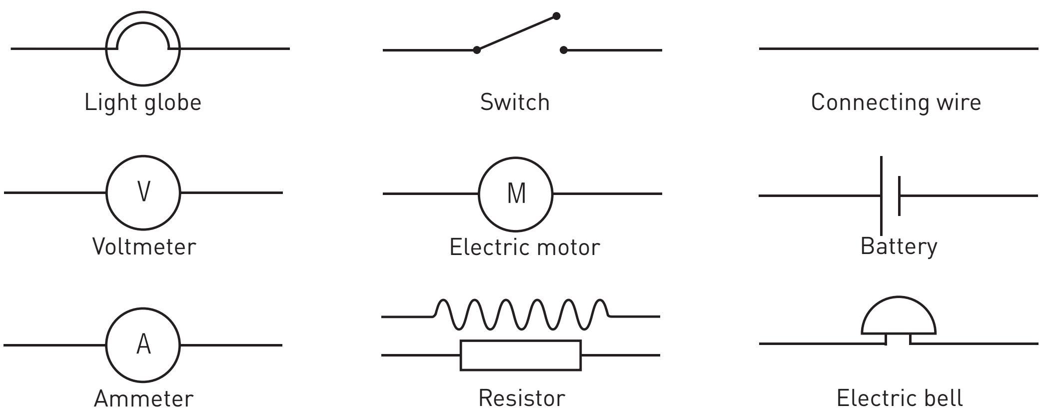


Figure 5.17 Some symbols used in circuit diagrams.

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. Measurement of the number of charged particles (current) has the unit of amperes (symbol A). The ampere is a large unit of current, so smaller units, such as the milliampere (1000 mA = 1 A), are often used. An ammeter measures 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.

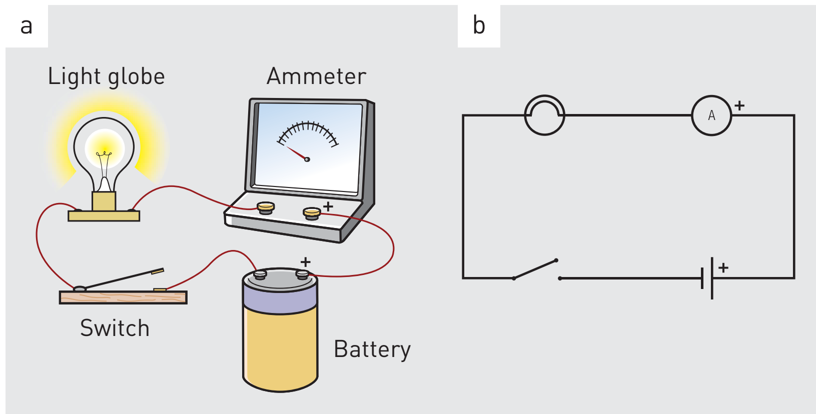


Figure 5.18 (a) A simple circuit. (b) A circuit diagram of the simple circuit.

Figure 5.19 An ammeter is used to measure electric current.

Check your learning 5.6

Remember and understand

1 List the main parts of a torch circuit. Explain the role of each part.

2 What travels through an electric circuit?

3 How can we stop electricity flowing?

4 What direction does the current flow in a circuit?

Apply and analyse

5 Which of the globes in Figure 5.20 will light up?

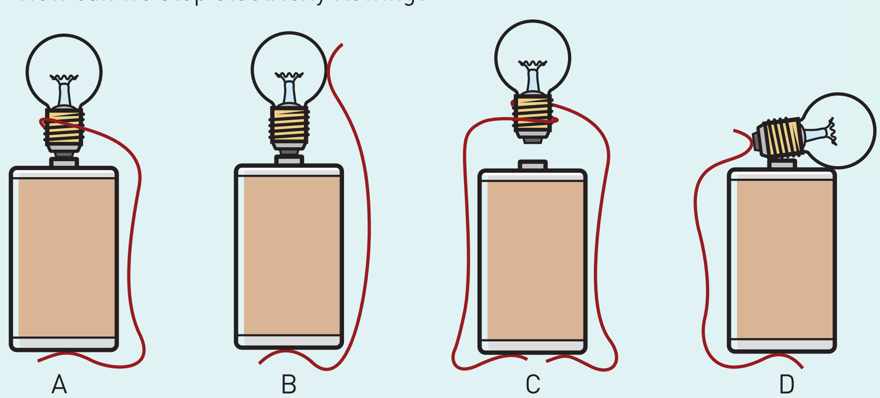


Figure 5.20

5.7 Current can flow through series and parallel circuits

*

In a series circuit, the loads (for example, lights) 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.

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 side by side so that the current goes through one globe and then the second (Figure 5.21a). In a parallel circuit, the circuit has two or more branches and the current splits between the branches (Figure 5.21b) and comes back together afterwards.

Comparing series and parallel circuits

If two globes are connected in a circuit in **series**, then all the current (the electrons) passes through both globes. This means that the current is always the same at all points in a series circuit.

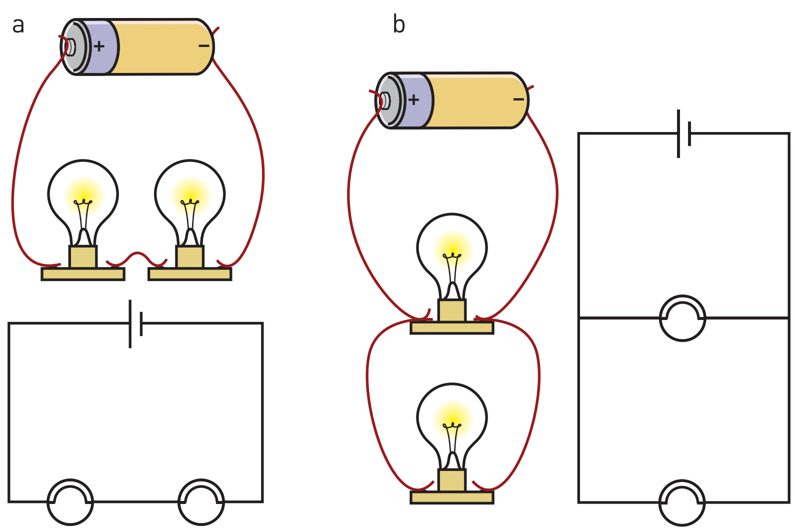


Figure 5.21 (a) In a series circuit, the current is the same anywhere in the circuit. (b) In a parallel circuit, the sum of the current going through globe A and globe B is equal to the total current from the battery.

Figure 5.22 Traditionally, Christmas lights were a series circuit. This meant that when one light broke, all the lights went out. Most modern Christmas lights are arranged in a parallel circuit.

However, if two globes are connected in **parallel**, the current must split. This means when the electrons reach where the wire splits, the current will travel down one path or the other. Part of the current passes through each globe, and then joins together again after passing through the globes. This means the current 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 (for example, from a switch) affects all the globes in the circuit. In a parallel circuit, a break in one of the wire branches of the circuit affects only the current 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, others will still work.

CHALLENGE 5.7A: MAKING SERIES AND PARALLEL CIRCUITS
GO TO PAGE 210.

CHALLENGE 5.7B: SHORT-CIRCUITING AN ELECTRIC CURRENT
GO TO PAGE 211.

Batteries in series and parallel

Batteries may be connected in series or parallel in a similar way to globes. When batteries are connected in series, an electron picks up a certain amount of energy as it passes through the first battery and then an additional amount as it pass through the second battery. This arrangement allows electrons to be given larger amounts of energy. For instance, a simple torch normally includes 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.

Short circuit

A **short circuit** occurs when a current (moving electrons) flows along a different path from the one intended. Electric charges will take the path of least resistance, which means that large currents can flow in a short circuit, causing batteries to go flat quickly. Short circuits are dangerous because they can also lead to wires heating up, causing damage or even fire.

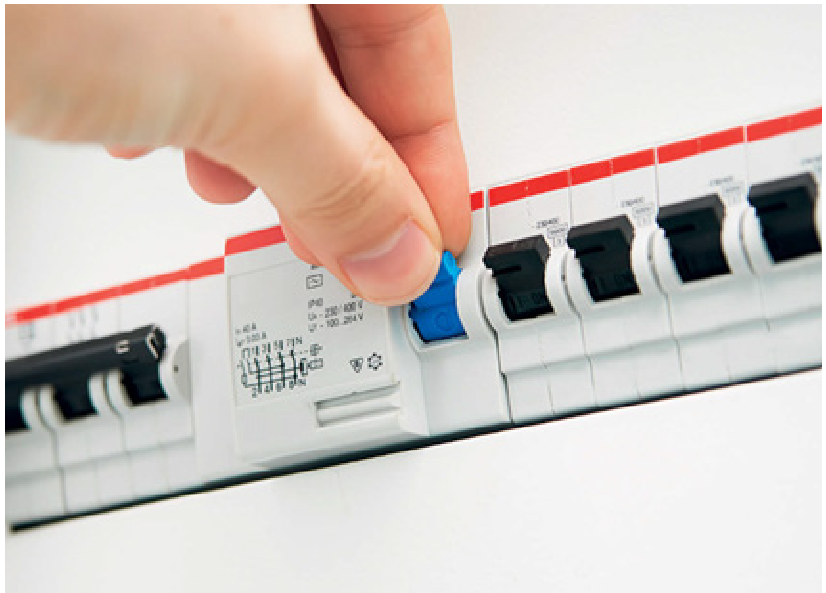


Figure 5.23 A sudden increase in current will cause fuses to break the circuit. This stops the current from flowing and may prevent electrocution.

Fuse

A fuse is a switch or thin bit of wire that burns up quickly when current starts flowing too fast in a circuit. This causes a break in the circuit so that the electrical energy stops flowing. This is to prevent damage to appliances from the high current, or loss of life.

Check your learning 5.7

Remember and understand

1 Are household appliances connected in series or in parallel? How do you know? Why is this the standard connection?

2 Look at the Christmas tree lights in Figure 5.22.
   a How could you easily find out if the globes are connected in series or parallel?
   b Draw a circuit diagram showing the connection of some of the globes.

3 What is the advantage of having a safety switch or fuse in the electric circuits of your house?

Apply and analyse

4 Double adaptors and power boards enable you to connect additional appliances onto a power point.
   a Are these series or parallel connections?
   b If you try to operate several appliances at one time from the same power point using power boards or double adaptors, you are likely to blow a fuse. Why?

SKILLS LAB 5.8A: USING OHM'S LAW TO FIND RESISTANCE
GO TO PAGE 211.

5.8 Voltage is the difference in energy between two parts of a circuit. Resistance makes it difficult for current to flow in a circuit

*

The difference in the electrical potential energy carried by charged particles at different points in a circuit is called the voltage. It can be measured using a voltmeter in parallel to the circuit. Resistance is a measure of how difficult it is for current to flow through part of the circuit. This higher the resistance, the lower the current.

Voltage

Each charged particle contains energy as it moves in an electric circuit. This potential energy can be transformed into sound as it moves through a speaker, or light and heat if it moves through a globe. This means the charged particle (electron) will have different amounts of energy before and after the speaker or globe. This difference in energy is called **potential difference** or **voltage**.

Voltage is measured with by a voltmeter in the unit volts (symbol V). To measure the potential difference of a current, voltmeters are set in parallel across the two points in a circuit that you want to measure (Figure 5.24).

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) gets 1.5 J of energy as it passes through the battery.

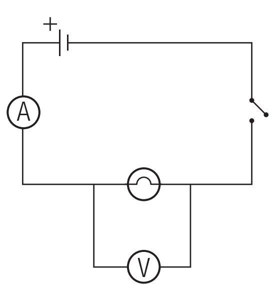


Figure 5.24 A voltmeter is used to measure voltage in a circuit.

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

Figure 5.25 Each unit of charge in this battery has 1.5 joules of energy.

measure of how difficult it is for charged particles to move through it. Electrons collide with the atoms in the wires and the various other components of a circuit and some of their electrical energy is converted into heat. Most connecting wires are thick and made

SKILLS LAB 5.8B: UNDERSTANDING RESISTOR COLOUR CODES
GO TO PAGE 212.

EXPERIMENT 5.8: INVESTIGATING OHM'S LAW
GO TO PAGE 213

from good conductors. Consequently, they have very low resistance and 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 wire glows red-hot and browns our toast.

Resistors are devices that are placed deliberately in circuits to control or reduce the size of the current. Resistance is measured in units called ohms (symbol Ω).

a
b

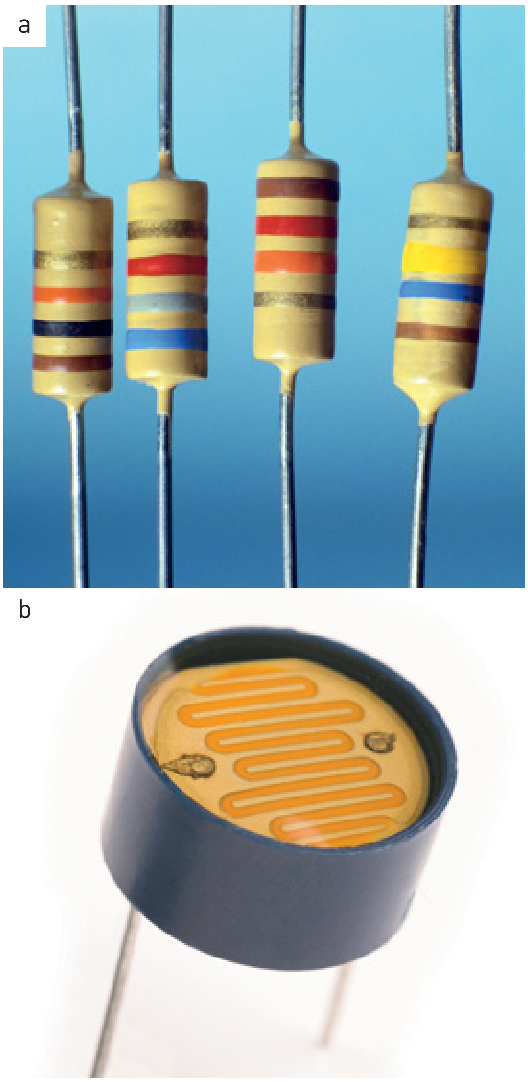


Figure 5.26 Many types of resistor are available. (a) The resistance of carbon resistors is indicated by the coloured bands on their plastic case. (b) The resistance of a light-dependent resistor (LDR) varies depending on the brightness of the light shining on it. This makes LDRs useful in sunset sensors that control automatic lighting circuits, like streetlights or security lights.

Thermistors are temperature-dependent resistors. They are useful in thermostats for controlling devices that heat or cool, such as central heating and fridges.

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.

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 will always be directly proportional to the current through the resistor. This relationship is known as Ohm's law and is written as:

$$V = IR$$

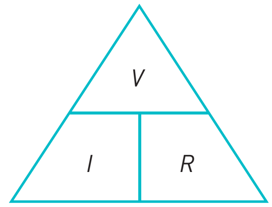


Figure 5.27 The Ohm's law triangle.

Check your learning 5.8

Remember and understand

1 What happens to the electrical energy carried by electrons as they flow around an electric circuit?
2 Which quantity measures the electrical energy carried by each unit of charge in an electric circuit?
3 Write the three equations that can be obtained from the Ohm's law triangle.

Apply and analyse

4 Calculate the current flowing through a 44 Ω resistor when it has a voltage drop of 11 V across it.
5 Calculate the voltage drop across a 25 Ω resistor when a current of 50 mA 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 9.2 on page 212 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.

Remember and understand

1 a What are the three processes by which energy can be transferred by heating? Use a labelled diagram to explain each type.

b Which of these processes is happening when you touch something hot?

2 In scientific terms, what do we mean when we say we 'use' energy?

3 A block of ice is melting (Figure 5.28).

Figure 5.28

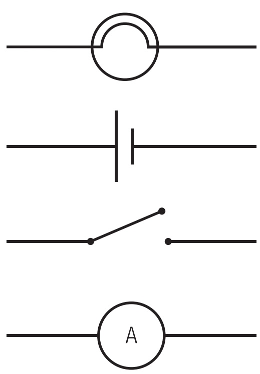
a What is happening to the molecules as the ice melts? Draw a diagram to illustrate your answer.

b Where does the energy to melt the ice come from? Explain how the energy is transferred to the molecules of ice.

4 Draw a circuit diagram for a circuit containing a battery, globe and switch. Show the direction of electron flow and the direction of conventional current.

5 Match each circuit symbol with its name.

ammeter battery globe switch



6 What is an ammeter and what does it measure?

7 If you don't connect the conducting wires to a globe correctly, the globe doesn't light up. This means that the energy from the charged particles is not being used in the globe. Where is it being used? How would you know?

Apply and analyse

8 Draw a circuit diagram showing a battery and a switch, with a globe either side of the switch.

a Does it matter where in the circuit the switch goes?

b Show the direction of electron flow and the direction of conventional current.

9 Use Table 9.2 on page 212 to find the value of a resistor with the following coloured bands (in order).

a Green, brown, black

b Brown, yellow, red

10 Use Table 9.2 on page 212 to determine what colour bands a 7.9 MΩ resistor would have.

Evaluate and create

11 Describe, in terms of particle motion, why:

a convection can only occur in liquids and gases and not solids

b when energy transfers by convection or conduction, the substance through which the energy transfers also gets heated

c good insulators are usually solids

d energy can transfer between two objects only from the warmer object to the cooler one

e neither convection nor conduction is a way of transferring energy through a vacuum.

12 In some countries, double-glazed windows are used for heat and sound insulation. They consist of two sheets of glass with a thin gap between them. How does this make them better insulators than other glass windows?

13 Molecular substances and metals both expand when they are heated.

a Explain why air expands when it is heated.

b Explain why a metal expands when it is heated.

c What is the same in both explanations for parts a and b? What is different?

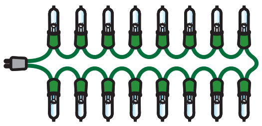


Figure 5.29

14 The lights in Figure 5.29 are connected in series. What happens if one globe fails?

15 Power lines carry electricity from power stations to cities and towns. They experience a voltage loss along the lines according to Ohm's law. How should the quantities of *I* and *R* change to minimise this voltage loss? How can this be done in real life? What changes would have to happen to the power line system to achieve this?

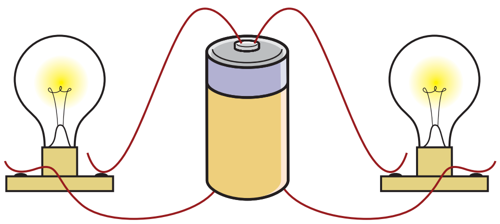


Figure 5.30

16 Is the circuit in Figure 5.30 a parallel or series circuit?

17 Calculate the current flowing through a 30 Ω resistor when it has a voltage drop of 12 V across it.

18 Calculate the voltage drop across a 50 Ω resistor when a current of 25 mA flows through it.

19 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.

20 A storm has blown a tree over on the main power line to your neighbourhood. The electricity supply is cut. Describe your day without electricity.

21 How do you think scientists come up with the star rating for electrical appliances? Design an experiment to measure the energy efficiency of a device. What is the input energy? What is the useful output energy? Include an aim, apparatus list and method. Assume there is an energy-measuring device for each energy form. How would you calculate the energy efficiency and how would you transform it into a star rating?

22 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

23 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. What does 'incandescent' mean? What are they made of? Why must the filament be contained in an inert gas like argon? What temperature does the filament need to be heated to so that it gives off light? How efficient are incandescent light globes?

> **Light-emitting diodes**
>
> What are diodes and how do they work? What are light-emitting diodes (LEDs)? Why are they used at traffic lights? What are the benefits of using LEDs? What other applications are LEDs used in? Why is this? How do LEDs last compared to compact fluorescent light globes and incandescent globes? Why are they more efficient?

> **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. What different types of energy-efficiency practices have humans used through the ages?

* KEY WORDS

5

circuit diagram
a diagrammatic way to represent an electric circuit

conduction
the transfer of thermal energy (kinetic energy of particles) through direct contact; the atoms do not change their position in the material

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 through convection

dry cell
an object such as a torch battery that uses a chemical reaction to produce electrical energy

electric charge
a positive or negative charge that can be produced by subatomic particles that results in electrical energy

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
the energy that results in the movement of electrons through a conductor towards a positive charge

electrical insulator
a material that does not allow the movement of charged particles

electromagnetic radiation
a form of energy that can be released into space by stars, including visible light, infrared radiation (radiant thermal energy), X-rays and gamma rays

electron
a negatively charged subatomic particle that moves in the space around an atomic nucleus

electrostatic charge
an electrical charge that is trapped in an object such as a balloon

insulation
a substance that prevents the movement of thermal or electrical energy

parallel
the positioning of loads (lights) in an electric circuit so that they are connected to the battery separately; they are in parallel to each other

proton
a positively charged subatomic particle in the nucleus of an atom

radiation
the transfer of thermal energy (via photons) across empty space or through another substance

resistance
a measure of how difficult it is for the charged particles in an electric circuit to move

semiconductor
a material that conducts electrical energy in one form and insulates against electrical energy in another form

series
the positioning of loads (lights) side by side in an electric circuit so that the electrical energy passes through one load at a time

short circuit
when electrical current flows along a different path from the one that was intended

temperature gradient
the difference in temperatures between two systems, such as an ice-block and warm air

thermal energy
heat; the kinetic energy of particles that increases as their temperature increases

thermal equilibrium
when two systems are at the same temperature; no heat moves from one system to another

van de Graaff generator
a machine that produces an electrostatic charge

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

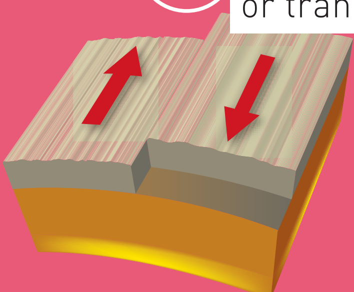
TECTONIC PLATES

6

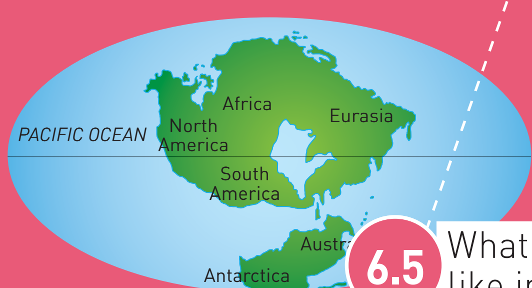
6.1 Is the Earth shrinking or moving?

6.2 The Earth has a solid core

6.3 Boundaries between the tectonic plates can be convergent, divergent or transform



6.4 Tectonic plates can be constructive or destructive



6.5 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 so that they are approximately 1 cm thick.
3. Gently slide each portion 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?

//SCIENCE AS A HUMAN ENDEAVOUR//

6.1 Is the Earth shrinking or moving?

Plate tectonics is a combination of two theories: continental drift and sea-floor spreading. Continental drift is the idea that the continents are continually moving and have significantly changed positions over millions of years. The theory of sea-floor spreading proposes that the middle of the ocean is spreading apart, moving very slowly in opposite directions.

Figure 6.1 The Himalayan Mountains have been pushed up by pressure from beneath the Earth.

There have been many theories that 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 is testable and was refined as new evidence became available.

Continental drift

Figure 6.2 Alfred Wegener pioneered the theory of continental drift in his book *The Origin of Continents and Oceans*.

One form of evidence was the similarities in shape between the coastlines of Africa and South America. They seem to fit together like a jigsaw puzzle. In the early 20th century, German meteorologist Alfred Wegener put this idea and some other evidence into a book in which he outlined the theory of **continental drift**. He proposed that the continents once all fitted together into 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 backed up 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 themselves that are moving. The large moving areas include both the continental and oceanic crust. 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** (underwater cliffs between the beach and the ocean) and deep trenches in the ocean floor. It also explains how earthquakes and volcanos are distributed, and the very young age of parts of the sea floor. **Plate tectonics** is a good example of how a scientific hypothesis can be suggested, discounted, modified and then reborn.

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. Hess's original hypothesis was that convection currents (see Chapter 5) deep inside the mantle caused spreading.

If convection does 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

CHALLENGE 6.1A: RECONSTRUCTING PANGAEA
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CHALLENGE 6.1B: MILO CONVECTION CURRENTS
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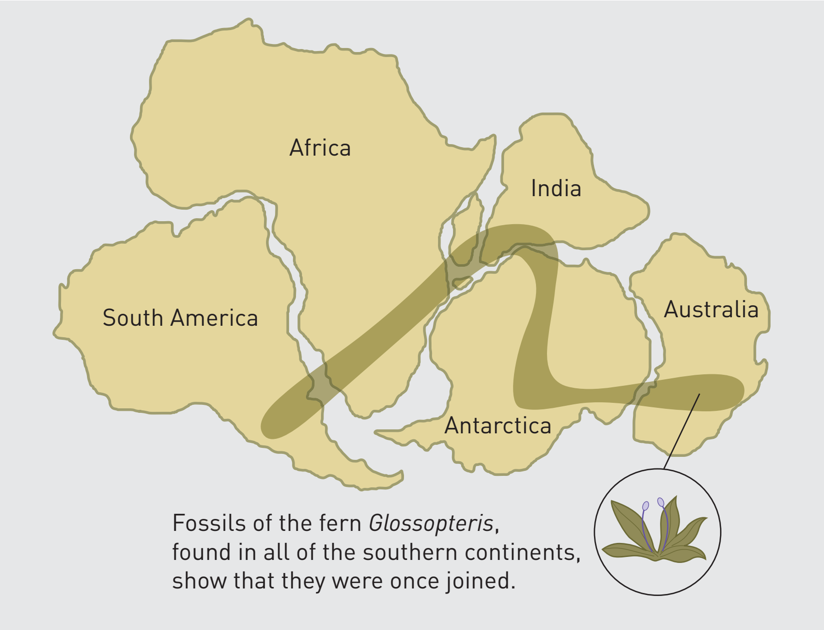

Figure 6.3 Given that the fossil fern *Glossopteris* cannot walk, swim or fly, how can its isolated occurrence in so many different parts of the world be explained?

splits and moves apart. As it is pushed away, tension between the surrounding rocks causes a rift zone and shallow earthquakes. As the mantle rock moves away from the ridge crest, it carries the sea floor with it like a piggyback ride. The rock cools, becomes denser and eventually sinks back into the mantle.

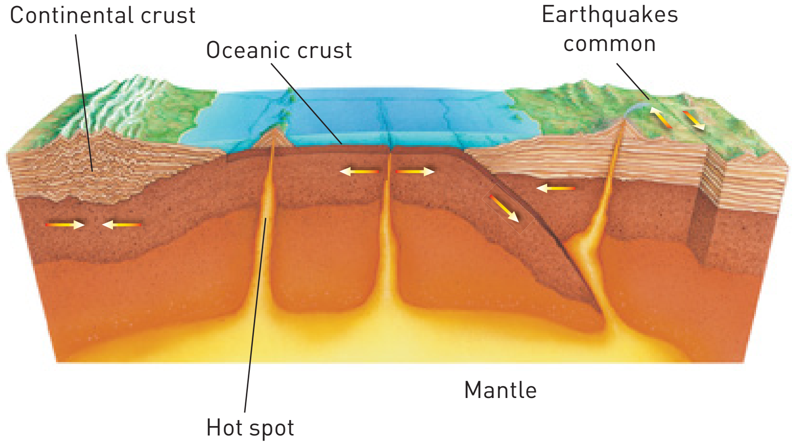

Figure 6.4 Tectonic plate movement.

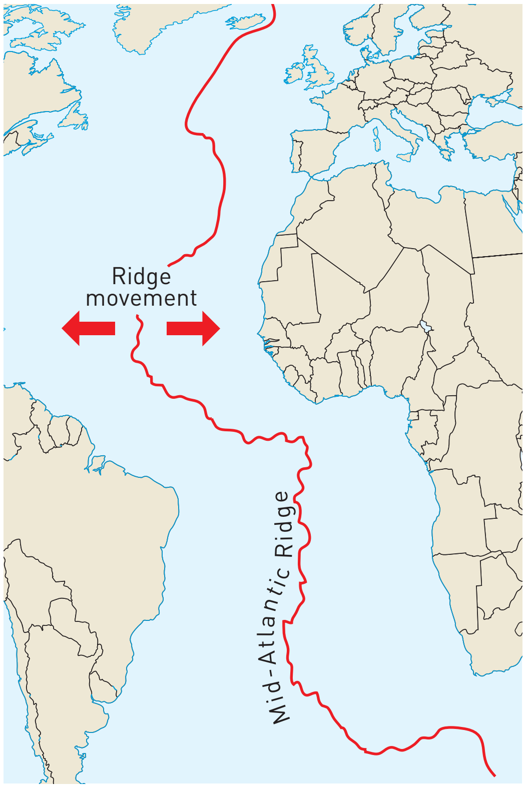

Figure 6.5 The Mid-Atlantic Ridge provided evidence of sea-floor spreading.

Extend your understanding 6.1

1. Examine a world map. Apart from Africa and South America, which other regions of the world look as if they could fit closely together?
2. In the face of the evidence that Wegener put forward in support of continental drift, why did many scientists reject the idea at the time?
3. How do convection currents work?
4. How does the rift zone form at the top of a mid-ocean ridge?
5. As plates move away from each other at the mid-ocean ridges due to sea-floor spreading, what forms in their place?

6.2 The Earth has a solid core

The Earth is made of several layers. We live on the crust (or lithosphere). Under the crust is the molten rock that makes up the mantle. Next, there is the core, which has two layers. The outer core is liquid iron and nickel, while the inner core is solid.

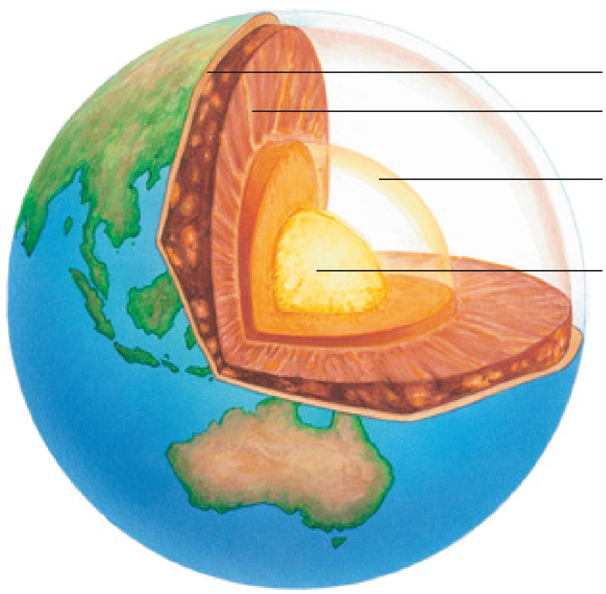

Figure 6.6 Layers of the Earth.

What is the Earth made of?

Although the Earth can be 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. As it hurtled through space, the outside layers cooled, forming a ball of solid rock and ice. 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. Some of this change is 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 make a journey deep inside the Earth, you would find that it is made of several layers.

Crust

The **crust** (or lithosphere) is the outer layer (7–50 km thick) of the Earth. It is made up of rocks and minerals and a lot of it is covered by water. The Earth's crust is the thin outer coating of the planet, like the shell on an egg. The Earth's surface is not smooth. It has hills, mountains, valleys, oceans and deserts. In fact, 70% of the crust is covered by oceans. The crust is thickest under the continents and thinnest under the oceans. Compared to the rest of the Earth's layers, the crust is very thin and brittle.

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 due to convection currents. The top part of the mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes.

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.

EXPERIMENT 6.2: COOLING AND LAYERS
GO TO PAGE 215.

CHALLENGE 6.2: MODELLING THE PARTS OF THE EARTH
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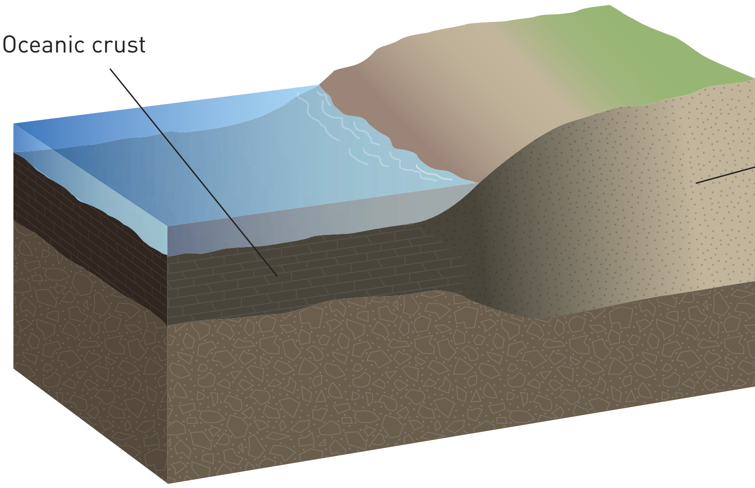

Figure 6.7 The oceanic crust is thinner beneath the ocean than it is beneath the continents.

The temperature of the inner core is almost 10 000°C. The inner core 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 our 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 fingernail growth: between 1 cm and 10 cm per year. Sometimes the tectonic plates crash into one other, causing one plate to slide under another. The plate on top buckles under pressure, pushing the land upwards. 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.

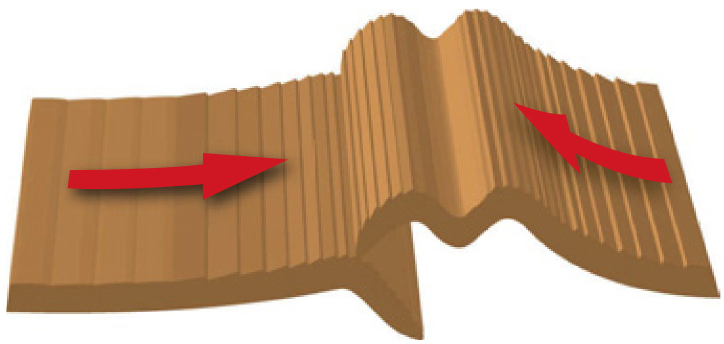

Figure 6.8 Colliding plates cause the Earth to buckle.

Check your learning 6.2

Remember and understand

1 In which layer of the Earth are the tectonic plates found?

2 If the Earth has a radius of about 6370 km, use the information about the crust and the mantle to work out the thickness of the Earth's core.

Apply and analyse

3 'The Earth's crust is the same thickness everywhere.' Discuss why you agree or disagree with this statement.

4 Could Figure 6.8 model the formation of the Andes Mountains? If so, which plate would be the South American Plate in this diagram?

6.3 Boundaries between the tectonic plates can be convergent, divergent or transform

Plate tectonics explains 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. At transforming boundaries, plates slide past one another; at converging boundaries they come together; at diverging boundaries they move apart.

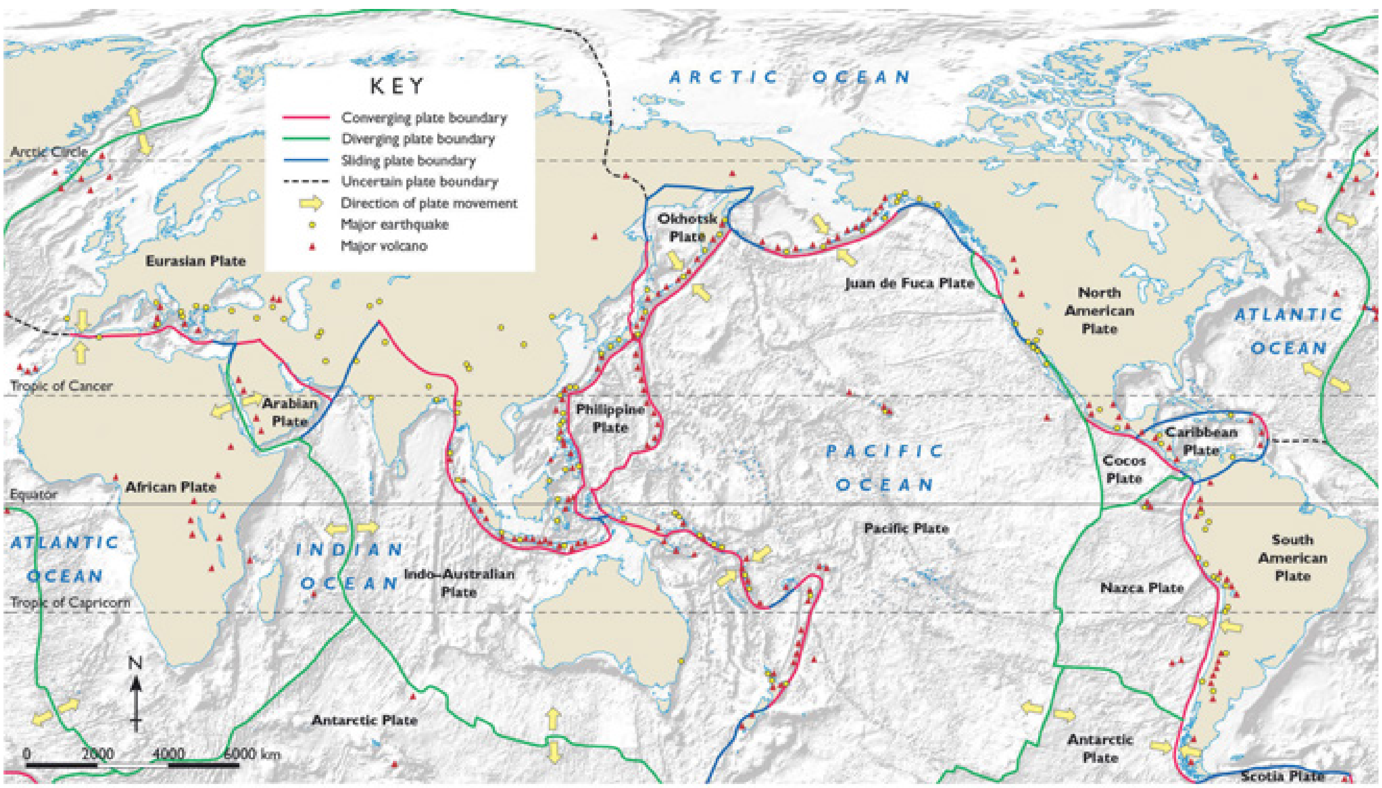

Figure 6.9 Volcanoes and earthquakes are located along the edge of the Earth's tectonic plates.

CHALLENGE 6.3: CHOCOLATE PLATES
GO TO PAGE 216.

Transform boundaries

One plate can slide past another along a single fault line (Figure 6.10). This is called a **transform boundary**. 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 metres.

Plate material is not created or destroyed; the plates just slide against each other.

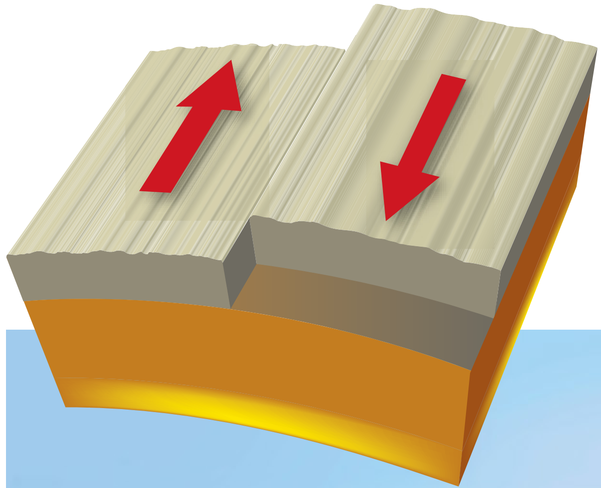

Figure 6.10 Transform boundaries: one plate slides against another.

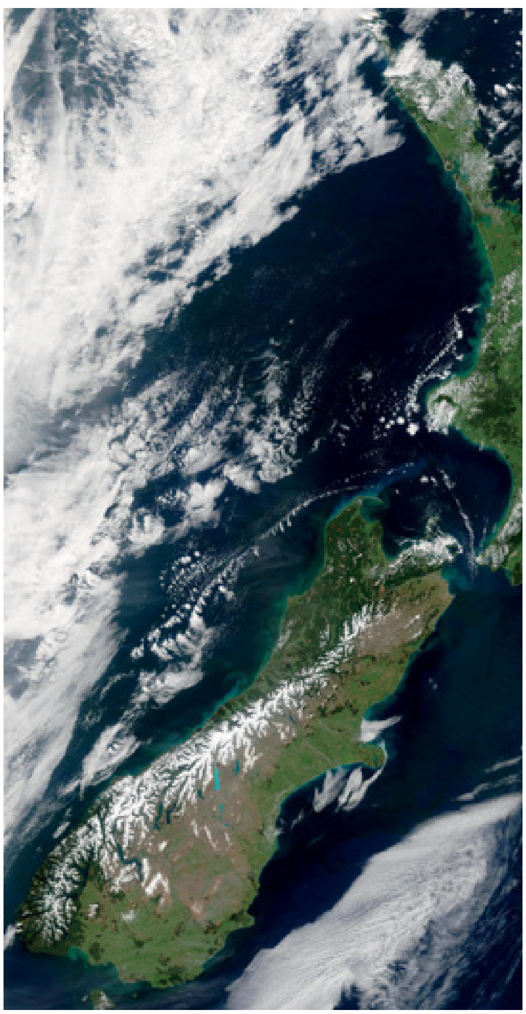

Figure 6.11 A satellite image of the Southern Alps, New Zealand. The Alpine Fault, a transform boundary, runs along the western edge of the snowline on the South Island.

Figure 6.12 The San Andreas Fault in the USA.

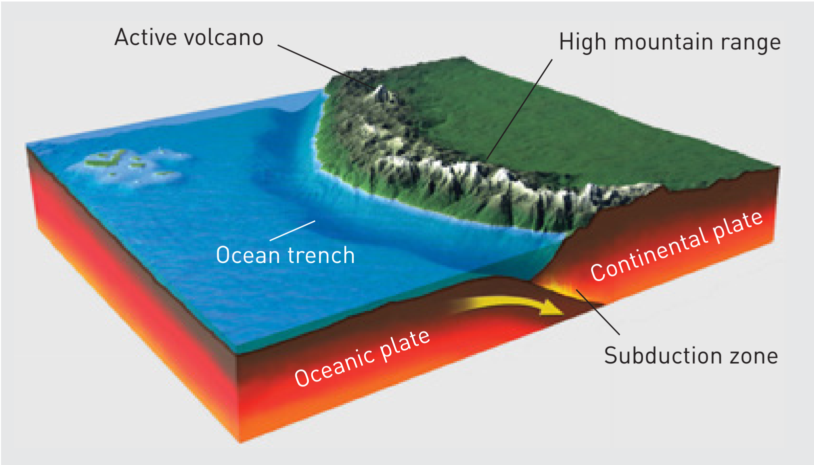

Figure 6.13 Ocean-to-continent collision causes subduction, and creates mountains, volcanoes and ocean trenches.

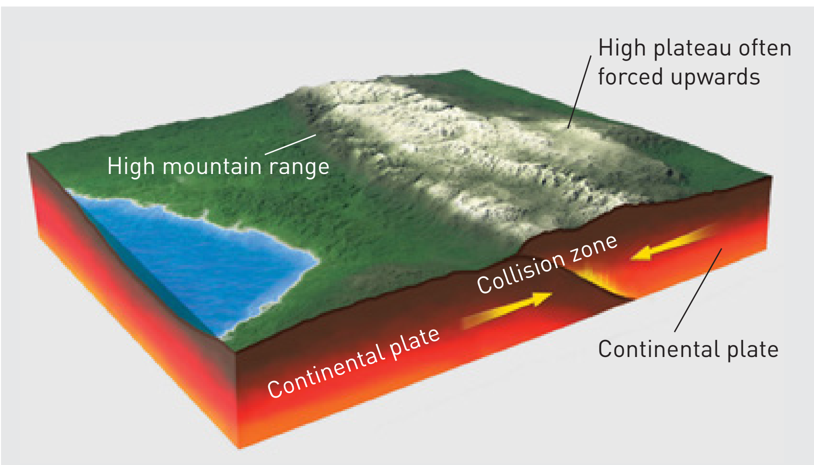

Figure 6.14 Continent-to-continent collision creates high mountain ranges.

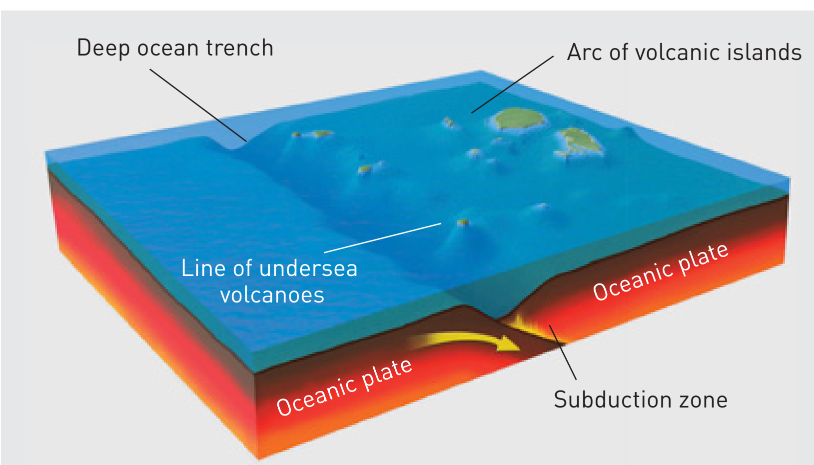

Figure 6.15 Ocean-to-ocean collision causes subduction and creates a trench and a line of undersea volcanoes.

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. 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 oceanic landform is pushed downwards into the mantle because it is denser. This is known as **subduction**. It creates a line of mountains along the crumpled edge, and also volcanoes as heat rises up through cracks in the crust. An **ocean trench** may form at the line of plate contact.

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.

Ocean-to-ocean collision

When two oceanic plates collide, the older, denser crust will subduct 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.

Diverging boundaries

Diverging boundaries or spreading plate boundaries form different features from 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 6.16 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. Eventually oceans are formed and a **mid-ocean ridge** is created.

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 6.17 The Red Sea has formed as the African and Arabian plates have diverged.

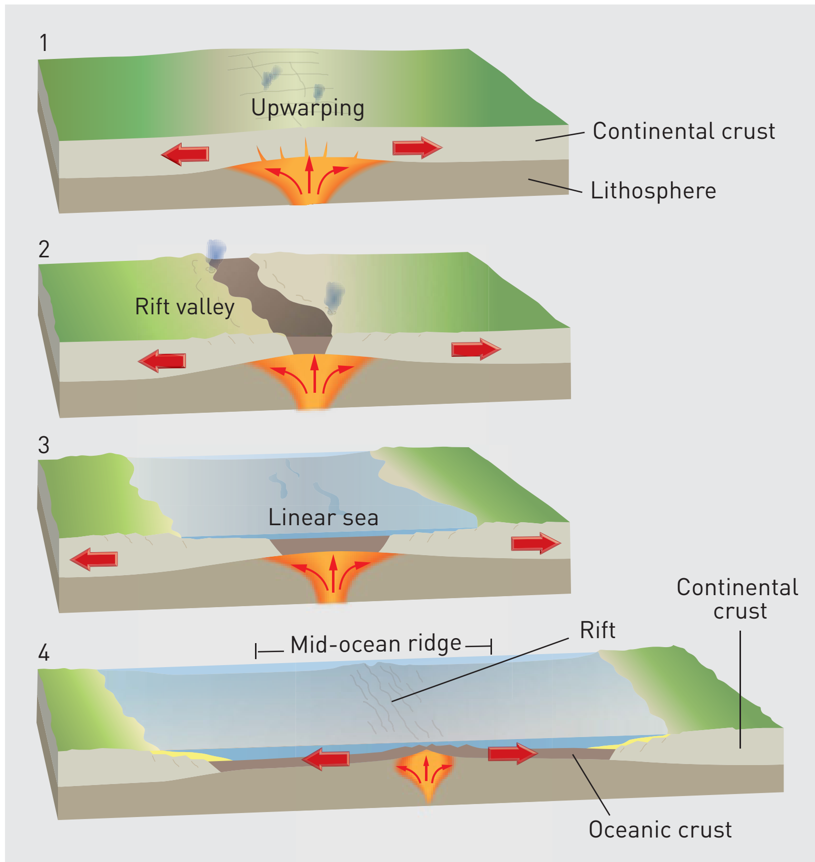

Figure 6.18 How diverging boundaries form oceans.

Check your learning 6.3

Remember and understand

1. What type of plate movement happens at a transform boundary?
2. What causes the continental crust to spread and break at a diverging boundary?
3. According to Figure 6.9 where are the major mid-ocean ridges located?
4. According to Figure 6.9 where are diverging plate boundaries located?
5. What determines which plate subducts at a converging boundary?
6. Why would divergent boundaries produce earthquakes and volcanic activity?
7. Transform boundaries are sometimes called strike–slip fault zones. Why do you think both names are appropriate?

Apply and analyse

8. According to Figure 6.9, in relation to the parts to plates, where do most volcanoes occur? Is this the same for earthquakes?

6.4 Tectonic plates can be constructive or destructive

*

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 a destructive earthquake, which in turn can form a tsunami. The crust of the Earth can also be very thin and this allows the molten mantle to escape and become lava. This lava may eventually construct new islands.

Figure 6.19 The San Francisco earthquake in 1906 destroyed much of the city.

Earthquakes causing tsunamis

Undersea earthquakes can move the sea floor and push up the water to form waves known as **tsunamis**. The earthquake in northern Japan in 2011 was a magnitude 9.0 on the Richter scale. The earthquake was centred 140 km off the coast and sent a 10-metre-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 seismic 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.

Volcanoes causing tsunamis

Volcanoes pose great dangers to those who live near them. The volcanic eruption of Krakatoa in 1883 caused a tsunami that raced 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

CHALLENGE 6.4: VOLCANIC BUBBLES
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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 6.21, page 126). 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. 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 built 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 nicely with the distribution of earthquakes and volcanoes around the world. Consider Australia's location and the frequency of earthquakes and volcanoes on our continent.

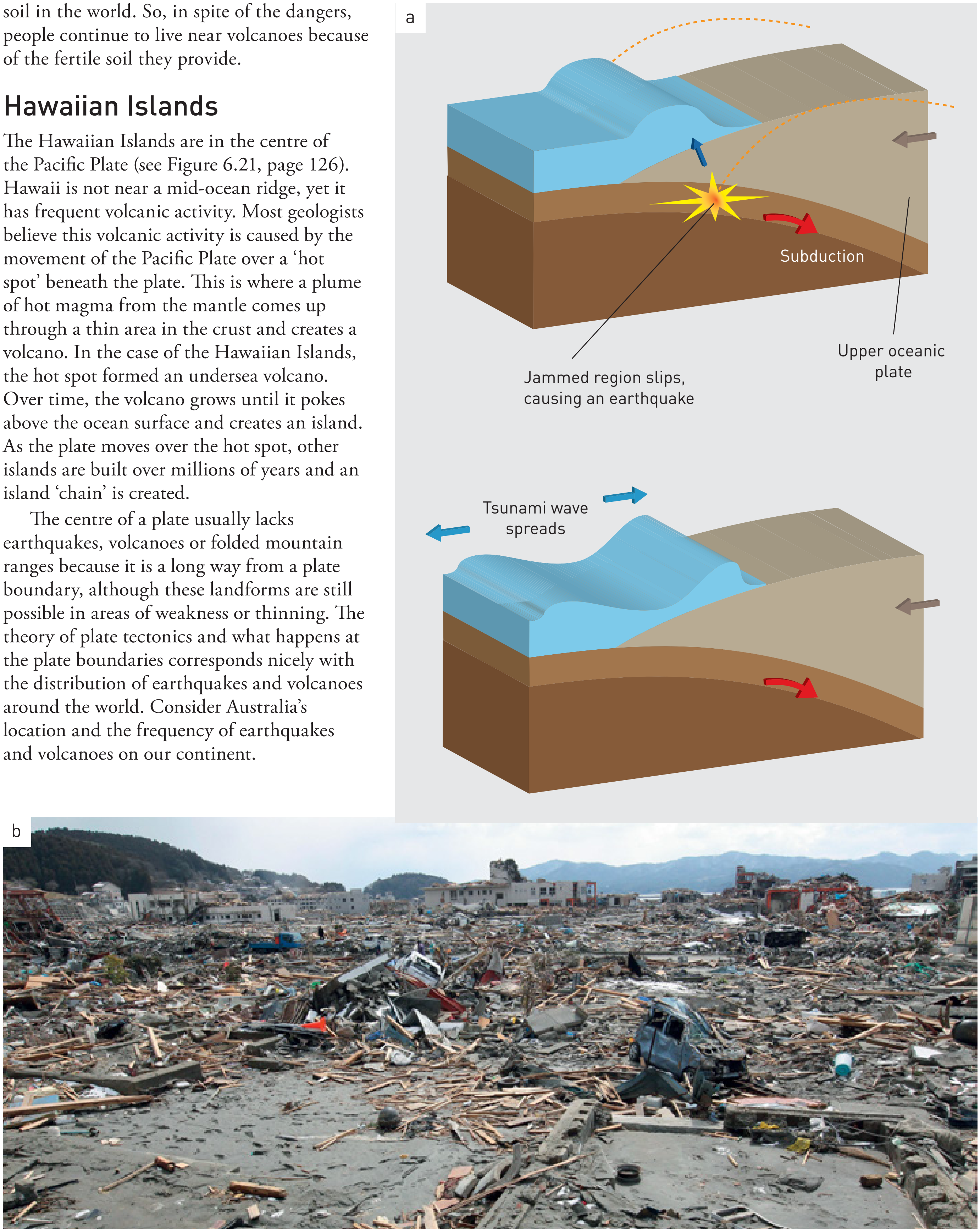


Figure 6.20 (a) How an earthquake causes a tsunami. (b) The aftermath of the earthquake and tsunami in northern Japan in 2011.

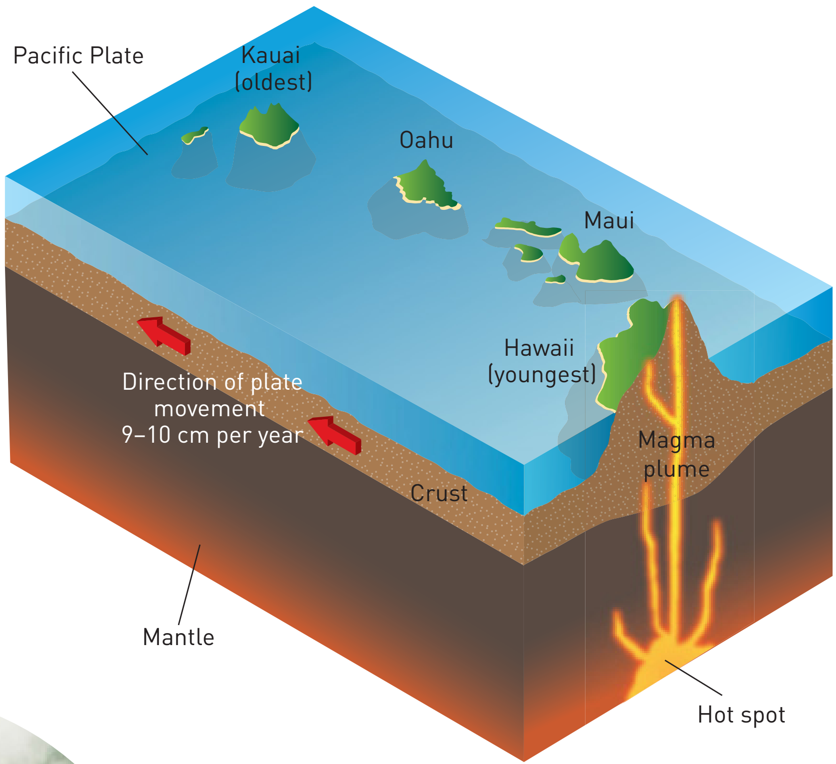


Figure 6.21 How the Hawaiian Islands were formed. (Only the largest islands are shown.) Hot spots result from magma pushing through the thin crust of the Earth.

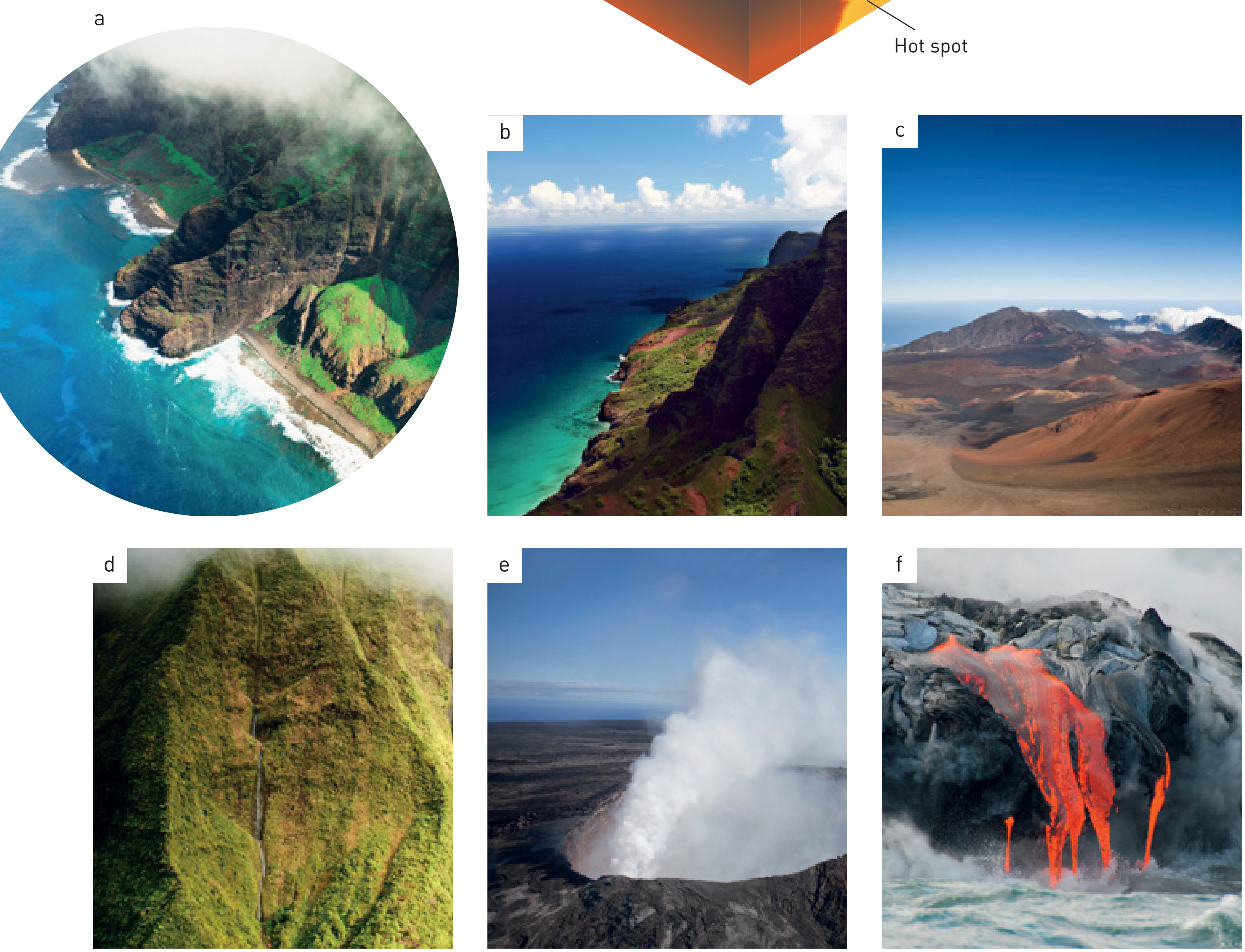


Figure 6.22 There is much evidence of volcanic activity on the Hawaiian islands such as (a) rocks that appear to flow into the sea formed from old lava flows, (b) mountains that rise out of the sea, (c & d) volcanic rock formations, (e) steam that rises from craters and (f) lava that flows from active vents.

Earthquakes in Australia

Unlike New Zealand, Australia is not located near a plate boundary and so our earthquake activity is minimal. 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 another 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 life.

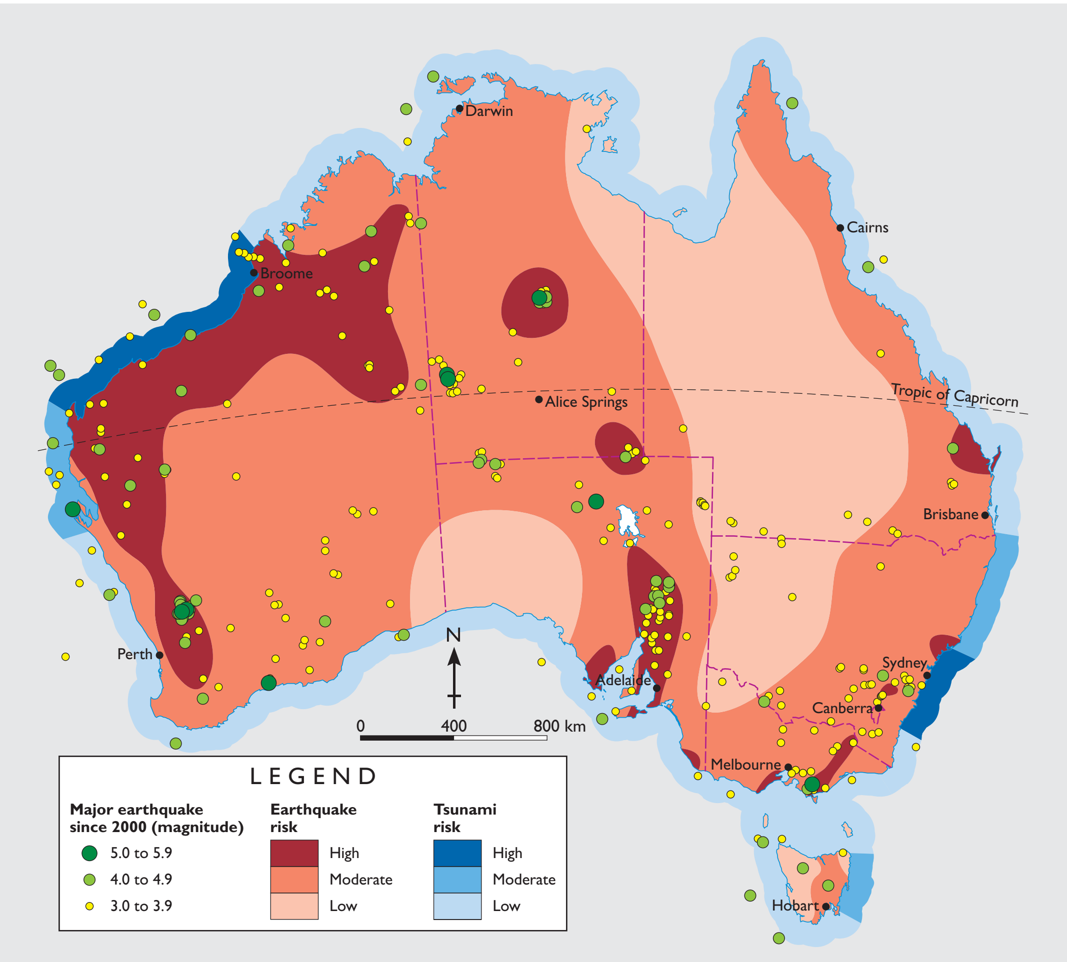


Figure 6.23 Australia: earthquake and tsunami risk.

Check your learning 6.4

Remember and understand

1. Describe two ways the movement of plate tectonics can be destructive.
2. What is a tsunami?
3. Where do most earthquakes occur? Suggest a reason why.
4. How can the movement of tectonic plates be constructive?
5. Why are there few earthquakes in Australia?

//SCIENCE AS A HUMAN ENDEAVOUR//

6.5 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 the Earth 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.

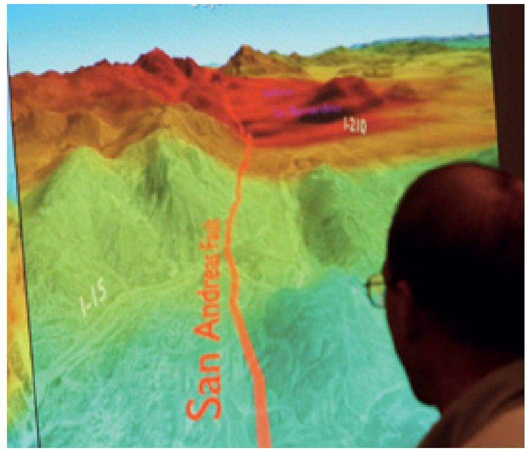
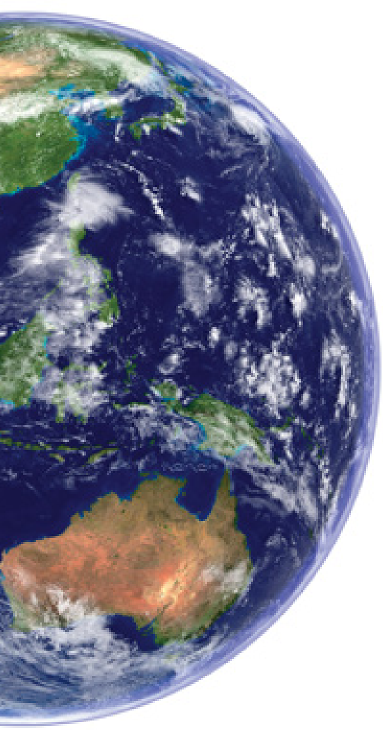


Figure 6.24 Scientists produce maps and animations that help to explain the Earth's geology to more and more people.

Figure 6.25 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, so that the plates will take up new positions. Forecasting future continental motion is a popular area of 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. 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. Researchers have produced several models that show how this plate movement might continue into the future. Since the theory of plate tectonics was proposed, geologists have worked hard to discover what it revealed about the Earth's past. The supercontinent of Pangaea was the result.

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 in the USA. 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.

US geologist Christopher Scotese and his colleagues have mapped out the predicted positions several hundred million years into 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. The massive Pacific Ocean will stretch halfway across the planet.

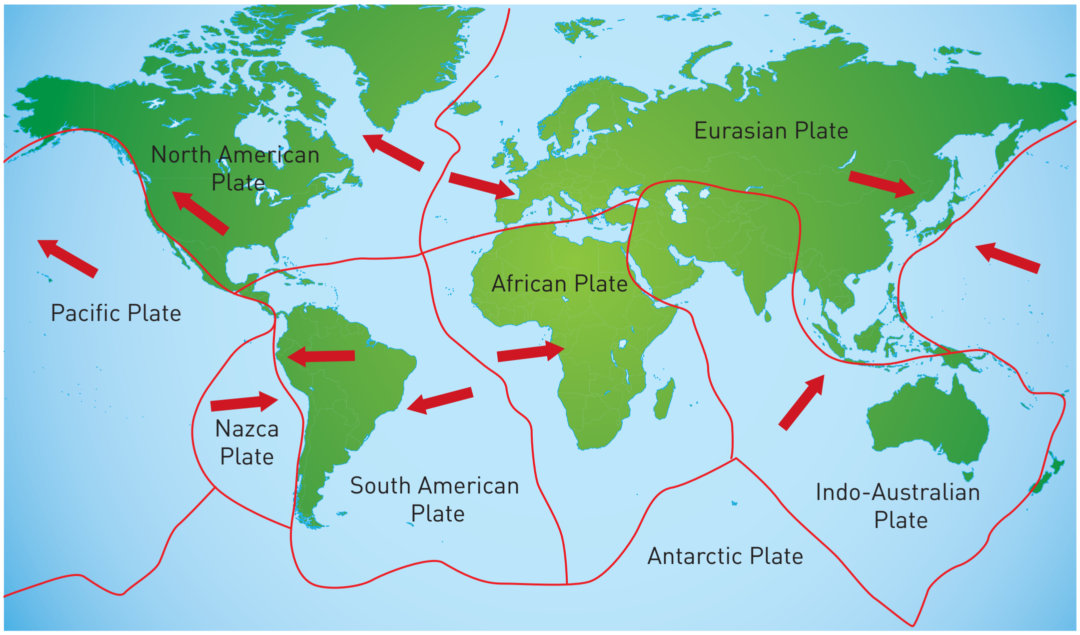


Figure 6.26 The present-day movement of the world's tectonic plates.

The formation of another supercontinent will dramatically affect the environment. The collision of plates will result in mountain building, changing climate patterns, and decreasing global 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 the art of plate forecasting easier.

While peering hundreds of millions of years into the future may seem like a stretch, geologists consider such spans of time to be the blink of an eye.

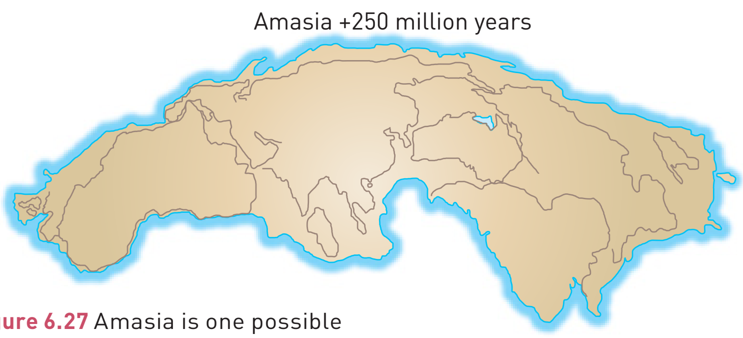


Figure 6.27 Amasia is one possible supercontinent modelled by geologists.

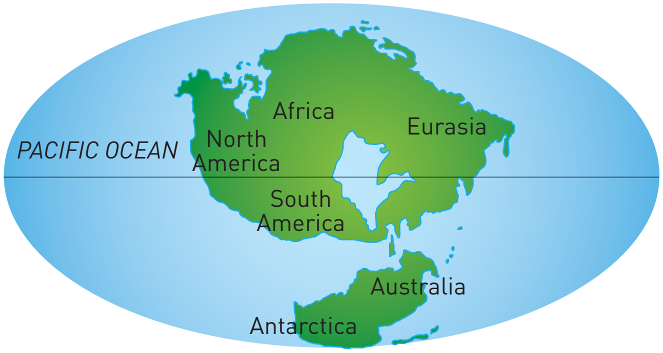


Figure 6.28 Pangaea Ultima: the world in 250 million years according to predictions by Scotese.

Extend your understanding 6.5

1. What could happen to Los Angeles and San Francisco as their plate motion continues?
2. How would future inhabitants of the Earth know that the Mediterranean Mountains were once under the sea?
3. What might be a good name for the merging of Africa and Europe?
4. If 50 million years is represented by 4 days, what would a month (30 days) represent? Using this scale, how old is the Earth?
5. Why do rift valleys cause a supercontinent to break apart?

* REVIEW

6

Remember and understand

1 Match the following terms with their definitions.

TERM	DEFINITION
Mantle	Centre part of the Earth
Crust	Layer of hot, semi-molten rock below the crust
Oceanic crust	Theory that states that the continents moved 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 in liquids or gases caused by the rising of hot material

2 Write a definition or description for:
  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.

3 What was Pangaea and what happened to it?

4 What evidence did Alfred Wegener use to support his theory of continental drift?

5 What provides the force for moving the tectonic plates over the surface of the Earth?

6 What causes major volcanic eruptions and earthquakes?

7 If Australia moves north to collide with Indonesia and Malaysia, what geographical features will form and how will our climate change?

Apply and analyse

8 Most earthquakes occur at plate boundaries. How can an earthquake occur in the middle of a plate?

9 Why can't continental crust be subducted?

10 How does sea-floor spreading account for the young age of the sea floor?

11 The Himalayas formed when India collided with the Eurasian Plate. Mt Everest, the highest mountain on the Earth, is 8848 metres high and continues to be uplifted at a rate of about 1 cm per year. How high might Mt Everest be in 1 million years if it maintains its current rate of increase?

12 Examine Figure 6.29, which shows a topographic image of the Mid-Atlantic Ridge. Explain how this provides evidence for sea-floor spreading.

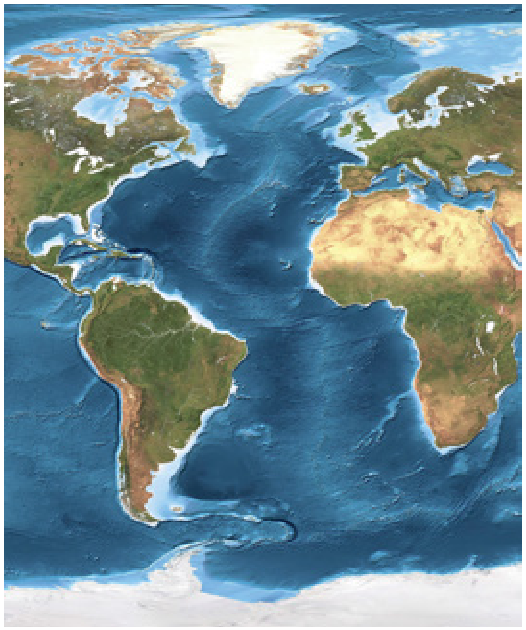


Figure 6.29

13 If a part of the Pacific Plate is moving at a rate of 10 cm per year, how far would it move in 100 years? In 10 000 years? In 1 million years?

14 Why are modern GPS systems useful for predicting future plate movements?

Evaluate and create

15 Create a poster or multimedia presentation about a famous earthquake or volcanic eruption. List 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.

16 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. Find out what lives so deep and how it survives.

17 Imagine you could travel into the future, to a time when your local environment is drastically different from how it is today. Base your imagination on the scenarios of plate movement described in the text. Write a travel brochure for a future tourist destination or journey on this new Earth.

18 Once there was one supercontinent called Pangaea. Initially it split in 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. Consider the climate changes each continent faced as it drifted to its current position and why, today, there are few links remaining between the plants and animals that originally inhabited the Gondwanaland subcontinents.

Research

19 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. What do geologists mean by subduction? Which plates are involved in subduction? What happens to the plates during subduction? What geological features are associated with subduction zones? How do new subduction zones form?

» **The Earth's crust**

The lithosphere and asthenosphere are different internal layers of the Earth. What is the lithosphere? What is the asthenosphere? How do the two 'spheres' interact? What other 'spheres' exist? How do they interact with the lithosphere and 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. What other theories exist? Choose one and find out what evidence supports the theory. Who proposed the theory? Why is it less accepted than the theory of convection currents?

» **Magnetic striping**

Magnetic striping was considered by some to be the final proof of plate tectonics. What is magnetic striping? Where does it exist? How is it linked to sea-floor spreading? What does it tell us about the age of rocks? What does it tell us about the Earth's history?

6 *KEY WORDS

continental drift
the continual movement of the continents over time

continental shelf
underwater cliffs between the beach and the ocean

converging
moving together

converging boundary
the boundary between two tectonic plates that are moving together

core
the centre of the Earth

crust
lithosphere; the outer layer of the Earth

diverging
moving apart

diverging boundary
the boundary between two tectonic plates that are moving apart

fault
a fracture in rock where the tectonic plates have moved

magma
semiliquid rock found beneath the Earth's surface

mantle
the layer of molten rock located beneath the Earth's crust

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

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

plate tectonics
the theory that the surface of the Earth is divided into a series of plates that are continually moving

rift valley
a deep valley that forms as a result of tectonic plates moving apart on land

sea-floor spreading
a theory that the middle of the ocean is spreading apart, forming new oceanic crust

subduction
the movement of one tectonic plate under another tectonic plate

tectonic plate
a large layer of solid rock that covers part of the surface of Earth movement of tectonic plates can cause earthquakes

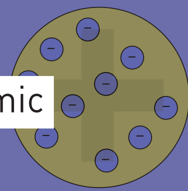
transform
to change form; tectonic plates transform when they slide past each other

transform boundary
the boundary between two tectonic plates that are sliding past each other

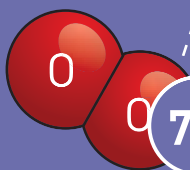
tsunami
a series of large waves that result from an underwater earthquake

MATTER 7

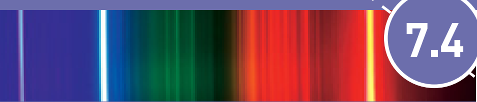
7.1 The history of the atom



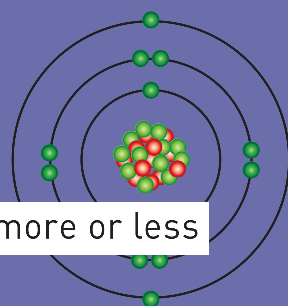
7.2 Atoms are made of subatomic particles



7.3 Atoms have mass



7.4 Electrons are arranged in shells



7.5 Ions have more or less electrons

7.6 Isotopes have more or less neutrons

7.7 Isotopes can release alpha, beta or gamma radiation

7.8 The half-life of isotopes can be used to tell the time

7.9 Radiation is used in medicine

What if?

Aluminium 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 in half.
2 Place one half of the aluminium foil in the bin. Cut the remaining piece in half.
3 Repeat step 2 until your piece of aluminium is too small to cut.
4 Examine the 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?)

//SCIENCE AS
A HUMAN ENDEAVOUR//

7.1 The history of the atom

* Although we cannot see atoms, there is much evidence to say that this basic form of matter exists. Our current understanding of the structure of an atom is described in the atomic theory that was originally proposed by John Dalton in 1810.

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 true 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.

By the 1780s, French chemist Antoine Lavoisier had made accurate measurements of the composition of chemical compounds. He found that compounds containing more than one element always had the same relative amounts of each element. For example, the compound now known as carbon dioxide used to be called 'fixed air'. This was because it was heavier than air and did not allow other substances to burn in it. It was discovered that the mass of oxygen in fixed air was always 2.66 times the mass of carbon in the compound. This meant there was always the same ratio of oxygen atoms to carbon atoms in the 'fixed air'.

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.

Figure 7.1 Antoine Lavoisier measured the composition of chemical compounds.

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, by using 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 to Dalton proposing the law of simple multiple proportions. It means that when elements combine, they combine in simple ratios, like 2:1 as in water (H_2O), 1:4 as in methane (CH_4) or 2:3 as in aluminium oxide (Al_2O_3).

CHALLENGE 7.1: WHAT IS THE RATIO OF ATOMS IN A COMPOUND?
GO TO PAGE 217.

This might seem obvious to us now, but only because of Dalton's atomic theory. This theory gave scientists a way to explain the evidence about 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 even available in Dalton's time still 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.

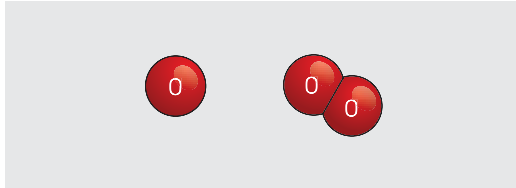


Figure 7.2 An oxygen molecule is formed by two oxygen atoms.

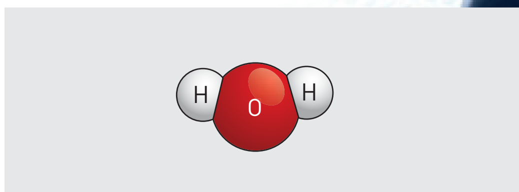


Figure 7.3 A water molecule is made up of one oxygen atom and two hydrogen atoms.

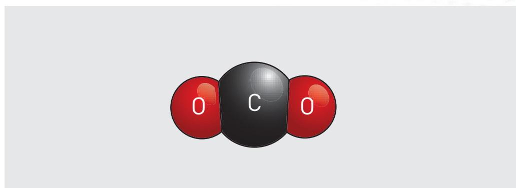


Figure 7.4 Carbon dioxide is a compound made up of one carbon atom and two oxygen atoms.

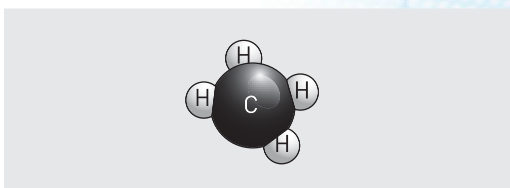


Figure 7.5 Methane is formed from one carbon atom and four hydrogen atoms.

Extend your understanding 7.1

1 What is the main difference between a philosopher such as Democritus and a scientist such as John Dalton?

2 Write the formula of:
   a carbon dioxide
   b carbon monoxide
   c methane.

3 The formula of water is H_2O. What does the '2' in the formula tell you?

4 Why is it important for us that scientists record the methods used in their experiments?

5 It wasn't until around 1906 that many other scientists finally became convinced that Dalton's ideas were correct and that atoms really existed. Why do you think they doubted his hypothesis?

6 Choose three of the forms of evidence above and explain why you think they could be used as evidence to support the existence of atoms.

7.2 Atoms are made of subatomic particles

The Rutherford model of the atoms is now widely accepted by the scientific community. It suggests that an atom has a central nucleus containing positively charged protons and neutrons with no charge. Negatively charged electrons travel around the space around the outside of the atom's nucleus. Atoms have no overall charge.

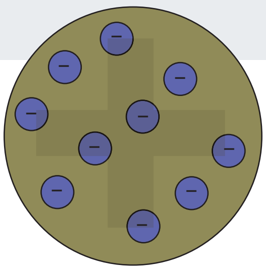


Figure 7.6 Thomson's plum pudding model of the atom.

Discovering more about atoms

A century after Dalton proposed his theory, in the early 20th century, the physicist Joseph John Thomson (known as 'JJ' by his colleagues) discovered that atoms were actually divisible and were made up of even smaller particles. His experiments showed that inside the atom are far smaller, negatively charged particles, which we now call **electrons**.

He also showed that the atom contained positively charged material, although it was not yet clear what this material was. From this evidence, 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. This was called the **Thomson plum pudding model** of the atom.

Rutherford's experiments on atoms

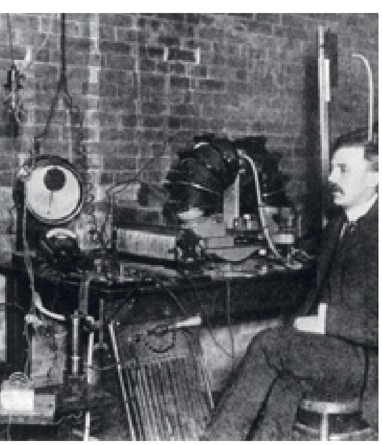


Figure 7.7 Ernest Rutherford in one of his laboratories.

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. They set up a very thin layer of gold and fired a stream of radioactive particles at it. Detectors to record the radioactive alpha particles were set up around the gold foil to identify whether the particles had gone straight through the foil, or had been deflected (made to change course) by the gold atoms in the thin sheet of gold foil.

Two aspects of the results surprised the scientists. The first evidence was that most of the alpha particles passed straight through the gold foil with hardly any deflection at all. Somehow they seemed to have passed through the gold, and therefore the atoms that made up the gold, without 'touching' anything. More amazing was the second piece of evidence. Alpha particles that were travelling with a high amount of energy bounced straight back in the direction that they had come from.

Rutherford concluded that the gold atoms must contain a lot of space, but some part of the atom must contain a relatively large amount of positive charge. This was called the 'nucleus' of the atom.

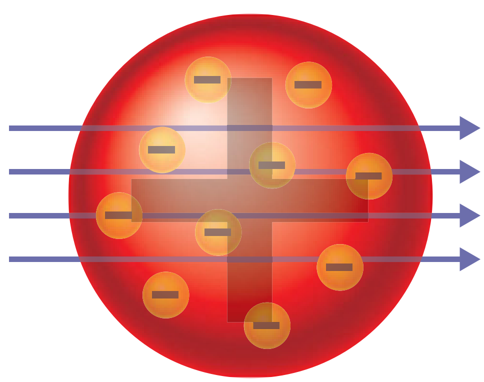


Figure 7.8 If the 'plum pudding' model of the atom were correct, it would be expected that most of the high-energy alpha particles would move through the gold with only minimal deflection.

CHALLENGE 7.2A: HOW CAN YOU TELL WHAT IS INSIDE?
GO TO PAGE 218.

CHALLENGE 7.2B: RUTHERFORD MODEL OF THE ATOM
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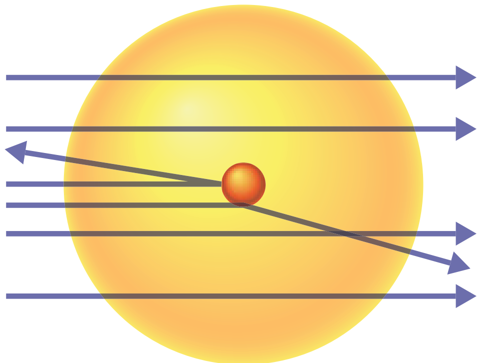

Figure 7.9 The gold foil experiment showed that high-energy alpha particles were deflected.

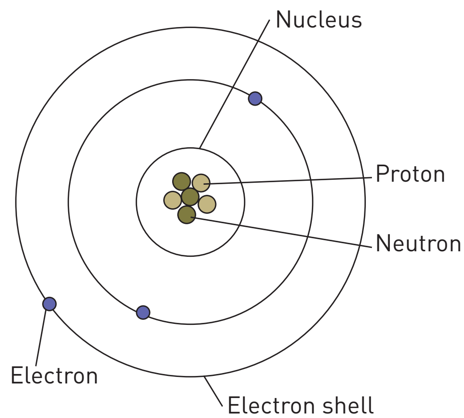

Figure 7.10 A model of an atom of the element lithium.

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.
> The mass of the atom is almost entirely due to the mass of the nucleus; electrons have very little mass in comparison.
> Electrons move around in the space outside the nucleus.
> Electrons have a negative electric charge.

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 still be no bigger than a pinhead.

Figure 7.11 Imagine the size of a pinhead compared to the Melbourne Cricket Ground.

An important thing to know about electric charge and atoms is that atoms are neutral. This means that overall they have no electrical charge – in any atom there is always the same number of positive protons as negative electrons.

Check your learning 7.2

Remember and understand

1 Use the evidence described to explain why you think Rutherford concluded that:
   a the atom contained a lot of space
   b there was a central area of positive charge.
2 Describe Thomson's plum pudding model of the atom.
3 What was the most important new understanding of the structure of the atom that Rutherford inferred from his experiment with alpha particles?
4 In his model of the atom, what did Rutherford say about the electrons?
5 Name and describe three types of particles we now know are found inside the atom.

Evaluate and create

6 Working with a partner, make 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.

7.3 Atoms have mass

All atoms have a mass. The mass of an atom is made up mainly of the protons and neutrons in the nucleus of the atom. Because atoms are so small, chemists have devised a relative mass scale for atoms that is more convenient to work with than actual units. It is this scale that is represented on the periodic table.

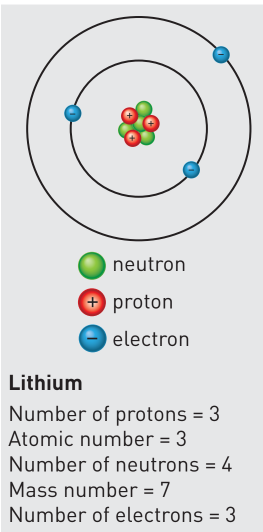

Figure 7.12 A lithium atom with mass number 7 and atomic number 3.

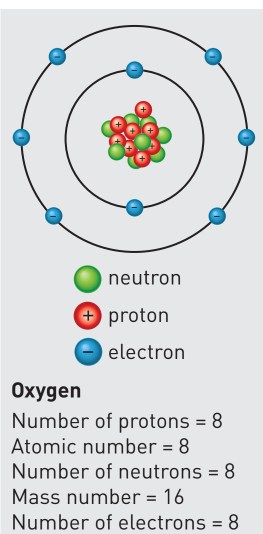

Figure 7.13 An oxygen atom with mass number 16 and atomic number 8.

Size is relative

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 has been in the shower for twice as long as I was.'
>
> 'I know, but you used three times as much shampoo as her!'

Being able to compare the masses of different atoms is very 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.

Atomic mass

On the relative atomic scale, the mass of a proton is equal to a value of 1. Neutrons have almost the same mass as protons, so they can also be said to have mass of 1 on this scale. Therefore, the mass of an atom can be worked out by considering how many protons and neutrons there in the nucleus. Remember that electrons do not affect the mass of atoms very much 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 will have a relative mass of 4. A carbon atom that contains six protons and six neutrons will have a relative mass of 12.

The total number of protons and neutrons in an atom is called the **mass number**.

Different atoms are defined by the numbers of protons, neutrons and electrons that they are made from. Because neutral atoms have no overall negative charge, the number of electrons in an atom is always the same as the number of protons (the atomic number). Figures 7.12 and 7.13 show examples of two common atoms.

Representing atoms

When it is important to show the number of particles within each atom, the method of representation as shown in Figure 7.14 can be used. As a whole, the elements can be presented in a form called the **periodic table**. One of the most common types is shown in Figure 7.15.

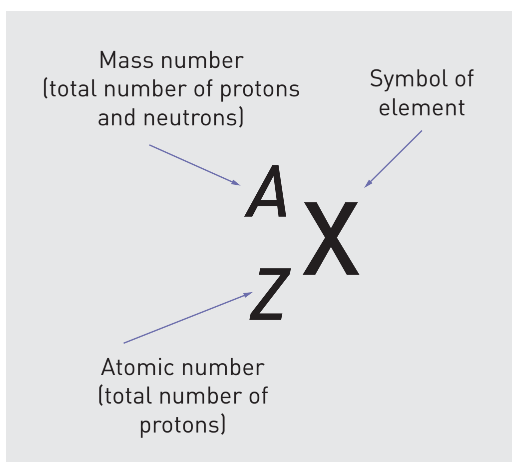

Figure 7.14 The conventional representation of an element.

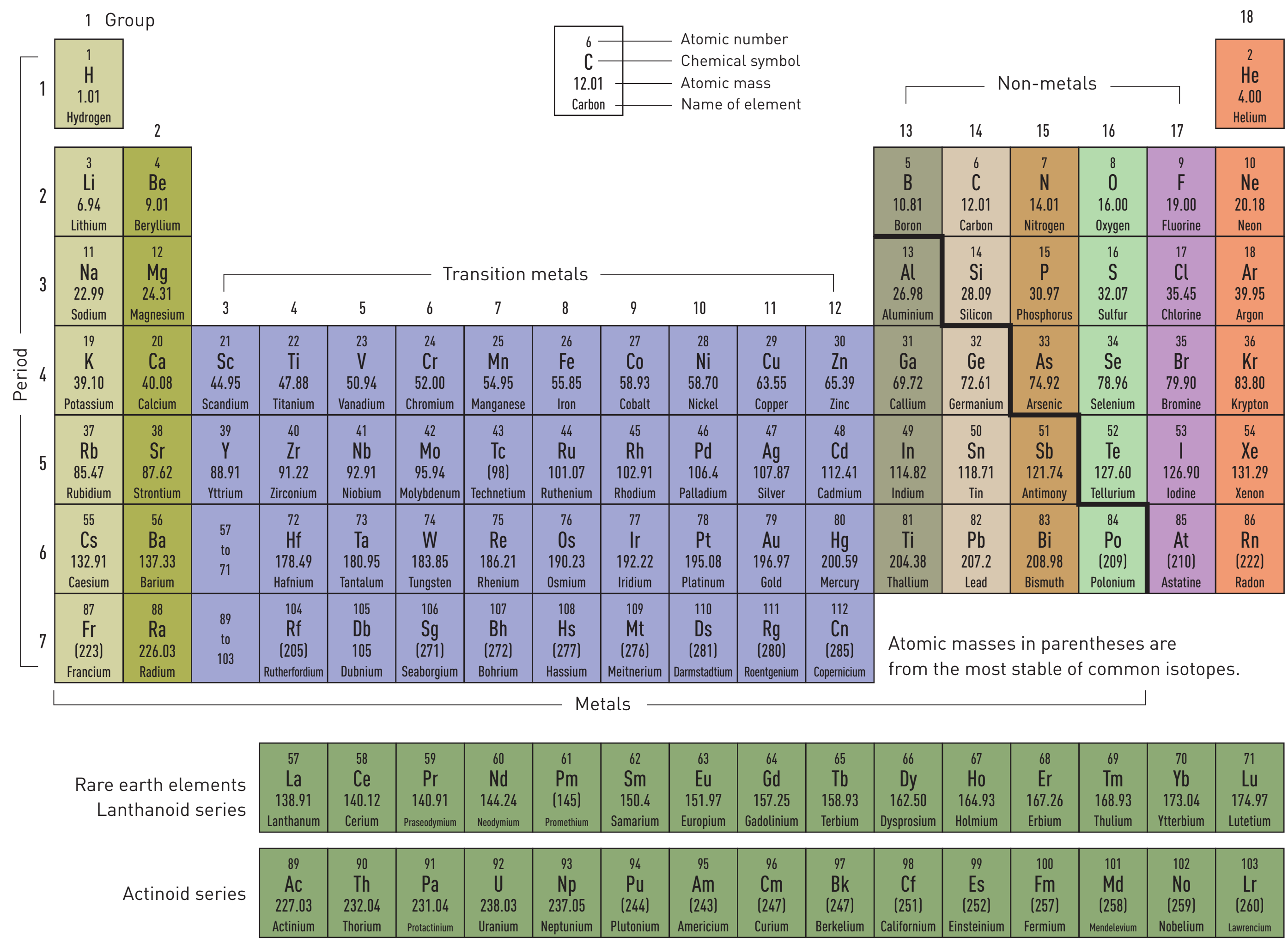

Figure 7.15 A periodic table of the elements.

Check your learning 7.3

Remember and understand

1 The following table shows the numbers of subatomic particles in a range of atoms.

a Complete the table.

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.

Apply and analyse

2 Imagine all the elements did not have names and were just identified by their atomic numbers. Do you think that this would make chemistry easier to understand? What problems do you think this would cause? What would be the advantages?

3 What subatomic particle is not found in the nucleus of the atom?

4 The atomic number of a nitrogen atom is 7 and the mass number is 14. How many electrons are in this atom?

5 What atom has twice as many protons as an oxygen atom?

Evaluate and create

6 Is there always the same number of neutrons as protons in an atom? Explain your answer with an example.

7.4 Electrons are arranged in shells

The Bohr model describes how electrons move in specific areas of space around atoms 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 its lower-energy shell, the excess energy is given off as light. The number of electrons in the outer shell is called its valency.

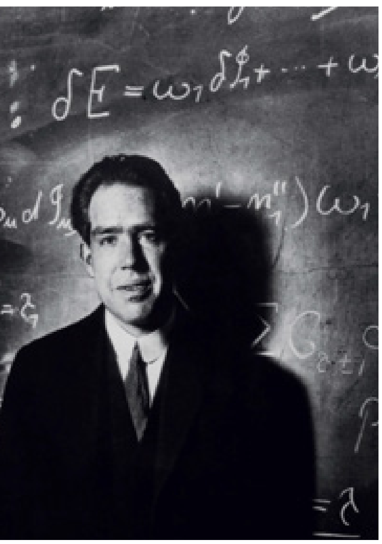

Figure 7.16 Niels Bohr proposed the idea of electron shells.

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 quite 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 they 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 found in any of the shells. This is called the **Bohr model** of the atom.

The arrangement of electrons in an atom is called its **electronic configuration**. Table 7.1 shows the 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 electronic configuration.

Table 7.1 Electronic 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

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, the shells are filled up from the inside.

The electronic configurations of oxygen and calcium are compared in Figure 7.17.

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.

Evidence for electron shells

Many substances give off coloured light when small samples are introduced into a flame. This light can be seen through a spectroscope – an instrument that breaks the light up into its colours. A pattern of coloured lines is observed. This pattern is known as an **emission spectrum** and is unique for each element. Bohr explained this by saying that a particular atom was 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 was unstable, the electrons then jumped back to their normal levels almost instantly. The extra energy that the electrons

EXPERIMENT 7.4: FLAME TESTS
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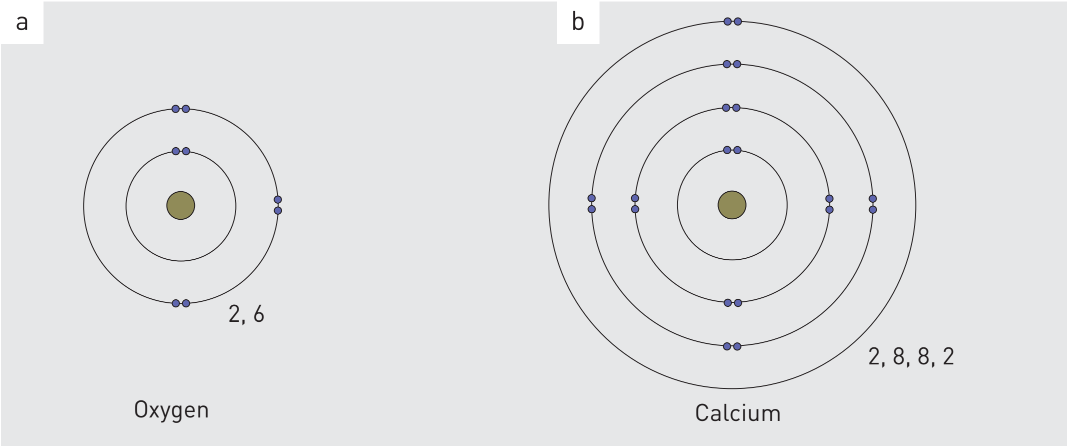


Figure 7.17 The electronic configurations for (a) oxygen and (b) calcium can be shown as simple shell diagrams.

no longer needed was released as light energy. The wavelength of the light (and therefore its colour) represented 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' for that element. This is how flame tests work.

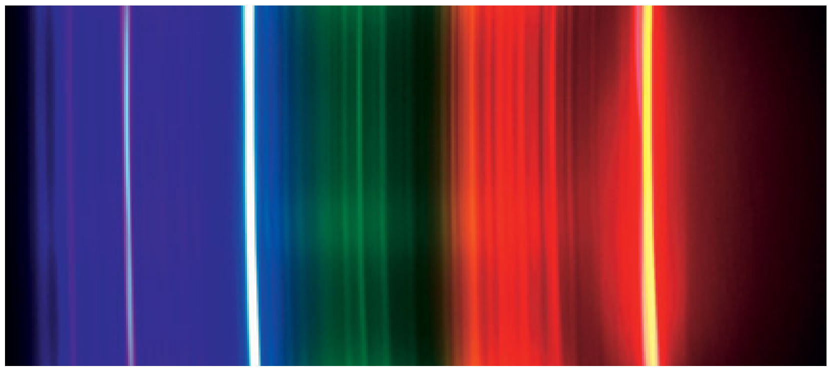


Figure 7.18 The emission spectrum of hydrogen.

Check your learning 7.4

Remember and understand

1 In the Bohr model of the atom, what is the maximum number of electrons that the second electron shell can contain?

Apply and analyse

2 Suggest why the second shell can contain more electrons than the first shell.

3 A potassium atom contains 19 protons.

a How many electrons are present in a potassium atom? Justify your answer.

b What is the electronic configuration of a potassium atom according to the Bohr model?

c How many electrons are in the valence shell of a potassium atom?

d What could be done to potassium atoms to make electrons jump into the fifth shell?

4 Complete the following table.

ELEMENT	ATOMIC NUMBER	ELECTRONIC 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 your results in the flame tests in Experiment 7.4, what atom do you think caused the yellow colour that Bunsen saw when he was heating glass?

7.5 Ions have more or less electrons

An atom can gain or lose electrons to become an ion. If an atom gains an electron, then there are more negative electrons than positive protons. This means a negative ion, called an anion, is formed. If an atom loses an electron, then there is an overall positive charge due to the extra proton compared to electrons. This is called a cation.

Atoms and ions

Atoms are neutral. This means that the amount of negative charge within the atom is the same as the amount of positive charge. 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 charged. Charged atoms are called **ions**, and the process for the formation of ions is called ionisation.

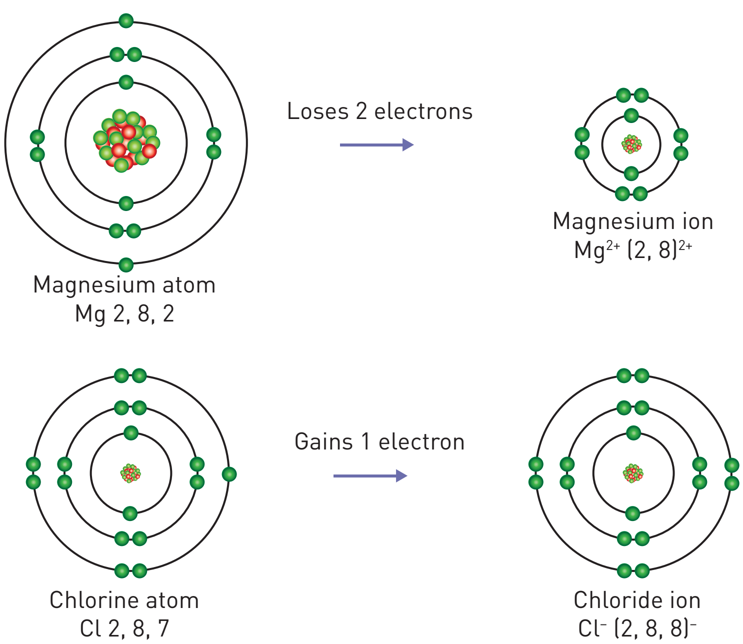


Figure 7.19 How magnesium and chloride ions are formed.

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 stable arrangement. The first three shells are full, with 2, 8 and 8 electrons respectively.

For example, an atom that originally had two electrons in its valence shell, such as magnesium, would lose both of 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 chorine, 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 ions are formed, the number of protons in an atom stays the same because protons are held 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. If two electrons are gained, then there is an overall charge of negative two.

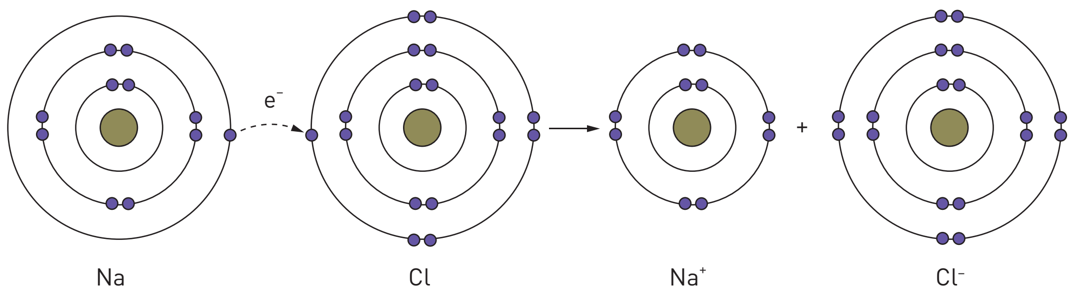
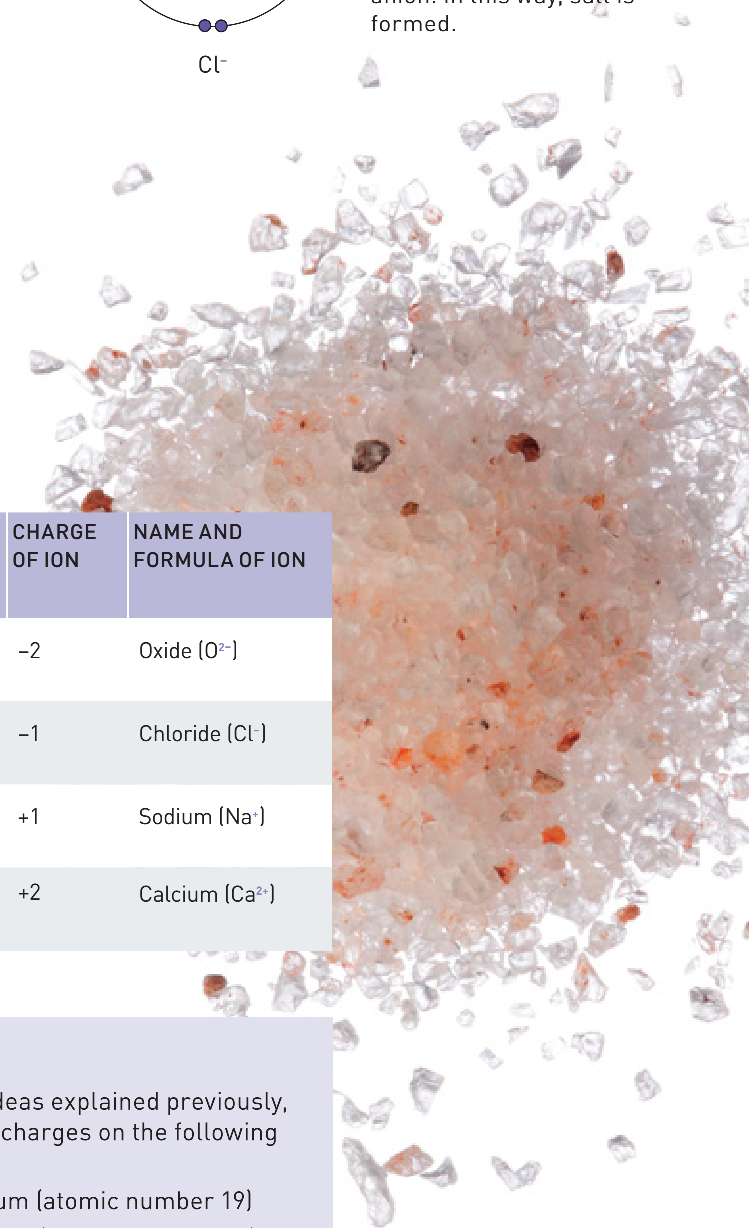


Figure 7.20 Sodium atoms lose an electron to become a positively charged cation. Chlorine gains an electron to become a negatively charged anion. In this way, salt is formed.



A negatively charged ion is called an **anion**. If an electron is lost, the resulting ion will have a charge of positive one. There will now be more protons than electrons. One electron lost means there is effectively one extra proton. A positively charged ion is called a **cation**. Table 7.2 contains some examples.

Table 7.2 Examples of positive and negative ions

NAME AND SYMBOL OF ATOM	ELECTRON CONFIGURATION OF ATOM	ELECTRON CONFIGURATION OF ION	CHANGE	CHARGE OF ION	NAME AND FORMULA OF ION
Oxygen (O)	2,6	2,8	Gained 2 electrons	–2	Oxide (O^{2-})
Chorine (Cl)	2,8,7	2,8,8	Gained 1 electron	–1	Chloride (Cl^{-})
Sodium (Na)	2,8,1	2,8	Lost 1 electron	+1	Sodium (Na^{+})
Calcium (Ca)	2,8,8,2	2,8,8	Lost 2 electrons	+2	Calcium (Ca^{2+})

Check your learning 7.5

Remember and understand

1 What is a cation?

2 Use an example from the periodic table to explain how an anion is formed.

Apply and analyse

3 In Table 7.2, what patterns do you notice about the:

a names of the negative ions?

b electronic configurations of the ions?

c differences between the metals and non-metals?

4 Using the ideas explained previously, predict 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 The elements neon (atomic number 10) and argon (atomic number 18) do not normally form ions. Suggest why this is.

7.6 Isotopes have more or less neutrons

*

An isotope is an atom that has more or less neutrons in its nucleus. This affects the mass 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 pretty 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 really enough to make much difference to the overall mass of the atom. So where do these atomic masses come from?

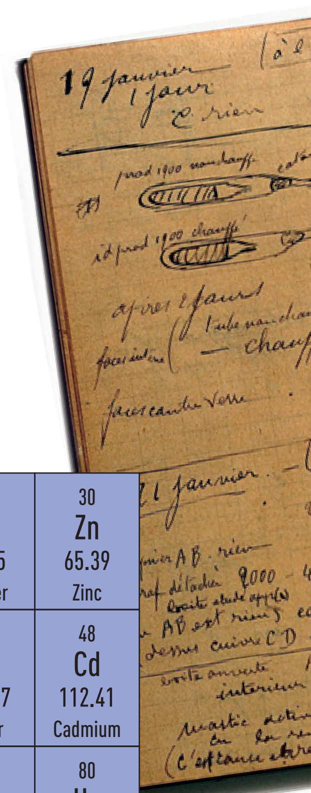
Generally, not all the atoms within an element have the same mass. This is because they are not identical. Why is this? What do they have in common and what is different?

All the atoms of an element have the same unique number of protons – their atomic number, sometimes shown by the letter *Z*.

The atomic number is used to identify the element. For example, all carbon atoms contain six protons in their nucleus, so their atomic number is 6. In the periodic table of the elements (Figure 7.21), you can see that the elements are listed in order of their atomic number. However, although all the atoms of one particular atom have the same number of protons, they may well have different numbers of neutrons.

Isotopes

For many of the 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 and some have eight. The different forms of the atoms of an element that have different numbers of neutrons are called **isotopes**.



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 7.21 Some atomic numbers and atomic masses in the periodic table.

CHALLENGE 7.6: CALCULATING RELATIVE ATOMIC MASS
GO TO PAGE 220.

Carbon-12 is the most common form of carbon atom in the natural world – 1.1% of natural carbon on the Earth is carbon-13 atoms (6 protons and 7 neutrons), and even smaller quantities are made up of carbon-14 atoms (6 protons and 8 neutrons).

Like most elements, carbon has more than one naturally occurring isotope. 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 are 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 mix this up with their atomic numbers.

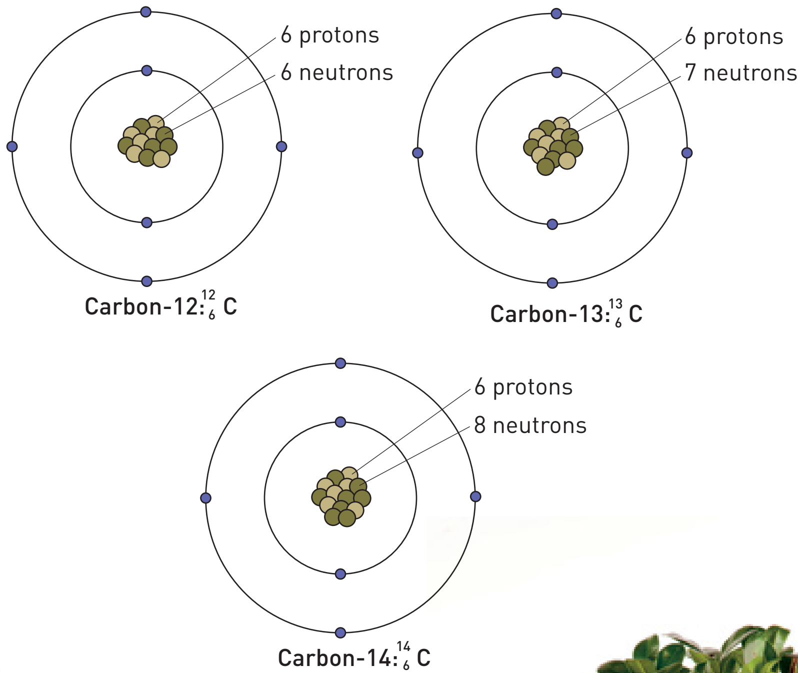


Figure 7.22 The three isotopes of carbon.

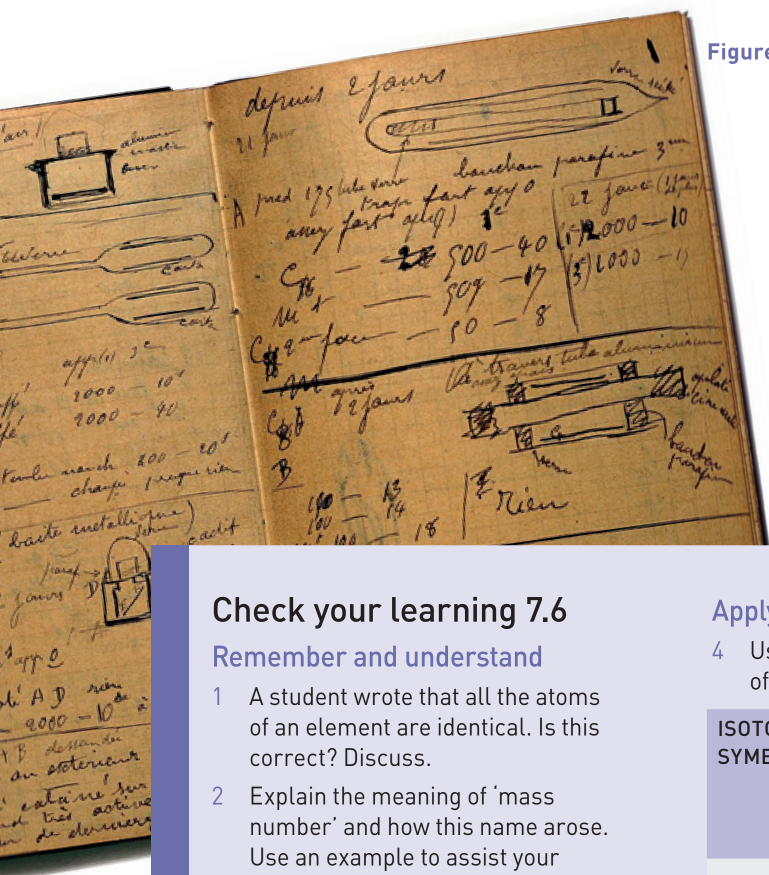


Figure 7.23 Marie Curie was one of the first scientists to study isotopes. Her notebook is still radioactive over 100 years later.

Check your learning 7.6

Remember and understand

1 A student wrote that all the atoms of an element are identical. Is this correct? Discuss.

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 Using your knowledge of isotopes and a copy of the periodic table, complete the table.

ISOTOPE SYMBOL	ISOTOPE NAME	ATOMIC NUMBER OF ELEMENT	NUMBER OF PROTONS	NUMBER OF NEUTRONS	NUMBER OF ELECTRONS IN UNCHARGED ATOM
	Oxygen-16				
			10	20	
				36	29
		30		34	

7.7 Isotopes can release alpha, beta or gamma radiation

Some isotopes are unstable. This means they may decay or change into another isotope and produce alpha, beta and/or gamma radiation. This is known as radioactive decay. The time it takes for half the remaining unstable isotopes to decay is called the half-life of the isotope.

Figure 7.24 Smoke detectors contain a radioactive source.

Isotopes and radioactive decay

Earlier in this chapter you learned about isotopes. Hydrogen, for instance, has three isotopes: hydrogen-1 ($^{1}_{1}H$), hydrogen-2 ($^{2}_{1}H$) and hydrogen-3 ($^{3}_{1}H$).

Each isotope of hydrogen has one proton but different numbers of neutrons. In some isotopes, when the ratio of neutrons to protons becomes too high, the nucleus is unstable and it decays or changes into another isotope.

This process 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 can occur naturally or they can 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 the nucleus of 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. It 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:

$$^{241}_{95}\mathrm{Am} \rightarrow {}^{237}_{93}\mathrm{Np} + {}^{4}_{2}\alpha$$

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:

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + \beta$$

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.

Figure 7.25 Alpha particles are stopped by paper. Beta particles are stopped by aluminium foil. Gamma rays can only be stopped by lead.

CHALLENGE 7.7: A TASTY WAY TO MODEL RADIOACTIVE DECAY
GO TO PAGE 220.

An example is when cobalt-60 decays to form nickel-60:

$$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{N} + \beta + \gamma$$

Cobalt-60 is an artificially produced radioisotope that it used in medical radiotherapy, sterilisation of medical equipment and irradiation of food. Because the gamma radiation is an electromagnetic wave, rather than a particle like alpha and beta radiation, the gamma radiation 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 and 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 substance is left and the radioactivity drops. The half-life of a radioactive material is the time taken for half of the radioactive nuclei in a sample to decay. This is also equivalent to the time taken for the radioactivity to drop to half of its original value.

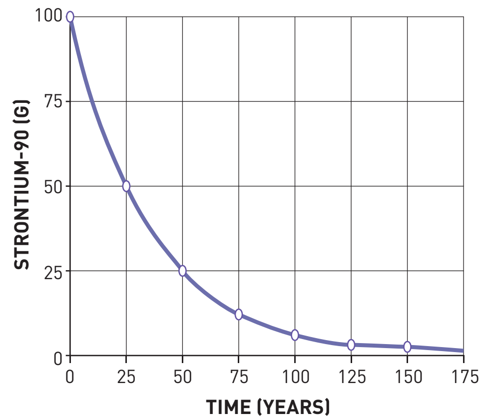


Figure 7.26 A radioactive decay curve for strontium-90, which has a half-life of 28.8 years.

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 7.26).

Table 7.3 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

Check your learning 7.7

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 find out the atomic number of the elements.
  a Iodine-131
  b Cobalt-60
  c Technetium-99
  d Fluorine-18

Apply and analyse

3 The rate of decay of a radionuclide falls from 800 counts per minute to 100 counts per minute in 6 hours.
  a What is the half-life of this radionuclide?
  b Sketch a radioactive decay curve for this radionuclide.
  c Predict what the count rate would be in another 4 hours.

4 A number of the elements have radioactive isotopes. In each case, it is the nucleus of the atom that is unstable. Investigate the kinds of particles and/or rays that can be emitted by radioactive atoms.

Evaluate and create

5 Investigate one radioactive isotope that is used in medicine. State the symbol of the isotope and its uses.

//SCIENCE AS A HUMAN ENDEAVOUR//

7.8 The half-life of isotopes can be used to tell the time

Radiation exists all around us from various sources. This is called background radiation. Radioactive minerals can be found in the ground and radiation in the form of cosmic rays comes from the Sun and space. The rate that a radioactive mineral decays can be used to determine how long the mineral has been outside a living organism.

Figure 7.27 A Geiger counter is used to detect radiation.

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 different atomic nuclei, but some nuclei, such as carbon-12 nuclei, with six protons and six protons, 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. The formation of carbon-14 occurs naturally in sunlight. Every time an organism breathes in or eats, it replaces the carbon-14 that is naturally in its body. When that organism dies, the carbon-14 is no longer replaced. Therefore, the decay becomes noticeable.

Because scientists know how long this process takes, carbon-14 isotope decay can be used to measure the age of objects, including matter from living things. This is called **carbon dating** and was used to measure the age of the Shroud of Turin (Figure 7.28). The Shroud of Turin is a linen cloth believed by many to be the cloth that covered Jesus' face after his crucifixion and burial. Carbon dating is the most common way of dating more ancient artefacts, and plant and animal material. Carbon dating showed that the Shroud of Turin was not as old as claimed.

The decay of radioactive isotopes is often very slow. One gram of carbon-14 today would take more than 5000 years until half of it had decayed. The remaining 5 grams would take another 5000 years to reduce to 2.5 grams, and another 5000 to reduce to 1.25 grams. Unless the amount of carbon is measured over a very long period, it might seem that no change is occurring. However, scientists would be able to 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. The problem would not be trying to detect how lithium-8 is changing, but actually detecting it at all. Carbon-14 is by not one of the slowest decayers. Uranium-235 would take 700 million years to reduce to half of the original amount. If you had some uranium-238, most of it would still be there 4 billion years later!

CHALLENGE 7.8: KERNELITE/POPCORNIUM DECAY
GO TO PAGE 221.

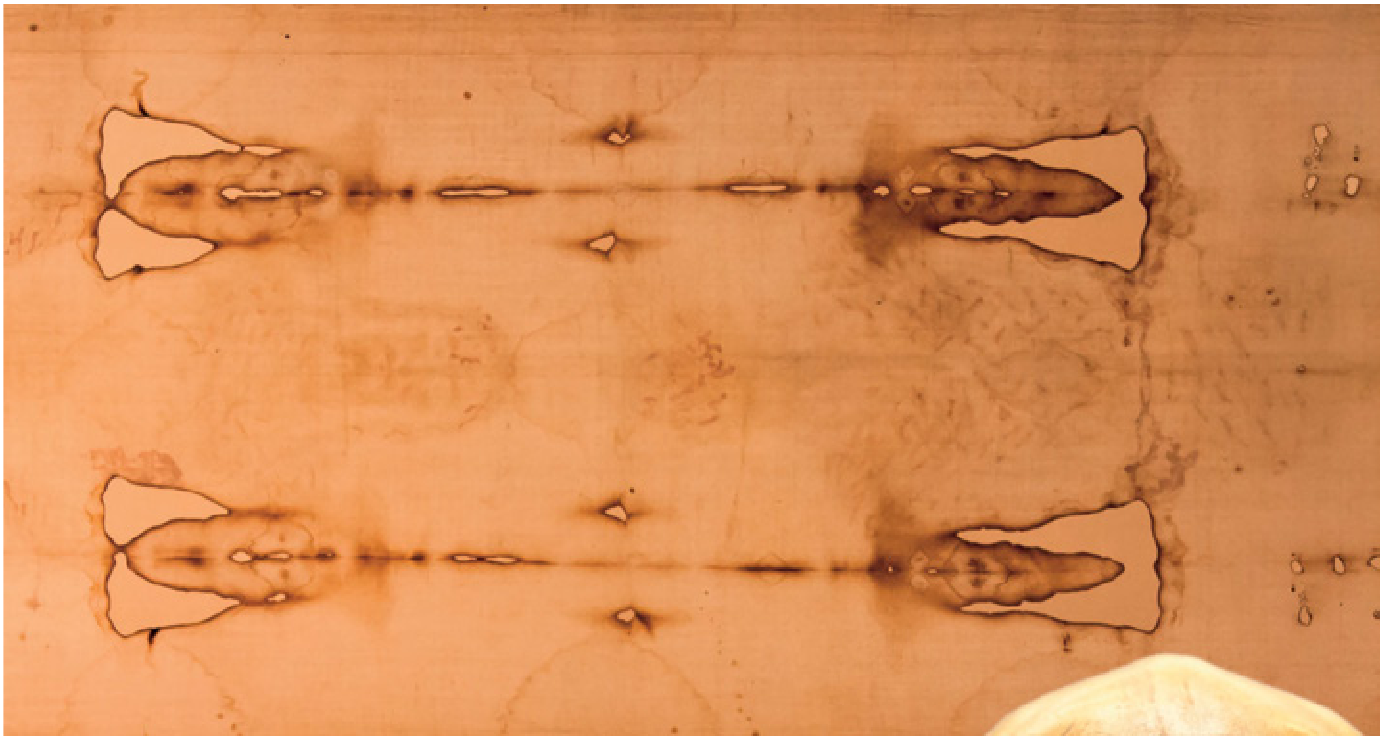


Figure 7.28 The Shroud of Turin was found to be less than 2000 years old when analysed using carbon dating.

In science, there are many situations where change takes place over a range of time scales. What makes radioactive decay special is that it is a purely 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.

Extend your understanding 7.8

1. Suggest a reason why carbon-12 atoms are more stable than carbon-14 atoms.
2. What would be the dangers of isotopes that decay very quickly?
3. What would be the dangers of radioactive isotopes that decay very slowly?
4. Think of other situations in science where change is a random process but the overall rate of that change can be measured. Try to describe one from the biological sciences, and one from Earth and space sciences.
5. Carbon dating works because, as isotopes decay, the amount of radiation released decreases over time. Therefore, the measured level of radiation will indicate the age of the object.
   a. Why would atoms that decay extremely slowly not generally be used for dating objects?
   b. Why would atoms that decay very quickly not generally be used for dating objects?

//SCIENCE AS A HUMAN ENDEAVOUR//

7.9 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 situated within X-ray departments in hospitals or in private clinics.

Figure 7.30 X-rays use radiation to make images of the bones in the body.

Effects of radiation

The main reason that radiation can be harmful is that it can cause atoms in other substances to become ions. The alpha and beta particles have enough mass and/or energy to remove electrons from the outside of atoms. This will change 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 has the ability to 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.

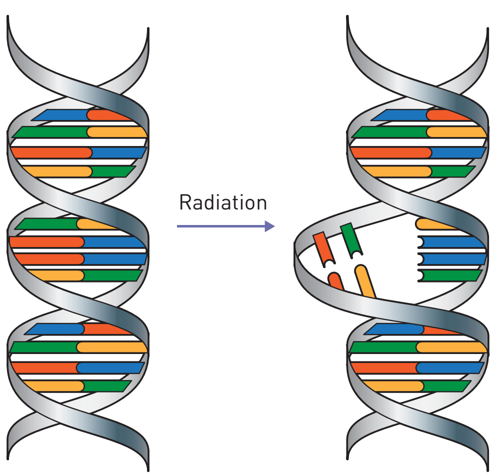


Figure 7.29 Radiation can damage the structure of DNA molecules.

Radiation and medicine

Despite the damage that can be caused by radiation, it has many uses in medicine. The most common medical application is using X-rays to identify damaged or broken bones. Less common is the injection of radioactive isotopes into a patient. This allows the radiation that accumulated at the site of a cancer, or other damaged tissue to be detected by special monitors.

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 it to grow very quickly. Radiotherapy uses radioactive isotopes to cause more damage to the cancer cell. Most commonly the radioactive particle released by the isotope is directed to the site of the cancer. Eventually when the cell is damaged enough, it dies (a process called apoptosis).

Careers in radiation

Before the first patient arrives at her department, nuclear medicine technologist Fran Maestrale 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.

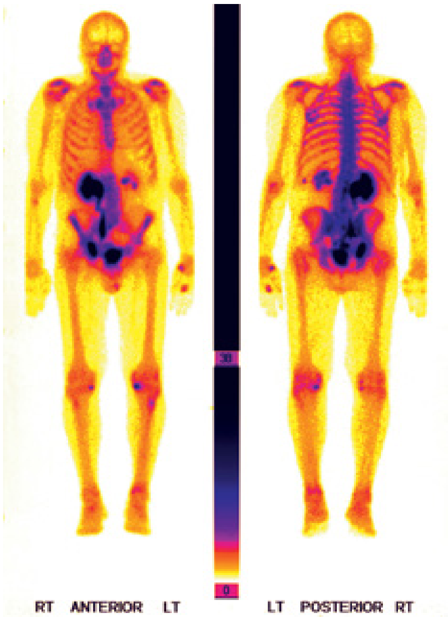


Figure 7.31 A technetium-99m bisphosphonate bone scan shows up abnormalities within bones.

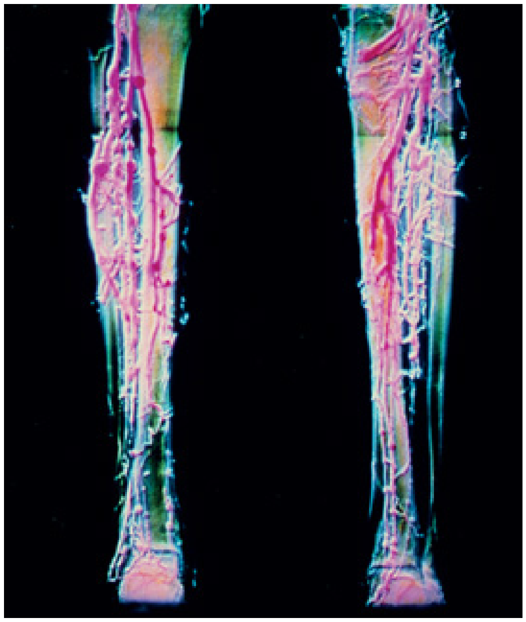


Figure 7.32 Radioactive dye injected into the blood shows blood flow in the blood vessels.

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.

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.

Fran typically performs a number of these different tests each day, looking at a variety of different 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 through practice they may be able to interpret images and determine what pathology a person has, nuclear medicine technologists are not qualified to do this. They must present the images to the radiologist, who is responsible for making a diagnosis. Nuclear medicine technologists have a close working relationship with radiologists, surgeons and nurses.

Extend your understanding 7.9

1. What training do you think a nuclear medicine technologist might need? Why is this?
2. Why do you think the day begins with measuring the amount of radioactivity delivered to the department?
3. Why do you think the nuclear medicine technologist must give the images to a radiologist to make a diagnosis?
4. When used in medicine, radioactive isotopes that decay relatively quickly are used. Explain why this might be.
5. Where else do we see elements and chemicals being used to treat disease? Can you think of the benefits and risks of such treatments?
6. What are the side effects of radiotherapy and chemotherapy? Do you think that these 'costs' outweigh the potential benefits?

Remember and understand

1 What does the '2' in the formula CO_2 represent?

2 Where are each of the following particles found in an atom and what are their charges?
 a Proton
 b Neutron
 c Electron

3 When an atom is uncharged, what is true of the number of protons and electrons present?

4 Explain why the mass numbers of isotopes are exact whole numbers but the relative masses of most atoms are not exact whole numbers.

5 Titanium is element 22 in the periodic table. It has five naturally occurring isotopes. What will the isotopes of titanium have in common and in what way(s) will they be different?

6 What is a beta particle? Write its symbol, including the atomic and mass numbers in the correct positions.

7 What does it mean if a substance is radioactive?

Apply and analyse

8 Why are the molecules of water impossible to see, even with powerful microscopes?

9 is an isotope of uranium that is used in nuclear reactors. In an uncharged atom, how many:
 a protons are present?
 b neutrons are present?
 c electrons are present?

10 Only 0.7% of the uranium atoms in naturally occurring uranium exist as uranium-235. The other isotopes present are uranium-234 (0.01%) and uranium-238 (99.3%). Write the symbols for these other two isotopes.

11 According to the Bohr model of the atom, the electronic configuration of the uncharged atoms of a particular element is 2,8,8.
 a What is the atomic number of the element?
 b What element must it be?
 c What will be the electronic configuration of the next element on the periodic table? State your reasoning.

12 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.

13 If a radioactive substance decays from 400 counts per minute to 50 counts per minute in 9 hours, what is its half-life?

Evaluate and create

14 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 Write the symbol for the isotopes of tellurium-127 and iodine-127.
 b Explain why the atoms of these two different elements can have the same mass number.

15 Scientists have had to infer what it is like inside the atom from indirect evidence, in the same way that astronomers have worked out the temperature and composition of stars. Write a list of the advantages and disadvantages of using indirect evidence to develop theories in science.

16 Describe the differences between a scientist and a natural philosopher.

17 Consider the composition of alpha and beta particles. When a beam of alpha particles and a beam of beta particles are fired into an electric field, they move in opposite directions. Why do you think this is?

18 Describe why the Bohr model gives us much more information than Dalton's early model of the atom.

19 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. Write a paragraph aimed at persuading the student that her teacher was correct.

20 Create a poster that shows the models of the atom, from the original theory that it was a solid sphere, as proposed by the

English chemist John Dalton, to the Bohr model. Use the Internet to find images of the scientists involved and place copies onto your poster. Investigate the year in which each model was proposed and include a timeline.

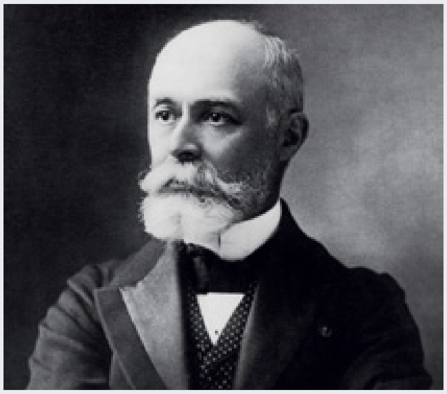
21 Use your understanding of atoms and elements to suggest reasons for the following.
   a Carbon dioxide is a heavier gas than oxygen.
   b Hydrogen and oxygen can be produced from water.
   c The relative atomic mass of argon (atomic number 18) is actually higher than the relative atomic mass of potassium (atomic number 19).
   d Beta particles can be stopped by a few millimetres of lead foil, but gamma rays will pass through several centimetres of lead.

Research

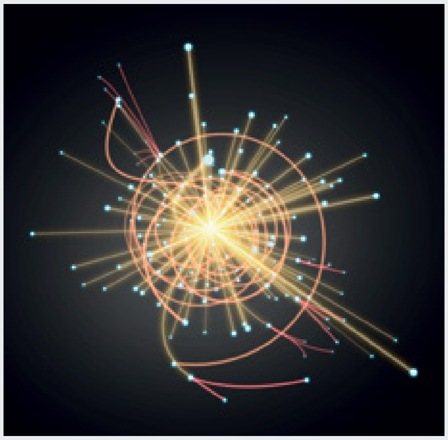
22 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

> **Targeted alpha therapy**
> Targeted alpha therapy (TAT) is a new therapy for the control of some cancers. How does this form of therapy work? What types of cancer are treated by this method? How widespread is its use? What are the risks associated with this form of radiotherapy and how are they reduced?

> **Henri Becquerel**
> Henri Becquerel shared a Nobel Prize with Marie Curie for work in discovering radioactivity. What did he contribute to this important work? What scientific units are named after him? Did his children, like those of Marie and Pierre Curie, also follow careers in science?



> **CERN**
> The European Organization for Nuclear Research is known as CERN and is based on the border of France and Switzerland. It has been responsible for developing scientists' understanding of atoms. What countries collaborate in this project? What types of scientist work at CERN? What current work is occurring at CERN? What is the Large Hadron Collider?



*KEY WORDS

7

alpha
a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

anion
a negative ion that results from an atom gaining electrons

atomic theory
the theory that all matter is made up of atoms

beta
a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

Bohr model
a way to represent the electrons of an atom in a series of shells around the atomic nucleus

carbon dating
a process that measures the age of an object by comparing the amount of carbon-14 that has decayed over time

cation
a positive ion that results from an atom losing electrons

electron
a negatively charged subatomic particle that moves in the space around an atomic nucleus

electron shell
the area of space around a nucleus where a specific electron may be found

electronic configuration
a numerical way of showing the number of electrons in each electron shell around a particular atomic nucleus

emission spectrum
the pattern of coloured lights released as an element loses thermal energy

gamma
high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

ion
a charged atom that results from an unequal number of electrons and protons

isotope
an atom that has more or less neutrons in its nucleus

mass number
the number that represents the total number of protons and neutrons in the centre of an atom

neutron
a neutral (no charge) subatomic particle in the nucleus of an atom

nucleus
(chemistry) the centre of an atom that contains protons (positive) and neutrons (no charge)

periodic table
a table that places elements in order of their atomic number, and groups them according to similar properties

proton
a positively charged subatomic particle in the nucleus of an atom

radioactive decay
the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

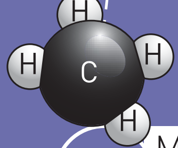
radionuclide
a radioactive isotope

relative atomic mass
the average mass of an element that includes the mass and prevalence of its different isotopes

shell diagram
a diagram that shows the number of electrons in each electron shell around a particular atomic nucleus

Thomson plum pudding model
an early model of an atom that suggested that the positively charged nucleus had negatively charged electrons scattered through it (like a plum pudding)

valence shell
the outermost electron shell that contains electrons



CHEMICAL REACTIONS 8

8.1 Mass is conserved in a chemical reaction

8.2 The rearrangement of atoms in a chemical reaction can be shown using a balanced equation

8.3 Endothermic reactions absorb energy from the surroundings. Exothermic reactions release energy

8.4 Acids have a low pH. Bases have a high pH

8.5 Acids can neutralise bases

8.6 Acids react with metals to produce hydrogen and a salt

8.7 Oxidation reactions use oxygen to form new products

8.8 Combustion reactions need fuel and oxygen to produce carbon dioxide and water

8.9 Fuels are essential to Australian society

What if?

What you need:

universal indicator, lemon juice, detergent, water, test tubes

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?

8.1 Mass is conserved in a chemical reaction

In chemical reactions, the substances on the left-hand side of the arrow are the substances we start with, and are called the reactants. The substances on the right-hand side of the arrow are the substances that are formed in the reaction, known as the products. The law of conservation of mass states that the total mass of the reactants is equal to the total mass of the products.

Representing chemicals

When examining chemical reactions, we can represent the substances in different ways. The substances that are present at the start of a chemical reaction are called the **reactants**. The substances formed by the chemical reaction are called the **products**. We can write this using a simple word equation. Consider the reaction of the acid in vinegar with sodium bicarbonate. This reaction produces water, carbon dioxide gas and a substance called sodium acetate, and it can be represented as:

acetic acid (in vinegar) + sodium bicarbonate →
sodium acetate + carbon dioxide + water

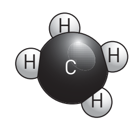
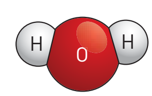
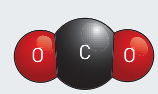
The acetic acid and sodium bicarbonate are the reactants for this reaction. The products formed by this reaction are sodium acetate, carbon dioxide and water.

The law of conservation of mass

If you did Experiment 8.1, you would have found out that when the products of a chemical reaction are not allowed to escape, the mass or quantity of elements of the products after the observed reaction is the same as the mass of the reactants that you started with. This is a very important observation. It shows that the total mass of the chemicals is not changed in a chemical reaction.

When a chemical reaction takes place, the chemicals interact, causing the atoms to break apart from each other before forming into new arrangements. However, no atoms are produced in the process and no atoms are destroyed. This is one of the most important laws in science.

Table 8.1 Representations of four chemicals

CHEMICAL NAME	FORMULA/ SYMBOL	DIAGRAM
Methane	CH_4	
Oxygen	O_2	
Water	H_2O	
Carbon dioxide	CO_2	

EXPERIMENT 8.1: COMPARING MASS BEFORE AND AFTER A CHEMICAL REACTION
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Figure 8.1 Methane gas burning on a stove.

Example of a chemical reaction

Methane gas (CH_4) is the main gas present in natural gas, which is used in the home for cooking and heating. When it burns, it combines with oxygen (O_2) in the air to form carbon dioxide (CO_2) and water (H_2O).

Figure 8.2 shows what happens to the atoms during this reaction. Different atoms are represented by different colours.

1 Count the number of each type of atom in the reactants (left-hand side of the arrow) and count the number of each type of atom in the products (right-hand side of the arrow). What do you notice?

2 Describe what has happened to the hydrogen atoms during the chemical reaction.

3 Describe what has happened to the oxygen atoms. Make sure you use the correct names of the chemicals in your description.

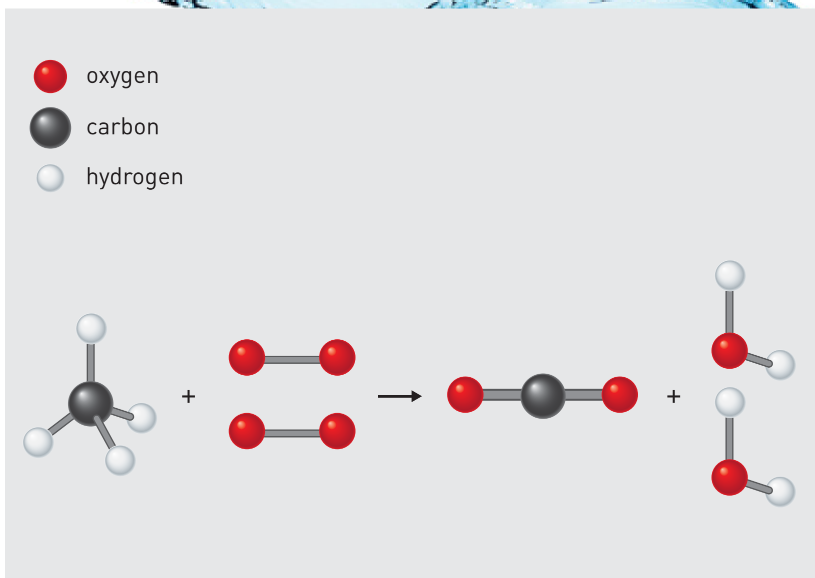

Figure 8.2 Atoms are rearranged during a chemical reaction.

Check your learning 8.1

Remember and understand

1 What is mass?

2 Use Table 8.1 to identify:

  a an element composed of molecules

  b a compound composed of molecules.

3 If no mass is lost or gained in a chemical reaction, what does this tell you about the atoms involved in the reaction?

Apply and analyse

4 Explain how the products have properties very different from those of the reactants, even though the total mass remains the same.

5 Early alchemists repeatedly tried to turn lead into gold. Explain using the conservation of mass, why this would be impossible.

8.2 The rearrangement of atoms in a chemical reaction can be shown using a balanced equation

Chemical reactions can be described through observations, word equations or symbols. The conservation of mass is used to write a balanced chemical equation. A balanced chemical equation has equal numbers of each type of atom on both sides of the equation.

Describing chemical reactions

Figure 8.3 shows sodium metal reacting with water. Perhaps you have seen this reaction at school or on the Internet. There are different ways to describe this reaction.

> *Describing observed changes:* The sodium metal dissolves in the water; heat is produced; fizzing is caused by the production of hydrogen gas. If there is enough heat, the hydrogen gas catches fire above the sodium metal.

> *Using a word equation:* The reactants are sodium and water and they interact to form the products, which are sodium hydroxide and hydrogen gas. A word equation summarises the changes:

sodium + water →
sodium hydroxide + hydrogen

Figure 8.3 Sodium metal reacts violently with water, undergoing a chemical change.

> *Using a chemical equation:* This includes the formulas of all the substances involved and the ratio in which they react:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Each representation tells us something different about the changes occurring in the chemical reaction.

Reacting hydrogen and oxygen

When hydrogen gas burns in oxygen, large amounts of heat energy are produced. If this reaction happens in uncontrolled conditions, it is very dangerous. This reaction caused the destruction of the *Hindenburg* airship in 1937 when a spark set a huge amount of hydrogen gas ablaze. Thirty-five passengers died. Under controlled conditions, hydrogen can be used safely as a fuel. In the future, your family might be driving a car fuelled by hydrogen. An advantage of using hydrogen as a fuel is that the only product is water. (There are no carbon emissions.)

In this reaction, the oxygen atoms and hydrogen atoms have split up from each other and have joined to form molecules of water (H_2O). The atoms have not been created or destroyed. You can show what is happening using a diagram, or by using a chemical equation.

CHALLENGE 8.2: MODELLING CHEMICAL EQUATIONS
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Writing chemical equations

Hydrogen combines with oxygen to produce water. The equation can be written by using the following steps.

1 Write out the word equation for the reaction.

hydrogen + oxygen → water

2 Write a simplified chemical equation using the formulas of the substances involved.

$$H_2 + O_2 \rightarrow H_2O$$

3 Work out the numbers of each type of atom in the reactants (left-hand side) and in the products (right-hand side).

	REACTANTS		→	PRODUCTS	
Type of atom:	H	O	→	H	O
Number of atoms:	2	2		2	1

4 Compare the number of each type of atom in the reactants with the number in the product. In this case, there are three atoms in the products and four atoms in the reactants. This doesn't fit the law of conservation of mass. We can't have just 'lost' an oxygen atom.
To ensure that there are the same numbers of each atom at the end of the reaction as there were at the start, we include numbers (called coefficients) before the formula of the substances. This allows the number of reactant atoms to equal the number in the product – the equation is said to be balanced.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Type of atom: H O H O
Number of atoms: 4 2 4 2
This balanced equation shows how the atoms are rearranged to form the water molecules.

Figure 8.4 The reaction of hydrogen with oxygen caused the *Hindenburg* explosion.

Check your learning 8.2

Remember and understand

1 Which way of describing this chemical reaction tells us most about what is happening to the atoms?

2 Which representation tells us most about the chemicals? Explain your reasoning or discuss your answer with others.

Apply and analyse

3 What do you think the '(s)', '(l)', '(g)' and '(aq)' stand for in the chemical equation for the reaction of sodium metal with water?

4 Why are chemical reactions that are not 'balanced' always incorrect?

5 Balance the following equations by adding numbers as required:

a ____Na + ____H_2O → ____NaOH + ____H_2

b ____H_2 + ____O_2 → ____H_2O

c ____CH_4 + ____O_2 → ____CO_2 + ____H_2O

d ____Mg + ____HCl → ____H_2 + ____$MgCl_2$

8.3 Endothermic reactions absorb energy from the surroundings. Exothermic reactions release energy

A chemical reaction that releases energy in the form of heat and light, is called an exothermic reaction. The reactants of this reaction have more stored energy than is needed to produce the products. In an endothermic reaction, more energy is needed to manufacture the products than is stored in the reactants. Therefore energy is taken from the surroundings, causing the temperature to decrease.

Energy changes in reactions

You may have noticed that a test tube or beaker sometimes feels warmer after a chemical reaction. All chemicals contain a certain amount of stored energy. Reactions that release energy are called **exothermic reactions** (*exo* means 'to give out', *thermic* means 'heat'). The energy released is usually heat energy but can also be light or electrical energy. An exothermic reaction can be as fast as a match burning or as slow as the rusting of iron.

In an exothermic reaction, the reactants have a lot of energy stored in the bonds between the atoms. When these bonds break, the energy is released. Some of this energy is taken up when the product is formed, but the bonds between the atoms of the product may not need as much energy. This means there is energy left over. We observe this energy as heat and light.

Reactions that absorb energy are called **endothermic reactions**. For example, for photosynthesis to happen, plants need energy from the Sun to produce glucose and oxygen from carbon dioxide and water.

In an endothermic reaction, the energy produced by the breaking of the bonds in the reactants is not enough to form the products. Extra energy is taken from the surroundings to use to make the high-energy products. The extra energy comes from the thermal energy of any molecule near the reaction. This means the surrounding molecules lose thermal (kinetic) energy and become cooler.

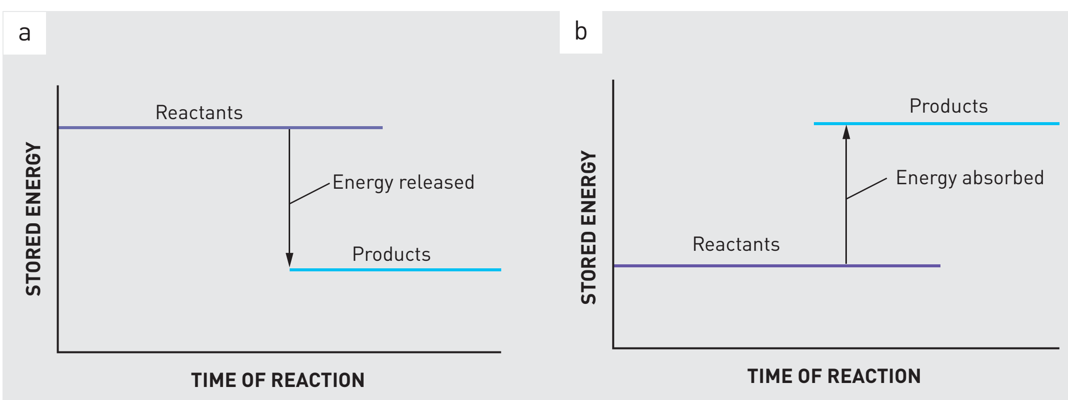

Figure 8.5 (a) In an exothermic reaction, energy is released and the products have less stored energy than the reactants. (b) In an endothermic reaction, energy is absorbed from the surroundings and the products have more stored energy than the reactants.

EXPERIMENT 8.3: ENERGY CHANGES
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Using energy changes

Compounds contain atoms held together by **chemical bonds**. Chemical reactions involve the breaking and making of these chemical bonds.

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 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. The extra energy is released as heat.

Cold packs reduce swellings and numb pain caused by injuries. They usually contain ammonium nitrate, which undergoes an endothermic reaction when the inner bag is broken. This allows the salt to dissolve in water, absorbing the thermal energy of the water in the process. This cools the water and makes the bag feels cold.

Figure 8.6 Athletes use cold packs to reduce swelling and pain.

Check your learning 8.3

Remember and understand

1 Classify the following as exothermic or endothermic processes. Explain your answers.
   a A candle burning
   b Ice changing to water
   c A cake baking

2 Give three examples of exothermic chemical reactions.

3 Complete the following sentences.
   During an exothermic reaction, the temperature of the surroundings ___________. The energy of the products is ___________ than the energy of the reactants. An example of an endothermic reaction is ___________.

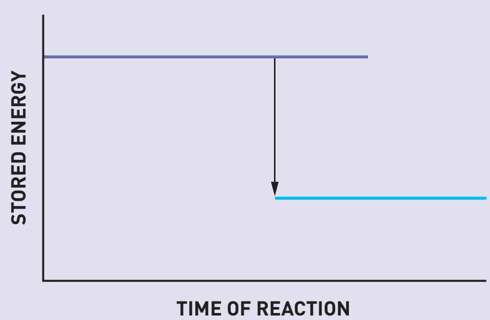
4 How do heat packs help athletes?

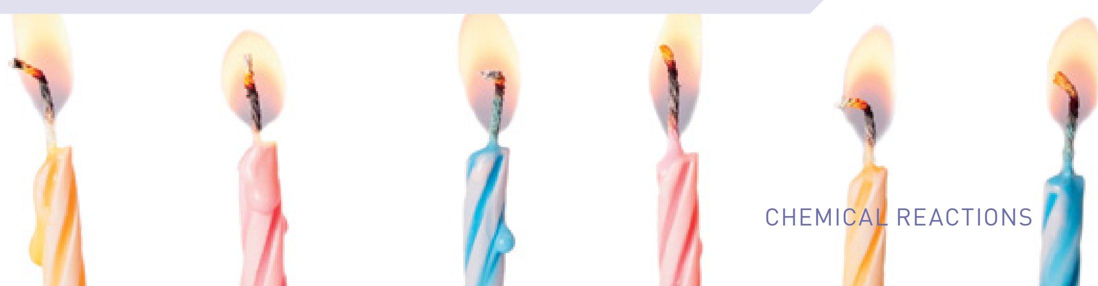
Apply and analyse

5 What happens to the thermal kinetic energy of the surrounding molecules during an exothermic reaction?

6 Figure 8.7 shows the energy changes of a chemical reaction. From the graph, determine if the reaction is an endothermic or exothermic reaction.

Figure 8.7





8.4 Acids have a low pH. Bases have a high pH

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 base (more than 7). An indicator is used to determine the pH of a solution.

Figure 8.8 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 contact skin. All acids contain at least one hydrogen atom. They tend to react with many metals.

Acids can be strong or weak. Strong acids are dangerous because they can burn through objects. Weak acids are much safer and we can eat and drink some of them. Acid also acts as a preservative by preventing the growth of microorganisms.

Bases

Bases can be described as the 'chemical opposite' of acids. They are bitter 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 8.2 Examples of common acids and bases

STRONG ACIDS	STRONG BASES
Hydrochloric acid, HCl	Sodium hydroxide, $NaOH$
Nitric acid, HNO_3	Potassium hydroxide, KOH
Sulfuric acid, H_2SO_4	Barium hydroxide, $Ba(OH)_2$

WEAK ACIDS	WEAK BASES
Ethanoic acid, CH_3COOH	Ammonia, NH_3
Carbonic acid, H_2CO_3	Sodium carbonate, Na_2CO_3
Phosphoric acid, H_3PO_4	Calcium carbonate, $CaCO_3$

Figure 8.9 Many cleaning products are alkaline solutions.

CHALLENGE 8.4: TESTING WITH PH PAPER
GO TO PAGE 224.

EXPERIMENT 8.4: WHAT IF PLANTS WERE USED TO CREATE AN INDICATOR?
GO TO PAGE 225.

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 plants are examples of these substances.

In the laboratory, scientists use **litmus paper** and **universal indicator** as indicators. Litmus paper is the most commonly used 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 a more accurate indicator because it indicates the strength of the acidic or the basic solution that it is testing.

pH scale

The **pH scale** describes the relative acidity or alkalinity of a solution. 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.

Acidic solutions have pH values of less than 7. The stronger the acid in a solution, the lower the pH of the solution will be. A pH of 1 or less indicates a very acidic solution.

Alkalis have pH values greater than 7. Strong bases, such as caustic soda (sodium hydroxide), can form solutions with a pH of up to 14.

Figure 8.10 Some vegetables, such as red cabbage, can be used to make pH indicators.

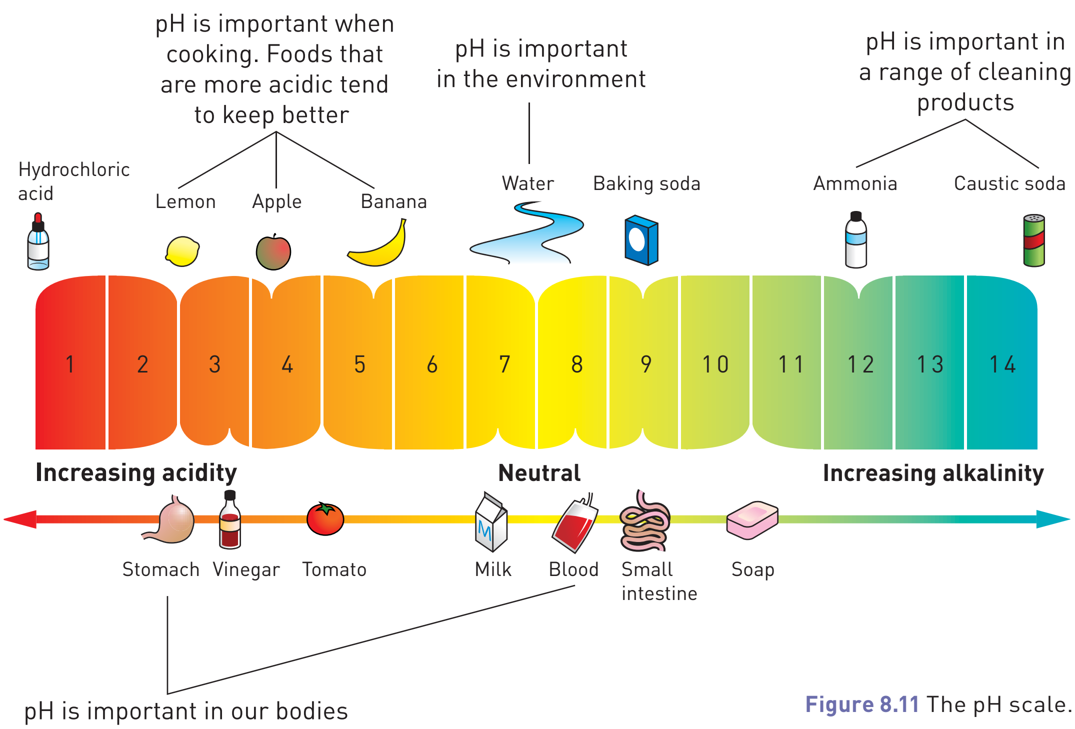


Figure 8.11 The pH scale.

Check your learning 8.4

Remember and understand

1 List the main properties of acids.

2 List the main properties of bases.

3 What pH would indicate a strong base? What about a strong acid?

4 What type of substance would have a pH of 7?

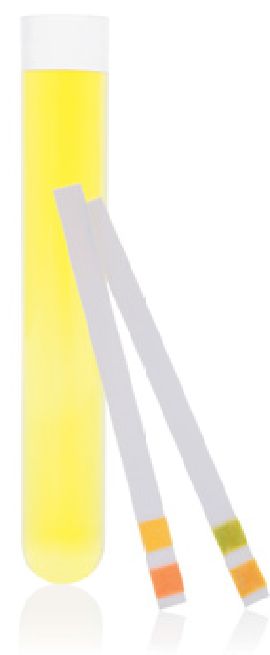
5 What colour is litmus paper in a solution of:

a an acid?

b a base?

Apply and analyse

6 What is the difference between a strong acid and a concentrated acid?



8.5 Acids can neutralise bases

When acids and bases react, they produce water and a salt. This is called neutralisation. If the base contains carbonate (for example, sodium bicarbonate), then carbon dioxide is also produced. The increasing level of carbon dioxide in the atmosphere is causing the ocean to become acidic. This is reacting with the calcium carbonate in the shells of sea creatures.

Reactions of acids

There are certain reactions that all acids have 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. Also, you can use them to predict the products of a reaction if you know the reactants being used.

Acids reacting with bases

When acids and bases react, they neutralise each other to form substances called **salts**. This is not the salt you will find on your dinner table. A chemical salt is a molecule that contains a metal cation (positive ion) and a non-metal anion (negative ion). Water is also produced in this reaction. This type of reaction is called a **neutralisation reaction**:

acid + base → salt + water

Different acids will produce different salts in neutralisation reactions. For example, citric acid will produce salts called citrates, and sulfuric acid will produce salts called sulfates.

For example, when hydrochloric acid reacts with sodium hydroxide, the salt sodium chloride (which is common table salt) and water are produced. The word equation is:

sodium hydroxide + hydrochloric acid → sodium chloride + water

The chemical equation is:

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Acids reacting with metal carbonates or bicarbonates

When an acidic solution reacts with a metal carbonate or bicarbonate, a salt, carbon dioxide and water are produced. The general reaction is:

metal carbonate + acid → salt + carbon dioxide + water

For example, the reaction of citric acid ($C_6H_8O_7$) with sodium bicarbonate ($NaHCO_3$) is used in sherbet to produce carbon dioxide. This causes the fizzy sensation in your mouth.

Acidic oceans and coral carbonates

Rising carbon dioxide levels in the atmosphere have caused the oceans to become acidic. Our oceans are a major carbon 'sink' and absorb much of the carbon dioxide (CO_2) in the atmosphere. Before the Industrial Revolution, the oceans were in equilibrium with the atmosphere, absorbing as much carbon dioxide as they released. When carbon dioxide dissolves in water, it forms carbonic acid (H_2CO_3).

Carbon dioxide levels have increased in our atmosphere due to large-scale burning of fossil fuels and industrial processes in which carbon dioxide is produced (for example, the production of steel, aluminium and cement).

EXPERIMENT 8.5: NEUTRALISATION REACTIONS
GO TO PAGE 226.

CHALLENGE 8.5: MAKING SHERBET
GO TO PAGE 226.

Figure 8.12 Coral reefs are made of the weak base calcium carbonate, which dissolves in acid.

The oceans have responded by absorbing more carbon dioxide, thus increasing their acidity. Scientists estimate that the oceans now absorb 30 million tonnes of carbon dioxide every day.

As the oceans become increasingly acidic, the effect on marine ecosystems is devastating.

Coral reef ecosystems rival rainforests in the huge diversity of species present. They also help protect coastlines from erosion. But coral reefs across the world are now struggling. One problem is that the coral itself is built from calcium carbonate ($CaCO_3$), which is a weak base. This reacts with the weakly acidic water, causing the calcium carbonate to slowly neutralise and crumble away. This affects the ability of molluscs, such as sea snails, to produce adequate protective shells. The lower pH of the water affects many species of marine organisms that reproduce by ejecting their sperm and eggs into the increasingly acidic water. If the number of successfully fertilised eggs decreases and some of these species die out, this will affect the entire food chain and hence the diversity of species that can survive.

Check your learning 8.5

Remember and understand

1. What are the two products of a neutralisation reaction between an acid and a base?
2. What gas is produced when an acid and a carbonate react?
3. What is the major cause of the increase in acidity of the oceans?
4. As the acidity of the oceans increases, how does the pH change?
5. Write out the chemical equations for two of the reactions you have investigated in this chapter. Count the number of each type of atom on both sides of the equation. What do you notice about the numbers of atoms? Are the equations balanced? What does this tell you about what is happening to atoms in these reactions?

Apply and analyse

6. If the carbon dioxide levels in the atmosphere stopped increasing and became stable, do you think that acidity levels in the oceans would change back to the levels of before the Industrial Revolution? Explain your answer.

8.6 Acids react with metals to produce hydrogen and a salt

*

Acids can react with metals in a predictable way. The products of such a reaction are hydrogen and a salt. We are able to use this reaction to produce decorative metalwork, such as jewellery and belt buckles. Understanding how this reaction occurs also helps us prevent corrosion as a result of acid rain.

Chemical reactions are happening all around us all the time. They affect living and non-living systems, and involve acids and bases, metals, gases – 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

The chemical equation is:

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

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 of this is how decorative metal is used 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.

Disadvantages of acid metal 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 can have a pH of 5 or 6.

Cars, other vehicles, factories and power plants 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 (H_2SO_4) and nitric acids (HNO_3). The result is acid rain. Acid rain can have a pH as low as 3. The stronger the acid, the quicker it reacts with metal.

EXPERIMENT 8.6: WHAT IF THE METAL WAS PROTECTED FROM THE ACID?
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Figure 8.13 Acid rain damage on a limestone statue.

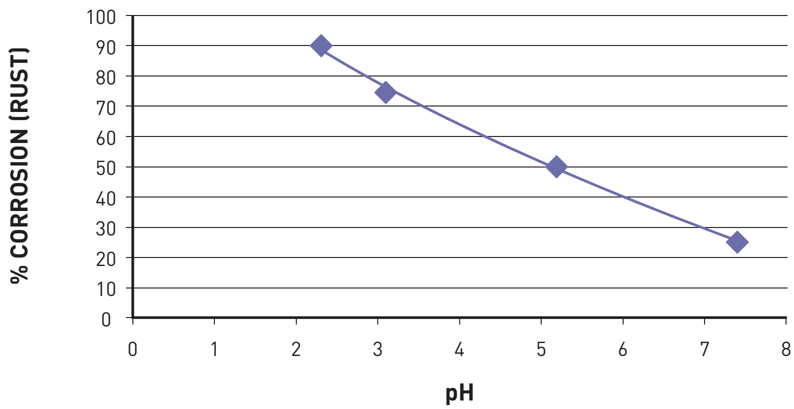

Figure 8.14 Effect of pH on corrosion.

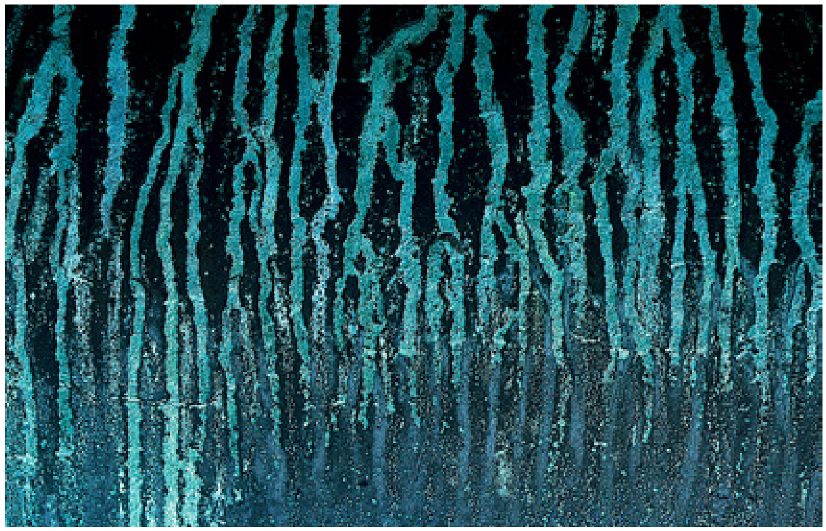

Figure 8.15 Acid rain damage on a roller door.

Acid rain is corrosive to building materials, marble and limestone. Many buildings have metal components that corrode as a result of the acid rain. 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 quicker it is able to cause damage to the metal.

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.

Check your learning 8.6

Remember and understand

1. What are the products of the reaction of an acid and a metal?
2. Write an equation for dilute nitric acid reacting with magnesium metal.
3. What is corrosion?
4. What acid is formed when levels of carbon dioxide in the air increase?

Apply and analyse

5. Would acid rain with a lower pH cause more, less or the same amount of damage on a metal bridge?
6. How could you protect the metal numbers on the front fence of your house from corrosion?

8.7 Oxidation reactions use oxygen to form new products

When an element reacts with oxygen, it is called an oxidation reaction. A metal oxide is formed when a metal is oxidised (undergoes a chemical reaction with oxygen). When a non-metal is oxidised, a molecular compound is formed. If this compound is dissolved in water, it will form an acidic solution.

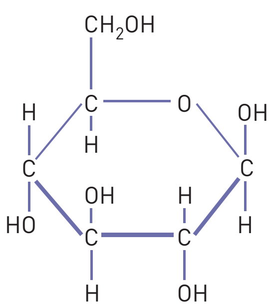

Figure 8.16 Glucose: oxygen reacts with glucose in living systems.

Reactions involving oxygen

Oxygen is one 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% of our atmosphere. It is a key component in many chemical reactions. Any substance that reacts and combines with oxygen is said to be **oxidised**. An **oxidation reaction** is the process of an element combining with oxygen. It is an exothermic reaction.

Figure 8.17 Oxidation of iron forms iron oxide, or rust.

Metals reacting with oxygen

When metal elements react with oxygen, a **metal oxide** is formed:

metal + oxygen → metal oxide

In the case of very reactive metals, this oxidation reaction is rapid and produces a lot of heat. For example, if magnesium metal is briefly exposed to a flame or is heated, it will start to react with the oxygen in the air, producing a brilliant white light (Figure 8.18). Never watch this reaction directly because the light can damage your eyes.

The word equation for this reaction is:

magnesium + oxygen → magnesium oxide

The chemical equation is:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

For moderately reactive metals like iron, the oxidation 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. We see this as the flaky, red-brown rust that forms on the surface of objects. The problem with rust is that it is porous. Liquid water can penetrate

EXPERIMENT 8.7: OXIDATION OF STEEL WOOL
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Figure 8.18 Burning magnesium produces a dangerously white light.

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.

Non-metals reacting with oxygen

Some non-metal elements do react with oxygen, which is also a non-metal. The result is generally a molecular compound. Consider the following reactions:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$
$$C(s) + O_2(g) \rightarrow CO_2(g)$$

Both of these 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.

Carbon dioxide, like the oxides of most non-metals, can dissolve in water. When non-metal oxides dissolve in water, they form acidic solutions, so they are called **acidic oxides**. Other examples of acidic oxides are sulfur dioxide (SO_2) and nitrogen dioxide (NO_2).

Not all elements react with oxygen. Group 18 non-metals are called noble gases because they do not usually react with other elements.

Figure 8.19 Burning coal produces carbon dioxide.

Check your learning 8.7

Remember and understand

1 Carbon dioxide (CO_2) and sulfur dioxide (SO_2) are both acidic oxides. What do you think the 'di' in their names relates to?

2 Which group of elements does not react with oxygen?

3 What is an oxidation reaction?

4 What is rust? How does the presence of rust suggest a metal object is weakened?

Apply and analyse

5 When carbon dioxide reacts with water, the product is carbonic acid (H_2CO_3), which is a weak acid.
   a Write a word equation for this reaction.
   b Write the chemical equation for the reaction.
   c Estimate the pH of a solution of carbonic acid.

8.8 Combustion reactions need fuel and oxygen to produce carbon dioxide and water

Combustion (or burning) is a chemical reaction in which a fuel reacts with oxygen to produce a large amount of heat very quickly. The products of this reaction are usually carbon dioxide and water. Hydrocarbons are one of the most common fuels used to produce energy in generators, engines and motors.

Figure 8.20 Oxygen takes part in combustion reactions.

When you see something burn, you are witnessing a substance reacting with oxygen in a chemical reaction. The amount of energy released 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. Chemists classify these as combustion reactions.

What happens when fuels burn?

In science, a **fuel** is a substance that will undergo a chemical reaction in which a large amount of useful energy is produced at a fast but controllable rate. It is an exothermic reaction. We use fuels to produce heat and/or electricity, and to run engines and motors.

When a fuel react in the presence of oxygen, it is called a combustion reaction. These reactions produce carbon dioxide and water.

fuel + oxygen → carbon dioxide + water

Hydrocarbons contain the elements hydrogen and carbon. When hydrocarbons burn in unlimited air, carbon dioxide and water are produced.

hydrocarbon + excess oxygen → carbon dioxide + water

When the air supply is more limited, which occurs when the combustion occurs in a confined space, carbon monoxide can be produced:

hydrocarbon + limited oxygen → carbon monoxide + water

Writing equations for the combustion of hydrocarbons

When hydrocarbons burn in excess air (and hence excess oxygen), they produce carbon dioxide and water. Consider the combustion of the simplest hydrocarbon, methane (CH_4). The chemical structure of the methane molecule can be represented as shown in Figure 8.21.

The combustion of methane can be described using a word equation:

methane + oxygen → carbon dioxide + water

The balanced chemical equation for this reaction is:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

For more complex hydrocarbons, balancing the equation can be more difficult. However, there is a systematic procedure you can use to make this easier.

Let us consider propane, which has the formula C_3H_8. Propane can be represented as shown in Figure 8.22.

CHALLENGE 8.8: COMBUSTION AND CANDLES
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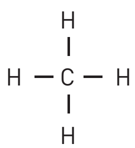


Figure 8.21 Methane (CH_4)

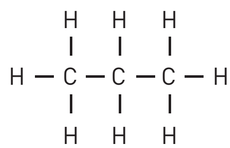


Figure 8.22 Propane (C_3H_8)

1 Write the word equation:

propane + oxygen → carbon dioxide + water

2 Write the correct formulas of the reactants and products:

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

3 Balance the carbon atoms – make sure the number of carbon atoms on the right is the same as on the left. There are 3 carbon atoms on the left, so we must have 3 on the right:

$$C_3H_8 + O_2 \rightarrow \mathbf{3}CO_2 + H_2O$$

4 Balance the hydrogen atoms. There are 8 hydrogen atoms on the left, so there must be 8 on the right. But two at a time are used to make H_2O, so we must produce half that number of water molecules (4):

$$C_3H_8 + O_2 \rightarrow 3CO_2 + \mathbf{4}H_2O$$

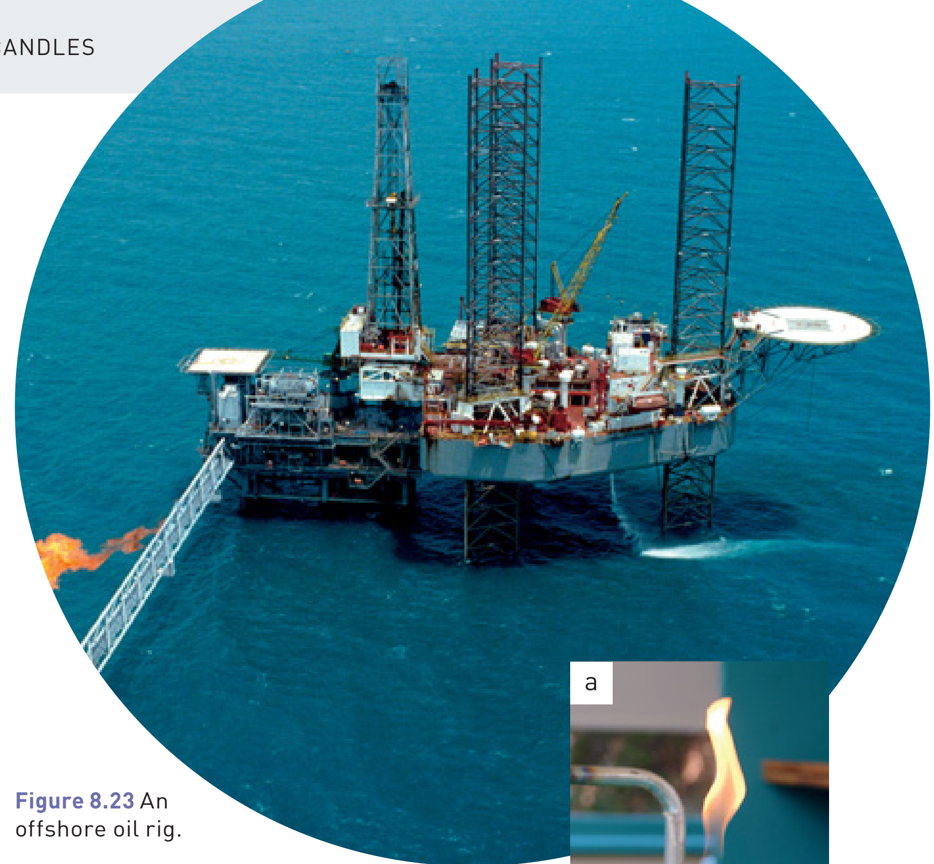


Figure 8.23 An offshore oil rig.

5 Balance oxygen atoms. This is tricky, because both products contain oxygen atoms. First, count how many are on the right. There are 6 + 4 = 10 oxygen atoms. So we must have 10 oxygen atoms on the left. As two at a time are used in the O_2 molecule, we must halve that number; that is, 5 oxygen molecules:

$$C_3H_8 + \mathbf{5}O_2 \rightarrow 3CO_2 + 4H_2O$$

When you are used to writing these equations, you will be able to do steps 2–5 along one line.

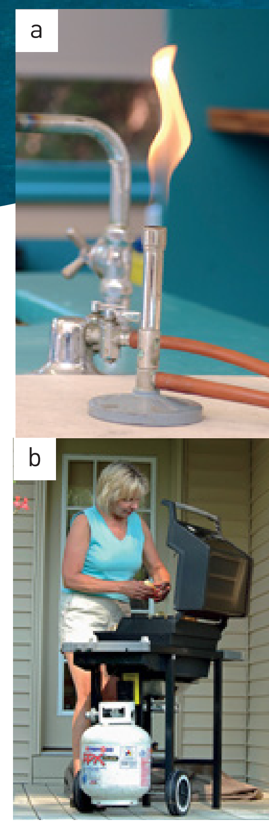


Figure 8.24 (a) Bunsen burners use natural gas, which is mainly methane. (b) Propane gas is one of the components of LPG, used in household barbecues.

Check your learning 8.8

Remember and understand

1 What gas is essential for combustion reactions?

2 What two elements are present in hydrocarbons?

3 Butane gas (C_4H_{10}) has many uses. Set out the steps for writing a balanced equation for the combustion of butane in excess air.

4 What is the main hydrocarbon that is burnt in natural gas?

Apply and analyse

5 The following equations are not balanced. Rewrite them correctly.

a $C_4H_8 + 6O_2 \rightarrow 4CO_2 + 3H_2O$

b $C_5H_{12} + 5O_2 \rightarrow 5CO_2 + 6H_2$

6 The fuels used in cars, trucks and buses are generally liquefied petroleum gas (LPG), petrol or diesel. These fuels are mainly hydrocarbons.

a What are the two main substances present in their exhaust gases?

b Explain why scientists are warning that excessive use of these vehicles is contributing to the enhanced greenhouse effect.

//SCIENCE AS A HUMAN ENDEAVOUR//

8.9 Fuels are essential to Australian society

The combustion of fuels has become an essential part of Australian society. However, there are consequences that come with our reliance on fuels. Increasingly, scientists are improving technology to improve the efficiency and decrease the effect of combustion on our environment.

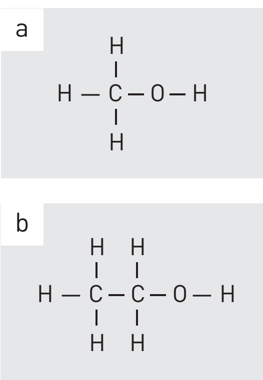


Figure 8.25 Chemical structures of (a) methanol and (b) ethanol.

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 very controlled. Examples of fuels we typically use in vehicles, aircraft and generators are petrol, diesel and kerosene.

If you have a gas stove and 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.

Alcohols and biofuels

In Australia, drivers can purchase petrol that contains a certain percentage of alcohol. Oil companies are allowed to include up to 10% ethanol, which is the

Figure 8.26 Large areas of Amazonian rainforest are being turned over to the production of soybeans for biofuel.

most common form of alcohol. Alcohols are an entire family of compounds that contain carbon, hydrogen and oxygen. The two simplest members of this family are methanol (CH_3OH) and ethanol (C_2H_5OH). Their formulas are written in this way to show how the atoms are bonded. Look at Figure 8.25 and see if you can work out the system used for writing their formulas. In this diagram, the atoms are represented by the chemical symbols and the lines represent chemical bonds.

Methanol blends have been used in racing cars for many years. 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 they fulfil the requirements of a fuel. The equation for the combustion of ethanol is:

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) + \text{energy}$$

Disadvantages of biofuels

Research by Oxfam in 2008, suggests that forcing the use of biofuels 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 that help remove carbon dioxide from the atmosphere. Although the growth of the biofuel crops will temporarily absorb carbon dioxide as they grow, their combustion will ultimately release the carbon dioxide back into the atmosphere.

Also, the use of agricultural lands to grow the biofuel crops will prevent the use of land for food production. This means the amount of food will be limited, driving up costs and contributing to food insecurity, hunger and inflation, which will hit poor people hardest.

Another reason is that alcohols burn more 'cleanly'. The greater the percentage of alcohol present, the lower the amount of pollutants produced. Some alcohols greatly improve engine performance.

Ethanol is used because it is regarded as a more sustainable fuel, because it can be produced by fermenting plant material, even wheat stubble. Its use will help decrease the rate at which we consume the hydrocarbon oils that are obtained from crude oil, a non-renewable resource.

Petrol is called a fossil fuel because the crude oil from which it is obtained was produced from ancient organisms, mainly plants, in a slow process that took millions of years. This process occurred with no oxygen. Alcohols such as ethanol are biofuels because they come from plant material that has only been recently grown. There is much debate about the long-term use of biofuels because the land required to grow plants cannot then be used to grow food crops.

Extend your understanding 8.9

1 Classify each of the following fuels as a hydrocarbon, an alcohol or neither.

   a aC_4H_{10}

   b bC_2H_4

   c CH_2

   d dC_3H_7OH

2 For each substance in question 1, conduct some research to discover the name and a common use of the fuel.

3 Give two reasons why many people are now using ethanol blends in their cars.

4 Petrol and ethanol were originally derived from living plant material. However, only ethanol is described as a biofuel. Explain why this is.

5 'The benefits of biofuels in Australia are touted as cheaper, cleaner, greener and locally made.' Is this statement true? Are biofuels going to solve our fuel crisis?

Remember and understand

1 What is an acid?

2 Name two acids and two bases.

3 True or false?

a Reactants are the substances made in chemical reactions.

b Oxygen is a fuel.

c Bushfires are endothermic reactions.

d Hydrocarbons require oxygen to burn.

e Sulfur dioxide will dissolve in water to form an alkali.

4 Give the names of the products when methane burns in an excess supply of oxygen.

5 Write the chemical formula of:

a carbon dioxide

b carbon monoxide.

6 Many lollies are deliberately made sour. Would a weak acid or base be added to the lollies in order to achieve this taste?

7 In an exothermic reaction, the products contain less stored energy than the reactants. What has happened to this energy during the reaction?

8 Give the names of the products when methane burns in an excess supply of oxygen.

9 Explain the advantages and disadvantages of using alcohol instead of petrol in cars.

10 Name and give the formula of two gases that contribute to the formation of acid rain.

11 What is a biofuel?

12 How many atoms of carbon, hydrogen and oxygen are present in a molecule of ethanol (CH_3CH_2OH)?

Apply and analyse

13 Consider the following equation:

potassium hydroxide + sulfuric acid
→ potassium sulfate + water

a Name the reactants and the products in this reaction.

b What type of reaction is this?

c What could you add to the reaction mixture to show whether all of the acid has been used up in the reaction?

14 A student told another student that they should never drink orange juice because it contains acid. Draft a response to this comment.

15 Belinda was asked to give an example of an endothermic reaction. She said that a burning candle was an endothermic reaction because she had to use heat energy from a burning match to set light to the candle. Do you think she was right? Explain your reasons.

16 Carbon dioxide (CO_2) is produced when hydrocarbons burn in oxygen. Suggest why carbon monoxide (CO) can be produced when the supply of oxygen to the fuel is reduced.

Evaluate and create

17 Do you think the process occurring in cold packs is a chemical or physical change? Explain.

18 Carry out a PNI ('positive', 'negative', 'interesting') analysis on the effect of acids on our lives.

19 Prepare a poster on the use of ethanol as a fuel. What are the advantages and disadvantages of using ethanol in this way? Include any relevant diagrams or images.

20 Consider two changes that occur as the following chemicals interact with each other.

> Carbon in brown coal reacts with oxygen in the air to form carbon dioxide.

> The carbon dioxide dissolves in water (containing universal indicator) to form a solution of carbonic acid (H_2CO_3).

For each change describe the reaction in terms of:

a the expected observations

b a word equation

c a chemical equation.

21 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 will occur in this process. Include the exothermic processes that produce the heat for the oven and the endothermic processes within the food itself. You may need to carry out some additional research to answer this question.

Research

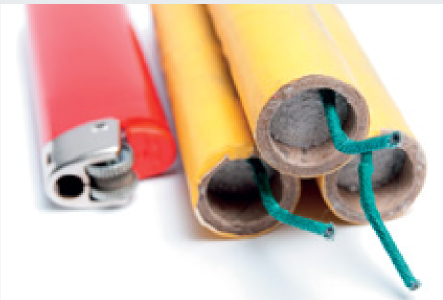
22 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

> **Phosphoric acid**

Phosphoric acid has a wide variety of uses – as a fertiliser, rust remover and food additive. It is even an ingredient of cola drinks. Find out how it is produced and more about its uses.

> **pH of blood**

If the pH of our blood is loo low or too high, we can become seriously ill. Find out the name given to the conditions in which the pH of blood becomes too low or too high and the effects of these conditions.



> **Explosives**

The history of the development of explosives is fascinating. Who discovered them? When were explosives first used and how do they work? What are the main chemicals used and what types are there? What part did Alfred Nobel play?

> **Carbon footprints**

What is meant by the phrase 'carbon footprint'? What chemical reactions contribute to an increase in carbon dioxide in the atmosphere? What other gases contribute to the enhanced greenhouse effect? How are carbon footprints measured? What is meant by the phrase 'carbon offset'?

*KEY WORDS

8

acidic oxide
a non-metal oxide that forms an acid when dissolved in water

alkali
a base that dissolves in water

alkaline solution
a solution that contains a base

chemical bond
a bond that forms between the atoms in a molecule

corrosion
the gradual destruction of materials by a chemical reaction with their environment

endothermic reaction
a chemical reaction that absorbs energy in the form of heat

exothermic reaction
a chemical reaction that releases energy in the form of heat or light

fuel
a substance that undergoes a chemical reaction that produces large amounts of energy

hydrocarbon
a molecule that contains hydrogen and carbon atoms

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

metal oxide
a molecule containing a metal and oxygen

neutral
(pH 7) neither an acid nor a base; for example, water

neutralisation reaction
a reaction between an acid and a base that produces water and a salt

oxidation reaction
a chemical reaction in which an element combines with oxygen

oxidised
when oxygen has been added to an element

pH scale
a scale that represents the acidity or basicity of a solution; pH < 7 indicates an acid; pH > 7 indicates a base; pH 7 indicates a neutral solution

product
a substance formed as a result of a chemical reaction

reactant
a substance present at the start of a chemical reaction; also called substrate

salt
a compound that contains a metal cation and a non-metal anion

solution
a mixture of a solute dissolved in a solvent

universal indicator
a solution that is used to determine the pH (amount of acid or base) of a solution

EXPERIMENTS

9

1.1
EXPERIMENT

What if the absorbency of different paper towels was compared?

Aim

To measure and compare the absorbency of different brands of paper towel, which vary in the 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 the paper towel.
2. Record the brand, price, number of sheets and their dimensions.
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, and 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 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.

- What brands of paper towel will you test?
- What is your independent variable?
- Name three variables you will need to keep the same as the first method.
- How will you measure if a paper towel is more absorbent?
- Predict what results you might expect.
- What equipment will you need to complete this experiment?
- Write down the method you will use to complete your investigation.
- What sort of table will you need to draw to show your results?

Results

- Calculate the total surface area and the cost per square centimetre for each paper towel, and record your results in a table.
- The total surface area of the paper towel roll is calculated as follows:

$$A = l \times w \times \text{number of sheets of paper towel}$$

- 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 a 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.
- Place the brands in order from the least expensive the most expensive. On each bar, state the price per square centimetre of that brand.

Discussion

1. Do the brands with the highest and lowest absorbency coincide with the predictions you made in your hypothesis?
2. 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.
3. Comment on how reliable and fair the design of this experiment was.
4. Is it reasonable to conclude that one brand of paper is more absorbent than another just on the basis of tests with water? Give reasons for your answer.

Conclusion

From your graph, was there any apparent relationship between the cost of the paper towel per square centimetre and its absorbency? Provide evidence from your results to support your answer.

1.2
CHALLENGE

Avoiding errors and improving accuracy

What you need

- Ruler
- Electronic scales
- Item from pencil case
- Analogue clock

What to do

1 Measure the following line.

---

2 Compare your answer to the person's next to you. Did you both get exactly the same value? What could be some reasons for any difference in your answers?

3 a Use the electronic scales to measure the mass of an item from your pencil case (such as a pen). Make four measurements. Are the measurements that same? Why might they be slightly different?

b Find the average of your measurements. How does the average compare with the individual measurements? Is it more accurate? Explain your answer.

4 Working in groups of three, read the time on a 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 at the right of the first person at an acute angle. Each person should read the clock and note the time.

a Are the times the same for all three people?
b What type of error is this?
c How could this type of error be avoided?

2.1
CHALLENGE

Making a biosphere

What you need

- Pond water containing macro-invertebrates (for example, water fleas, pond snails)
- Aquatic plants
- Mud or sand from a pond
- Large glass jar with a lid
- Electronic balance

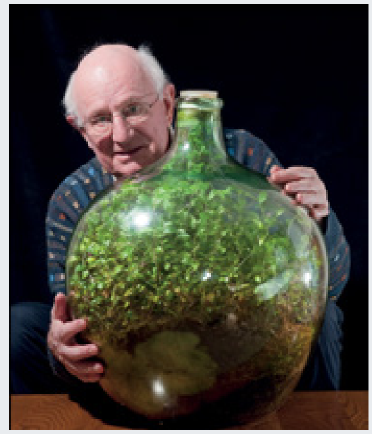


Figure 9.1 This biosphere has only been watered once in 53 years.

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 some 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 Reweigh your jar and contents when you have finished the experiment.

Discussion

1 How did the weight of your jar and contents change over time? Explain what might have caused this change.

2 Plants are important in a biosphere because they make oxygen and sugar from carbon dioxide, water and sunlight. What is this process called?

3 Animals consume sugar and oxygen to produce carbon dioxide. What is this process known as?

4 Research other homemade biospheres on the Internet and suggest some improvements you could make to the design of your experiment.

2.1 EXPERIMENT

Purification of water

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
- 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 established themselves in the pot before proceeding with this experiment.

1 Prepare two plastic pots: one with just gravel; the other with gravel then sand and finally a layer of dirt. You should now have three pots, as in Figure 9.2.

2 Mix the castor oil, dirt, small pieces of paper, water, salt and any other materials you wish to include into a bucket of water. The mixture should be very cloudy and have an odour.

3 Pour an equal amount of the mixture through each of the three pots and collect the solution that filters out of the base of each pot. Time the rate of flow of solution out of the base of each pot.

Results

Record the time it took for the water to drain through the pots.

Record your observations of the odour and quality of the drained water.

Discussion

1 Suggest a reason for any differences you observed between the flow rate of drained water
   b the cloudiness of the drained water
   c the odour of the drained water.

Conclusion

What affect does the different soil type and the presence of native grasses have on the quality of water available?

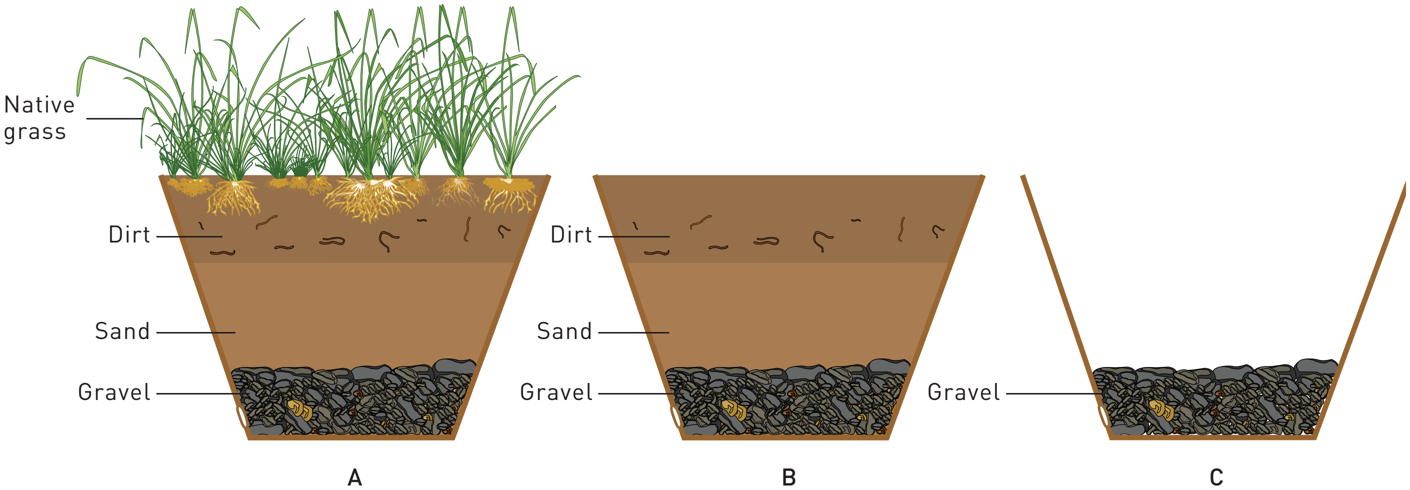


Figure 9.2 Experimental set-up.

2.2
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

What if more seeds were planted in a pot?

Method

1. Prepare the plots (or pots) so the soil is moderately deep and smooth. Label them plot 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.

1. What (independent variable) are you changing from plot A?
2. Name three variables you will need to keep the same as plot A.
3. How will you measure if the growth of the seedlings was affected?
4. Predict which seedlings will grow the best.
5. What equipment will you need to complete this experiment?
6. Write down the method you will use to complete your investigation.
7. What sort of table will you need to draw to show your results?

(Show your teacher your planning for approval.)

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. What would be your advice to another student who wants to perform the experiment?
2. Was there evidence of competition between the seeds as they germinated? Explain using evidence from your results.
3. Are there other factors that might affect the growth of seeds?
4. Have you previously observed competition between organisms in the natural environment? If so, describe it.

Conclusion

Write a conclusion regarding the factors that affect competition between germinating seeds.

Figure 9.3 What affects the growth of seeds?

2.3
CHALLENGE

Delicious counting

What you need

- Smarties®
- M&M's®
- Paper bag
- A4 graph paper
- Pencil
- Ruler

What to do

PART A: CAPTURE–RECAPTURE

CAUTION: DO NOT EAT IN THE LABORATORY. THIS EXPERIMENT SHOULD BE DONE IN A CLASSROOM OR CANTEEN/CAFÉ IF THE LOLLIES WILL BE CONSUMED.

1 Place a random number of Smarties in a paper bag.
2 Draw 10 Smarties out of the bag and replace them with 10 M&M's. This is equivalent to tagging the Smarties and releasing them.
3 Mix the lollies in the bag and draw another 10 out of the bag. Count the number of M&M's you collected in the 'recapture'.
4 Use the formula to determine how many lollies are in the bag.

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

Where N_1 is the number of Smarties drawn out the first time (10), N_2 is the number of lollies caught the second time (10) and M_2 is the number of M&M's that were drawn out during the second draw.

5 Count the number of lollies that were actually in the paper bag.

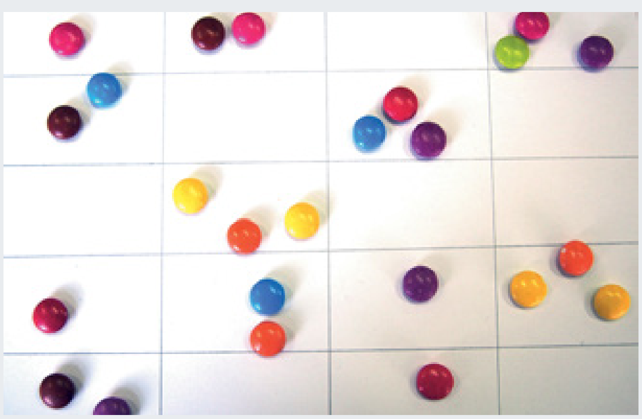


Figure 9.4 Counting the number of Smartie insects.

PART B: QUADRATS

1 Divide the graph paper into 20 equal-sized squares.
2 Spread a large handful of Smarties over the graph paper. These represent insects in an ecosystem.
3 Count the number of 'Smartie insects' found in 4 of the squares. Include the Smarties that are on the top lines and left lines of the squares. Do not include the smarties that are resting on the bottom lines and right lines of the squares. Divide the number counted by 4 to determine the average number of Smartie insects in each square.
4 Multiply the number of 'Smartie insects' found in each square by 20 to determine the size of the population in the ecosystem.
5 Count the number of Smarties that were actually spread over the graph paper.

Discussion

1 What populations would you use the following methods to determine their size?
  a capture–recapture
  b quadrats
2 How accurate was the capture–recapture method in determine population size? Provide evidence to support your answer.
3 Would animals that had already been caught be more or less like to be recaptured? Provide a reason for your answer.
4 How accurate was the quadrat method for determining the population size? Provide evidence to support your answer.
5 How large would a quadrat have to be to measure a population of full-grown trees?

Rabbit and fox chasey

What you need

- Large packets of popcorn
- Material for rabbit tails
- Outdoor space
- Container

What to do

PART A: RABBIT POPULATIONS

1. Measure a 30-metre section 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. 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 cross the area, again collecting popcorn as they cross. 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 the following table. Highlight the seasons that are droughts (poor food supplies) and bumper years (good food supplies).

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 his or her belt (similar to flag football).
2. Record your data for six seasons in the table.

Discussion

1. Graph the results of the simulation as a bar graph showing the number of each animal at the end of a time period.
2. Write a description of the simulation, explaining the effect of
   a. increased food supplies
   b. decreased food supplies
   c. competition on predator populations.
3. Explain what characteristics in a population help some animals survive.

Populations of rabbits over many seasons

	SEASON 1	SEASON 2	SEASON 3	SEASON 4	SEASON 5	SEASON 6
Number of rabbits at end of season						

Populations of rabbits and foxes over many seasons

	SEASON 1	SEASON 2	SEASON 3	SEASON 4	SEASON 5	SEASON 6
Number of rabbits at end of season						
Number of foxes at end of season						

2.5 CHALLENGE

Photosynthesis role play

This is a group activity.

What you need

- Balloons (6 black, 12 white, 18 red)
- Torch

What to do

1. Work in groups of 9: 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.

Figure 9.5

Discussion

1. Explain why photosynthesis is a 'synthesis' reaction.
2. Trace the entry of energy and the final location of the energy in a food chain.
3. The energy in the Sun can be considered to be 'disordered', but it is then 'ordered' in the form of glucose and ATP. Explain what you think this means.

2.5A EXPERIMENT

Inputs and outputs of photosynthesis

Aim

To examine the role of carbon dioxide in photosynthesis

Materials

- Bromothymol blue solution
- 4 test tubes with rubber stoppers
- *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. Use the straw to gently blow into each test tube. The colour of the solutions should change from blue to yellow. This indicates that carbon dioxide from your breath has been added to the water.
3. Label the test tubes A, B, C and D. Prepare them as follows.

TEST TUBE	SET-UP
A	Place the paper clip 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 paper clip 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 cupboard for 20 minutes. Record any colour changes. Count any bubbles that may have formed on the *Elodea* plants.

Results

Record all your observations in a table.

Discussion

1. What caused the bromothymol blue to change from blue to yellow?
2. What would happen to the bromothymol blue if the carbon dioxide was removed from the water?
3. In which test tube would you expect photosynthesis to occur? Explain your answer.
4. In which test tubes would you expect no changes in the colour to occur? Explain your answer.
5. Did your results correlate with your predictions? Use evidence from your results to support your answer.
6. You may have observed bubbles forming around the *Elodea* leaves in test tube A. What gas would you expect this to be?
7. Name one variable that was difficult to control in this experiment. How could you control this better next time?

Conclusion

What are the reactants (inputs) and products (outputs) of photosynthesis?

2.5B
EXPERIMENT

Effect of carbon dioxide on starch production

Aim
To find out how the concentration of carbon dioxide affects the amount of starch produced in leaves grown under different conditions

Materials
- 3 soft-leaved plants (for example, 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
- Tongs
- Timer
- Paper towel
- Felt-tipped pen

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. RINSE YOUR HANDS IMMEDIATELY IF YOU GET SODA LIME ON YOUR SKIN.

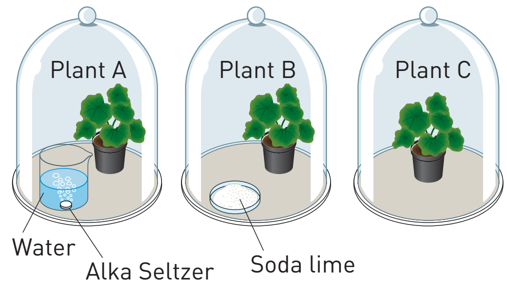


Figure 9.6 Experimental set-up.

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 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.

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. Remove the 250 mL beakers from the pot using the tongs.

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.

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 over a light source (e.g. light box) and describe the iodine solution's colour change on each leaf. Draw each leaf to show the colour of the iodine solution.

Results
Include your observations and diagrams in an appropriate format.

Discussion
1 Which plant was the control? Give reasons for your answer.

2 Which plant had the least carbon dioxide gas available?

3 Which plant had the most carbon dioxide available?

4 Was there a difference in the amount of starch that was produced under the different conditions? Describe any differences.

5 Explain why a positive test for starch indicates that photosynthesis has occurred.

Conclusion
What evidence is there that carbon dioxide is necessary for photosynthesis? What effect does increasing or decreasing the amount of carbon dioxide have on photosynthesis?

2.6
CHALLENGE

Food for thought

What you need

- 2 L bottle of coloured water
- 10 mL and 100 mL measuring cylinders
- Plastic cups (4 for each organism)
- Dropper

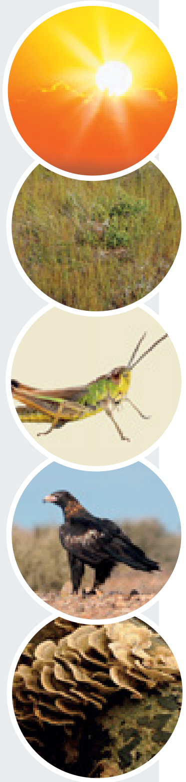


Figure 9.7

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 eaglehawk (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% of the solar energy available to it: 3% of 2000 mL = 60 mL. Measure and pour 60 mL of coloured water into the plant's cup.

5 The herbivore receives 10% of the energy: 10% of 67 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% of this energy: 10% 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% of its energy: 10% of 0.6 mL = 0.06 mL. This can be represented by adding a single drop into the decomposer's cup.

Discussion

1 Which organism would have been 'most satisfied' by the amount of energy/food it received? Which would have been least satisfied?

2 Explain what has happened to the 1940 mL of 'energy' from the Sun that did not pass into the plant.

3 How much 'energy' did the herbivore receive? How was 90% of that used by the insect (cricket)?

4 Which consumer in the food chain will have to find the most food to gain enough energy to survive? Explain your answer.

2.8
CHALLENGE

Natural disasters in Australia

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 9.1

Table 9.1 Some natural disasters in Australia, 1970–2011

YEAR	NATURE OF DISASTER	LOCATION
December 1974	Cyclone Tracy	Darwin, NT
1979	Cyclone Hazel	Carnarvon, WA
February 1983	Ash Wednesday bushfires	Adelaide Hills, SA
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
January–February 2009	Heatwave	South Australia and Victoria
December 2010–January 2011	Flooding	Queensland and Victoria
February 2011	Cyclone Yasi	Queensland

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.

Discussion

1 Were some areas affected by these natural events more than others?

2 Should monsoonal rains have been included in this map? Discuss.

3 Brainstorm some possible effects, both positive and negative, of these events.

4 Does there seem to be any pattern for the alternation of floods and droughts?

Field trip

Figure 9.8 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 9.9 Increased rainfall and open areas allow an undergrowth to develop.

Figure 9.10 Plants that survive in drier areas have unique adaptations such as thin, needle-like leaves.

Figure 9.11 The level of acid in the soil can affect the growth of a plant.

Figure 9.12 Air temperature is an abiotic factor.

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 make a conclusion about how they 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: Dataloggers 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 this 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 the following table for your chosen ecosystem.

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.

Discussion

1 What conclusion can you make about the effects of the abiotic factors that you have measured on the vegetation in this ecosystem?

2 Suggest how this environment may be affected by increased human population in the future.

CAUTION: MAKE SURE IT IS SAFE TO PUT YOUR HAND IN THE WATER.

3.1
CHALLENGE

Testing your senses

PART A: TEMPERATURE RECEPTORS

What you need

- Very warm water
- Room temperature water
- Ice cubes
- 3 ice-cream containers
- Thermometer

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 cold water and the other in the very warm water for 2 minutes.
5. Remove both hands from the cold water and place them in the room temperature water.

Discussion

1. What was the stimulus for the hand in hot water?
2. What change did the hand detect when it moved from the ice water to the room temperature water?
3. Is there a set temperature that acts as a stimulus for your hand?
4. Why do scientists use a thermometer rather than their hands to test the temperature of solutions?

PART B: TOUCH RECEPTORS

You will need:

- 2 toothpicks
- Ruler
- Cork
- Blindfold

What to do

1. Work in pairs. One person puts on the blindfold.
2. Place the toothpicks 50 mm apart in the cork.
3. Carefully use the cork to place the pointed ends of the toothpicks on the blindfolded person's finger. They should indicate whether they feel 'one point' 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 your results in a table.
7. Repeat this procedure for the palm of the hand, back of the hand and forearm.

Discussion

1. Are the 'two point' distances the same on different areas of the skin?
2. Which part of the body was best at detecting when two close points are touching it?
3. Which skin areas do you think have more touch receptors? Use your results to support your answer.

3.2
CHALLENGE

Pipe cleaner neurons

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
- Red felt-tipped pen
- Sticky tape

What to do

1. Roll a pipe cleaner into a ball to make 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. 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.

3.3A

CHALLENGE

How fast is the nervous system?

What you need

> Metre ruler
> Blindfold

Figure 9.13 Testing responses.

What to do

1 Work in pairs. One student holds the ruler between their thumb and forefinger so that the ruler hangs with the zero mark at the bottom. The other student needs to wait with their thumb and forefinger at the bottom of the ruler, level with the zero mark.
2 The first student drops the ruler without warning. The other student 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 the second student's thumb and forefinger on the ruler (Figure 9.13).
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 ear to your brain to your fingers.
7 Blindfold one student to try the experiment using touch. Tap the person on the head when you drop the ruler. Does this make a difference to the reaction distance?
8 Blindfold one student to try the experiment using hearing. Say 'now' when you drop the ruler. Does this make a difference to the reaction distance?

Discussion

1 Which experiment had the fastest results? Why might this be?
2 How could you make sure the results are as accurate as possible?
3 Do you think this is a 'fair test'? Why or why not?

3.3B

CHALLENGE

Testing reflexes

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 pupil.
   > How big are the pupils? Has their size changed?
   > Why do you think this happened?
3 Turn the lights back on. Check the size of your classmate's pupils again.
   > How big are the pupils this time?
   > Why do you think this happened?
   > What other reflexes do you think you could safely test? With a partner, design an experiment of your own. Make sure you write out a full report, including your aim, equipment, method and discussion.

Figure 9.14 Which pupil is in low light and which is in bright light?

3.4
SKILLS LAB

Sheep brain dissection

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)

CAUTION: WEAR YOUR LAB COAT, SAFETY GOGGLES AND PLASTIC GLOVES. BE CAREFUL WITH THE SCALPEL BECAUSE IT IS LIKELY TO BE VERY SHARP.

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. Using the different coloured pins, identify the two hemispheres, the four lobes of the brain, the spinal cord, the cerebellum and the cerebrum. Check this with your teacher before continuing.

2 Turn the brain over. Identify the medulla and pons.

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. Separate the two hemispheres of the brain. Record what you see.

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 what you see at two magnifications. Follow the same procedure with a section of the cerebellum, and then compare and contrast the two.

Discussion

1 Was the sheep's brain similar to a human brain in structure? Why do you think this is so?

2 What does the brain feel like? Was it easy to dissect?

3.6
CHALLENGE

Glands and organs of the endocrine system

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 onto the paper.

2 With your partner, draw in the different glands and organs of the endocrine system. Using the information in Table 3.1 (page 54), 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.

4 Choose one gland or organ to research. Include:
- the hormone it secretes
- what the hormone does
- disorders related to this organ or gland.

3.7
EXPERIMENT

Experiencing homeostasis

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 Do step-ups or star jumps for 2 minutes.

4 Measure your heart rate immediately after stopping exercise.

5 Measure your heart rate every 2 minutes for 10 minutes.

Results

1 Plot the data in a table.

2 Draw a line graph showing how your heart rate varied after exercise.

Discussion

1 What happened to your breathing rate during exercise?

2 Why did your heart rate increase during exercise?

3 Describe what happened to your heart rate during the 10 minutes after exercise.

4 Use homeostasis to explain why your heart rate was different before, during and after exercise.

Conclusion

How does homeostasis ensure your muscles get enough nutrients and remove wastes during exercise?

3.9 CHALLENGE

Investigating pathogens

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 different diseases as you can think of.
2. You now have 2 minutes to predict what sort of organism 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 for the best results. You must use at least two different types of resource.
4. You now have 10 minutes to research the list of diseases to confirm which group of organisms causes the disease.

Discussion

1. How many diseases did you think of? How many of your predictions were correct?
2. What resources did your team use? Which ones were fastest? Find out what resources were the most useful for the other teams.
3. Draw a bar graph showing the number of diseases you listed for each type of organism.
4. Was there an organism that dominated your list? If so, can you think of reasons why you might be more familiar with the causes of some types of disease?

3.9 EXPERIMENT

Investigating germ theory

Aim

To determine what factors affect the growth of airborne microbes

Materials

- Agar plates
- Various disinfectants
- Sticky tape or Parafilm®
- Felt-tipped pen

CAUTION: DO NOT OPEN THE TAPE SEALS.

Method

1. Open the lid of your 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.
3. Leave one agar plate unopened. Seal it with sticky tape.
4. Label each agar plate with the felt-tipped pen.
5. Incubate the agar plate at 35–37°C for approximately 3 days.
6. Examine the plate for any growth.

Inquiry

What if the agar plate was sprayed with a disinfectant before being incubated?

Answer the following questions with regard to your inquiry question.

- What (independent variable) are you changing from the first agar plate?
- Name three variables you will need to keep the same as the first agar plate.
- How will you determine if the disinfectant was effective?
- Write a hypothesis for your experiment.
- What equipment will you need to complete this experiment?
- Write down the method you will use to complete your investigation.
- What sort of table will you need to draw to show your results?

Show your teacher your planning for approval.

Results

Record all your results. You could take photos showing the microbe growth on the agar plates.

Discussion

1. Did all the colonies look the same? Why or why not?
2. Why did you leave one agar plate unopened?
3. Do your results support germ theory? Provide evidence from your results to support your answer.
4. Was your hypothesis supported? Provide evidence from your results to support your answer.

Conclusion

Describe the factors that affect the growth of microbes.

3.10
CHALLENGE

Modelling infection and vaccination

What you need

- 1 M sodium hydroxide
- 0.1 M hydrochloric acid
- Water
- Phenolphthalein indicator
- Plastic cup
- Pipette

What to do

1. Add half a cup of water to each plastic cup.
2. Place all the cups on one table.
3. All students should turn their back while the teacher adds 2 mL of sodium hydroxide to one cup. This represents a student having an infection.
4. Students should then collect their cups and use the pipettes to exchange 3 mL of water with three other people. 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 step 1–5, this time choosing whether or not to become vaccinated. This involves adding 2 mL of hydrochloric acid to your cup of water.
8. Repeat this activity, increasing the number of people vaccinated.

Discussion

1. How many people become infected without vaccination?
2. How many people become infected when a few people were vaccinated?
3. Did it make any difference if more people were vaccinated against the disease? Explain why you think this happened.
4. Can you think of any real-life examples of how vaccination can protect vulnerable members of the community?

4.1
CHALLENGE

Modelling sound waves

What you need

- Slinky spring
- Pipe cleaner

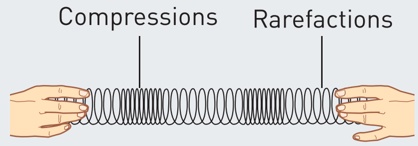


Figure 9.15 Experimental set-up.

What to do

1. Twist a pipe cleaner around a single curl in the slinky spring so that the rest of the spring can move easily.
2. Two people slowly stretch the spring out slightly beyond its normal length along the floor.
3. One person pushes their end of the spring firmly towards the other person. This will create areas where the coils are pushed together (compressions) and areas where the coils are stretched out (rarefactions). These areas will travel along the spring to the other end. The person at the other end needs to hold the spring firmly and still.
4. Try to make the wave have more or less energy by pushing the end harder while keeping the speed of the wave the same. This is the same as making a sound louder. Pushing less models a softer sound.
5. Try to change the frequency (number of waves per second) of your wave. Try to create four waves per second (a higher frequency) and 0.5 waves per second (a lower frequency).
6. Draw labelled diagrams of the waves you created, carefully indicating how the waves show that different frequencies have been achieved.

Discussion

1. How far did the pipe cleaner move as the wave moved along the spring?
2. What happened when the wave reached the other end of the spring?
3. What is this called in real life? Think of what happens to sound waves as they hit a hard surface. What do you hear?
4. What do you notice about how far apart the waves are when they are travelling at the higher frequency?
5. Are the distances between the compressions bigger or smaller at the lower frequency?

4.2A CHALLENGE

The speed of sound

This is a whole class activity.

What you need

- Tape measure or trundle wheel
- Stopwatches
- 'Slap sticks' (or two large sticks that make a sound when hit together)

What to do

1. On the school oval, measure a distance of 100–200 metres.
2. One person takes the slap sticks to the far end of the measured distance. When everyone is ready, slap the sticks together to make a noise.
3. The rest of the class should start their stopwatches when they see the sticks hit together, and stop them when they hear the 'slap'.
4. Repeat this measurement five times.
5. Record your measurements in a table.

Discussion

1. Why did you need to repeat this measurement many times?
2. What was the average amount of time it took for sound to travel the measured distance?
3. Use the formula:

$$\text{Speed} = \frac{\text{distance travelled (m)}}{\text{time (s)}}$$

   to determine the approximate speed of sound.
4. How does your measurement compare to the accepted value of 340 m/s? Explain any differences.

4.2B CHALLENGE

Racing dominoes

What you need

- Large set of dominoes
- Metre ruler

What to do

1. Set up two rows of dominoes 1 metre long on the floor (Figure 9.16). One set of dominoes should be spaced far apart from each other (but still close enough to knock each other over).
2. Use the metre ruler to knock over the first domino of each row at the same time.

Discussion

1. Which row of falling dominoes reached the end first? Suggest a reason for this result.
2. How does the between the space between the dominoes relate to the space between the particles of liquids and gases?
3. Will sound travel faster in gas or liquid? Use evidence from your results to support your answer.

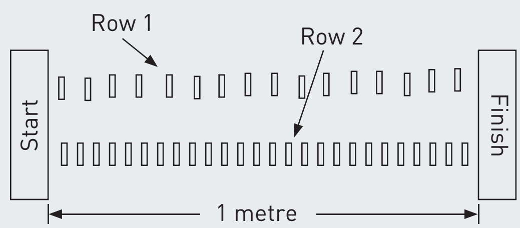


Figure 9.16 Experimental set-up.

4.3 EXPERIMENT

Aim

To investigate why we need two ears

Materials

- Chair
- Blindfold (optional)

Why do we need two ears?

Method

1. Work in groups of three. Allocate one person to be tested, one person to be the tester and one person to be the recorder.
2. The person being tested sits on the chair and closes his or her eyes (or is blindfolded) during the whole test.
3. The tester clicks his or her fingers approximately 1 metre away from the ear of the person seated.
4. The tester makes the clicking sounds and the seated person points to where he or she thinks the sound came from.
5. The recorder writes down whether this is correct.
6. The tester tries a total of 10 different positions, including one from directly above the seated person's head.
7. Record the seated person's score out of 10.
8. Swap roles so that everyone has a turn at each role.
9. Repeat the experiment, with each person covering one ear with the palm of their hand.

Results

Present the results in a table.

Discussion

1. According to your results, which system – two ears or one – is the more accurate way to locate a sound?
2. Were most people's results for two ears more correct when sounds were heard in front of the ear or when sounds came from behind the ear? Why do you think this is so?
3. Was there any difficulty in detecting sounds made directly above your head? If so, why do you think this happens?

Conclusion

Why do we have two ears rather than one?

Figure 9.17 Experimental set-up.

4.4
CHALLENGE

Is school bad for your health?

CAUTION: NEVER EXPOSE YOURSELF TO VERY LOUD NOISE OR YELL INTO SOMEONE'S EAR. WHEN YOU ARE MEASURING LOUD SOUNDS AT YOUR SCHOOL, AND TESTING THE VOLUME OF YOUR CLASSMATE'S YELL, STAND 1 METRE AWAY FROM THE SOURCE OF SOUND.

What you need

- 1 sound level meter per group
- Map of your school
- Metre ruler

What to do

Conduct a survey of the noise levels around your school.

1 Visit your allocated part of the school and measure the sound levels inside rooms and outside. (Make sure someone checks the library.)

2 When outside and far away from any classes, check the loudness levels of the individual voices in your group. First, speak as softly as possible and measure the sound level at 1 metre. Then, measure a loud yell, again at 1 metre distance. Collect these results for each person in the group.

Discussion

1 What was the average sound level of your group for a loud yell?

2 What would you recommend about yelling in someone's ear?

3 Find the average noise level in classrooms. Which rooms were the noisiest?

4 List the loudest and quietest places in your school.

4.5
CHALLENGE

Modelling light waves

What you need

- Slinky spring
- Clear space on the floor

What to do

1 Two people hold the spring, one at each end. On the floor, slowly stretch the spring out slightly beyond its normal length. One person flicks their end of the spring firmly to one side. This will create a sideways 'pulse' in the spring. The other person needs to hold the spring firmly and still. The pulse will travel along the spring to the other end (Figure 9.18).

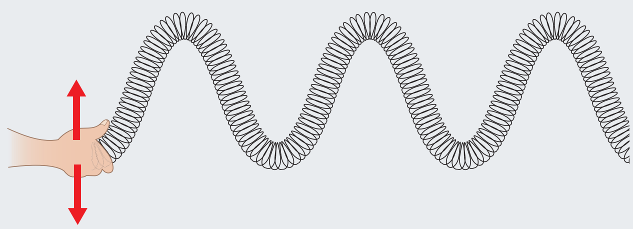


Figure 9.18 Flicking the slinky creates a pulse.

2 Continue flicking the spring to create a continuous transverse wave. Can you see the peaks and troughs of the wave?

3 Make the wave have more or less energy by changing how hard you flick the end. Try to keep the speed of the wave the same.

4 Increase the number of waves per second. You have just modelled a wave of higher frequency.

5 Try to reduce the number of waves. This model represents a lower frequency wave.

6 Draw labelled diagrams of the waves you created, carefully indicating how the waves show that different wavelengths have been achieved.

Discussion

1 What is the link between frequency and the distance between the peaks of the wave?

2 What else in your world behaves as a transverse wave?

Using a Hodson light box

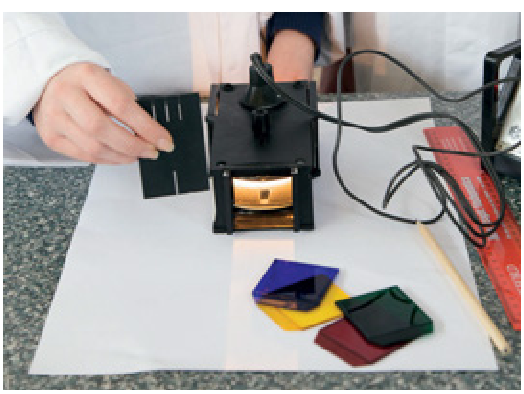
A Hodson light box is often used to experiment with light. This six-step process outlines how to use a Hodson light box.

What to do

1 Place the light box on a piece of white A4 paper.

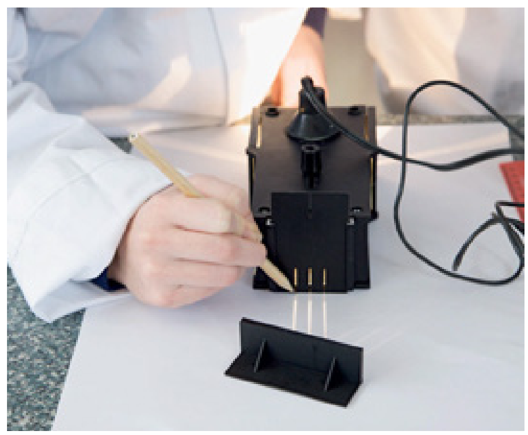
2 Plug the light box into either the AC or DC sockets of a power supply. The voltage dial controls the brightness of the light globe.

3 Slide a slot former into the opposite end of the light box to where the mirror flaps are. Usually a single-slot or a three-slot former is used.



4 Aim the light ray at the target, in this case a plane mirror.

5 Use a sharp pencil to mark the incident and reflected rays with dots.



6 Remove the light box and join the dots with thin, straight pencil lines.

4.6 EXPERIMENT

Reflection from plane mirrors

Aim

To investigate the law of reflection: the angle of incidence equals the angle of reflection

Materials

- Hodson light box kit
- Power supply
- Sheet of white A4 paper
- Plane mirror from light box kit
- Blu Tack
- Ruler
- Pencil
- Protractor

Method

1. Rule a straight line in pencil centrally across the width of the A4 paper. The mirror surface will be placed along this line.
2. Use the protractor to construct a normal line at 90° in the centre of the first line.
3. Position the back edge of the plane mirror along the first pencil line. Keep it in place with Blu Tack.
4. Set up the Hodson light box, darken the room and aim a single incident ray at the centre of the mirror where the normal begins. Mark the position of the incident and reflected rays with pencil dots.
5. Move the light box to a different angle and aim another incident ray so that it hits the mirror at the same place as it did the first time. Mark the rays and repeat until five sets of lines are obtained.

Results

1. Remove the light box and rule lines to show the positions of the incident and reflected rays.
2. Carefully use the protractor to measure the five angles of incidence and the five angles of reflection.
3. Line up the 0° of the protractor along the normal each time and read the angles between the normal and incident rays, and between the normal and reflected rays.
4. Record your results in a suitable table.

Discussion

1. Why was the back edge and not the front edge of the plane mirror lined up on the pencil line?
2. Compare your angles of incidence to your angles of reflection. Are they close to equal?
3. List some sources of error in this experiment.

Conclusion

What do you know about the relationship between the angle of incidence and the angle of reflection?

4.6A CHALLENGE

Mirror writing

What you need

- Large plane mirror
- Logbook/workbook
- Pencil

What to do

1. Hold a large plane mirror in front of your page in your logbook and try to write your name so that it is readable in the mirror. Practise with other words until you get good at this.
2. In some countries, ambulances have their name spelt backwards so drivers can see it in their rear-view mirror. See if you can work out how to write the word 'ambulance' backwards in capital letters so it would read correctly when viewed this way. Have a friend hold the word up behind you and hold the mirror up in front of your eyes.
3. Draw a short maze, then attempt to guide your pen through the maze by only looking in the mirror. A friend may cover the real maze so you are not tempted to look. Just look in the mirror.

Discussion

Which was the hardest of all these activities? Suggest a reason for your answer.

4.6B
CHALLENGE

Using curved mirrors

What do you need

- Convex mirror
- Concave mirror
- Pen
- Hodson light box

What to do

1 Investigate the behaviour of a concave mirror. Place an object, such as a pen tip, close to the mirror and observe the image. Try to describe the nature of the image.
   - Is it upright or inverted (upside down)?
   - Is it larger (magnified) or smaller (reduced) than the object?
   - Is it real (capable of being captured on a screen or piece of paper) or virtual?

2 Move the object further from the mirror and repeat your observations.

3 Repeat step 1 with a concave mirror. It is possible to form a real image with a concave mirror and there is more variation in the nature of the image as the object is moved further from the mirror. Summarise your findings in a table that compares the two types of mirrors.

4 Use the Hodson light box kit to investigate curved mirrors. There should be a convex and concave mirror in the kit. Use the three-slot former in the kit to draw diagrams of the incident and reflect rays for both types of curved mirror.

4.7A
EXPERIMENT

Bending of light

Aim

To investigate the path of light rays during the process of refraction

Materials

- Hodson light box kit
- Power supply
- Sheet of white A4 paper
- Perspex block from light box kit
- Blu Tack
- Ruler
- Pencil
- Protractor

Method

1 Place the Perspex block in the centre of the A4 paper. Trace around the outside of the Perspex block with your pencil.

2 Remove the block and use the protractor to construct a normal at 90° to one of the long sides of the block.

3 Position the block on the paper again. Keep it in place with the Blu Tack.

4 Set up the Hodson light box, darken the room and aim a single incident ray at the face of the block at the normal line. Does the light bend as it enters and then exits the block?

5 Move the light box so that the ray is aimed at the face of the block at an angle of approximately 45°. Mark the position of the incident ray and the ray that exits the block on the other side with pencil dots. Ignore any reflected rays at this time.

6 Remove the block and turn off the light box.

Results

1 Join the end of the incident ray to where it exits the block on the other side. Construct a normal to the face of the block where the ray exits.

2 Use the protractor to measure the four angles on your diagram. Line up the 0° line of the protractor along the normal each time and read the angles between the normal and incident rays and between the normal and the refracted rays. Record your results in two tables for refraction from air to Perspex and refraction from Perspex to air.

Discussion

1 Explain your observation when the incident light travelled along the normal.

2 Compare your angles of incidence to your angles of refraction as the light entered the Perspex block. Explain your observation.

3 Do your results support the rules of light passing from a less dense medium into a denser medium and vice versa? Explain your answers.

4 List some sources of error in this experiment.

Conclusion

What do you know about the path of light rays during the process of refraction?

4.7B EXPERIMENT

Creating images with convex lenses

Aim

To investigate the behaviour of a convex lens and the nature of the image produced at different object–lens distances

Materials

- Hodson light box kit
- Candle
- Matches
- Convex lens
- Lens holder
- Rulers (30 cm, 1 m)
- White paper screen
- Blu Tack

Method

1. Determine the focal length of the lens by placing the lens on a piece of paper and shining three rays of light through it so the light converges into a single focal point. Measure the distance from the centre of the lens to the focal point. This is the focal length *f*. Double the focal length. This is called 2*f*.
2. Light the candle. Mount the lens in the lens holder and check to see if the centre of the lens is in line with the candle flame. If not, raise it to the correct height.
3. Darken the room and position the lens at a distance of more than twice the focal length from the candle flame (the object). Try to capture an image on the paper screen by moving the screen slowly until a focused image of the candle is formed. Describe the size of the image compared to the object (magnified, same size or reduced), the type of image (real or virtual) and the orientation of the image (inverted or upright).
4. Move the lens closer to the candle so that they object–lens distance is between *f* and 2*f*. Repeat your observations.
5. Repeat for the other lens positions in the results table. In some cases, the image may not form on the screen. Instead, it can be found by looking into the lens towards the candle flame. This will be a virtual image. In one case, there may be no image – real or virtual.

Results

Complete the table below.

Discussion

1. When did the lens produce a real image and when did it produce a virtual image?
2. Try to explain any other observations you made or ask your teacher about them.
3. How do your results compare with those of other members of the class?
4. Can you suggest any changes to your method that might have improved your results?

Conclusion

What do you know about the behaviour of a convex lens and the images it produces?

OBJECT–LENS DISTANCE	SIZE OF IMAGE	TYPE OF IMAGE	ORIENTATION OF IMAGE	ANY OTHER OBSERVATIONS
Larger than 2*f*				
Equal to 2*f*				
Between *f* and 2*f*				
Equal to *f*				
Less than *f*				

4.8 EXPERIMENT

What colour is it?

Aim

To investigate the addition of coloured light and explore the behaviour of coloured filters

Materials

- Hodson light box kit
- Power supply
- Sheet of white paper

Method

1 Connect the light box to a power supply and place it on the sheet of paper.

2 Place the three primary filters (red, green and blue) in each of the three separate slotted sections in the light box. Adjust the mirror flaps so that the colours can overlap on the paper. Change the combination of filters and copy and complete the following table.

ADDITION OF PRIMARY COLOURS	COLOUR PRODUCED
Red + green + blue	
Red + blue	
Green + blue	
Red + green	

3 Replace one of the primary filters with the secondary filters (yellow, cyan and magenta) and copy and complete the following table.

ADDITION OF COLOURS	COLOUR PRODUCED
Yellow (side slot) + blue (front slot)	
Magenta (side slot) + green (front slot)	
Cyan (side slot) + red (front slot)	

4 Switch off the light box and remove the filters. Select a red, green, blue and yellow surface from the light box kit. Hold each of the coloured surfaces against the back of each primary filter. Record the colour that each surface appears.

SURFACE COLOUR	COLOUR SURFACE APPEARS WHEN VIEWED THROUGH A		
	RED FILTER	GREEN FILTER	BLUE FILTER
Red			
Green			
Blue			
Yellow			

Discussion

1 What patterns did you observe in each of the tables? Explain the patterns you observed.

2 Name two possible sources of error in the experiment.

3 What difficulties did you have and how did you overcome the?

Conclusion

What do you know about what happens when coloured light is added to each other?

4.9
EXPERIMENT

Aim

To determine the wavelength of a microwave

Materials

- Microwave oven with the turntable removed
- Large flat plate at least 20 cm in diameter (safe for use in a microwave)
- Oven mitts
- Egg
- Ruler

CAUTION: SOME STUDENTS MIGHT HAVE EGG ALLERGIES.

What is the wavelength of a microwave?

Background

A microwave oven uses electromagnetic waves to heat food. These waves move through the cooking area in a set fashion. All microwave ovens have turntables to rotate food so that it cooks evenly. This is because of the wavelike motion of the energy. Without the turntable, the energy is focused in fixed parts of the oven.

You can use this to determine the wavelength of the microwaves in your microwave oven.

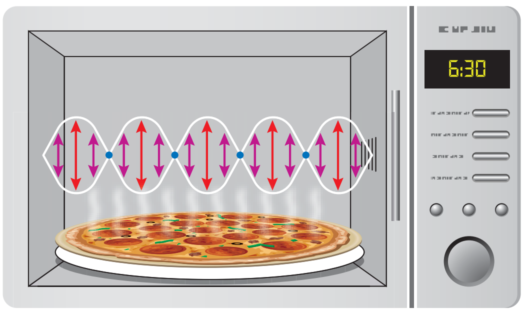


Figure 9.19 A microwave oven uses electromagnetic waves to heat food.

Figure 9.20 A microwave oven with the rotating platter removed and drive mechanism removed.

Method

1. Crack the egg and separate the egg white from the egg yolk.
2. Spread the egg white evenly over the large flat plate.
3. Place the plate in the oven and turn on for 15–30 seconds (depending on the power of the microwave). The egg should start cooking in stripes/patches.
4. Remove the plate from the microwave and identify the centre of the cooked stripes/patches. Measure the distance between two of the stripes.

Figure 9.21 Using the cooked portions of the egg white to measure the distance between 'hot spots' in the microwave oven.

5. Repeat this experiment several times and determine an average distance between the cooked egg white.

Results

1. Record all your observations in a table.
2. Multiply the average distance between the cooked eggwhite by 2 to determine the length of a full wavelength.

Discussion

1. What is the wavelength of the microwaves in your microwave oven?
2. How difficult was it to determine the centre of the cooked portion of egg? Can you determine the error margin of your calculation (± the width of the cooked egg bands)?
3. Why did you have to repeat your experiment several times?

Conclusion

What do you know about the wavelength of microwaves?

Vision tests

PART A: NEAR POINT OF VISION

The closer an object is to the eye, the thicker the lens needs to be. However, there is a limit to how much the lens can change shape and at very close distances the lens cannot clearly focus on an object. The distance from the eye to the nearest point that can be focused clearly (minimum focal length) is called the **near point of vision**.

What you need

> Ruler
> Sheet of A4 paper
> Pencil

What to do

Work in pairs.

1 Hold a pencil at arm's length.
2 Place a hand over your left eye.
3 Focus your right eye on the tip of the pencil.
4 Slowly bring the pencil closer to your eye until the tip becomes blurred.
5 Hold the pencil in this position and ask your partner to measure the distance from your eye to the tip of the pencil with the ruler.
6 Repeat the steps to find the near point for your left eye, then swap with your partner.
  > How does the near point for your left eye compare with that for your right eye?
  > How do your partner's near points compare with yours?

PART B: TESTING BINOCULAR VISION

What you need

> Sheet of A4 paper

What to do

1 Roll the sheet of A4 paper into a tube of 3–4 cm diameter and hold it up to one eye so that only the view through the tube can be seen.
2 With the other eye, look at your hand, palm open, held alongside the end of the tube. Keep both eyes open.

Discussion

1 What do you see?
2 Explain this phenomenon.

PART C: FINDING THE DOMINANT EYE

What you need

> Sheet of A4 paper

What to do

1 Roll the sheet of A4 paper into a tube of 3–4 cm diameter and hold it out in front of your eyes. Look through it with both eyes open at an object across the room.
2 Keeping the tube steady, close one eye, open it and then close the other eye.

Discussion

1 Which is your dominant eye?
2 How do you know?

PART D: JUDGING DISTANCES

What to do

1 Hold your arms outstretched to the side and at shoulder height, with elbows slightly bent and just your index fingers pointing.
2 Keeping both eyes open, try to make your fingertips meet in front of you.
3 Repeat this procedure with one eye closed. Repeat for the other eye.

Discussion

1 Can you judge distance as accurately with one eye closed?
2 Why do you think this is so?

PART E: FINDING YOUR BLIND SPOT

What you need

> Sheet of A4 paper

What to do

1 On the piece of paper, draw a dot and a cross in line with each other but about 7 cm apart.
2 Hold the paper approximately 15 cm from your eyes.
3 Close your right eye and concentrate on the cross with your left eye.
4 Slowly move the paper away from you until the dot disappears from your vision.

Discussion

1 Explain why the dot disappears.
2 Why doesn't the dot disappear if both eyes are kept open?

4.10
EXPERIMENT

Aim

To examine the structure of the eye and consider how the various components work separately and together

Materials

- Animal eyeball (fresh cow eyes are best)
- Dissecting board
- Scalpel
- Scissors
- Forceps
- Newspaper

CAUTION: WEAR YOUR LAB COAT, SAFETY GOGGLES AND GLOVES. BE CAREFUL WITH THE SCALPEL BECAUSE IT IS LIKELY TO BE VERY SHARP.

Eye dissection

Method

1. With the forceps and the scalpel or scissors, carefully remove the fatty tissue from around the eyeball.

2. Look for the optic nerve. It should look like a thick strand coming from the back of the eyeball.

3. Rotate the eyeball until the pupil is facing you. Notice the tough white outer coating extending over much of the eye.
4. Observe that in front of the eye the coating is transparent. Note that this transparent portion of the sclera is more sharply curved than the rest of the coating.
5. Use the scalpel to make a small cut on the side of the eye, then use the scissors to carefully cut the eye into two equal parts, front and rear. Taking care not to squeeze the eyeball, cut all the way around the eyeball until the two halves can be separated.

6. Carefully separate the lens from the rest of the eye by slicing through the fine muscles then put it on a piece of newspaper. The lens is colourless and transparent in life, but it is usually white in preserved specimens.

7. Pick up the lens with your forceps and move it about above the newspaper print as you look down on it. Squeeze the lens from the side as you look down through it. Note what you observe.

8 Examine the rear half of the eyeball and notice the black/pearly inside layer.

9 Examine the back of the front part of the eye from which you earlier took the lens. The iris, the muscular ring-like structure surrounding the pupil, is now exposed.

10 Leave your gloves on until you have finished the experiment. All dissecting equipment must be washed. All parts of the eye must be wrapped in newspaper and placed in the special bag provided. Disinfect your workspace and, finally, wash your hands thoroughly.

Results

Include labelled diagrams and observations in your results.

Discussion

1 What are the muscles attached to the outside of the eyeball used for?

2 What does the optic nerve do?

3 What is the white outer coating of the eye called?

4 What is the transparent part of the sclera called?

5 What is the name of the watery-like substance in the eyeball? What function does it serve?

6 The space between the cornea and the lens is also filled with a colourless, transparent, watery fluid. What is this fluid called?

7 Is the lens convex or concave?

8 What is the name of the black/pearly inside layer of the eye? What function does this layer have?

9 What function does the iris serve? How does it work?

Conclusion

What do you know about the structure and function of the eye?

4.11
CHALLENGE

Make a jelly lens for your smartphone

You will need

- Gelatine powder (no colours or flavours)
- Petri dish
- Boiling water
- Small beaker
- Measuring spoons
- Pipette

What to do

1 Add 2 teaspoons of boiling water to one of the small beakers.

2 Add a quarter of a teaspoon of gelatine to the water and stir it for 4 minutes until it starts to thicken.

3 Use the pipette to place 1 drop of the mixture on the underside of a Petri dish.

4 After 5 seconds, turn the Petri dish over so that the drop of gelatine hangs down. The drop will form a parabola shape without dripping off the petri dish.

5 Let the jelly set for 15 minutes.

6 Repeat steps 3–5 several times so that the best lens can be used.

7 Gently lift off the gelatine drop and place it over the lens of your smart phone.

8 Try taking close-up photos of things using your lens. When finished, remove the gelatine lens and carefully wipe the phone clean.

Discussion

1 How far away did the phone need to be to focus without the gelatine lens?

2 How far away did the phone need to be to focus with the gelatine lens?

3 Explain how the lens changed the light moving into the phone. (Use terms such as 'refraction', 'convex' and 'converge'.)

5.1 EXPERIMENT

Aim

To investigate the difference between thermal energy and temperature

Materials

- Water
- Small iron weight
- Iron nail
- 2 × 100 mL beakers
- Bunsen burner
- Tripod
- Heatproof mat
- 2 thermometers
- Tongs

Thermal energy versus temperature

Method

1 Set up the experiment as shown in Figure 9.22.
2 Boil some water in a beaker.
3 Record the temperature in a table.
4 Using tongs, place the iron nail carefully in the beaker.
5 Continue to boil the water in the beaker and record the highest water temperature reached.
6 Repeat steps 1–3 with the second beaker, this time using the small iron weight in place of the nail.
7 For each beaker, calculate the change in the temperature of the water when the metal object was added.

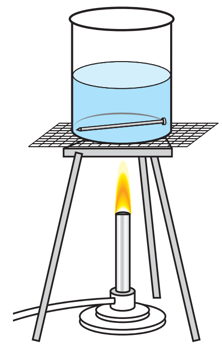


Figure 9.22 Experimental set-up.

Results

Include your results in the table.

Discussion

1 Which object – the iron nail or iron weight – had the highest water temperature? Why?
2 Which object had the most thermal energy? Why?

Conclusion

What is the difference between thermal energy and temperature?

5.2 EXPERIMENT

Aim

To investigate heating water by convection

Materials

- Water
- Potassium permanganate crystals (or a few drops of food colouring)
- Bunsen burner
- Tripod
- Heatproof mat
- 600 mL beaker
- Dropper or pipette

Investigating heating by convection

Method

1 Set up the experiment as shown in Figure 9.23.
2 Fill the beaker with water. Put individual crystals of potassium permanganate on the bottom of the beaker, at the edge. Alternatively, add a drop of food colouring to the bottom of the full beaker using a dropper or pipette.
3 Heat the water gently over the Bunsen burner and observe the movement of the crystal. (If possible, use a small flame and no heatproof mat between the Bunsen burner and the beaker – you can do this with Pyrex beakers.)
4 Note the path that the coloured water takes from the burner to the top of the water and back down again.

Results

Draw a labelled diagram showing the movement of the coloured water.

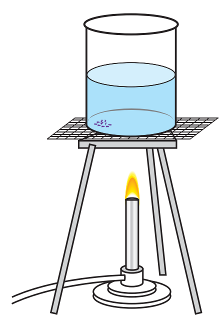


Figure 9.23 Experimental set-up.

Discussion

1 Describe the movement of the coloured water.
2 Why do you think the coloured water moved like this?
3 What was happening to the particles in the water when the water was being heated?

Conclusion

What do you know about heating water by convection?

5.3
CHALLENGE

Protection from heat radiation

Design brief

Design protective equipment that will protect firefighters against the radiant heat of bushfires.

Criteria limitations

Any material must be easily available and be able to be sewn or glued into the required shape. The commercial cost of the material must be within the limit set by your teacher.

Questioning and predicting

> What materials will you use to construct the protective equipment?
> How much material will you need to construct your garment?
> What colour should your garment be? (Does this make a difference?)
> What added features (such as pockets) will you need to add?

Planning and conducting

> How will you measure the radiant heat that passes through the material?
> How long will you expose the material to the heat source?

Figure 9.24 shows the general set-up of the experiment.

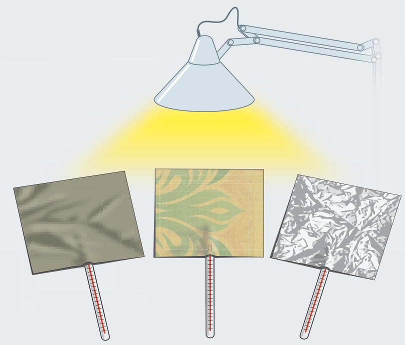


Figure 9.24 Experimental set-up. Place the bulbs of thermometers under the different materials and then place them in the sun (or at 6 cm from a lamp).

Processing, analysing and evaluating

1. Use a graph to describe the rate of temperature increase under all the tested material.
2. Which material was the most successful at reflecting the radiated heat?
3. What were the limitations of this material? Availability? Cost? Useability?
4. Would it be possible to create a large-scale version of your design for a firefighter? What would be the cost of your design?
5. If you were doing this experiment again, how would you modify your design? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

5.4
CHALLENGE

Which is the more energy efficient?

What you need

> 2 electric kettles of the same power rating (for example, 2000 W)
> 500 mL measuring cylinder
> Thermometer
> Stopwatch

What to do

1. Empty both kettles and fill them each with exactly 500 mL of cold tap water.
2. Check that the temperature of the water in both kettles is the same.
3. Plug both kettles in and turn them on at the same time. Time how long each one takes to boil the water.
4. Double-check at the end that the temperature of the water in both kettles is 100°C.
5. When both kettles have cooled down, tip the water out and repeat the experiment.

Discussion

1. How do you know which kettle is the most energy efficient?
2. Why was it important to keep the conditions exactly the same for both kettles?
3. Was it really necessary to check the water temperature at the end of the test? Why?
4. Why should the activity be repeated?

Demonstrating electrostatics

What you need

> Plastic comb
> Wool cloth
> Rice Bubbles®
> Large plastic bag with tie
> Plastic rod or pen
> Ebonite rod
> Small pieces of paper
> Balloons
> Felt-tipped pens
> String

What to do

PART A

1 Rub the plastic rod with the wool and then place it near the Rice Bubbles.
2 Put some of the Rice Bubbles in the plastic bag. Blow air into the bag and seal it with the tie.
3 Rub the wool over the plastic bag.
4 Rub the wool over both the plastic bag and the comb.
5 Record what happens.
6 Explain your observations using the idea of electrostatic charge.

PART B

1 Rub the plastic rod or pen and bring it close to some small pieces of paper.
2 On a piece of paper, draw four positive and four negative charges. Show what happens to these charges when the positively charged wool is brought close to them.
3 Explain why the paper is attracted to the plastic rod or pen by discussing the movement of charges.

PART C

1 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 face with a wool cloth and walk towards it.
4 Record what happens.
   > How close do you have to be before your 'balloon face' is attracted to you?
   > 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.
   > What happens when you bring it close to your other balloon?
   > Explain your observations using the idea of electrostatic charge.

PART D

1 Set up a thin stream of water from a tap.
2 Rub a plastic rod with a piece of wool.
3 Place the charged rod near the stream of water without touching it.
4 Record what happens.
   > Explain your observations using the idea of electrostatic charge.

5.5B
CHALLENGE

Separating charges with a van de Graaff generator

What you need

- Van de Graaff generator
- Smaller sphere
- Paper streamer
- 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
3. Explain what happens in each example, using your knowledge of electric charge.

5.6A
CHALLENGE

Making a simple torch circuit

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

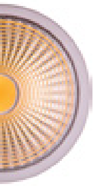
1. Try different arrangements of the wires, battery and torch globe to make the globe light up.
   - How many arrangements work?
   - How many arrangements do not work?
2. Use circuit diagrams to record some of the arrangements that work and some that do not.
   - Can you explain why some arrangements work and others 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.
   - How does this explain why the wires have to be connected in a particular way for the globe to light?
4. Look at how a globe holder (the base of a globe) is constructed.
   - Can you see how the connections are made inside the holder?

5.6B
CHALLENGE

Connecting circuits

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, light globe and switch. It is a good idea to start at a particular part of the circuit, for example, the positive terminal of the battery, and work your way sequentially around.
2. Draw the circuit diagram for this circuit.
3. Pull the first circuit apart and reuse the components. Construct a 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.
   - Where might a circuit like this be useful?
5. Pull the circuit apart and reuse the components. Connect up a 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?

5.7A
CHALLENGE

Making series and parallel circuits

Find out how many different 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

What you 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.
   - What effect did the switch have in each case?
3. Connect an ammeter at different places in each circuit and measure the current at each point.
   - What did you find out?

5.7B
CHALLENGE

Short-circuiting an electric current

What you need

- Battery
- Switch
- Connecting wires
- Lamp

What to do

1 Set up the circuit shown in Figure 9.25.
  - What do you think will happen if the switch is closed?

2 Close the switch.
  - What happened? Explain your observations in terms of current flow.

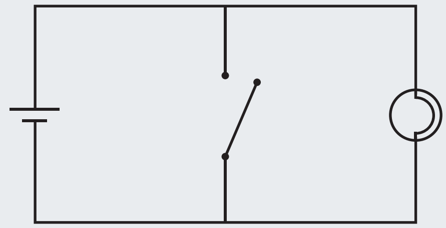


Figure 9.25 Circuit set-up.

5.8A
SKILLS LAB

Using Ohm's law to find resistance

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. 50 mA (milliamps) needs to be converted to amps. The prefix 'milli' means 0.001 (or × 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 9.26). The *V* is over the *I*, so we use:

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

3 Substitute the numbers for *V* and *I*:

$$R = \frac{6}{0.05}$$

4 Do the calculation: 6 ÷ 0.05 = 120 Ω.

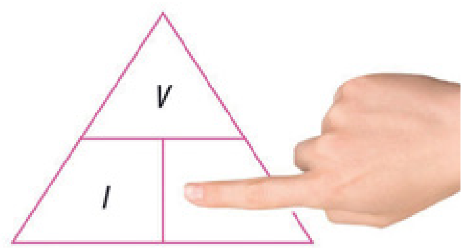


Figure 9.26 Using the Ohm's law triangle.

Your turn

1 This law can also be used to work out the voltage or the current. What is 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, then multiply.)

2 If a 12 V battery was placed in a circuit with a 470 Ω resistor, how much current will flow through the circuit?

3 If the current of a circuit with a 12 V battery was 0.004 A, what is the resistance of the circuit?

5.8B
SKILLS LAB

Understanding resistor colour codes

Carbon resistors typically have four colour-coded bands on their case. 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 accuracy of the resistor. Gold means a 5% accuracy, silver means a 10% accuracy and no fourth band means a 20% accuracy. The lower the percentage, the more accurate the resistor should be.

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 9.2). The third band tells you how many zeros to put after the number.

Look at the resistor in Figure 9.27. What does its code mean?

1 The tolerance band is gold, so the resistor has 5% accuracy.
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 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.

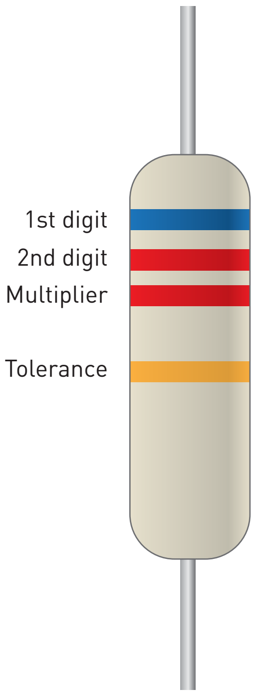
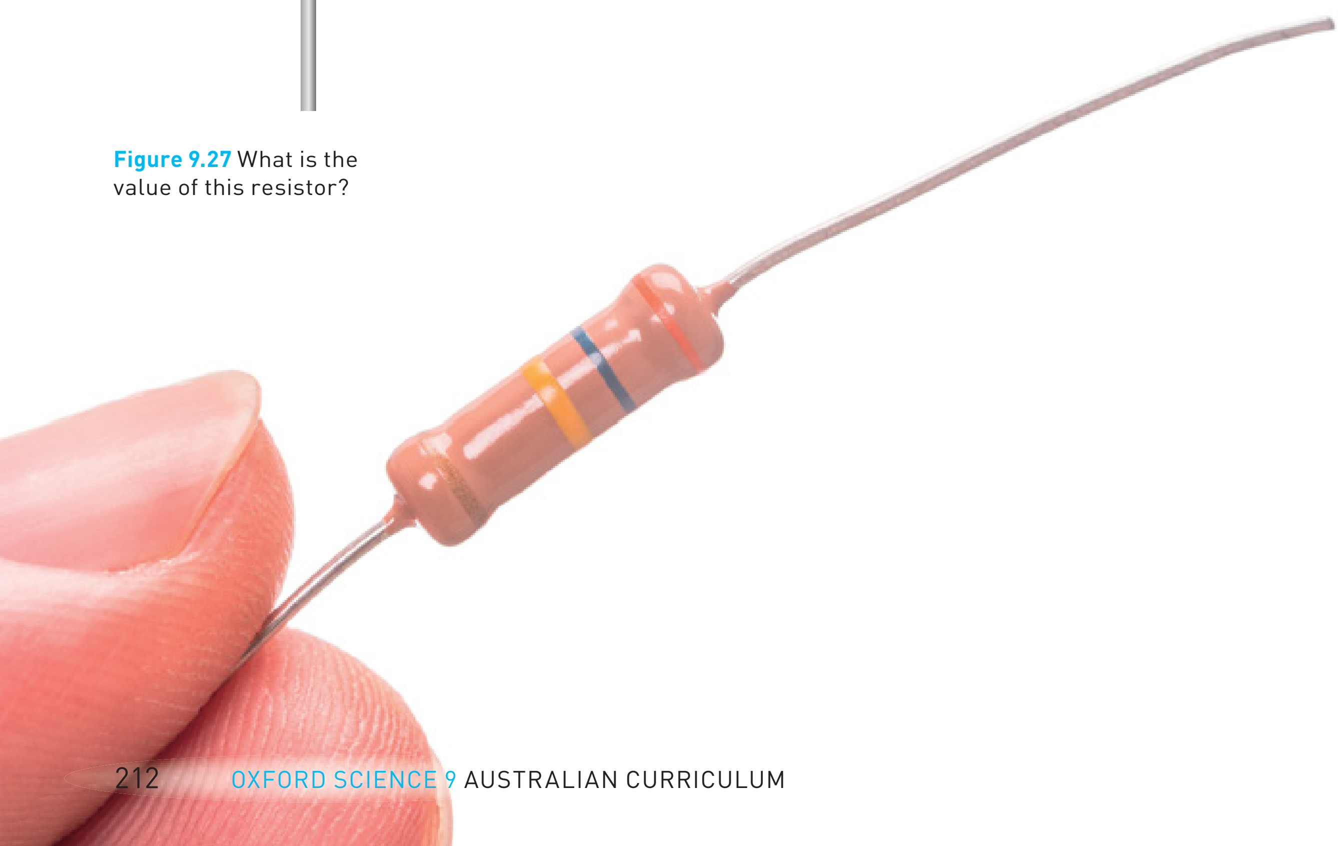


Figure 9.27 What is the value of this resistor?

Table 9.2 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



5.8
EXPERIMENT

Investigating Ohm's law

Aim

To investigate the voltage drop across and the current flow through a resistor, and hence calculate an average value of the resistance

Materials

- 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 9.28. 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.

5 Complete the following results table.

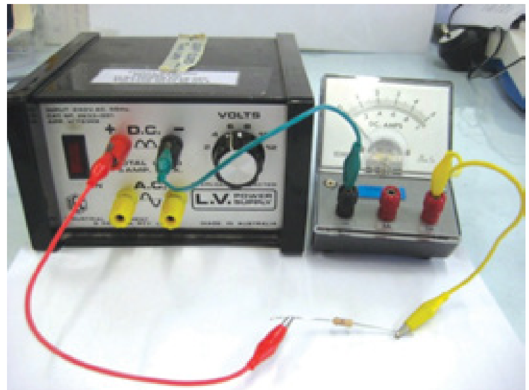


Figure 9.28 Circuit set-up.

RESISTOR	VOLTAGE (V)	CURRENT (mA)	VOLTS ÷ AMPS

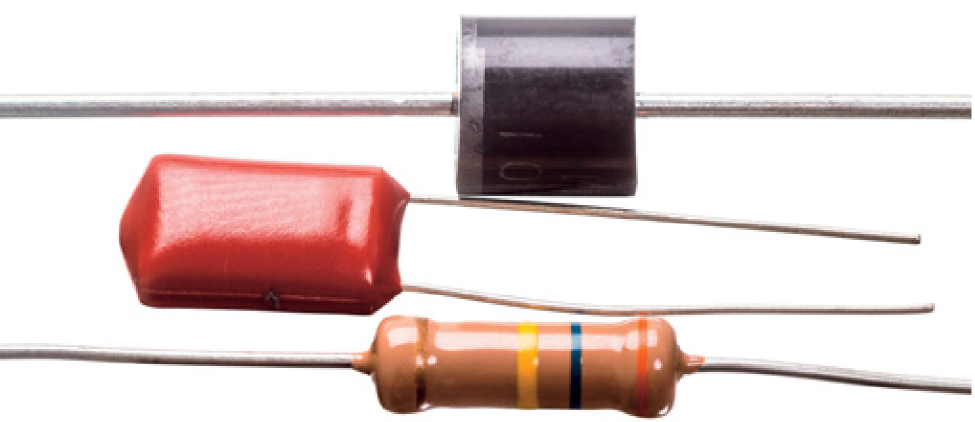
6 Repeat the experiment for the other three resistors, without reading their coloured bands.

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 in this section.



Discussion

1 From your results table, what can you say about the values in the last column?

2 What quantity does the last column calculate?

3 For the three masked resistors, how close were the values you obtained to those marked on their coloured bands?

4 Can you write the difference as a percentage of the average?

5 Which value – the one obtained by reading the coloured bands or the one obtained from your calculations – gives the most accurate measure of a resistor's resistance? Explain your answer.

Conclusion

What do you know about Ohm's law?

6.1A
CHALLENGE

Reconstructing Pangaea

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.

Discussion

1. Fossil twigs, roots and pollen found in Antarctica are almost identical to those found in Tasmania. Can you provide an explanation for this?
2. Name one other country that may have fossils that are similar to those found in Australia.

6.1B
CHALLENGE

Milo convection currents

This is a whole class activity.

What you need

- 1 small container of Milo®(Nesquik® will dissolve too easily)
- 1 litre 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 without stirring.
3. Record your observations of how the Milo cracks and moves as a result of the hot milk rising to the surface.

Discussion

1. Why did the Milo move as it did when the milk was heated?
2. How does this experiment relate to the breaking up of Pangaea into smaller pieces?

6.2
EXPERIMENT

Aim

To investigate if cooling of a substance forms layers

Materials

- 250 mL beaker
- Copper sulfate
- Spatula
- Glass stirring rod
- Bunsen burner
- Heatproof mat
- Tripod
- Gauze mat

Cooling and layers

Method

1 Set up the heating equipment and boil 50 mL of water in the beaker.

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. Stop when no more copper sulfate will dissolve.

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 cooled, without moving your beaker, examine its contents and where any solid copper sulfate might be located.

Results

Describe what happened as the beaker cooled and where any solid copper sulfate is located.

Discussion

1 Which is more dense, copper sulfate or water? How do you know?

2 How does this experiment relate to the structure of the Earth, which formed from a molten mass that gradually cooled like your beaker?

3 Can this experiment explain the fact that some iron and other heavy elements inside the Earth are also found near the surface?

Conclusion

Are layers formed when a substance cools? Explain why.

6.2
CHALLENGE

Modelling the parts of the Earth

CAUTION: SOME STUDENTS MIGHT HAVE EGG ALLERGIES.

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.

Discussion

1 In your model, the shell represented the Earth's crust. What happened when you pushed two pieces of shell towards each other? Give an example of how this can happen with the Earth's crust.
2 Which parts of the egg should be liquid in a more accurate model of the Earth?

6.3
CHALLENGE

Chocolate plates

What you need

> Chocolate bar (such as Mars® Bar or Milky Way®)
> Spatula

What to do

1 Wash your hands before starting this activity.
2 Use a clean spatula to cut the chocolate bar in half lengthways.
3 To illustrate a transform boundary, gently push the 'plates' back together, then slide one half of the chocolate bar forwards and the other backwards. Describe what happens.
4 To illustrate the force of compression associated with mountain building when continental plates collide, push on both sides of the chocolate bar to squeeze it together. What do you notice about the plates now?

Discussion

1 Was there any vertical movement of the top chocolate crust of the bar when you modelled a transforming boundary?
2 Describe what happened to the top chocolate crust of the bar when you modelled a converging boundary.
3 How would you model a diverging boundary?

6.4 CHALLENGE

Volcanic bubbles

What you need

- Powdered chalk
- Vinegar
- Red food dye
- Bottle of lemonade

What to do

1. 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.

Discussion

1. What happens to the bubbles in a lemonade bottle when the pressure is released?
2. How is this similar to a volcano?

Figure 9.29 Gas bubbles formed the holes in this piece of pumice rock.

7.1 CHALLENGE

What is the ratio of atoms in a compound?

What you need

- 2 Maltesers® (representing hydrogen)
- 2 chocolate frogs (representing oxygen)
- Lolly pop (representing carbon)
- Scales
- Paper bags

What to do

1. Place two Maltesers and one chocolate frog in a paper bag.
2. Use the scales to weigh the bag.
3. Add one lolly pop and two chocolate frogs into a paper bag.
4. Use the scales to weigh the bag.
5. Your teacher will prepare a mystery bag of lollies in one of the same combinations as step 1 or 3. Without opening the bag, use the scale to determine its weight. Prepare a hypothesis of what lollies 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.

Discussion

1. What molecule was formed in step 1?
2. What molecule was formed in step 3?
3. How accurate was your hypothesis?
4. How could you use your measurements to determine what lolly atoms were in a completely new compound?

7.2A
CHALLENGE

How can you tell what is inside?

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

What to do

1. Form two teams (A and B) of three students to work with each other.
2. Team A places the ball in one of the small boxes, the wooden block in another, and the two nails in the last box. The boxes are then closed.
3. Team B has to work out a way of determining what is inside each of the boxes without opening or touching them.
4. Team B can then touch and examine the boxes, still without opening them.

Discussion

1. Was team B more successful at identifying what was inside the box when they could touch and examine the box?
2. How might scientists have used indirect evidence to model what is inside an atom?
3. Identify at least one other field of scientific investigation in which scientists would have to use indirect evidence to develop their theories.

Figure 9.30 How can you determine what is in the box?

7.2B
CHALLENGE

Rutherford model of the atom

You will need

- Hula hoop
- String
- Matchbox
- Popcorn

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 should throw a single popcorn at a time at the hula hoop.
4. Record how many kernels of popcorn go through the hoop and how many bounce off the matchbox.

Discussion

1. The hula hoop represents a gold atom in Rutherford's experiment. What does the matchbox represent?
2. How many kernels of popcorn bounced off the matchbox?
3. Explain how your model of Rutherford's experiment provides supporting evidence for the Rutherford model of the atom.

7.4

EXPERIMENT

Flame tests

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
- Wire loops

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. WASH SKIN WITH TAP WATER IMMEDIATELY.

Method

1. Set up your Bunsen burner, observing safety instructions, and light your Bunsen burner on the safety flame.
2. Adjust your 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.

Results

Include your results in a table.

Discussion

1. Why was the loop treated with hydrochloric acid before any carbonates were tested?
2. What caused the flames to change colour?
3. What kind of change is the colour change – chemical or physical? Explain.
4. Why do electrons in different elements produce different colours?
5. Is it the metal or the carbonate part of the powder that causes the colour change? How do you know?

Conclusion

What can you infer about the different coloured flames produced by different elements?

7.6

CHALLENGE

Calculating relative atomic mass

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. ^{4}Lg is the smallest, ^{5}Lg is the next in size. It has an atomic mass of ^{5}. The largest of the isotopes is ^{6}Lg. It 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, 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.

Discussion

1 For each legumium isotope, show the symbols with its mass, atomic number and symbol.

2 How many protons, neutrons and electrons are in each isotope?

3 According to your sample, which legumium isotope is most common in nature?

$$\text{Average atomic mass legumium} = \frac{(\text{number of } ^{4}\text{Lg} \times \text{mass } ^{4}\text{Lg}) + (\text{number of } ^{5}\text{Lg} \times \text{mass } ^{5}\text{Lg}) + (\text{number of } ^{6}\text{Lg} \times \text{mass } ^{6}\text{Lg})}{= \text{total number of isotopes}}$$

7.7

CHALLENGE

A tasty way to model radioactive decay

The aim of this activity is to illustrate the idea of exponential decay and half-life. You can use M&M's® to represent the nuclei of atoms.

What you need

> Pack of M&M's®

> A4 plain paper

> Disposable plastic cup

What to do

1 Complete the table to record your results.

NUMBER OF SHAKES	NUMBER OF UNDECAYED 'ATOMS'			
	0 START	TRIAL 1	TRIAL 2	TRIAL 3
1				

2 Count the total number of M&M's that you have, record this number and place them in the plastic cup.

3 Shake the cup and tip all the M&M's onto the paper.

4 Those that have the 'M' facing upwards represent atoms that have decayed. Move these to a 'discard' pile.

5 Count the remaining 'nuclei' and record this number.

6 Place the remaining nuclei back into the cup, shake them and tip them out again.

7 Move the decayed nuclei to the discard pile and count those remaining.

8 Continue until you have three or fewer nuclei.

9 Repeat the whole process two more times.

10 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.

Discussion

1 The atomic nuclei were represented by M&M's. What represented the half-life of the decay process?

2 Are the shapes of the three curves similar or different?

3 Do you think the overall shape of the curves would be different if you started with more atomic nuclei? Explain your answer.

4 In this activity, could you predict when each individual nucleus would decay? Why is this similar to the behaviour of real radioactive atoms?

5 In this experiment, you would eventually end up with no 'undecayed' M&M's. Would this be the case with a real radionuclide? Explain your answer.

Kernelite/popcornium decay

Unpopped popcorn can be used to represent a radioactive isotope called kernelite (Ke). Heating the popcorn starts the radioactive decay clock, causing the kernelite to decay into the more stable popcornium (Pc) – the fluffy white popped corn. The half-life of kernelite is the time it takes for half the corn kernels to pop. Your goal is to determine the half-life of kernelite and then use it to determine the 'age' of the unknown sample.

What you need

- 6 mini bags of microwave popcorn
- Pre-popped popcorn bag labelled 'Unknown' (this will have been put in the microwave for different time periods by your teacher)
- Graph paper
- Microwave oven
- Timer

What to do

1. Label six bags of microwave popcorn 't = 0 s', 't = 10 s', 't = 20 s', 't = 30 s', 't = 40 s', 't = 50 s'.
2. Place the 't = 10 s' bag in the microwave oven and set the microwave timer for 2 minutes.
3. Turn on the oven and start heating the popcorn. Start the timer when the first kernel of popcorn is heard to pop. Stop the microwave after 10 seconds.
4. Repeat steps 2 and 3 for the remaining bags of popcorn at t = 20, 30, 40 and 50 s.
5. Count the number of popped kernels in each bag and record the numbers in an appropriate table.
6. Determine the percentage of kernelite remaining in each bag.

$$\%\text{kernelite} = \frac{\text{number of unpopped kernels in each bag} \times 100}{\text{total number of kernels}}$$

7. Plot the percentage of kernelite against the time it was heated in a scatter graph. Draw a line of best fit.
8. Use the graph to determine the time it took for half the kernelite to decay into popcornium (i.e. how long it took for 50% of the corn to pop.)
9. Count the number of unpopped popcorn in the unknown sample. Determine the percentage of kernelite remaining.
10. Use the graph you drew to determine how long the unknown bag of popcorn was placed in the microwave.

Discussion

1. What was the half-life of the kernelite?
2. Name two factors that could have affected your results.
3. Suggest one example of how your method could mimic how scientists use radioactive decay in their work.

8.1

EXPERIMENT

Aim

To determine if mass is conserved in a chemical reaction

Comparing mass before and after a chemical reaction

Materials

- Sodium bicarbonate
- Vinegar
- Balloon
- Balance
- Measuring cylinder
- 2 conical flasks
- Watch glass
- Spatula

Method

PART A

1 Copy the results table for Part A to record your results.

2 Weigh 2.0 g of sodium bicarbonate onto a watch glass.

3 Add 20 mL of vinegar to a flask.

4 Ensure the balance is reading zero. Weigh the vinegar and flask. Record this mass (M_1).

5 Predict whether the mass of the flask and vinegar after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.

6 Add 2.0 g of sodium bicarbonate (M_2) to the flask containing the vinegar and swirl until the bubbling stops.

7 Weigh the flask after the reaction has stopped. Record the final mass (M_3).

PART B

1 Copy the results table for Part B to record your results.

2 Weigh 2.0 g of sodium bicarbonate onto a watch glass.

3 Add 20 mL of vinegar to a flask.

4 Ensure the balance is reading zero. Weigh the vinegar, flask and a balloon. Record this mass (M_1).

5 Predict whether the mass of the flask, vinegar and balloon after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.

6 Add 2.0 g of sodium bicarbonate (M_2) to the flask and quickly stretch the opening of the balloon over the neck of the flask to collect gas.

7 Weigh the flask, with the balloon still attached, after the reaction has stopped. Record the final mass (M_3).

Results

Results for Part A

MASS OF FLASK AND VINEGAR (M_1)	MASS OF SODIUM BICARBONATE (M_2)	TOTAL MASS BEFORE REACTION ($M_1 + M_2$)	MASS AFTER REACTION (M_3)

Results for Part B

MASS OF FLASK, VINEGAR AND BALLOON (M_1)	MASS OF SODIUM BICARBONATE (M_2)	TOTAL MASS BEFORE REACTION ($M_1 + M_2$)	MASS AFTER REACTION (M_3)

Discussion

1 Compare the initial and final masses for each part of the experiment.

2 Is this what you expected? Explain why or why not.

3 What gas was produced?

4 What was the purpose of the balloon?

5 How could the design of this experiment be improved?

Conclusion

Do you think that mass was conserved in this chemical reaction?

8.2 CHALLENGE

Modelling chemical equations

You will need

- Paper bags
- Model atom kit (or laminated squares labelled oxygen (O) atom, carbon (C) atom, hydrogen (H) atom)
- Felt-tipped pen or pen

PART A

What to do

1. Each paper bag represents a molecule. Create a molecule of oxygen (O_2) by placing two oxygen 'atoms' in a paper bag. Write 'O_2' on the bag.
2. Use two paper bags and four model hydrogen atoms to create two molecules of hydrogen (H_2). You have now created the reactants in the chemical reaction:

   $$2H_2 + O_2 \rightarrow 2H_2O$$

3. Label the two remaining paper bags 'H_2O'. Take the model atoms out of the reactant bags and place them in the product H_2O bags. Are there enough atoms to fill the H_2O bags?

Discussion

1. Why were there more molecules/bags of hydrogen than oxygen?
2. What would happen if one more molecule of oxygen was added to the reaction? Could it react?
3. How does this model reaction conserve mass?

PART B

What to do

1. Use new bags and the model atoms to create two molecules of methane (CH_4).
2. How many molecules of oxygen (O_2) would you need to turn these methane molecules into carbon dioxide (CO_2) and water (H_2O)?

Discussion

1. How many molecules of oxygen did you need to balance this equation?
2. How many molecules of carbon dioxide and water were you able to create with two methane molecules?
3. Write the word equation for this reaction.
4. Write the balanced chemical equation for this reaction.

8.3 EXPERIMENT

Energy changes

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
- 2 foam cups (or temperature sensor)
- 2 spatulas
- Stopwatch
- Wash bottle
- Residue bottle

CAUTION: WEAR YOUR LAB COAT, SAFETY GOGGLES AND PLASTIC GLOVES. CHECK THE MATERIAL SAFETY DATA SHEETS TO SEE HOW TO HANDLE THE CHEMICALS IN THIS EXPERIMENT SAFELY.

This experiment may be carried out using a temperature probe and datalogging 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 full of calcium chloride into 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.

Results

Draw a graph of temperature against time and plot your results from the two chemicals on the same graph. Make sure that you label both axes and use the correct units.

Discussion

1 Which reaction was endothermic and which was exothermic?

2 In which reaction did the products have less energy than the reactants?

3 In which reaction did the products have more energy than the reactants?

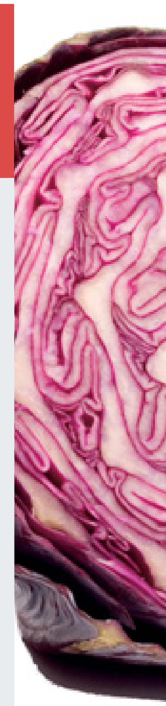
4 Use the graphs to describe how quickly the temperature rose or fell.

5 Did the temperature reach a steady value after some time? Discuss why you think this.

Conclusion

Suggest how the method used in this experiment could be changed to improve the accuracy of the results.

8.4 CHALLENGE



Testing with pH paper

What you need

- pH paper and pH colour chart
- White tile
- Variety of laboratory acids and bases
- Vinegar
- Milk
- Toothpaste
- Lemon juice

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 and the other substances.

5 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.

Discussion

1 Which was the most acidic solution that you tested (lowest pH)?

2 Which was the most basic solution that you tested (highest pH)?

3 What happens to the pH of an acid when the acid is diluted in water? Is it more or less acidic?

4 Using your answer to question 3, suggest a way of treating a burn caused by acid.

8.4 EXPERIMENT

What if plants were used to create an indicator?

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.

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
- 250 mL beaker
- Strainer
- 0.1 M hydrochloric acid
- Hotplate or Bunsen burner, tripod and gauze mat
- Test tubes and test-tube rack

Method

1 To make the indicator:
   - a Cut a few red cabbage leaves into smaller pieces and place in a beaker.
   - b Cover the cabbage leaves with water and boil the mixture until the water is purple.
   - c Cool the liquid and then strain it, discarding the cabbage leaves.

2 To test the indicator:
   - a Add a small amount of hydrochloric acid 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.
   - g Test a variety of products, such as shampoo, vinegar and baking soda, by adding a few drops of red cabbage indicator solution to them.
   - h 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.

- What (independent variable) are you will you use instead of red cabbage?
- Name three variables you will need to keep the same as the red cabbage method.
- How will you measure if the plant, flower or fruit is an indicator?
- Predict what colour changes you might expect.
- What equipment will you need to complete this experiment?
- Write down the method you will use to complete your investigation.
- What sort of table will you need to draw to show your results?

(Show your teacher your planning for approval.)

Results

Include your table of observations here.

Discussion

1 What colour is the extract from red cabbage?

2 What colour does the extract become in:
   - a an acid?
   - b a base?
   - c water?

Conclusion

What do you know about indicators and how they are produced?

8.5 EXPERIMENT

Neutralisation reactions

Aim

To investigate neutralisation reactions

Materials

- 1 M hydrochloric acid
- 1 M sodium hydroxide solution
- Universal indicator solution
- Test tubes and test-tube rack
- Dropping pipettes
- 10 mL measuring cylinder
- 100 mL beaker
- Petri dish
- Microscope or magnifying glass

CAUTION: ENSURE THAT YOU WEAR SAFETY GOGGLES AT ALL TIMES DURING THIS EXPERIMENT AND AVOID SKIN CONTACT WITH THE HYDROCHLORIC ACID AND THE SODIUM HYDROXIDE SOLUTIONS.

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.
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 the sodium hydroxide from the measuring cylinder to the acid in the beaker.
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.
7. Carefully empty and rinse out your glassware and repeat the whole experiment. Instead of adding universal indicator, use the same amount of sodium hydroxide as you did before.
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. Why was it essential to rinse the measuring cylinder with water after it was used?
2. Why was the experiment repeated without the indicator?
3. How could you produce the solid salt more quickly in the last step of the method?
4. Should you taste the product of this reaction to check whether salt has been produced? Explain your reasoning.
5. What do you notice about the shape of the salt crystals produced? What can you infer from this about the arrangement of the particles inside the salt crystals?

Conclusion

What have you observed about neutralisation reactions?

8.5 CHALLENGE

Making sherbet

Figure 9.31 Sherbet fizzes in a chemical reaction involving saliva.

What you need

- 1 tablespoon of icing sugar
- ¼ teaspoon of sodium bicarbonate (baking soda)
- ¼ teaspoon of citric acid
- 1 teaspoon of flavoured jelly crystals
- Small zip-lock sandwich bag

What to do

Perform 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.
3. Dip a spoon into the mixture and put a small amount on your tongue.

Discussion

1. What happened to the sherbet when it mixed with the saliva in your mouth?
2. What three substances were formed?
3. How did the sherbet feel on your tongue? What differences in tastes did you observe?
4. Do you think that carbonates and bicarbonates should be described as bases? Explain your answer, carrying out research if required.

8.6 EXPERIMENT

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 (for example, aluminium, copper, iron, magnesium, tin and zinc) to fit into test tubes
- Matches
- A variety of materials that could be used as a barrier (such as Vaseline, candle wax, masking tape, sticky tape)

What if the metal was protected from the acid?

CAUTION: ENSURE THAT YOU WEAR SAFETY GOGGLES AT ALL TIMES DURING THIS ACTIVITY AND AVOID SKIN CONTACT WITH THE ACID.

Method

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. Light a match and bring it to the end of the test tube as you take your thumb away.
4. Observe what happens (for example, 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.

- Choose one metal for your inquiry. Which metal will you use?
- What will you use to prevent the acid and metal reacting?
- How long will you expose your metal to the acid?
- What is your independent variable?
- Name three variables you will need to keep the same as the first method.
- How will you measure if your method of protection is successful?
- Predict what results you might expect.
- What equipment will you need to complete this experiment?
- Write down the method you will use to complete your investigation.
- What sort of table will you need to draw to show your results?

(Show your teacher your planning for approval.)

Results

Describe your observations. Draw or take pictures of the metal before and after exposure to the acid.

Discussion

1. What observations did you make about how the different metals reacted with the acid?
2. Which metal was the most reactive with the acid?
3. Which metal was the least reactive with the acid?
4. How successful was your method of protection on the metal? Use your observations to support your answer.
5. Compare your results to those achieved by the rest of your class. Which method was the most successful?
6. How could you improve your results if you repeated this experiment?

Conclusion

What do you know about how metals and acid react?

8.7
EXPERIMENT

Oxidation of steel wool

Aim

To examine the oxidation of steel wool

Materials

- Steel wool that has been soaked in vinegar
- Tape
- Thermometer
- Paper towel
- 2 × 250 mL beakers
- Water
- Stopwatch
- Foam insulation with drawstring that will fit around a beaker (used for sports bottles)

Method

1. Place one beaker into the insulation.
2. Measure the temperature of the temperature of the:
   a. steel wool/vinegar mixture
   b. room
   c. insulated beaker.
3. Remove the steel wool from the vinegar and quickly use the paper towel to squeeze and remove all the vinegar from it.
4. Immediately wrap the steel wool around the thermometer and secure it with the tape.
5. Place the thermometer and steel wool into the insulated beaker and cover the top of the beaker with the insulation.
6. Record the temperature changes of the steel wool every minute for 10 minutes. The original temperature of the steel wool and vinegar mix should be $t = 0$ minutes.

Results

Record your observations and temperature measurements in an appropriate table. Draw a graph of your results.

Discussion

1. Describe what happened to the temperature around the steel wool. (Use the term 'exothermic' or 'endothermic' in your answer.)
2. What changes to the steel wool could have caused this change in temperature?
3. What were the reactants in this reaction?
4. What were the products for this reaction?
5. Write a word equation for this reaction.

Conclusion

Use an example to describe oxidation reactions.

8.8
CHALLENGE

Combustion and candles

What you will need

- Tealight candle
- Beaker large enough to fit over candle
- Matches

What to do

1. Light the tea candle with the match.
2. Place the beaker over the candle and observe what happens.

Discussion

1. What was the fuel for the chemical reaction occurring with the candle?
2. Why did the candle go out shortly after it was covered with the beaker?
3. Did you notice any moisture on the inside of the beaker? Where did this water come from?
4. Write a word equation for the combustion of the candle wax.

GLOSSARY

A

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

acidic oxide
a non-metal oxide that forms an acid when dissolved in water

aerobic respiration
a chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy (34 ATP)

alkali
a base that dissolves in water

alkaline
a solution that contains a base

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

alpha
a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

amplitude
the distance a particle moves from its position of rest

anaphylaxis
a life-threatening response of the immune system as a result of a pathogen

angle of incidence
the angle between the incident ray and the normal (the line drawn at right angles to a reflective surface)

angle of reflection
the angle between the reflected ray and the normal (the line drawn at right angles to a reflective surface)

angle of refraction
the angle between the refracted ray and the normal (the line drawn at right angles to a refractive surface)

anion
a negative ion that results from an atom gaining electrons

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

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 the 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
a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

biological control
releasing a living organism (a parasite or consumer) into an ecosystem in order to control a population

biosphere
the intersection between the atmosphere, hydrosphere and lithosphere

biotic
all the living organisms in an ecosystem

Bohr model
a way to represent the electrons of an atom in a series of shells around the atomic nucleus

C

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

carbon dating
a process that measures the age of an object by comparing the amount of carbon-14 that has decayed over time

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

cataract
a cloudiness of the eye lens

cation
a positive 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

chemical bond
a bond that forms between the atoms in a molecule

circuit diagram
a diagrammatic way to represent an electrical circuit

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

colour-blindness
when a person has difficulty identifying different colours; red-green colour blindness is an inherited condition

commensalism
a relationship between two organisms of different species; one organism benefits; the other organism is not affected

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

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

compression
part of a sound wave where air particles are forced close together

concave
a lens or mirror in which the centre is thinner than the two ends

conduction
the transfer of thermal energy (kinetic energy of particles) through direct contact; the atoms do not change their position in the material

continental drift
the continual movement of the continents over time

continental shelf
underwater cliffs between the beach and the ocean

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 through convection

converge
when rays of light move towards a single point

converging
moving together

converging boundary
the boundary between two tectonic plates that are moving together

convex
a lens or mirror in which the centre is thicker than the two ends

core
the centre of the Earth

cornea
a transparent layer at the front of the eye

corrosion
the gradual destruction of materials by a chemical reaction with their environment

critical angle
the angle at which total internal reflection occurs

crust
lithosphere; the outer layer of the Earth

D

decibel
the unit for sound level

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

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

dependent variable
the variable being tested in an experiment

derived units
units of measurement that are calculated from the international system of units; for example, volume (cm^3) and area (cm^2)

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

dispersion
the separation of white light into its different colours

diverge
when rays of light move away from each other

diverging
moving apart

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

E

ecosystem
a community of living organisms (biotic) together with their non-living (abiotic) factors

electric charge
a positive or negative charge that can be produced by subatomic particles that results in electrical energy

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
the energy that results in the movement of electrons through a conductor towards a positive charge

electrical insulator
a material that does not allow the movement of charged particles

electromagnetic radiation
a form of energy that can be released into space by stars, including visible light, infrared radiation (radiant thermal energy), X-rays and gamma rays

electron
a negatively charged subatomic particle that moves in the space around an atomic nucleus

electron shell
the area of space around a nucleus where a specific electron may be found

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 coloured lights released as an element loses thermal energy

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, which results in increased warming of the Earth

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

evaporation
the process of liquid water gaining thermal energy and changing into gas

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

filter
a transparent material that allows only one colour of light to pass through

focal length
the distance between the centre of the lens and the focus

focus
the point where rays of light cross

frequency
the number of waves that pass a point every second; measured in hertz

fuel
a substance that undergoes a chemical reaction that produces large amounts of energy

G

gamma
high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

H

habitat
the place where a population of organisms lives

hertz
the unit used to measure frequency

hibernation
when an organism becomes inactive, usually as a result of low temperatures

homeostasis
the process of regulating the internal conditions of the body

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

hydrocarbon
a molecule that contains hydrogen and carbon atoms

hyperopia
long-sightedness; when a person has difficulty seeing a close object

I

image
a likeness of an object that is produced as a result of light reflection or refraction

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
the variable that is deliberately changed or tested during an experiment

indicator
a substance that changes colour in the presence of an acid or a base

insulation
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
a charged atom that results from an unequal number of electrons and protons

iris
the coloured part of the eye

isotope
an atom that has more or less neutrons in its nucleus

L

lens
a curved piece of transparent material

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

litmus paper
paper containing an indicator that turns red when exposed to an acid and blue when exposed to a base

long-sighted
having difficulty seeing a close object

longitudinal wave
a type of (sound) wave where the particles move in the direction of travel of the wave

M

magma
semiliquid rock found beneath the Earth's surface

mantle
the layer of molten rock located beneath the Earth's crust

mass number
the 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 is made of matter; matter is made of atoms

medium
a substance or material through which light can move

memory cell
an immune system cell that is produced in response to an infection, and 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

mirror
a material that is able to reflect light

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

mutualism
a 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

myopia
short-sightedness; when a person has trouble seeing objects in the distance

N

neuron
a nerve cell

neutral
(pH 7) neither an acid nor a base; for example, water

neutralisation reaction
a reaction between an acid and a base that produces water and a salt

neutron
a neutral uncharged subatomic particle in the nucleus of an atom

normal
(light) an imaginary line that is drawn at right angles to the surface of a reflective or refractive material

nucleus
(chemistry) the centre of an atom that contains protons (positive) and neutrons (no charge)

O

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

opaque
a substance that does not allow light to pass through

optic fibre
a thin fibre of glass or plastic that carries information/data in the form of light

optic nerve
the nerve that carries information from the eyes to the brain

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

oxidation reaction
a chemical reaction in which an element combines with oxygen

oxidised
when oxygen has been added to an element

P

parallax error
an error that occurs when the reader's eye is not placed directly above a mark

parallel
the positioning of loads (lights) in an electric circuit so that they are connected to the battery separately; they are in parallel to each other

parasitism
a relationship in which one organism (parasite) benefits and the other organism (host) is harmed

pathogen
anything that causes disease

periodic table
a table that places elements in order of their atomic number, and groups them 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 basicity 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

photosynthesis
the process in plants in which glucose is made from water and carbon dioxide

plate tectonics
the theory that the surface of the Earth is divided into a series of plates that are continually moving

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

potential difference
voltage; the difference in the electrical potential energy carried by charged particles at different points in a circuit

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

primary colours of light
the three colours of light (red, blue and green), which can be mixed to create white light

product
a substance formed as a result of a chemical reaction

proton
a positively charged subatomic particle in the nucleus of an atom

pupil
the dark opening in the centre of the eye that allows light to pass through

Q

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

R

radiation
the transfer of thermal energy (via photons) across empty space or through another substance

radioactive decay
the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide
a radioactive isotope

rarefaction
a part of a sound wave where air particles are forced apart

reactant
a substance present at the start of a chemical reaction; also called substrate

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

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

reflex
an involuntary movement in response to a stimulus

refracted ray
a ray of light that has bent as a result of light speeding up or slowing down

refraction
the bending of light as a result of light speeding up or slowing down

refractive index
a measure of the bending of light as it passes from one medium to another

relative atomic mass
the average mass of an element that includes 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

retina
the layer of cells at the back of the eye

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

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 a experiment

sea-floor spreading
a theory that the middle of the ocean is spreading apart, forming new oceanic crust

secondary colours of light
the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

semiconductor
a material that conducts electrical energy in one form and insulates against electrical energy in another form

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

series
the positioning of loads (lights) side by side in an electric circuit so that 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

short-sighted
when a person has difficulty seeing distant objects

SI system
international system of units based on the metric system; for example, kg, m, km

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

solution
a mixture of a solute dissolved in a solvent

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

sound level meter
an instrument for measuring the level of sound

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

subduction
the movement of one tectonic plate under another tectonic plate

symbiosis
a close physical relationship between two members 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 Earth movement of tectonic plates can cause earthquakes

temperature gradient
the difference in temperatures between two systems, such as an ice-block and warm air

thermal energy
heat; the kinetic energy of particles that increases as their temperature increases

thermal equilibrium
when two systems are at the same temperature; no heat moves from one system to another

Thomson plum pudding model
an early model of an atom that suggested that the positively charged nucleus had negatively charged electrons scattered through it (like a plum pudding)

total internal reflection
when a light ray passes from a more dense material at a large angle, it can be reflected back into the dense medium

transform
to change form; tectonic plates transform when they slide past each other

transform boundary
the boundary between two tectonic plates that are sliding past each other

translucent
a substance that allows light through, but it diffuses so that objects cannot be seen clearly

transmit
to allow light to pass through

transparent
a substance that allows all light to pass through

transpiration
the process of water evaporating from plants

transverse wave
a type of (light) wave where the vibrations are at right angles to the direction of the wave

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 the disease

valence shell
the outermost electron shell that contains electrons

van de Graaff generator
a machine that produces an electrostatic charge

variable
anything that can change the outcome or result of an experiment

virtual focus
the point at which a virtual image appears

virtual image
an image that appears in a mirror; it cannot be captured on a screen

visible spectrum
the variety of colours or wavelengths of light that can be seen by the human eye

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

W

wavelength
the distance between two crests or troughs of a wave

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 was taken

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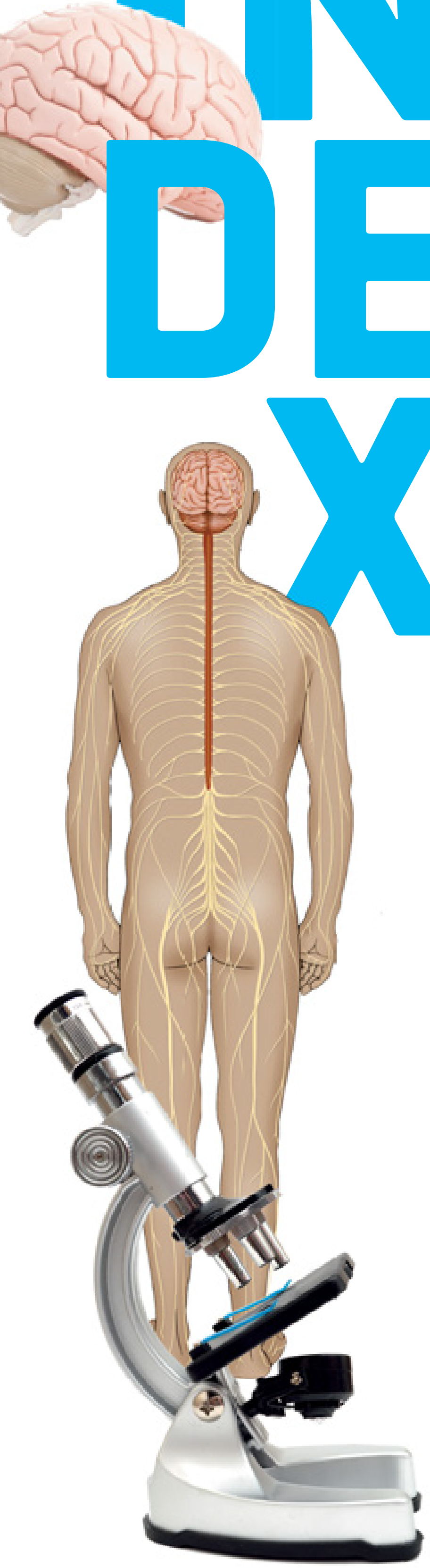

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