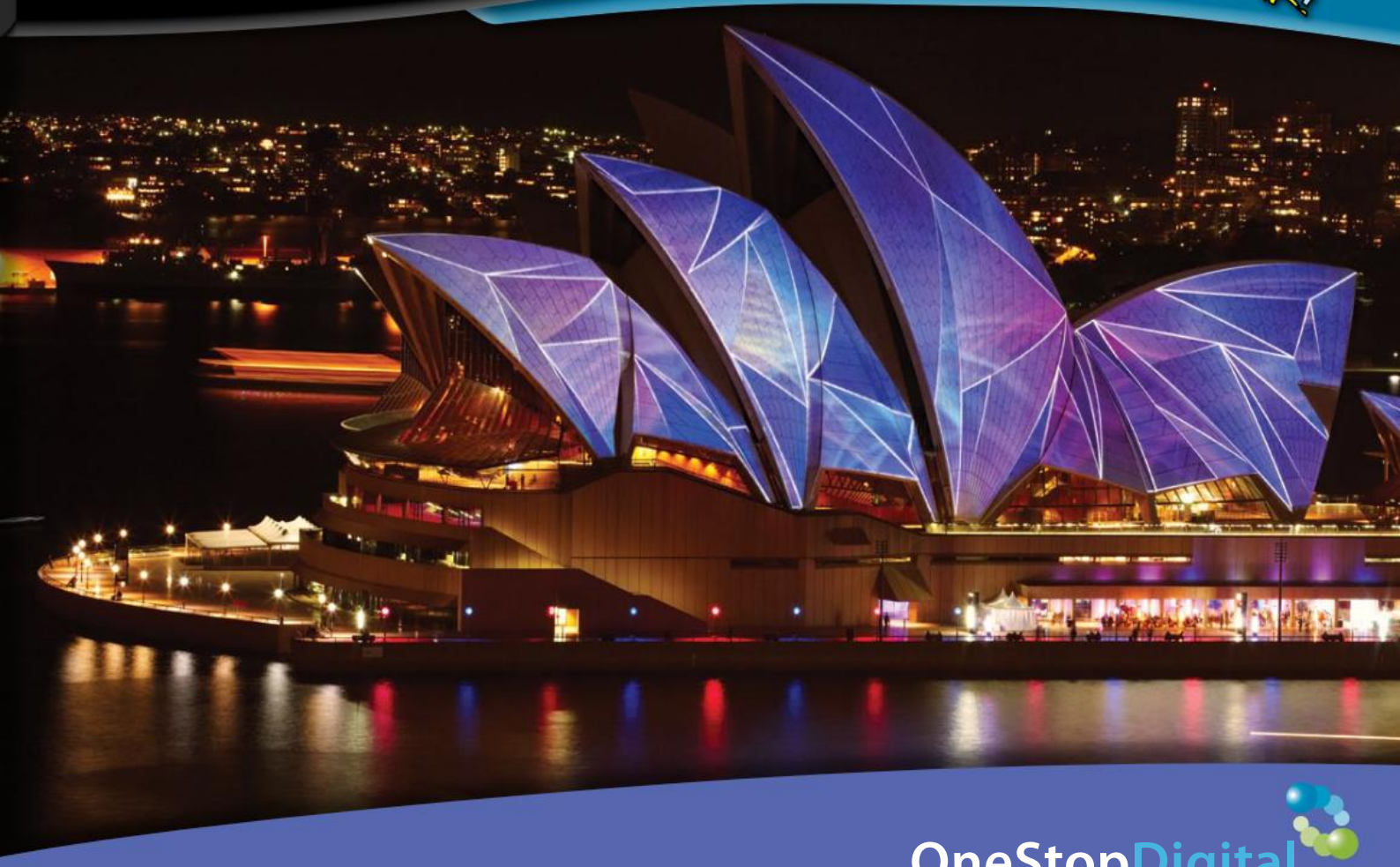
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Science Essentials for NSW 9

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Anne Garton

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As usual there is Problem solving in each chapter. For example, in Chapter 1, you design an experiment with acids and bases and pH.

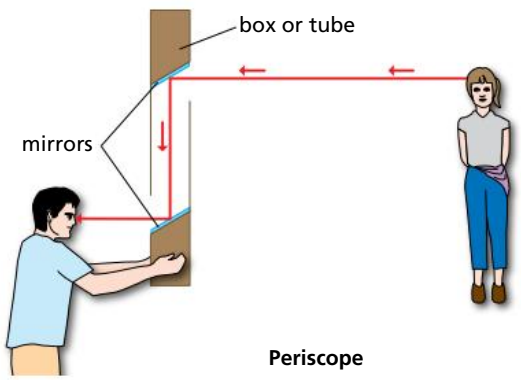
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Getting to know the book

In writing this book we have tried to make science enjoyable by talking about things in your everyday life and making them easy to understand. To get to know the book we suggest you work through the questions on this page and the next. You may want to do this in a small group.

Focus for learning

At the beginning of each chapter there is a short section which explains how the chapter is relevant to you and the world around you. There is also a list of what you will do in the chapter and important words.



At the start of each chapter there is also a problem for you to work on over several weeks. You will often work with other students on this problem. Sometimes you will design your own experiments, sometimes you will prepare a presentation for the class, and sometimes you will make something. For example, in Chapter 7 page 143 you have to build an electrical gadget. As you work through the chapter you will learn things that will help you with your problem.

Throughout the chapter you will find *Problem solving* reminders and suggestions to help you complete your problem.

- Find the *Problem solving* tasks in each of the 12 chapters. Which one of these looks the most interesting to you?

Inquiries and investigations



Most chapters have five short sections. In most lessons there are activities called *Inquiries*—to help you understand things better. There are also about three *Investigations* per chapter, where you will work in a science laboratory and write a report.

- Look through the book. What differences do you notice between *Inquiries* and *Investigations?*

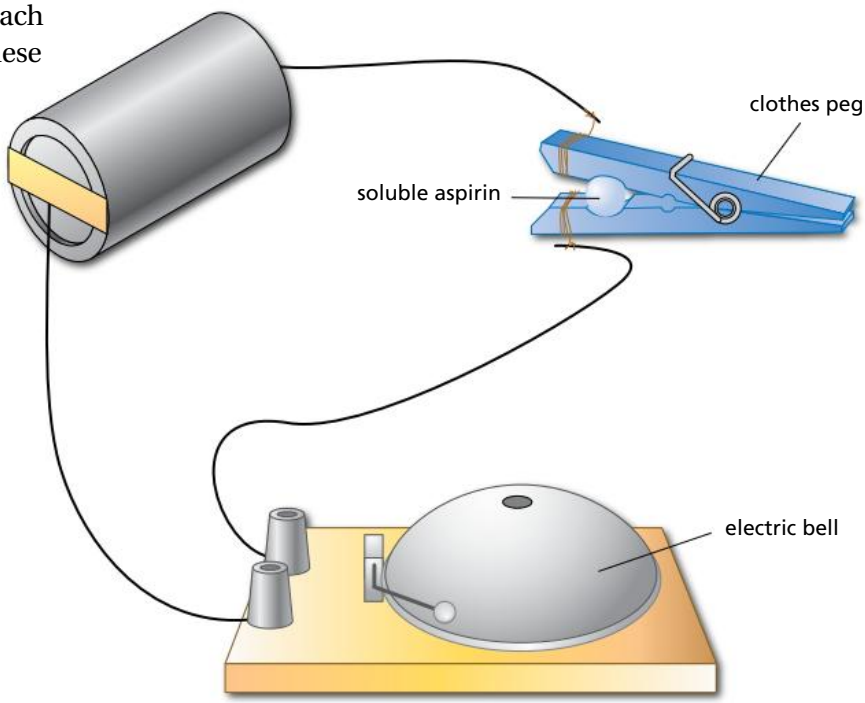
At the beginning of each *Investigation* there is a section called *Risk assessment and planning*. It is essential that you read the investigation carefully before you start. You then discuss with your teacher any risks involved and how to reduce these risks. If necessary you also prepare data tables or spreadsheets where you can record your results.

- Have a look at *Investigation* 1 on page 7.



In each chapter there is a page where you learn science skills such as handling chemicals safely. You also learn communication skills such as reading scientific articles, and science inquiry skills such as predicting.

- Use the Contents on the previous pages to find some of the *Skills*.



In Chapter 7 you build an electrical gadget like this rain alarm.

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SCIENTISTS AT WORK

In each chapter there is a page where you can find out about the work done by scientists now and in the past.

- Make a list of the scientists featured in *Scientists at work*. There are also special pages called *Science as a human endeavour* which are designed to show how science is used in everyday life.

At the end of each section there is a set of exercises called *Over to you*. These are designed to test your science knowledge and understanding.

THINKING SKILLS

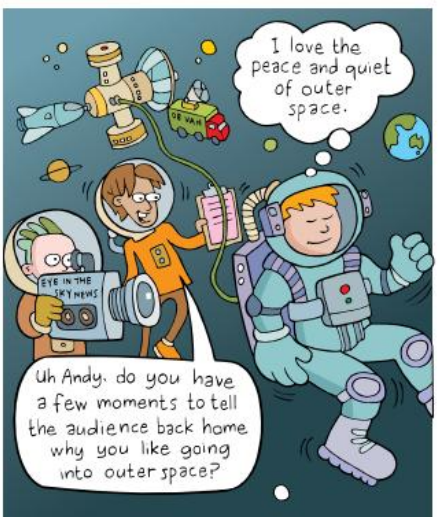
Towards the end of each chapter there is a section called *Thinking skills*. The exercises here are more difficult than those in *Over to you* and are designed to check how well you understand the chapter and whether you can think for yourself.

- Have a look at *Thinking skills* for Chapter 1 on page 23. Could any of these exercises be turned into a science project? Which ones?

Self-management

At the end of each chapter there is a page to help you summarise and revise the chapter.

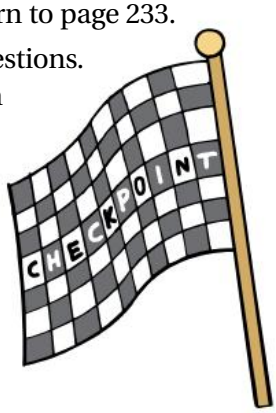
- Turn to page 280. Check the *Knowledge and Understanding* where you use the words on the right to fill in the gaps. See if you can do any of them.
- What is the purpose of the *Self-management* section on page 280?



Checkpoint

Checkpoint is where you can check your knowledge, understanding and skills from the chapter before any tests your teacher gives you. Turn to page 233.

- Try one or more of these questions. Then check your answers on page 287.
- What should you do if you can't do the *Checkpoint* questions?



Glossary and Index

- Important new words are in bold in the text and their meanings are in the Glossary starting on page 289. Look through it and find a word you haven't seen before. Read its meaning and then find where the word is used in the book.
- Use the index to find out which page you would find information on
  - quarks
  - O.J. Simpson
  - pH of soil.

Check the page to see what information there is.



We hope you enjoy *Science Essentials*.

Ken Williamson
and Anne Garton

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Links to the NSW syllabus

The content statements in the right-hand column are listed at the beginning of each chapter. They are based on those in the NSW Science Years 7–10 Syllabus, but have been simplified and re-written in terms more meaningful to students. They indicate some of the ways in which the NSW syllabus content can be developed using *Science Essentials 9 for NSW*. All Stage 5 Working Scientifically outcomes are covered in *Science Essentials 9 for NSW*, but the Knowledge and Understanding outcomes are spread across Years 9 and 10.

Working Scientifically outcomes	Content statements for *Science Essentials 9 for NSW*
Questioning and predicting Develops questions or hypotheses to be investigated scientifically (SC5-4WS)	**Chapter 12 Problem solving** pages 258, 266, 279 • formulate questions or hypotheses about space that can be investigated scientifically (4a)
Planning investigations Produces a plan to investigate identified questions, hypotheses or problems, individually and collaboratively (SC5-5WS)	*WS5.1 Identify data sources* **Chapter 3 Investigation 2** page 58 • describe the purpose of an investigation (5.1a) **Chapter 10 Forensic skills** • explain why various types of forensic evidence need to be collected to solve a crime (5.1b) **Chapter 12 Problem solving** pages 258, 266, 279 • select sources of information for a space experiment (5.1c) *WS5.2 Plan first-hand investigations* **Chapter 3 Investigation 1** page 54 • explain the need for an experimental control (5.2e) **Chapter 5 Problem solving** pages 95, 99, 113 • plan and select appropriate methods to collect reliable data (5.2a) **Chapter 6 Investigation 3** page 137 • plan and select appropriate investigation methods to collect reliable data on water quality in a creek or pond (5.2a) **Chapter 8 Inquiries** pages 170–171 and **Investigation 1** page 174 • select appropriate methods to collect and record reliable data on how mirrors and lenses work (5.2a) **Chapter 10 Inquiry 11** page 227 and **Investigation 2** page 228 • describe the logical procedures for collecting different types of forensic evidence (5.2b) *WS5.3 Choose equipment or resources* **Chapter 3 Investigations** • identify the equipment and materials needed to perform various experiments (5.3a) • assess risks associated with laboratory experimentation (5.3d)
Conducting investigations Undertakes first-hand investigations to collect valid and reliable data and information, individually and collaboratively (SC5-6WS)	**Chapter 3 Investigation 5** page 65 • construct an appropriate data table to record the results of an experiment (6e) **Chapter 4 Investigation 1** page 79 • use laboratory equipment to safely dissect a kidney (6b) • assess the effectiveness of an experiment and whether its design could be improved (6f) **Chapter 5 Investigations** pages 99, 102 and **Inquiry 3** page 101 • select and safely use laboratory equipment, either individually or in a group (6a)

continued >>>

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	Chapter 6 Investigation 2 page 135 • select and use equipment to systematically and accurately collect and record data on plant growth (6c) **Chapter 8 Investigation 2** page 177 • safely construct, assemble and manipulate laboratory equipment (6b)
Processing and analysing data and information Processes, analyses and evaluates data from first-hand investigations and secondary sources to develop evidence-based arguments and conclusions (SC5-7WS)	*WS7.1 Processing information* **Chapter 4 Problem solving** pages 73, 84, 90 • research drugs and suggest ways to convince people to say 'No' to them (7.1c) **Chapter 8 Skill** page 175 • apply numerical procedures and mathematical concepts to draw ray diagrams for mirrors and lenses (7.1d) **Chapter 10 Forensic skills Problem solving** • use a table to record and analyse evidence from a crime scene (7.1a) • identify data that supports or discounts a question or hypothesis being investigated (7.1e) **Chapter 12 Inquiry 6** page 270 • use the internet to access information on terraforming Mars (7.1c) *WS7.2 Analysing information* **Chapter 5 Skill** page 107 • detect bias when interpreting information in tables and graphs (7.2f) **Chapter 9 Science as a human endeavour** page 203 • discuss the reliability of scientific studies, using a mobile phone study as an example (7.2g) **Chapter 10 Forensic skills Problem solving** • use knowledge or scientific concepts to draw conclusions that are consistent with evidence (7.2d) • evaluate conclusions and evidence, identifying sources of uncertainty and possible alternative explanations (7.2f)
Problem-solving Applies scientific understanding and critical thinking skills to suggest possible solutions to identified problems (SC5-8WS)	**Chapter 4 Problem solving** pages 73, 84, 90 • suggest a range of possible solutions to an identified problem (8a) **Chapter 7 Problem solving** pages 143, 152 • assess strategies that have been identified as possible solutions to a problem (8b) **Chapter 8** page 181 and **Problem solving** pages 168, 183 • use cause-and-effect relationships to explain ideas such as why the sky is blue (8d) • evaluate approaches used to solve problems (8g) **Chapter 11 Inquiry 4** page 238 • use models to explain geological phenomena and make predictions (8e) **Chapter 12 Inquiry 7** page 271 • apply critical thinking in considering a proposal to mine Mars (8f)
Communicating Presents science ideas and evidence for a particular purpose and to a specific audience, using appropriate scientific language, conventions and representations (SC5-9WS)	**Chapter 2 Skill** page 28 and **Problem solving** pages 27, 46 • prepare and present a persuasive speech to the class on nuclear energy (9e) **Chapter 5** pages 105–106 • discuss whether vaccination for children should be compulsory (9a) **Chapter 7 Electrical energy** • draw circuit diagrams using the correct symbols (9a) **Chapter 9 Inquiry 4** page 204 • use mathematical equations to describe relationships between the variables of wavelength, frequency and speed (7.2b/9c) **Chapter 12 Science as a human endeavour** page 277 • propose coherent and logical ideas about space exploration (9d)

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Knowledge and Understanding outcomes	Content statements for *Science Essentials 9 for NSW*
Physical World Applies models, theories and laws to explain situations involving energy, force and motion (SC5-10PW) Explains how scientific understanding about energy conservation, transfers and transformations is applied in systems (SC5-11PW)	*PW1 Energy transfer through different mediums can be explained using wave and particle models.* **Chapter 8 Light energy** • distinguish between the absorption, reflection and refraction of light and identify everyday situations where each occurs (1f) **Chapter 9 Using radiation** • identify situations where waves transfer energy (1b) • describe the features of waves—wavelength, frequency and speed (1c) • name and describe the properties of the different types of radiation that make up the electromagnetic spectrum (1e) • relate the properties of different types of radiation to their uses in everyday life, including communications technology (1e) **Chapter 12 Going into space** page 278 • explain the transmission of sound in different mediums (1d) *PW3 Scientific understanding of current electricity has resulted in technological developments designed to improve the efficiency in generation and use of electricity.* **Chapter 7 Electrical energy** • describe electric current, voltage and resistance using analogies (3a) • describe qualitatively the relationship between voltage, resistance and current (3b) • compare the characteristics and uses of series and parallel circuits (3c) • discuss Cathy Foley's career with superconductors (3d)
Earth and Space Describes changing ideas about the structure of the Earth and the universe to illustrate how models, theories and laws are refined over time by the scientific community (SC5-12ES) Explains how scientific knowledge about global patterns of geological activity and interactions involving global systems can be used to inform decisions related to contemporary issues (SC5-13ES)	*ES2 The theory of plate tectonics explains global patterns of geological activity and continental movement.* **Chapter 11 Plate tectonics** • outline how the theory of plate tectonics has changed ideas about the structure of the Earth and continental movement over geological time (2a) • describe how heat energy and convection currents in the Earth's mantle cause the movement of Earth's plates (2b) • outline how the theory of plate tectonics explains global patterns of geological activity, including earthquakes and volcanoes (2c) • describe how technological developments have increased scientific understanding of global patterns of geological activity (2d) *ES3 People use scientific knowledge to evaluate claims, explanations or predictions in relation to interactions involving the atmosphere, biosphere, hydrosphere and lithosphere.* **Chapter 11 Plate tectonics** • describe some impacts of volcanic eruptions and earthquakes (3b)
Living World Analyses interactions between components and processes within biological systems (SC5-14LW) Explains how biological understanding has advanced through scientific discoveries, technological developments and the needs of society (SC5-15LW)	*LW1 Multicellular organisms rely on coordinated and interdependent internal systems to respond to changes in their environment.* **Chapter 3 Health and nutrition** • explain how the digestive system provides cells with the requirements for life (1b) **Chapter 4 Body balance** • describe some examples of how multicellular organisms respond to changes in their environment (1a) • outline how the nervous and endocrine systems work together to maintain humans as functioning organisms (1d)

continued >>>

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	Chapter 5 Disease • outline some responses of the human body to infectious and non-infectious diseases (1c) • discuss how the values and needs of society can influence the focus of scientific research (1e) *LW2 Conserving and maintaining the quality and sustainability of the environment requires scientific understanding of interactions within, the cycling of matter and the flow of energy through ecosystems.* **Chapter 6 Ecosystems** • recall that ecosystems consist of communities of interdependent organisms and distinguish between biotic and abiotic components of their environment (2a) • analyse how changes in biotic and abiotic components of an ecosystem affect populations of organisms (2d) • discuss how Aboriginal people recognise relationships in local ecosystems and use their knowledge to conserve and manage their environment (2e) • evaluate some examples of strategies used to balance human activities and the needs of ecosystems (2f)
Chemical World Explains how models, theories and laws about matter have been refined as new scientific evidence becomes available (SC5-16CW) Discusses the importance of chemical reactions in the production of a range of substances, and the influence of society on the development of new materials (SC5-17CW)	*CW1 Scientific understanding changes and is refined over time through a process of review by the scientific community.* **Chapter 2 Atomic structure** • describe the structure of atoms in terms of the nucleus, protons, neutrons and electrons (1a/b) • outline historical developments of the atomic theory to demonstrate how models and theories change over time (1c) • identify that natural radioactivity arises from the decay of the nuclei in atoms, releasing particles and energy (1d) • evaluate the benefits and problems associated with medical and industrial uses of nuclear energy (1e) *CW3 Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction, mass is not created or destroyed.* **Chapter 2 Atomic structure** • recall that matter is composed of atoms and has mass (3a) **Chapter 1 Everyday reactions** • identify a range of compounds using their common names and chemical formulas (3b) • classify compounds into groups based on their chemical properties (3c) • investigate the reactions of acids, including neutralisation (3d) • investigate a range of important chemical reactions that occur in living and non-living systems and involve energy transfer (3e) • construct word equations from observations and written descriptions of a range of chemical reactions (3f) *CW4 Different types of chemical reactions are used to produce a range of products and can occur at different rates and involve energy transfer.* **Chapter 1 Everyday reactions** • identify that chemical reactions involve energy transfer and can be exothermic or endothermic (4a) • compare combustion and respiration as types of chemical reactions that release energy but occur at different rates (4b)

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1



Everyday reactions

By the end of this chapter you will be able to …

Knowledge and Understanding

- identify a range of compounds using their common names and chemical formulas (CW3b)
- classify compounds into groups based on their chemical properties (CW3c)
- investigate the reactions of acids, including neutralisation (CW3d)
- investigate a range of important chemical reactions that occur in living and non-living systems and involve energy transfer (CW3e)
- construct word equations from observations and written descriptions of a range of chemical reactions (CW3f)
- identify that chemical reactions involve energy transfer and can be exothermic or endothermic (CW4a)
- compare combustion and respiration as types of chemical reactions that release energy but occur at different rates (CW4b)

LITERACY FOCUS

In a notebook, write the meaning of each of the following terms, *in your own words*. If you aren't sure of their meaning, check the glossary at the back of the book, or a dictionary. This way, as you work through the book, you can build up your own alphabetical glossary. You should also be able to spell the words correctly.

acidity
alkali
antacid
bacteria
botulism
caustic soda
combustion
indicator
indigestion
litmus
neutralisation
ozone
pH
phenolphthalein
photosynthesis
plaque
respiration
sodium hydroxide
sulfur dioxide
sulfuric acid

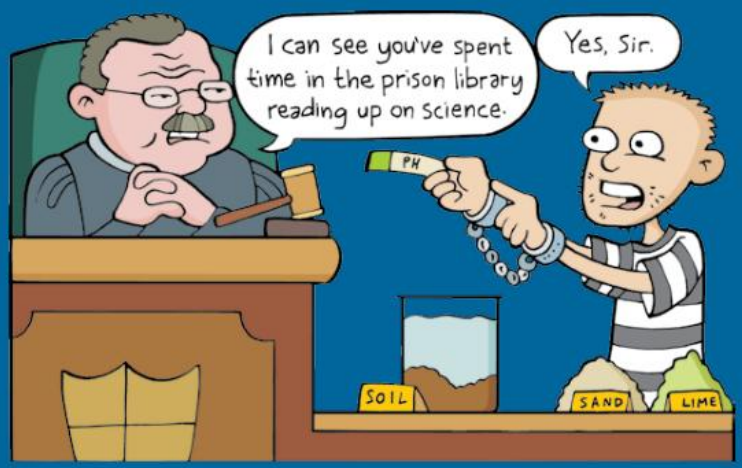
PROBLEM SOLVING

Your own design

In this chapter you will investigate the properties of acids and bases, and learn how to measure the pH of a solution. The pH tells you how acidic the solution is. Your task is to design an experiment to investigate something about acids that interests you. Here are a few ideas. You will find more ideas throughout the chapter.

1 Nifty Ned has been arrested for stealing a lawn mower from a garden shed. The police say that powder found on his shoes is lime from the floor of the shed. Nifty claims that he has been surfing and that the white powder is sand.

Imagine you are the crime scene investigator (CSI). Can you tell the difference between lime, sand, soil and other substances by measuring their pH when mixed with water?



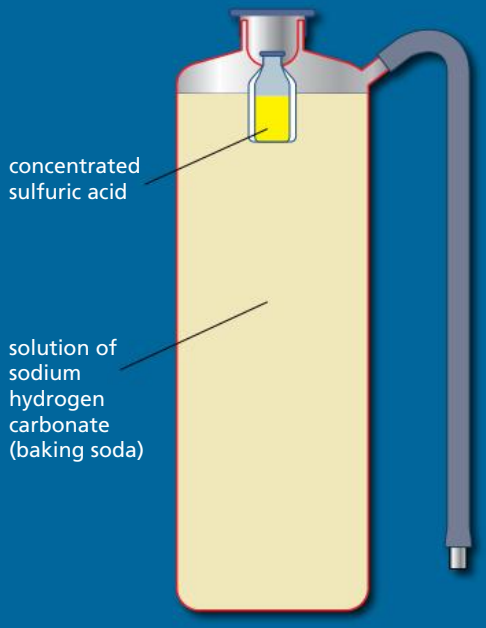
2 Do you have an old tooth at home—perhaps a baby tooth? Weigh it, place it in soft drink for several days, then weigh it again. Try to explain your results.

3 What effect does acid rain have on the growth of plants? Before you start, check your plan with your teacher.

4 Next time you cut your hair, keep some to test. Do the properties of the hair change when it is soaked in shampoo, conditioner or water? What is the pH of the liquids you used?



5 The diagram below shows a soda acid fire extinguisher. When it is tipped upside-down the acid and the baking soda mix, producing carbon dioxide gas. Can you make a simple fire extinguisher by using laboratory equipment? For safety you will need to use a dilute acid rather than a concentrated one.



Focus for learning

The acids in a science laboratory must be handled with care. This is because they are corrosive and will burn your skin and clothes. However, there are many different types of acids and some of these are quite safe to handle. For example, vinegar contains acetic acid—an acid that is safe enough to put on hot chips.

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1.1 Important chemical reactions

There are three important chemical reactions that take place in and around all living things. Do Inquiry 1 and see what you can remember.

INQUIRY 1 *Quick quiz*

Which chemical reaction:

1. Do plants use to make food in their leaves?
2. Increases levels of nitrogen in our atmosphere from the burning of fossil fuels?
3. Is taking place in your body to give you the energy to read this page?
4. Is the basis of all food chains and food webs?
5. Uses carbon dioxide from the air and produces oxygen?
6. Is needed from time to time by Australian forests to clear the undergrowth and stimulate new plant growth?
7. Releases carbon dioxide into the atmosphere?

Turn to the end of this section on page 5 to see if your answers are correct.

There are important reactions that take place every day that you are probably not aware of. However you could not function without chemical reactions taking place inside you, and other living things are the same.

Think of a plant in a forest. It may appear that the plant is doing nothing, but it is really quite busy.



There are many chemical reactions that are occurring within its leaves to keep the plant alive. Two of the most important chemical reactions are photosynthesis and respiration. Let's review these reactions from earlier studies.

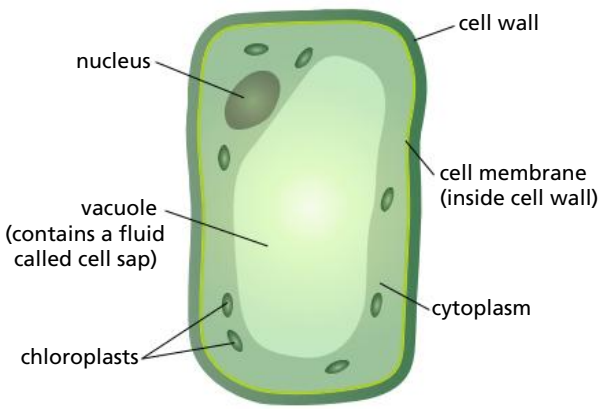
Photosynthesis

Plants use energy from the sun to produce food in the form of a simple sugar called glucose. This can be written as the following word equation:

carbon dioxide + water + sunlight → glucose + oxygen

This type of reaction which needs energy to make it go is said to be **endothermic**. It takes in energy. (*Endo* means 'in'.)

From your work on cells you know that plant cells contain structures called chloroplasts. These are made up of chlorophyll which gives plants their green colour. Chlorophyll absorbs energy from the sun to start the process of photosynthesis.



Life on Earth could not survive without photosynthesis. It is vital for producing oxygen in the atmosphere. Half of the world's oxygen is produced by land plants such as trees, shrubs and grasses. The other half is produced by phytoplankton (tiny microscopic plants) that drift around in our oceans. Scientists infer that it wasn't until organisms in the ocean started to carry out photosynthesis and release oxygen 2.7 billion years ago that other life forms could exist.

Organisms that carry out photosynthesis (producers) are the basis of all food chains and food webs on Earth. As producers are eaten, the energy that they captured from the sun is passed along the food chain. So life on Earth would cease to exist without photosynthesis.

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Cellular respiration

The plant in the forest is also carrying out respiration. Some of the sugar and oxygen made in photosynthesis is used to make energy for the plant. This energy is needed for other processes such as growth and reproduction. It is hard to imagine that a plant is carrying out thousands of chemical reactions every second, but it is. Without the energy made from respiration these would cease.

glucose + oxygen → carbon dioxide + water + energy

This process is referred to as **cellular respiration** because it takes place inside cells, in structures called mitochondria. It is different from breathing in and out, which some animals do, which is also called respiration.

Like a plant your body carries out cellular respiration. You need energy for all the chemical reactions that take place inside you. This is called your *metabolism*. You also need energy to move and carry out daily tasks.

Since you are an animal, not a plant, you are unable to carry out photosynthesis and make your own food. So you have to eat and digest (break down) the food to be able to use it. This requires energy. Some of the energy released from cellular respiration is also used by your body for heat. To maintain a constant body temperature you need heat. Growth and reproduction, removal of wastes, transportation of substances around your body and repair of cells are also processes that you carry out that require energy, just as plants need energy.

Combustion

Combustion is the burning of a fuel with oxygen to produce heat and light. This type of reaction which releases energy is said to be **exothermic**. It gives out energy. (*Exo* means 'out'.) The process of cellular respiration is often referred to as 'combustion' in the body because it is the slow burning of fuel (glucose) with oxygen to produce energy in the cells. It is different from the combustion of fuels like wood or petrol, however, because it occurs very slowly and at body temperature.

The combustion of wood or petrol requires a large amount of energy to get it started. For example combustion of petrol in a car engine requires a spark from a spark plug to ignite the petrol-and-oxygen mix in the pistons. A large amount of energy is also released, mainly in the form of heat.

In many combustion reactions a flame or explosion occurs, producing heat and light.

fuel + oxygen → carbon dioxide + water + energy (heat + light)

In complete combustion, water and carbon dioxide are produced. However, more often than not, incomplete combustion occurs when fuels are burnt in air. This produces other substances too, such as soot and carbon monoxide. Nitrogen oxides are also produced because air contains nitrogen as well as oxygen. These substances contribute to air pollution.



Combustion (burning) is an everyday reaction.

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Reactions in non-living systems

Living things rely on the non-living world to survive. For example, air, the weather, the availability of water and minerals in the soil can all affect life on Earth.

Living things rely on chemical reactions that take place in non-living systems, for example the reaction of ozone with ultraviolet light. The ozone layer in our atmosphere protects all living things on Earth from the harmful effects of ultraviolet radiation from the sun. It also helps prevent extreme temperature changes from day to night.

Oxygen molecules (O_2) in our atmosphere are constantly being broken down by UV light to produce single oxygen atoms (O + O). These atoms are then free to bond with other O_2 molecules to produce ozone: $O_2 + O \rightarrow O_3$ (ozone).

UV light in the atmosphere is needed for ozone to form, but once formed, ozone absorbs the UV light and stops it reaching the lower levels of the Earth's atmosphere. The ozone layer therefore shields all living things on Earth from the effects of UV light. Too much UV light can cause cell **mutations** (changes). This can affect the DNA or genetic code of living things and may lead to cancer. UV light can also cause eye and skin damage and affect the immune system of living things. So the chemical reactions that occur to make ozone are vital to life on Earth.

Scientists have also discovered that nitric oxide (NO) and nitrogen dioxide (NO_2) in the atmosphere also help with ozone formation. These nitrogen oxides are formed by natural processes such as lightning, forest fires (combustion) and chemical processes that take place in the soil. Natural systems could not exist without such important chemical reactions.

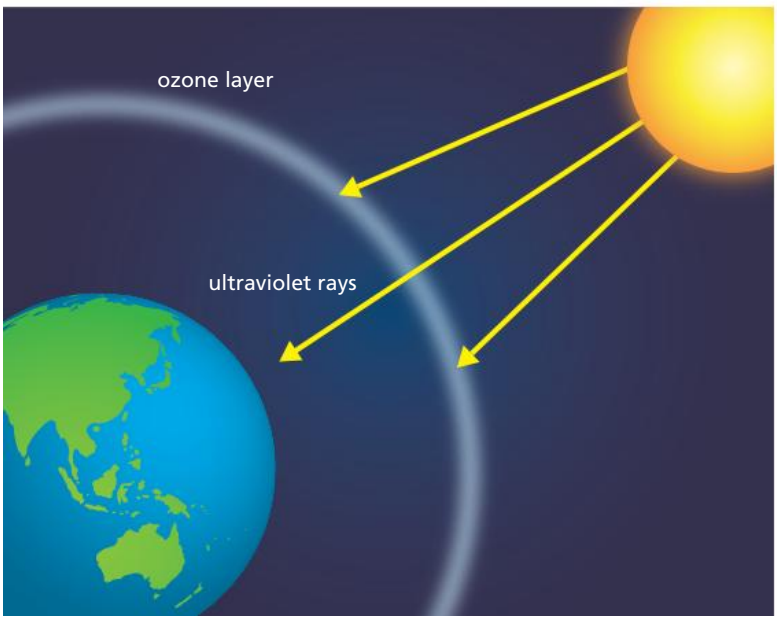
Natural systems are also being affected by unwanted chemical reactions that are occurring in the environment. For example, the burning of fossil fuels produces large amounts of carbon dioxide. This gas can dissolve in water to produce carbonic acid. This process occurs in our atmosphere to produce **acid rain** which is killing forests and living systems in many parts of the world. It is also damaging concrete in buildings, mortar (cement) in brickwork and marble in statues by reacting with the calcium carbonate in these materials. You will learn more about acids in the rest of this chapter.

Over to you

1. What is the difference between living and non-living things?
2. What is the difference between an atom and a molecule?
3. Where does cellular respiration occur?
4. Give an example of how a chemical reaction is needed for a living organism to survive.
5. Give an example of a wanted chemical reaction and an unwanted one.

Answers for Inquiry 1:

1. photosynthesis
2. combustion
3. respiration
4. photosynthesis
5. photosynthesis
6. combustion
7. respiration



How the ozone layer protects us from harmful UV radiation from the sun.

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1.2 What are acids?

Acids are very common substances used in everyday life. Some acids are *strong* and some are *weak*. Strong acids like sulfuric and hydrochloric acid can be dangerous if not handled correctly. This is because they are *corrosive* and can burn through solid objects. Car batteries contain sulfuric acid. Hydrochloric acid is used to clean mortar from bricks, and to clean the surface of tin before soldering. In industry acids are used to produce a wide range of products including drugs, explosives, fertilisers and plastics.



Hydrochloric acid is used to clean unwanted cement from newly laid bricks.

Weak acids, however, can be safe enough to eat and drink. For example, vinegar contains acetic acid, citrus fruits contain citric acid, and the bubbles in soft drink are caused by carbonic acid. For other examples of weak acids, see the photo below.

Properties of acids

All acids have a sour taste, as you will know if you have tasted a lemon. In fact, **acid** comes from the Latin word *acidus* meaning 'sour'.

Because acids are corrosive they attack your body tissues. This is why lemon juice stings if it gets in a cut on your finger. Similarly, bees and ants sting because they inject formic acid into you. Fruit and vegetables contain acids but they can be eaten because these acids are very dilute. A *dilute* acid is one that contains a large amount of water and a small amount of acid. The opposite of dilute is *concentrated*, and concentrated acids must be handled with great care.

If acid is spilt on your skin or clothes, you must wash the area immediately with plenty of water. Adding water makes the acid more dilute.



Acids taste sour.



Some foods and drinks contain dilute acids.

ISBN 978 1 4202 3246 2

INVESTIGATION

1 Properties of acids

Aim

To investigate the properties of acids.

Risk assessment and planning

Do not handle concentrated acids. The dilute acids you will be using are less dangerous than concentrated acids, but they must be handled with care. Before doing this practical, make sure you can answer all these questions.

1 What does the corrosive symbol below mean?
2 How can you protect your school clothes from acid spills?
3 What should you do if any acid (or alkali) is spilt on your skin or clothes?
4 How will you protect your eyes when working with acids?
5 What should you do if a corrosive liquid splashes into your eyes?

Part A: Teacher demonstration

Apparatus

- bull's eye from butcher
- petri dish
- concentrated sulfuric acid

Method

1 Your teacher will place a bull's eye in a petri dish and add a few drops of concentrated sulfuric acid. Observe what happens to the eye in the next 5 minutes.

Part B: Reaction with metals

Apparatus

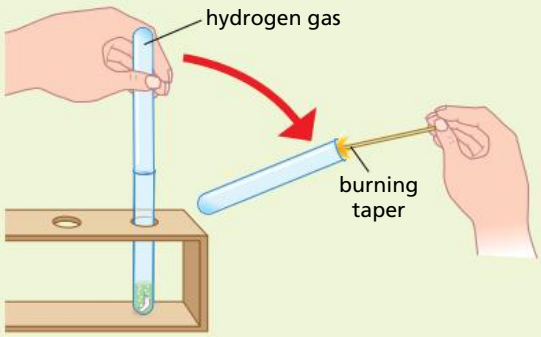
- *dilute hydrochloric acid (1 M)*
- test tubes and test tube rack
- small pieces of metals such as aluminium, copper, iron, magnesium, tin and zinc (to fit into test tubes)
- taper and matches

Method

1 You will be adding acid to each of the metals provided. Draw up a data table to record your observations.
2 Put one of the metals into a test tube and add a small amount of acid (just enough to cover the metal). Observe carefully for these signs of a reaction: bubbling, metal disappearing, a colour change or the test tube getting warm (exothermic reaction).

✻ Record your observations.

3 Repeat this with the other metals.
4 You can test the gas released by collecting it in an upside-down test tube, as shown. Put your thumb over the end of the tube, tilt the tube upwards, remove your thumb and quickly put a burning taper near the mouth of the tube. A loud pop means that the gas is hydrogen.



✻ List the metals from the most reactive to the least reactive.

5 If you have time you could repeat the test using other acids, e.g. dilute sulfuric acid and vinegar.

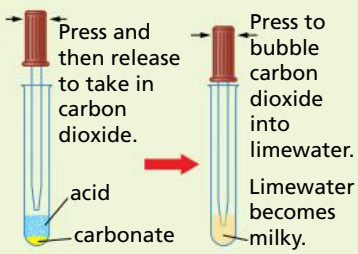
Part C: Reaction with carbonates

Apparatus

- *dilute hydrochloric acid (1 M)*
- test tubes and test tube rack
- various carbonates, e.g. calcium carbonate (marble chips), sodium carbonate (soda ash), sodium hydrogen carbonate (baking soda), copper carbonate
- dropper
- fresh limewater (calcium hydroxide solution)

Method

1 Repeat Part B with carbonates instead of metals.
2 You can test the gas in the test tube using limewater as shown.



3 You could repeat the test with other acids.

Conclusion

Write down three properties of acids that you have observed in this investigation. Write them as generalisations that are true in most cases.

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Reactions of acids

As you found in Investigation 1, when an acid reacts with a metal, hydrogen gas is produced. A **salt** was left in solution in the test tube. This is an ionic compound containing the ions left over from the reaction. The general reaction can be written as:

metal + acid → salt + hydrogen

For example:

zinc + hydrochloric acid → zinc chloride + hydrogen

Some metals such as sodium react violently with acids, even when they are cold and dilute. Other metals such as lead need hotter or more concentrated acid to make them react.

In Part C of Investigation 1 you would have found that when an acid reacts with a carbonate, carbon dioxide gas is produced. A salt and water were also produced. They were both left in the test tube.

carbonate + acid → salt + carbon dioxide + water

For example:

calcium carbonate + hydrochloric acid →
calcium chloride + carbon dioxide + water

Bases

Bases are the chemical opposite of acids—they cancel out each other. Strong bases, like strong acids, attack living tissue and cause serious burns. But while strong acids are corrosive, we say that strong bases are *caustic*. Bases that dissolve in water are called **alkalis**.

Alkalis have a soapy feel and are very good at dissolving grease. For example, oven cleaner usually contains caustic soda or sodium hydroxide (NaOH). It reacts with oils to form soap, which can then be washed away. The table below shows some common bases and their uses.

Base	Chemical name	Uses
caustic soda	sodium hydroxide NaOH	making soap, oven cleaners
ammonia	ammonium hydroxide NH_4OH	cleaning products, making fertiliser
baking soda (bicarbonate of soda)	sodium hydrogen carbonate $NaHCO_3$	to make cakes rise in cooking
soda ash (washing soda)	sodium carbonate Na_2CO_3	making glass, household cleaner
lime	calcium hydroxide $Ca(OH)_2$	reducing acidity in soil



Household cleaners contain alkalis such as ammonia and caustic soda.

Over to you

1 Match the names in the following lists:

acetic acid	yoghurt
carbonic acid	car batteries
citric acid	soft drink
lactic acid	grapes
phosphoric acid	vinegar
sulfuric acid	lemons
tartaric acid	Coca-Cola

2 Monica has spilt some acid on her jumper sleeve. What should she do?

3 Acids have a sour taste but you must never taste anything in the laboratory to find whether or not it is an acid. Why?

4 What does it mean if a substance is corrosive?

5 What is the difference between a dilute solution of nitric acid and a concentrated one?

6 How can you test for:

a hydrogen gas?

b carbon dioxide gas?

7 Give the names and uses of two alkalis found in the home.

8 Name the acid, the metal and the salt in this reaction:

sulfuric acid + magnesium →
magnesium sulfate + hydrogen

9 Describe a test you could carry out to show that egg shells and limestone are both made of calcium carbonate.

10 Suggest ways of increasing the rate (speed) of the reaction between a metal and an acid.

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INVESTIGATION

2 Changing colours

Aim

To extract the colour from red cabbage and other plants, then use it to test if household substances are acidic or basic.

Risk assessment and planning

Read the investigation carefully and do a risk assessment.

Apparatus

- 2 or 3 large leaves from a fresh red cabbage
- sharp knife and chopping board
- 2 × 250 mL beakers
- electric hotplate or Bunsen burner equipment
- stirring rod
- 6 test tubes and a test tube rack
- *dilute hydrochloric acid (0.1 M)*
- *sodium hydroxide solution (0.1 M)*



- distilled water
- various household substances, e.g.:

antacid tablet	milk
baking soda	shampoo and conditioner
cream of tartar	vinegar
household ammonia	vitamin C tablet
lemon juice	

- mortar and pestle
- sieve (optional)
- colourful flower petals or leaves with strong colours

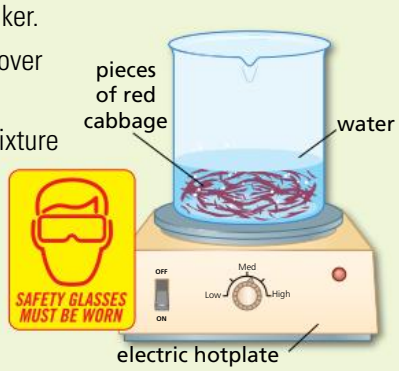
Part A: Red cabbage

Method

1 Cut up the large red cabbage leaves into small pieces. Put them into a beaker.

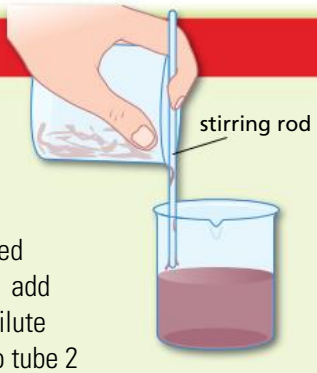
2 Add water to just cover the cabbage.

3 Boil the cabbage mixture for 5–10 minutes. The water should turn a dark colour and the leaves should almost lose their colour.



4 Let the mixture cool, then decant the coloured solution into a second beaker. (Alternatively, you could strain the mixture through a sieve.)

✻ What colour is the cabbage extract?



Decant the coloured extract

5 Prepare three labelled test tubes. To tube 1 add a small amount of dilute hydrochloric acid. To tube 2 add distilled water. This is neutral—neither acidic nor basic. To tube 3 add sodium hydroxide solution, which is basic. Add a few drops of red cabbage extract to each tube.

✻ Note the colour of the extract in acidic, neutral and basic solutions.

6 Now use your cabbage extract to test the various household substances provided.

✻ For each substance record any colour change. Is the substance acidic, neutral or basic?

Results

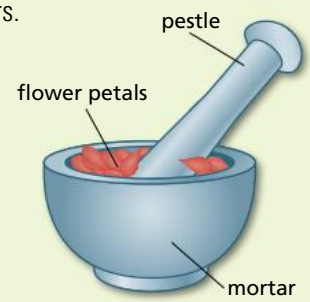
1 Which household substances are acidic? Which are basic?

2 How could you order these substances from the *most* acidic to the *most* basic? Try it.

3 Suggest why red cabbage extract is called an indicator.

Part B: Flower petals

1 Extract the colour from brightly coloured flowers or leaves with strong colours. You could also try fresh beetroot or tea leaves. Grind the petals in a mortar with a little water, then decant the liquid. If you have a blender you could use it. Alternatively, heat the petals as in Part A, but don't boil them as this can destroy some of the colour.



2 Test whether your extract is an acid–base indicator.

Part C: Other things to try

1 Try mixing the extracts from two or more different flowers. Does the mixture work as an indicator?

2 To make indicator paper, wet strips of filter paper with your favourite plant extract and leave the paper to dry. Dip the paper into the test solutions.

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1.3 Acid test

You cannot taste a liquid to find whether it has the sour taste of an acid. A much better way is to use an acid–base **indicator**, as you did in Investigation 2. An indicator on a car tells you whether someone is turning left or right. So too, acid–base indicators tell you whether a substance is acidic or basic. Many natural substances like red cabbage are good indicators.

Litmus is a purple dye that is extracted from certain lichens which grow on rocks. In acidic solutions it turns red, and in basic solutions it turns blue. The red dye cochineal is another indicator. Cochineal is made from the dried and ground-up bodies of female scale insects that live on cactus plants in Mexico. It is also used as food colouring. Other indicators are synthetic. For example, phenolphthalein (fee-nol-THAL-een) was first made by the German chemist Adolf von Baeyer in 1871. It is bright pink in basic solutions, but colourless in acidic solutions.

INVESTIGATION

3 Using indicators

Aim

To investigate how indicators change colour in acidic and basic solutions.

Risk assessment and planning

Read the investigation and do a risk assessment.

Draw up a suitable data table to record your results in Part A. You may be able to use coloured pencils.

Part A: Common indicators

Apparatus

- distilled water
- test tubes and test tube rack
- *dilute hydrochloric acid (0.1 M)*
- *dilute sodium hydroxide solution (0.1 M)*
- various indicators, e.g. red and blue litmus, methyl orange, bromothymol blue, phenolphthalein



Method



1. Set up three test tubes containing dilute hydrochloric acid, distilled water and dilute sodium hydroxide solution.
2. Add 2 drops of red litmus to each tube and record the colour in each tube.
3. Repeat steps 1 and 2 with the other indicators, recording the colours carefully.

Conclusion

Nadia adds some red litmus to a colourless solution and it stays red.

a Can she conclude from this that the solution is an acid? Explain your answer.

b What would she need to do to be sure the solution was an acid?

Part B: Invisible ink

Apparatus

- paper towel
- phenolphthalein
- spray-on window cleaner
- small paint brush

Method

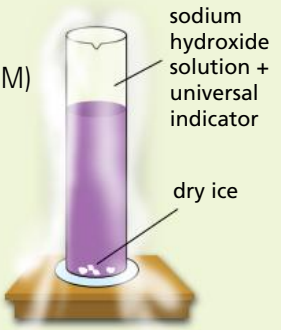
1. Use a paint brush and phenolphthalein solution to paint an invisible message on the paper towel.
2. Allow the paper to dry.
3. Soak the paper with spray-on window cleaner.

✻ Explain what causes the invisible ink to appear. (Hint: The window cleaner contains ammonia.)

Part C: Teacher demonstration

Apparatus

- sodium hydroxide solution (1 M)
- dry ice
- large measuring cylinder
- metal tongs
- universal indicator
- white background



Method

1. Two-thirds fill the measuring cylinder with water and arrange a white background behind it.
2. Add the sodium hydroxide solution, then a few drops of universal indicator to make the solution blue-violet.
3. Use tongs to add dry ice to the cylinder and observe carefully.

✻ Dry ice is frozen carbon dioxide that turns to a gas as it warms up. This gas dissolves in water to form carbonic acid. Explain why the solution in the cylinder changed colour the way it did.

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SKILL

Measuring pH

Most indicators usually have only two colours. For example, litmus is red in acidic solutions and blue in basic solutions. Universal indicator is a mixture of several different indicators. Because of this, universal indicator can show how acidic or basic the solution is by changing to a range of different colours, as you found in Part C of Investigation 3.

The various colours can be matched to numbers that indicate how acidic or basic the solution is. These are called **pH** numbers (lower case p, capital H). The scale ranges from 0 to 14. Note that acidic solutions have a pH between 0 and 6. Basic solutions have a pH between 8 and 14. Neutral solutions, such as tap water, have a pH of 7.

To measure the pH of a solution you add a few drops of universal indicator and note any colour change. You then compare the colour obtained with the colour chart and note the pH value. With pH paper (see photo below) you simply dip the paper into the solution and note the colour of the paper. For more accurate measurements, an electronic pH meter or a datalogger with a pH probe can be used.



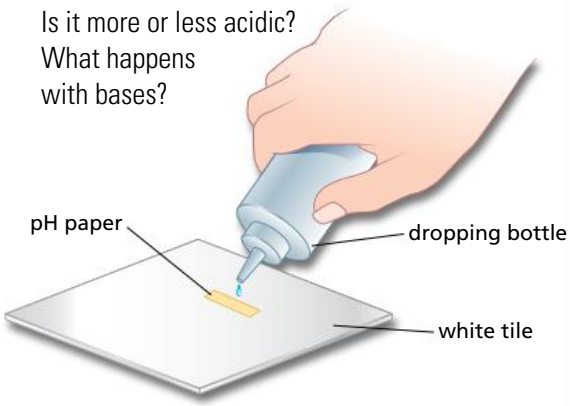
The pH scale, with the pH of some common substances

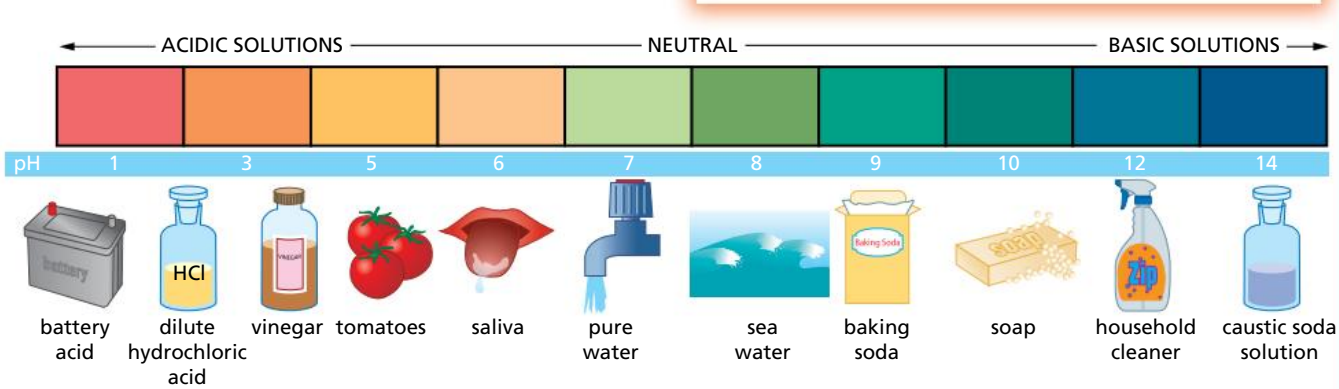
INQUIRY 2

Using pH paper

You will need: pH paper dispenser, a white tile, laboratory acids and bases, various household substances in dropping bottles, e.g. lemon juice, lemonade, Coca-Cola, detergent, milk, disinfectant, saliva, baking soda, toothpaste, spray-on cleaning solution, oven cleaner, vinegar

1. Tear off a small piece of pH paper (about 1 cm).
2. Put a drop of one of the solutions onto the paper.
3. Compare the colour of the wet spot on the paper with the colour chart on the dispenser.
4. For each substance tested, record the pH colour and number, and whether the substance is acidic, neutral or basic. To measure the pH of a solid substance, first dissolve it in water.
5. Your teacher may show you how to use a pH meter.
   - Which was the most acidic substance you tested (lowest pH)? Which was the most basic (highest pH)?
   - What happens to the pH of an acid when you dilute it (add water to it)? Is it more or less acidic? What happens with bases?





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Explaining acids and bases

Why do acids and bases have such special properties? It was once thought that acids had a sour or sharp taste because the invisible particles in them had sharp points. Similarly, bases were thought to be slippery because their particles were round. Scientists have since discovered that all acids contain the element hydrogen. The special properties of acids in solution are due to hydrogen ions, H^+. These are hydrogen atoms that have a single positive charge because they have lost one electron. For example, hydrochloric acid has the formula HCl. In solution it forms positive H^+ ions and negative chloride Cl^- ions (chlorine atoms that have gained an electron).

The p in pH comes from the German word *potenz* meaning power. So pH means 'power of hydrogen', and it is a measure of the concentration of H^+ ions in a solution.

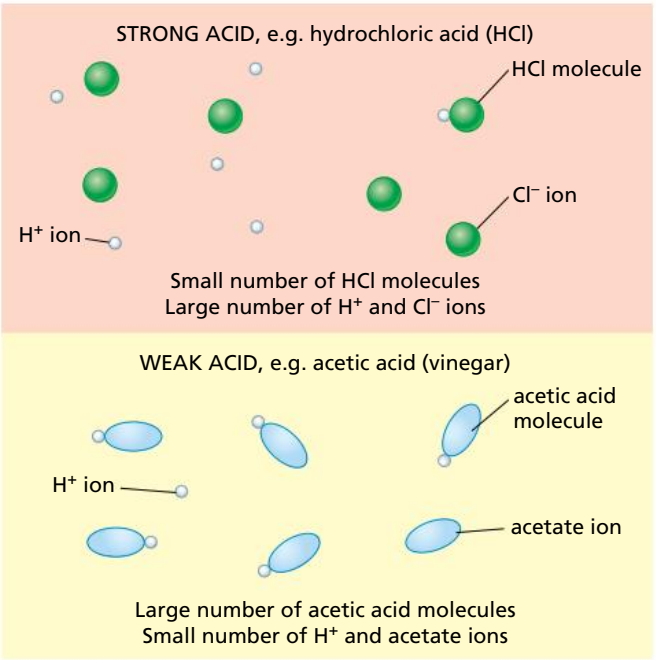
When a base dissolves in water it forms *hydroxide* ions. These consist of an oxygen atom and a hydrogen atom joined together, and they have a single negative charge. This is why they have the formula OH^-. For example, sodium hydroxide has the formula NaOH. In solution it forms positive Na^+ ions and negative OH^- ions.

Strengths of acids and alkalis

Hydrochloric acid, sulfuric acid and nitric acid are called *strong acids*. Acids such as vinegar that are found in food and drinks are called *weak acids*. The difference between strong and weak acids can be explained in terms of H^+ ions.

Strong acids break up into H^+ ions very easily. For example, hydrochloric acid contains a large number of H^+ ions and very few HCl molecules. On the other hand, weak acids do not break up so easily into H^+ ions. For example, the acetic acid in vinegar contains more acetic acid molecules than H^+ ions. There are also strong and weak alkalis. For example, sodium hydroxide is stronger than ammonia because it breaks up into OH^- ions more easily.

You must be careful not to confuse the terms strong and weak with the terms concentrated and dilute. Strong and weak refer to the *type* of acid. Concentrated and dilute refer to the amount of water that has been added to the acid. For example, it is possible to have a concentrated strong acid and a dilute strong acid. The difference is due to the amount of water that has been added to dilute the acid.



Over to you

1 Copy and complete the following sentences:
- **a** Litmus turns _____ in basic solutions and _____ in acidic solutions.
- **b** Solutions may be acidic, _____ or basic.
- **c** Vinegar is _____ and ammonia solution is _____.
- **d** An acidic solution has a pH of _____ than 7.
- **e** A _____ solution has a pH of more than 7.
- **f** All acids contain the element _____.

2 Attila has four different liquids: A, B, C and D. The liquids are vinegar, table salt solution, nitric acid and caustic soda. He tests them with blue litmus and pH paper. Use his results below to work out which is which.

Liquid	Colour of blue litmus	pH
A	blue	13
B	red	1
C	blue	8
D	red	4

3 When a solution becomes more acidic, does the pH get higher or lower?

4
- **a** Which ion is found in all acids?
- **b** Which ion is found in all alkalis?

5 Explain the difference between:
- **a** a strong acid and a weak acid
- **b** a concentrated acid and a dilute acid.

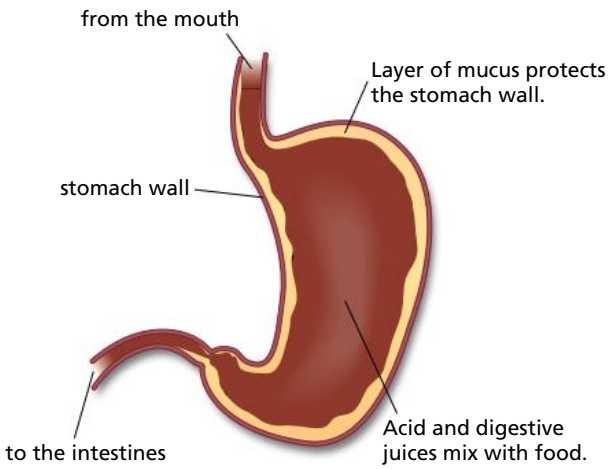
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1.4 Acids in your body

Stomach ulcers

Did you know that your stomach contains hydrochloric acid? In fact the pH in your stomach is usually about 1.5.

Your stomach is lined with a slimy substance called *mucus*, which prevents the acidic contents from touching the walls of the stomach. If bacteria called *Helicobacter pylori* enter your stomach they somehow affect this mucus, allowing the acid to eat away the lining of the stomach. This causes an ulcer that can be very painful.



Indigestion

The digestion process that occurs in your stomach uses enzymes, which need acidic conditions to work. During digestion the stomach breaks down proteins to simpler substances that can pass into the bloodstream. If you eat too much food or your stomach produces too much acid, you can get *indigestion*. This is a burning sensation in your chest caused by the stomach acid rising up into the tube above your stomach (the oesophagus). One way to overcome indigestion is to take *antacids*, which can be bought from a chemist or supermarket. Antacids contain weak bases such as calcium carbonate or magnesium hydroxide and these neutralise some of the acid in your stomach, bringing the pH back towards the normal 1.5. Each antacid differs in the amount of acid it can neutralise and the rate at which it acts.

Some antacid powders contain sodium hydrogen carbonate (baking soda) and citric acid, a weak acid. When dissolved in water these two chemicals react, causing fizzing and the release of carbon dioxide gas. This dissolves the antacid and allows it to work faster. The carbon dioxide is forced out of your stomach when you burp.

INVESTIGATION 4

Comparing antacids

Aim

To investigate how antacids work and to compare different brands.

Risk assessment and planning

Read the investigation and do a risk assessment.

Apparatus

- 100 mL conical flask
- universal indicator
- *dilute hydrochloric acid (0.05 M)*
- antacid powder
- spatula



Method

1. Pour 20 mL of 0.05 M hydrochloric acid into a flask. This represents the acid in your stomach. Add 3 drops of universal indicator.
   - ✲ Use the colour chart on the universal indicator to estimate the pH of the acid.
2. Add a spatula of antacid powder to the flask and swirl the flask to dissolve it.
   - ✲ Was there a chemical reaction? Explain.
   - ✲ What is the pH of the solution now? Was the level of acidity reduced by the antacid (i.e. did the pH increase)?
3. Design an experiment to find out which brand of antacid tablet or powder gives the best results. Consider these questions:
   - Do all antacid tablets react with the acid in the same way?
   - How can you tell when all the acid has been neutralised?
   - How can you make the test a fair one? Which variables will you need to control?

Write your report

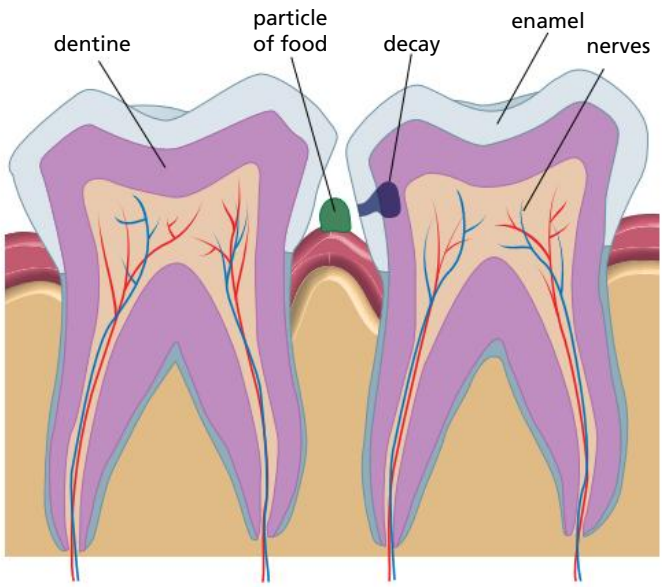
For your report, write a short article for a health magazine saying which antacid is the most effective, and which is the best *value for money*. Make sure you include a description of your tests and what you did to make them fair.

ISBN 978 1 4202 3246 2

Tooth decay

When you eat, food sometimes remains between your teeth. Bacteria in your mouth then feed on this food. Chemical reactions occur and the bacteria give off weak acids such as lactic acid as waste products. These acids react slowly with your teeth, causing tooth decay. The mixture of bits of food, bacteria, acids and saliva is called **plaque** (PLARK).

The top of a tooth is covered with enamel, which is the hardest substance in your body. The inside of the tooth is made of a softer substance called dentine. If the hard enamel decays, allowing the acids and bacteria to get into the dentine, the tooth can be damaged very rapidly. Once the decay reaches the nerve endings, you get a toothache.



The best way of getting rid of bacteria, food and acids from your teeth is by brushing them after you eat. Dental floss helps clean in between your teeth. Toothpastes contain abrasives such as finely powdered chalk. These help scrape food particles and stains from your teeth. Before toothpaste was invented, some people used salt or soot to clean their teeth. These substances are also abrasives.

Toothpastes usually also contain a small amount of soap or mild detergent. This makes a foam that helps brushing. Toothpastes may also contain fluoride compounds. These react with the enamel in young people's teeth to form a substance that is more resistant to acid attack and less likely to decay. Fluoride also decreases the rate at which bacteria produce acids.

INQUIRY 3 Teeth

Part A: Plaque

You will need: plaque-disclosing tablet, toothbrush, toothpaste, mirror, dental floss

1 Plaque-disclosing tablets contain a dye which stains plaque and shows you where it is on your teeth. Chew half a tablet, then use a mirror to check where the plaque is.

2 Brush your teeth using toothpaste. Rinse your mouth and test again for plaque.

- Did brushing get rid of all the plaque?

3 Now use dental floss. Does it get rid of the plaque between your teeth?



Part B: Effect of cola

You will need: baby tooth or tooth from sheep or bullock, cola, petri dish

1 Put the tooth in the petri dish and cover it with cola.

2 After a day or two, take the tooth out of the cola.

- What changes have occured?
- Suggest a reason for these changes.

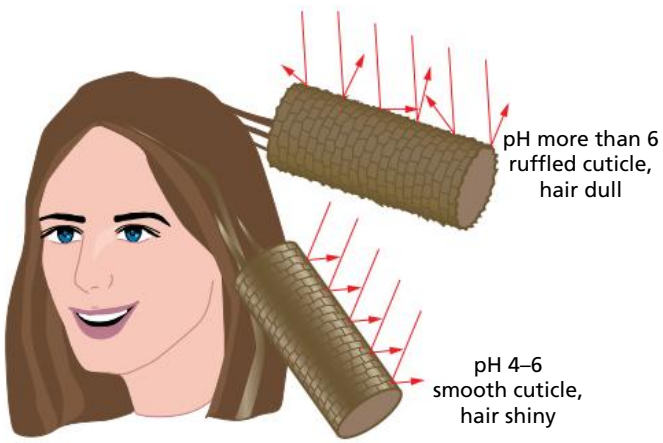


ISBN 978 1 4202 3246 2

pH in the body

The pH of the body varies from one part to another. It also changes throughout the day. In your mouth the pH is roughly neutral (7), but it becomes more acidic as saliva is released when you eat. In your stomach, gastric juices are released to digest the proteins in food, and the pH falls to 1.5. After the stomach, the pH rises suddenly and in the small intestine it is as high as 8. This pH is necessary to digest the carbohydrates in food. Beyond the small intestine the pH drops and is slightly acidic at the anus.

Your skin and hair are acidic, with a pH between 4 and 6. Your hair is made of a protein called keratin. Each strand of hair consists of a central core surrounded by a scaly covering called the cuticle. At a pH of 4–6, the scales of the cuticle lie flat, as shown in the diagram. They reflect light evenly, making the hair look shiny. If the pH is higher than 6 the cuticle becomes damaged or 'ruffled'. Light is reflected in all directions and the hair looks dull. This is why shampoos and conditioners contain substances to keep the pH in the range 4–6.



Most tablets we take need to be absorbed in the duodenum rather than in the stomach. This means they have to survive the acidic conditions in the stomach. For this reason they are often coated with keratin which is not affected by low pH. Once the tablet reaches the more alkaline conditions of the duodenum it dissolves and is absorbed into the bloodstream.

The pH of urine is normally 6.5–7 in the morning, but in the evening it is more alkaline (7.5–8). This is a result of the chemical reactions that occur in your body as food is processed. Your blood has a pH of 7.4 and any variation of more than 0.5 from this is fatal. Many body processes produce acids and these must be removed quickly. One of these is uric acid. It is normally filtered by the kidneys and excreted in tiny amounts in urine. If there is an excess of uric acid in your body it can build up in your joints. This causes a form of arthritis called gout. The uric acid forms sharp crystals in the joints, causing severe pain.

Lactic acid is another acid found in the body. It is produced by your muscles during vigorous exercise, making them sore. This soreness disappears after a few minutes as the blood removes the lactic acid.

Acids can also help relieve pain. Aspirin is acetylsalicylic acid, which is only slightly soluble in water. However, soluble aspirin contains sodium hydrogen carbonate and citric acid which react together in water and cause fizzing. This helps the aspirin to dissolve.

Over to you

1 Which acid is produced in your stomach?

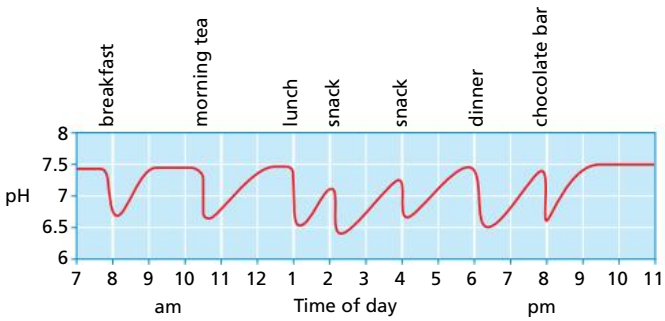
2 Blood has a pH of 7.4. Is this acidic, neutral or basic?

3 Explain how antacids relieve indigestion.

4 Gastric juice digests proteins, and your stomach is mostly muscle, which is made of protein. So why doesn't gastric juice digest your stomach?

5 When you exercise, your muscles produce lactic acid. Predict what effect this has on the pH of your blood.

6 The graph shows how the pH in someone's mouth changed during the day.



a When the mouth becomes more acidic, does the pH increase or decrease?

b Why does the pH go up and down during the day?

c What damage could be done while the pH is low?

d Would brushing your teeth with toothpaste change the graph? If so, how?

7 It is unwise to take too many antacid tablets. Why do you think this is so?

8 Aspirin can cause stomach ulcers. Suggest a reason for this.

ISBN 978 1 4202 3246 2

1.5 Acids around us

Swimming pools

Swimming pools must be maintained to keep the pH at safe levels for swimmers. The pH should be between 7.4 and 7.6, about the same as that of human tears. Leaves, twigs and dust fall in the pool, and sweat, sunscreen, hair spray, face cream, deodorants and perfumes are washed off swimmers' bodies. Some of these are removed by the filter, but others dissolve in the water and can change its pH.

The major problem in swimming pools is the growth of algae and bacteria. Algae can cause the water to become green and can also block the filter. Bacteria can cause infections. Together the algae and bacteria make the pool water basic.

Chlorine compounds are usually used to disinfect the water by killing the algae and bacteria. The 'liquid chlorine' sold for use in home pools is a solution of sodium hypochlorite (NaOCl). 'Dry chlorine' is solid calcium hypochlorite. When these compounds are added to the pool they react with the water to form hypochlorous acid (HOCl):

sodium hypochlorite + water → hypochlorous acid + sodium hydroxide

In large public pools chlorine gas is usually added:

chlorine + water → hypochlorous acid + hydrochloric acid

It is the hypochlorous acid which prevents the growth of algae and bacteria. It also acts as a bleach, and this is why your swimsuit gradually loses its colour. The same chemicals are used in household bleaches such as Domestos.

The hypochlorous acid determines the pH of the water in the pool. If the pH is too high (too basic) there is not enough hypochlorous acid to disinfect the pool properly. If the pH is too low (too acidic) the water can sting your eyes and irritate your skin. Too much acid can also damage the walls and floor of the pool, and corrode the metal pipes and filters.

If the pH is too high, a strong acid has to be added to neutralise the base. The acid used is muriatic acid, which is just another name for hydrochloric acid (HCl):

base + hydrochloric acid → salt + water

Alternatively, solid sodium hydrogen sulfate may be added.

If the pH is too low it can be raised by neutralising some of the acid with a base. Sodium carbonate (soda ash) or sodium hydrogen carbonate (baking soda) are usually used:

acid + sodium carbonate → salt + water + carbon dioxide

If people have been on holidays or haven't maintained their pool properly, the water may be unsafe to swim in. If the pool goes cloudy it needs to be superchlorinated using a large dose of calcium hypochlorite. If green slime or black spots appear on the walls of the pool, an algicide needs to be added to kill the algae.

Some pools, especially public pools, have a 'chlorine' smell. This smell is not due to the chlorine, but to chloramines that are formed when chlorine reacts with the ammonia in urine.

To test the pH of pool water the indicator phenol red is used. It changes from red (basic) to yellow (acid) at a pH of 7.5.

INQUIRY 4 Testing pool water

You will need: pool test kit, samples of pool water, pool acid (dilute hydrochloric), soda ash (sodium carbonate)

1 Fill the testing container with pool water as shown. Add 2 or 3 drops of phenol red indicator.



2 Use the colours on the scale to estimate the pH of the water. Is it in the ideal 7.4–7.6 range?

3 Add a few drops of pool acid to the water in the container. How does this change the pH?

4 Now add a small amount of soda ash to the water. How does this change the pH?

5 You could also test the chlorine level of pool water. Check the test kit instructions or ask your teacher about this.

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pH of soil





Look at these two different hydrangea plants. The pink one is growing in soil that is basic, the blue one is in soil that is acidic. When acidic substances such as leftover tea or tea leaves are added to the soil in which pink hydrangeas grow, the flowers gradually turn blue.

Over the years farmers and gardeners have found that some plants like acidic soil, others like neutral soil and others like basic soil. See the table below.

Plant	Preferred pH
rhododendrons, azaleas, camellias	4.5–5.5
potatoes	4.5–6.0
Australian native plants	5.5–6.5
daffodils	6.0–6.5
roses, tomatoes	6.0–7.0
wheat, corn, wattle	5.5–7.5
citrus fruits	6.0–7.5
carrots	6.5–7.5
violets, barley	6.0–8.0
cactus	7.0–8.0

Soils contain many substances, including minerals that dissolve in water and are used by plants. Soil acidity has to be right for plants to get the minerals they need from the soil. To make use of the minerals, some plants need to be in acidic soil while others need to be in basic soil. For example, rhododendrons need iron but cannot take in and use iron if the soil is basic, even if there is plenty of iron in the soil. This is because the iron compound that forms in a basic soil is insoluble, so it will not dissolve and cannot be taken in and used by the rhododendrons.

Over time, soils tend to become acidic. Rainwater is slightly acidic and it also washes out some of the basic substances in the soil. When dead plants and animals fall to the ground, soil bacteria and fungi decompose them. In the decay process, the fungi and bacteria release acidic substances. Fertilisers also tend to make the soil acidic.

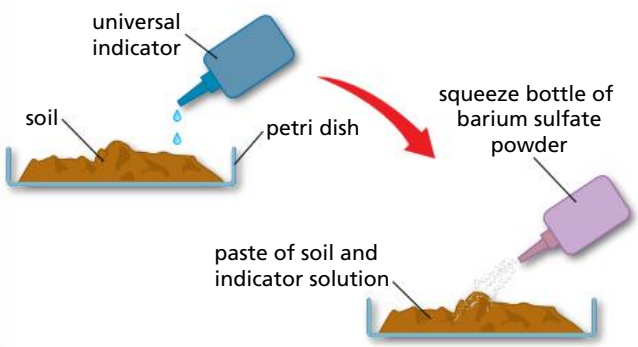
In areas where the soil is too acidic it is necessary to add powdered limestone, lime or dolomite. If the soil is too basic, powdered sulfur, ammonium sulfate, compost or manure can be added.



INQUIRY 5 Testing soil pH

You will need: soil samples, petri dishes, universal indicator, barium sulfate powder

1. Place about half a teaspoon of soil in a petri dish. Add enough universal indicator to make a thick paste.
2. Cover this paste with a thin layer of white barium sulfate powder. It absorbs the indicator so you can see the colour.
3. After 2 to 3 minutes match the colour of the powder with the colours on the indicator colour chart. Is the soil acidic or basic?
4. Design an experiment to see if the soil acidity can be changed by adding lime or powdered sulfur.



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Foods and pH

pH is important in the treatment and cooking of foods. For example, because untreated olives are very bitter (acidic), they are usually treated with dilute sodium hydroxide solution to make them edible. The pH of uncooked foods varies. For example, plums have a pH of 2.5, tomatoes 4.5 and peas 6.3. Those foods that are naturally very acidic keep better than those that are not so acidic.

Bacteria in food can cause botulism, a very serious form of food poisoning. Botulism bacteria are sometimes found in home-canned foods and occasionally in commercially canned foods. These bacteria produce such a deadly poison that one kilogram of it could kill every person on Earth!

Bacteria grow on foods with a pH of 4 or more. To destroy bacteria, acid must be added until the pH is less than 4. The bacteria can also be killed by boiling. If you find a can with a bulging lid throw it away. The contents have not been treated correctly and bacteria are active in the food inside, producing gases.

Pickling is a process in which foods are cooked and stored in salt and acid. The acid is usually vinegar (acetic acid), which has a pH of 2.8. It is also important to control the pH when brewing beer, as it affects the taste.

INQUIRY 6 Design an experiment

Measure the pH of various foods. Design a controlled experiment to test whether foods that are naturally acidic keep better than other foods. (This could be your chapter problem.)

Acid rain

Rainwater is slightly acidic (pH between 5 and 6). This is because the carbon dioxide in the air dissolves in water vapour to form carbonic acid:

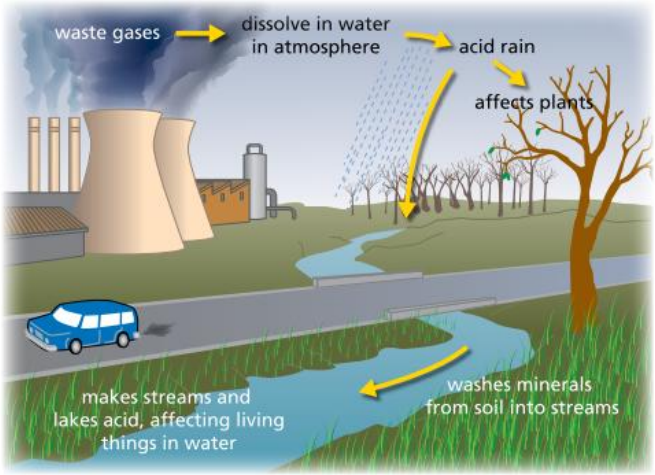
carbon dioxide + water → carbonic acid

Sulfur dioxide is released into the air when fossil fuels are burnt, for example in power stations. This sulfur dioxide gas dissolves to form sulfurous acid:

sulfur dioxide + water → sulfurous acid

Sulfur dioxide is also produced as a waste in the smelting of sulfide ores to produce copper, lead and iron. It is produced naturally by volcanoes, forest fires and rotting marine algae.

Another pollutant in the atmosphere is nitrogen dioxide, which is produced in car engines. This nitrogen dioxide dissolves in water in the air to form a mixture of nitrous acid and nitric acid. As a result of these gases in the atmosphere, the rain that falls can be more acidic than normal. This is acid rain. In Europe and North America rain with a pH as low as 2.9 has been recorded.



Apart from its effect on human health, acid rain affects plant growth. It also speeds up the corrosion of metals, and damages buildings and statues. The photo below shows the effects of acid rain on a statue. The sulfuric acid in the rain has reacted with the calcium carbonate in the marble of the statue to form calcium sulfate, a powdery dust that is washed away by the rain:

calcium carbonate + sulfuric acid → calcium sulfate + carbon dioxide + water

As acid rain runs through soil it washes out aluminium ions, which end up in rivers and lakes. Aluminium is toxic to fish and as a result some rivers and lakes in Europe and North America now contain hardly any fish.



The effect of acid rain

ISBN 978 1 4202 3246 2

SCIENTISTS AT WORK

Dr Greg Ayers and acid rain in Australia

Dr Greg Ayers is head of CSIRO Marine and Atmospheric Research. He has measured the acidity of rain in various parts of Australia and Indonesia. He has found that acid rain is not as serious a problem in Australia as it is in Europe and North America.

This does not mean that the pollutants that cause acid rain are not in the air. Smog alerts sometimes occur in Melbourne and Sydney, and on these 'smog days' huge amounts of nitrogen dioxide and sulfur dioxide are present. Dr Ayers and his team measured the acidity of rain in Sydney. They found that the rain was more acidic towards the centre of the city, due to motor vehicles and industry. Similar measurements in Melbourne showed that acid rain is less of a problem there because the westerly winds clear the pollution quickly.

Australia is a large country with few people. The cities, power stations and industrial centres are a long way apart. So any pollutants released into the air are soon spread out and don't become a problem. Also, we have no near neighbours whose pollution is blown across into our country, as happens in Europe. However, the situation could change in the future, and this is why Dr Ayers and his team are continually monitoring acid rain in Australia.



Dr Ayers' team designed this device to sample rainwater and measure its acidity. It can be set up anywhere to monitor acid rain.

INQUIRY 7

Acid rain

This is a teacher demonstration and must be done in a fume cupboard.

You will need: gas jar, deflagrating spoon and cap, sulfur, Bunsen burner, litmus and pH paper, marble chips, magnesium ribbon, brightly coloured petals

1. Put a small amount of sulfur in a deflagrating spoon and light it over a Bunsen flame.
2. Immediately put the burning sulfur in a gas jar with about a centimetre of water in the bottom.
3. When the sulfur stops burning, shake the jar to dissolve the sulfur dioxide in the water.
4. Test the water in the jar with litmus and pH paper. What effect does the water have on a coloured flower petal? Is the water acidic enough to react with a marble chip or magnesium ribbon?

PROBLEM SOLVING

Have you decided on an experiment to investigate some aspect of acids, bases and pH? There are some suggestions on page 2. You could also modify one of the investigations or activities.

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Over to you

1. Why do your eyes sometimes sting in a swimming pool? If they sting, what needs to be done to the water in the pool?
2. List substances added to soil to make it:
   - **a** more basic
   - **b** more acidic.
3. Look at the table on page 17.
   - **a** Design a chart or graph to display this information as clearly as possible.
   - **b** Trang found the pH of three different soils. Soil A has a pH of 5, soil B is 6 and soil C is 7. Which soil is the most acidic?
   - **c** Which plants would grow best in soil B?
   - **d** What would Trang have to do to grow tomatoes in soil A?
4. When preserving food the pH must be less than 4. Why?
5. From where do most of the pollutants that cause acid rain come?
6. If you were the federal minister for the environment, what would you do to make sure acid rain did not become a serious problem in Australia in the future?

1.6 Neutralise it

When the *Apollo 13* astronauts were returning to Earth in the lunar module, there was a dangerous build-up of the carbon dioxide they breathed out. Using hoses, cardboard, plastic bags and duct tape they were able to connect some lithium hydroxide canisters into their air circulation system. Lithium hydroxide is a base and it neutralised the carbon dioxide (which is acidic) by reacting with it.



Neutralisation is a reaction in which an acid and a base cancel each other out. To neutralise an acid you add a base, and to neutralise a base you add an acid.

You have already read about several examples of neutralisation in this chapter. If someone has indigestion they take antacid to neutralise some of the acid in their stomach. If a swimming pool becomes too basic, pool acid is added to neutralise it. If soil is too acidic, lime is added to neutralise it. If lakes become too acidic due to acid rain, lime is sometimes added.

Have you ever been bitten by an ant? It can be quite painful, because the ant injects formic acid into you. To treat the bite you can add a weak base such as baking soda to neutralise the formic acid.

INQUIRY 8 Neutralisation

You will need: test tube, dilute sodium hydroxide solution, bromothymol blue indicator, dilute hydrochloric acid, pH paper

1. Add 20 drops of dilute sodium hydroxide to a test tube. Add a drop of bromothymol blue indicator.
2. Add dilute hydrochloric acid a drop at a time. Swirl the tube gently after each drop. Keep adding drops until the colour changes from blue to yellow. Count the drops.
   - How many drops of acid did you add?
   - How can you explain the colour change?
3. Use pH paper to check whether the final solution is acidic, neutral or basic.

Bee stings can be treated in the same way. However wasp stings contain a basic substance, which needs a weak acid such as vinegar to neutralise it. If you aren't sure what has bitten you, it is best to put ice on the bite to deaden the pain.



The smell of fish is due to the presence of bases called amines. Adding lemon juice, which is acidic, neutralises these amines and gets rid of the smell. You can also use lemon juice to remove the fishy smell from your hands.



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Understanding neutralisation

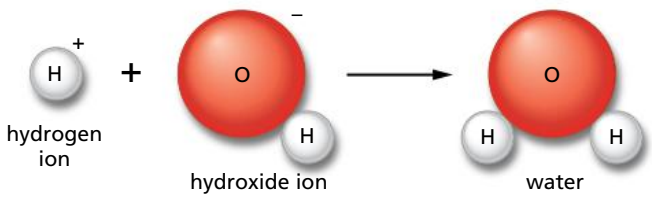
What happens when you mix hydrochloric acid and sodium hydroxide? The hydrochloric acid contains hydrogen ions H^+ and chloride ions Cl^-. There are the same number of hydrogen ions as chloride ions:

$$\text{hydrochloric acid (HCl)} \rightarrow H^+ + Cl^-$$

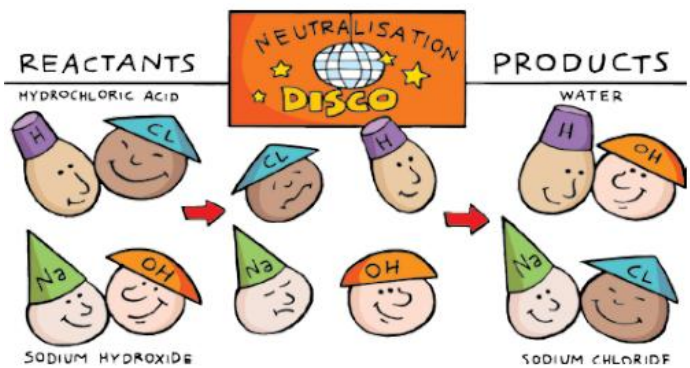
Sodium hydroxide solution contains sodium ions Na^+ and hydroxide ions OH^-.

$$\text{sodium hydroxide (NaOH)} \rightarrow Na^+ + OH^-$$

When the two solutions are mixed, the four ions also mix. The ions are constantly moving. There is a good chance that they will bump into each other and possibly combine. Being positive, the hydrogen ions can combine with the negative chloride or hydroxide ions. They can't combine with the positive sodium ions, because like charges repel. What actually happens is that the positive hydrogen ions prefer to combine with the negative hydroxide ions. When this happens they form a molecule of water (HOH or H_2O), which is neutral.



This means that the positive sodium ions are left to combine with the negative chloride ions to form sodium chloride. This is an example of a salt.



All acids contain hydrogen ions, and all soluble bases form hydroxide ions. So, whenever an acid and a base neutralise each other in solution, water is formed. However, the salt formed will depend on the acid and the base that are involved. Here are two examples.

hydrochloric acid + calcium hydroxide → calcium chloride + water

sulfuric acid + sodium hydroxide → sodium sulfate + water

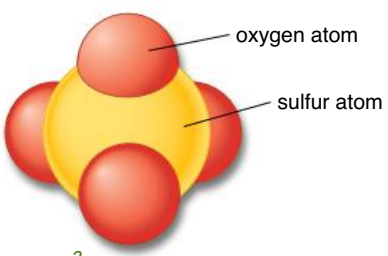
The general equation for a neutralisation reaction is:

acid + base → salt + water

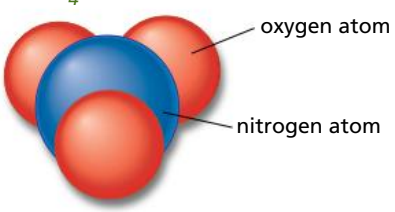
Different acids make different salts, as shown in the table below.

Acids	Salts	Examples of salts
hydrochloric acid HCl	chlorides	sodium chloride NaCl calcium chloride $CaCl_2$
nitric acid HNO_3	nitrates	potassium nitrate KNO_3 ammonium nitrate NH_4NO_3
sulfuric acid H_2SO_4	sulfates	copper sulfate $CuSO_4$ magnesium sulfate $MgSO_4$
carbonic acid H_2CO_3	carbonates	calcium carbonate $CaCO_3$ sodium hydrogen carbonate $NaHCO_3$

You will notice that some negative ions contain more than one atom. For example, hydroxide ions OH^- consist of a hydrogen atom joined to an oxygen atom. Overall the ion has a single negative charge. The sulfate ions (SO_4^{2-}) in sulfuric acid have two negative charges and consist of a sulfur atom joined to four oxygen atoms as shown. These five atoms tend to stay together as an ion during chemical reactions. Similarly, the nitrate ions (NO_3^-) in nitric acid have one negative charge, and consist of a nitrogen atom joined to three oxygen atoms.



A sulfate ion SO_4^{2-}



A nitrate ion NO_3^-

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INVESTIGATION

5 Making copper sulfate

Aim

To make copper sulfate by reacting copper oxide (a base) with sulfuric acid.

Risk assessment and planning

- Read the investigation, then describe to your partner what you have to do.
- What precautions will you need to take with the sulfuric acid?
- Why is it important to test the pH in step 4?

Apparatus

- retort stand and ring
- Bunsen burner equipment
- thermometer
- evaporating basin
- pipeclay triangle
- *dilute sulfuric acid (1 M)*
- stirring rod
- tongs
- filter funnel
- filter paper
- pH paper
- spatula
- beaker
- copper oxide



Method

1. Put 100 mL of dilute sulfuric acid into the beaker and heat it to 60°C.
2. Take the beaker off the burner. Add a spatula of copper oxide to the acid and stir until the solid has reacted.
3. Keep adding copper oxide, a spatula at a time, stirring all the time, until no more will dissolve.
4. At this stage the solution in the beaker should be neutral (pH 7). You can test this with pH paper using tongs. If the solution is still acidic, add some more copper oxide.
5. Filter the mixture into an evaporating basin.
6. Use the burner and pipeclay triangle to evaporate the solution until only a small volume remains.



Do not boil the solution dry or it may spit and burn you.

7. Leave the solution to cool overnight. Crystals of copper sulfate will form.

Discussion

1. Were you successful in making copper sulfate?
2. Would you do anything differently if you repeated the investigation? Why?

Conclusion

Write a word equation for the reaction you used to make copper sulfate.

Over to you

1. **a** Explain what neutralisation is.
   b Write down the general word equation for neutralisation.
   c Give at least three examples of everyday neutralisation reactions.
2. Someone has just spilt some vinegar onto the carpet. Explain whether you should use lemon juice or baking soda to help clean it up before the vinegar discolours the carpet.
3. In northern Australia it is suggested you take vinegar with you when swimming in case you get stung by a jellyfish. Why?
4. Which acids would you use to make:
   a carbonates?
   b chlorides?
   c nitrates?
   d sulfates?
5. **a** Write a word equation for the neutralisation reaction between nitric acid and calcium hydroxide.
   b How could the salt formed be recovered from the solution?
6. What happens when hydrogen ions react with hydroxide ions?

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THINKING SKILLS

1 Shanika did an experiment to test the effect of hydrochloric acid on magnesium. In each case she added the magnesium to 10 mL of 0.1 M hydrochloric acid. Here are her results.

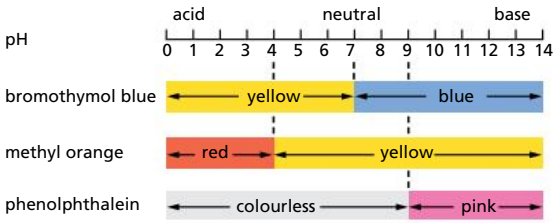
Temperature of acid (°C)	Length of magnesium ribbon (cm)	Time for magnesium to dissolve (s)
10	2	60
10	4	80
10	6	100
20	2	30
40	2	15

a Predict how long it would take for a 5 cm piece of magnesium to dissolve at 10°C.

b Write a generalisation linking the temperature of the acid to the time taken to dissolve the magnesium.

c At what temperature do you predict this acid could dissolve a 2 cm piece of magnesium in 45 seconds?

2 Three acid–base indicators and the pH at which they change colour are shown below.



a A mixture of phenolphthalein and methyl orange is used to test some liquid spilt from a car battery. What colour would you expect the indicator mixture to be?

b When a mixture of all three indicators is added to some rainwater, the water turns yellow. Estimate the pH of the rainwater.

3 How could a chemist change some sodium hydroxide into sodium sulfate?

4 In a neutralisation experiment sodium hydroxide solution was added to sulfuric acid.

a Write a word equation for the reaction.

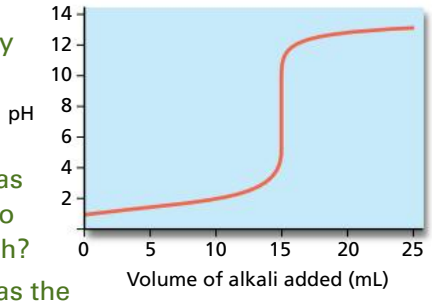
b What ions were present before the reaction?

c Which ions combined during the reaction?

d What salt would be produced if the solution remaining from the reaction was evaporated?

e What *molecules* were formed in the reaction?

5 Lynda put 15 mL of dilute hydrochloric acid into a beaker. She slowly added dilute sodium hydroxide and used a datalogger to measure and display the pH.



a What was the pH to start with?

b What was the pH at the end of the experiment?

c How much sodium hydroxide was needed to neutralise the acid?

d Explain the shape of the graph, relating it to the neutralisation reaction.

e If Lynda had used more concentrated sodium hydroxide, what effect would this have on the shape of the graph?

6 The labels are missing from four bottles which contain the following colourless solutions:

A hydrochloric acid **C** sodium hydroxide

B phenolphthalein **D** sodium carbonate

Using the four solutions, test tubes and magnesium ribbon, design a series of tests to work out which bottle is which. Describe the results you would expect.

7 CHEMCO is a company that makes chemicals in a small town in central Victoria and employs 400 local people. CHEMCO is in trouble because the factory is releasing sulfur dioxide into the air and local residents have complained about the smell. They say the gas is attacking the paint on their houses and making their garden soil acidic. CHEMCO says that trapping the sulfur dioxide in the factory would cost $20 million. They cannot afford this without sacking 40 workers.

Discuss what you think the local residents should do.

8 Weak acids such as cola drinks will clean dirty coins. Do all brands of cola clean coins? Which brand is the best? Experiment to find out.

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Knowledge and Understanding

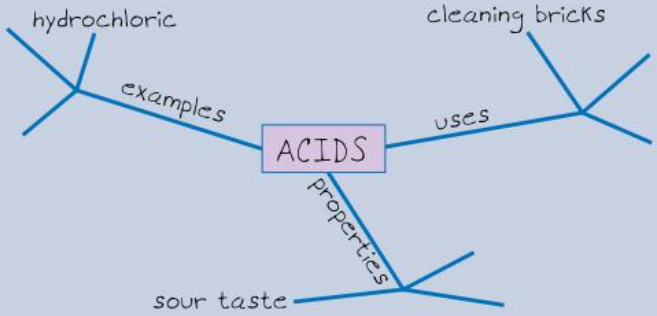
Copy and complete these statements using the words on the right to make a summary of this chapter.

1. Chemical _____, including photosynthesis, cell respiration and combustion, are important in both living and non-living _____.
2. Dilute acids react in a predictable pattern.
   - They react with most _____ to produce hydrogen gas.
   - They react with carbonates to produce _____ gas.
3. Bases are the opposite of acids. _____ are bases that are soluble in water.
4. An acid–base _____ is a substance that changes colour depending on whether it is in an acidic or basic solution.
5. Acids break up into _____ ions when they dissolve in water. Bases break up into _____ ions when they dissolve in water.
6. pH is a number that indicates how acidic or basic a solution is. A pH of 1 is very _____ and a pH of 14 is very _____.
7. Acids and bases are important in everyday life, for example in swimming pools, in the garden and in your _____ .
8. _____is produced when waste gases from motor vehicles and industry dissolve in water vapour in the air to form acids.
9. Acids and bases react together to _____ each other. The general equation for the reaction is: acid + base → _____ + water

acidic
acid rain
alkalis
basic
body
carbon dioxide
hydrogen
hydroxide
indicator
metals
neutralise
reactions
salt
systems

Self-management

1. Copy and complete the branches on this concept map for acids. Try to add more branches of your own to summarise what you have learnt in this chapter.



Now do a concept map for bases.

2. Look at the cartoon at the bottom of page 20. Draw your own cartoon about some aspect of acids and bases.
3. Write a question and a correct answer for an ASK A SCIENTIST website. Try to make your question and answer interesting. Here is an example.

Question: If your stomach contains acid, why doesn't it get eaten away?

Answer: The hydrochloric acid in your stomach is strong enough to eat through a piece of metal. However, the walls of your stomach are covered in a slimy substance called mucus, which is not affected by the acid. The mucus stops the acid from attacking the walls. If *Helicobacter pylori* bacteria enter your stomach, the coating on the stomach wall can be damaged and an ulcer may be formed, which is very painful.

Share your questions and answers with the class.



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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 Which of the following household substances is a base? (There may be more than one.)

A ammonia
B lemon juice
C oven cleaner
D vinegar

2 A woman thinks that the flowers in her window box are not growing well because the soil is too acidic. Which of the following solutions should she add to reduce the acidity?

A lime
B orange juice
C rainwater
D vinegar

3 When Mithun heated some flower petals in water, the resulting solution was yellow. He poured the solution into three test tubes: A, B and C. To test tube A he added hydrochloric acid and the solution turned orange. To B he added sodium hydroxide and the solution turned green. He did not add anything to tube C.

a In the alkaline solution Mithun's indicator turned:

A blue
B green
C orange
D yellow

b Mithun placed some of the flower petal indicator in an unknown liquid X and it turned orange. What do you think X was?

A a base
B an acid
C hydrochloric acid
D water

4 Devena was given seven different solutions. She found the pH of each of them using indicator paper and here are her results:

Solution	A	B	C	D	E	F	G
pH	3	4	9	6	8	5	7

a Which solution is the most basic?
b Which solution is the most acidic?
c Which solution is neutral?

5 Which of the following important reactions are *endothermic* and which are *exothermic*?

a cell respiration in your body
b combustion of coal in a power station
c formation of ozone in the atmosphere
d photosynthesis in plants

6 Copy and complete these word equations.

a acid + base
b acid + metal

7 Why is rain slightly acidic even when there is no air pollution?

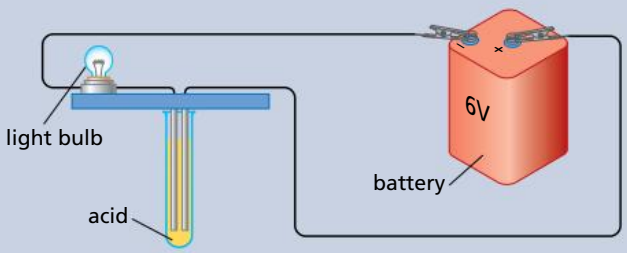
8 Aidan tested two unknown substances with hydrochloric acid. Both substances reacted with the acid, producing bubbles. He suspected that one of the substances was a carbonate. How could he test this?

9 Suggest why you get a burning sensation in your oesophagus, throat and mouth when you throw up.

10 Tamara was bitten by a green ant. She rubbed the bite with vinegar but this only made it worse. What did she do wrong? What should she have done?

11 Solutions containing a high concentration of ions are better conductors of electricity than solutions with a low concentration of ions. Using the apparatus shown, a scientist tested three different acids. Her results are below.

Which is the strongest acid? Explain your answer.



Acid	Glow of bulb
A	glowed brightly
B	did not glow
C	dull glow

12 Which two of the following would you mix to make sodium chloride?

A calcium hydroxide
B copper oxide
C hydrochloric acid
D nitric acid
E sodium hydroxide

Explain your answer.

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2



Atomic structure

By the end of this chapter you will be able to …

Knowledge and Understanding

- recall that matter is composed of atoms and has mass (CW3a)
- describe the structure of atoms in terms of the nucleus, protons, neutrons and electrons (CW1a/b)
- outline historical developments of the atomic theory to demonstrate how models and theories change over time (CW1c)
- identify that natural radioactivity arises from the decay of the nuclei in atoms, releasing particles and energy (CW1d)
- evaluate the benefits and problems associated with medical and industrial uses of nuclear energy (CW1e)

Skills–Working Scientifically

- prepare and present a persuasive speech to the class on nuclear energy (9e)

LITERACY FOCUS

alpha particles
atomic number
beta particles
chain reaction
gamma rays
half-life
irradiation
isotope
mass number
neutrons
nuclear fission
nuclear fusion
nuclear reaction
nuclear reactor
nucleus
plasma
quarks
radioactivity
radioisotope
subatomic particles

Focus for learning

World War II ended with giant explosions when nuclear bombs were dropped on the Japanese cities of Hiroshima and Nagasaki. After this, various countries around the world produced more and more nuclear bombs in what became known as the nuclear arms race. This race has now stopped, but some countries are still trying to make nuclear weapons. The thought of these weapons falling into the hands of terrorists is a terrifying one. Even the peaceful use of nuclear power has its problems.

Australia does not have any nuclear power stations, but it does have a small nuclear reactor at Lucas Heights in Sydney. This reactor is used for research and to produce radioactive materials for use in medicine. Australia has about a third of the world's uranium, which is presently being mined in the Northern Territory and in South Australia. This uranium is all exported.

Nuclear issues are often in the news, and you will need to think about questions such as these:

- Should Australia export uranium, which could be used to make nuclear bombs?
- Should nuclear power stations be built in Australia?
- Should radioactive wastes be stored in outback Australia?
- Should our food be exposed to nuclear radiation to make it last longer?
- Nuclear medicine uses radioactive materials to check whether the organs in our body are working properly. Is this safe?

PROBLEM SOLVING

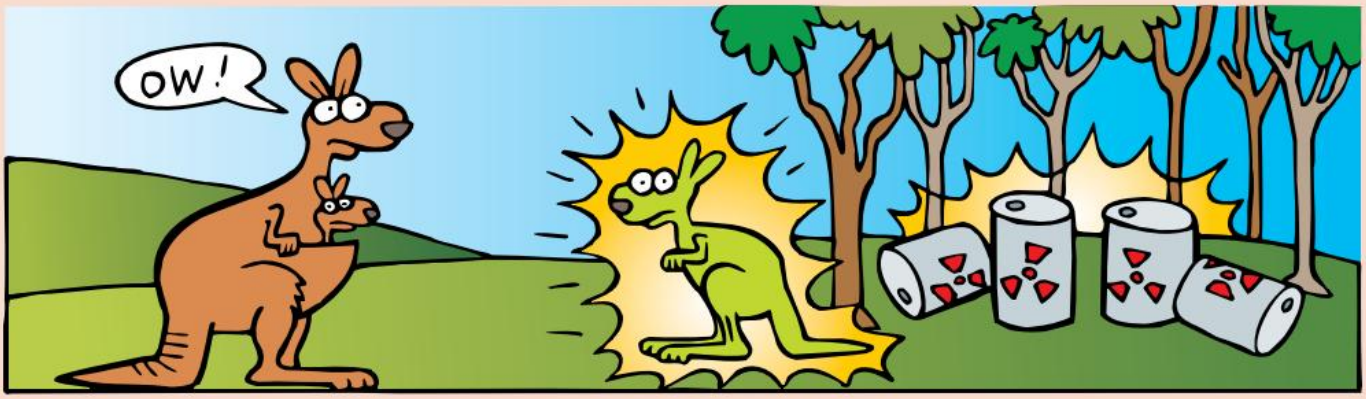
Nuclear debate

Decide on a topic to do with nuclear energy. Choose a catchy title if you can. Prepare and present a persuasive speech to the class. You will find information throughout the chapter to help you with your speech. The Skill on the next page will also help you. You should include at least one newspaper article to support your argument.

Here are some topic ideas:

- Leave our uranium in the ground.
- Radioisotopes are for peace, not war.
- Solar energy is the way forward, not nuclear energy.
- The advantages of nuclear energy outweigh the hazards.
- Nuclear energy is the answer to global warming.
- Our nuclear wastes should be sent to the moon.

At the end of each person's speech you could take a vote. Who agrees with what the speaker has said? Who disagrees?



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SKILL

Persuasive writing and speaking

In everyday life you often need to be persuasive. For example, you might need to persuade your parents to let you go to a party. You might want to persuade your friend to do something, or not to do it. You might have to persuade someone at a job interview that you are the right person for the job.

Doing your research

Before writing a persuasive speech you need to do some research. People will take more notice if you can back up your argument with facts and figures and quote other people who agree with you. To research a topic, follow these steps:

1. Find websites, books, videos, newspaper articles etc. that are relevant to the topic.
2. Use headings, search engines, contents lists and indexes to find the information you need.
3. Scan the information and decide how useful it is.
4. If the information is relevant and interesting, read it carefully and make notes.

It helps to have a few questions in mind as you do your research. Suppose you have selected the topic *Leave our uranium in the ground*. Questions you would need answers to include:

- Where and how is uranium mined in Australia?
- Are there any hazards in mining it? How does mining it affect the environment?
- What happens to the uranium after it is mined?
- How is the uranium used, and what hazards are there?

For each source you use, write down the information on each question in a table on a large chart, as shown. You can then summarise the information at the bottom of the chart.

Leave our uranium in the ground

	Mining	Mining hazards	What happens after mining?	Hazards in using uranium
Source 1 Source 2				
Summary				

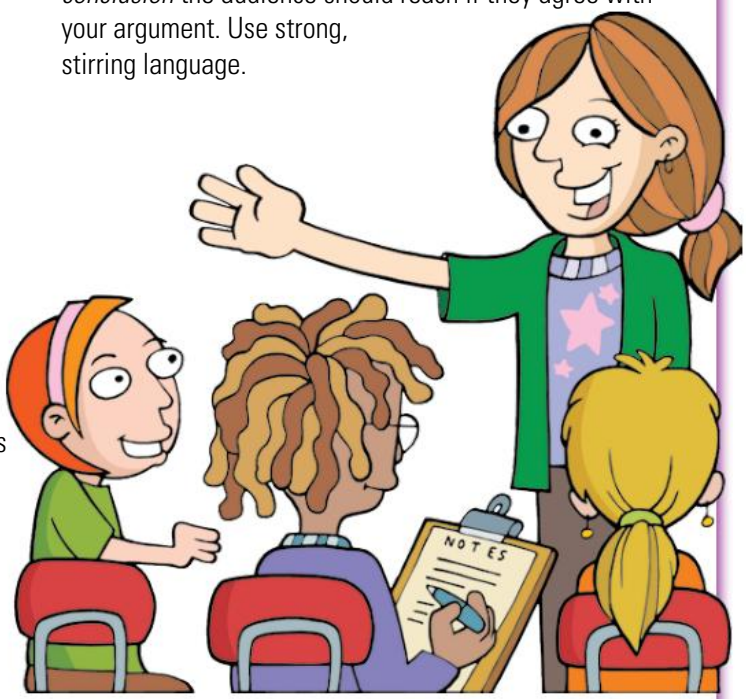
Always check who is the author of the website or book. For example, you would expect the World Nuclear Association to be in favour of nuclear power. On the other hand, the Greenpeace site would be against it.

Preparing your speech

Your speech should have an *introduction* in which you state your position clearly and firmly.

In the *body* of the speech you need to develop your argument in clear steps. Wherever possible, support your argument with evidence.

To end the speech you need to state the logical *conclusion* the audience should reach if they agree with your argument. Use strong, stirring language.



Presenting your speech

There are several techniques that can be used to improve your presentation. First, avoid long, complicated sentences. A logical approach can be balanced by appealing to the personal and emotional side of your audience, so that they feel involved. For example: 'Every one of us here today has a duty to protect our children and their children from the dangers of radioactivity.'

You can ask rhetorical questions that you answer yourself, to involve the audience. For example: 'What can we do about this? First of all we …' You might even be able to come up with a smart saying, using words starting with the same letter, for example, **p**oisonous, **p**olluting **p**lutonium.

Finally, the secret of a good speech is to prepare what to say, and practise, practise and practise how to say it.

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2.1 Inside the atom

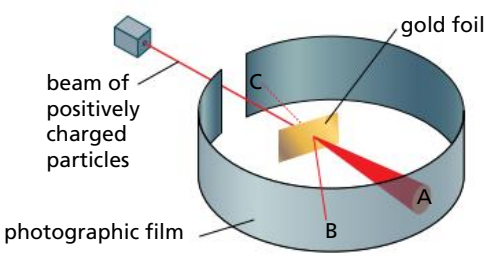
To understand nuclear power and radioactivity you first need to know more about atoms. Until about the end of the 19th century scientists thought that atoms were like tiny balls that could not be split into anything smaller. But discoveries were being made which suggested that there might be even smaller particles *inside* the atom. This idea was difficult to test because nobody could see atoms, and they certainly couldn't see inside them. However, from the results of their experiments, scientists were able to form models or pictures representing what is inside the atom.

The plum pudding model

In 1897 an Englishman called Joseph John Thomson (or J.J. as he was usually called) was experimenting with electricity in gases. He found tiny, negatively charged particles that were much, much smaller than an atom. These new particles were called *electrons*, and scientists thought they might be found inside atoms. Thomson suggested a model for the atom which was like a plum pudding of positive charge with negatively charged electrons scattered through it like raisins.

Rutherford's experiment

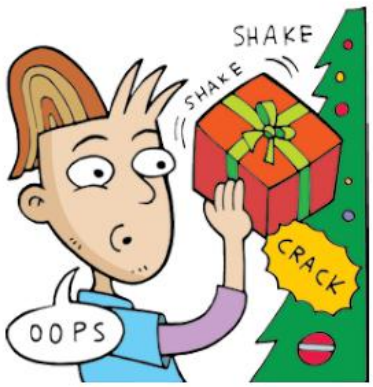
The next major discovery was made eight years later by a New Zealander, Ernest Rutherford. He and two other scientists were doing an experiment at Cambridge University in England. They were shooting positively charged particles from the radioactive substance radium towards an extremely thin piece of gold foil in a vacuum. Around the foil they placed photographic film to record any particles that hit it. What they found was that most of the particles passed straight through the foil and ended up at point A (see the diagram below). Some passed through but changed direction slightly, striking the film at, for example, point B. But occasionally a particle bounced straight back (point C).



INQUIRY 1 **Mystery box models**

You will need: a numbered mystery box

1 Each mystery box contains an unknown object. Your task is to find out as much as you can about the object, *without opening the box.* You can tilt the box, shake it, or anything else,

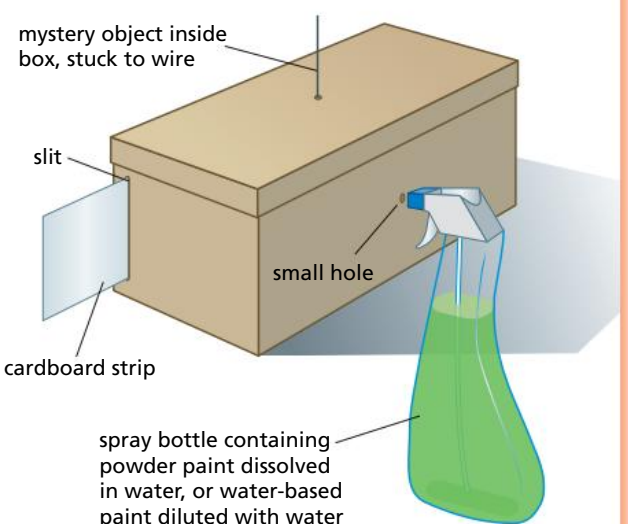


but you are not to open it or damage it in any way.

- Each time you do something with the box, record your observations.
- The idea is not so much to guess what the object is, but rather, you need to be able to describe the size, shape and any other properties of the object. You can then draw it. Your drawing is a model of the object.
- How is what you have done in this activity similar to the way scientists found out what is inside atoms?

2 If you have time, try another mystery box. Your teacher may tell you what is in each box. If so, you can compare your model with the real thing.

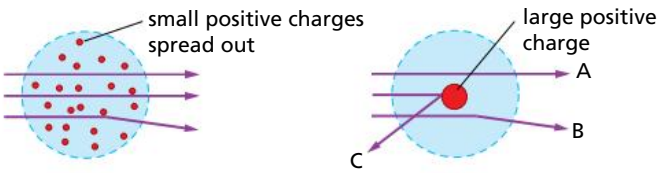
3 The diagram below shows a novel method some students worked out to obtain information about an unknown object in a box by examining the paint left on the cardboard strip. You could try this yourself.



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Rutherford's model

Rutherford described his experiment like this. 'It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15 inch shell (a missile 40 cm in diameter) at a piece of tissue paper and it came back and hit you.' Thomson's raisin cake model didn't fit Rutherford's observations, because you wouldn't expect the large positively charged particles to bounce straight back. So he proposed a new model in which the positive charges in the atom were concentrated in a small central core or **nucleus**. This nucleus would have a big enough charge to repel the positively charged particles, causing them to bounce straight back. Most of the particles did not bounce back because they went through the empty space inside the gold atoms.



What Thomson's model predicted

What Rutherford's model predicted

Improving the model

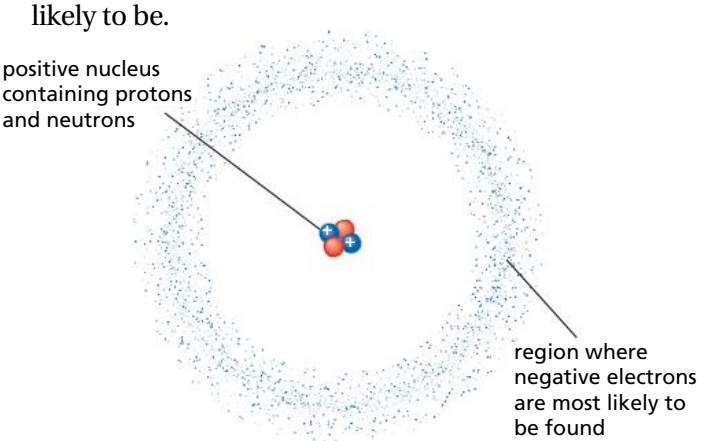
Rutherford's model of the atom explained where the positive charges are, but not where the electrons are. Niels Bohr, a Danish scientist, worked with Thomson and Rutherford. In 1913 he did some calculations that suggested that electrons move rapidly around the nucleus in fixed orbits, like planets orbiting the sun.

In the years that followed, scientists began to think that the nucleus itself could be made up of even smaller particles. They fired particles at the nucleus and found that much smaller particles were occasionally knocked out. One of these was the positively charged **proton**. The other was the **neutron**, which wasn't affected by other charges and therefore had no charge. Protons and neutrons have about the same mass, and are about 2000 times heavier than an electron.

From all these discoveries scientists have put together the following picture (model) of what is inside the atom. There are three kinds of particles—protons, neutrons and electrons. These are often called *subatomic* particles (*sub* means 'smaller' or 'under'). The protons and neutrons are packed together tightly in the nucleus of the atom. The electrons are attracted to the positively charged nucleus, and move rapidly in the area around it.

If the atom was enlarged to the size of a football stadium, the nucleus would be the size of a small marble in the centre of the field. The electrons would be moving rapidly around the stadium, but even at this scale they would be too small to see. As you found in Inquiry 2, most of the atom is empty space.

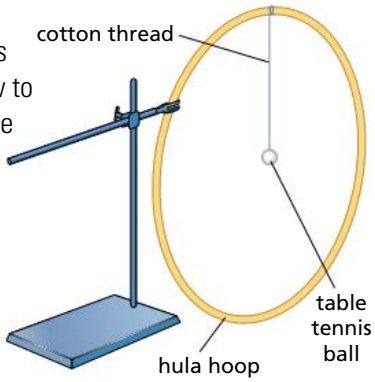
The electrons are so small and move so rapidly that it is impossible to say exactly where they are at any particular time. This is why they are sometimes shown as an electron cloud—a sort of fuzzy area around the nucleus where the electrons are most likely to be.



INQUIRY 2 Inside the atom

You will need: hula hoop, straw, rice grains, cotton thread, table tennis ball, sticky tape, retort stand and clamp

1. Clamp a hula hoop to the stand and suspend a table tennis ball in the middle of it, as shown. The hoop represents an atom and the ball represents its nucleus.
2. From several metres away, use the straw to fire rice grains at the table tennis ball. Count how many grains go straight through the 'atom' and how many hit the 'nucleus'.



- How is this activity similar to Rutherford's experiment with the gold foil?

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Quarks

Scientists now think that protons and neutrons are made of even smaller particles. Using special machines they have accelerated protons to enormously high speeds, almost the speed of light (300 000 km/s). When these speeding protons hit neutrons and other protons, they are shattered into even smaller particles. To explain the results of these experiments scientists have proposed that protons and neutrons are made of particles they called **quarks**. They infer that there are many different types of quarks, held together by strange particles called gluons. The quarks combine to form protons and neutrons.

Atom *Radioactive	Number of protons (atomic number)	Number of neutrons	Number of protons + number of neutrons (mass number)	Number of electrons
hydrogen-1	1	0	1	1
hydrogen-2	1	1	2	1
hydrogen-3*	1	2	3	1
carbon-12	6	6	12	6
carbon-14*	6	8	14	6
nitrogen	7	7	14	7
oxygen	8	8	16	8
aluminium	13	14	27	13
uranium-234*	92	142	234	92
uranium-235*	92	143	235	92
uranium-238*	92	146	238	92



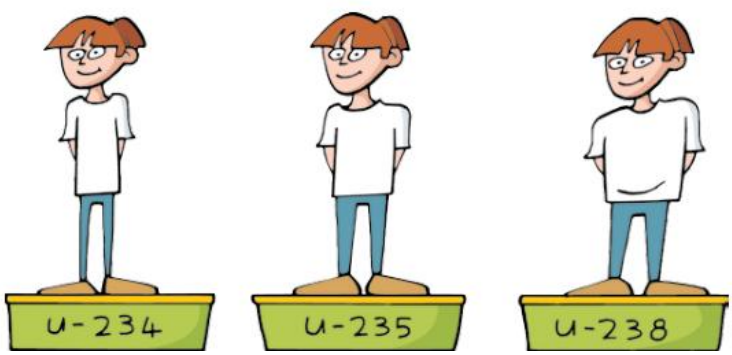
Isotopes

Different atoms have different numbers of protons in their nucleus. For example, hydrogen atoms have only one proton, but uranium atoms have 92 protons. The number of protons in an atom is called its **atomic number**. The number of electrons is the same as the number of protons. This means that the positive and negative charges balance each other, and the atom has no overall charge—it is neutral.

The only thing that makes one atom different from another is the number of particles it contains. For example, the only difference between a nitrogen atom and an oxygen atom is that the oxygen atom has one more proton and one more electron. The table top right shows the numbers of subatomic particles in a few common atoms. Note that the number of protons is always the same as the number of electrons. So each atom is neutral.

Early in the 20th century it was found that many elements contain atoms that are not all exactly the same. For example, there are three different forms of the element hydrogen. These are called hydrogen-1, hydrogen-2 (deuterium) and hydrogen-3 (tritium). The nucleus of a hydrogen-1 atom contains only one proton, but hydrogen-2 has a proton and a neutron in its nucleus. Hydrogen-3 has a proton and *two* neutrons.

The three different forms of hydrogen are called **isotopes** (EYE-so-topes). *Iso* comes from a Greek word meaning 'equal' or 'the same'. These isotopes have the same chemical properties, because they all have the same number of electrons. However, they have different masses, because their nuclei are different. The number 1, 2 or 3 after the name is used to tell them apart. This number is the total number of protons and neutrons in the nucleus. It is called the **mass number**.



Three isotopes of uranium

If the number of neutrons is much greater than the number of protons, the nucleus may be unstable and break up. When this happens a nuclear reaction occurs and the isotope is said to be radioactive. An isotope that is radioactive is called a **radioisotope**.

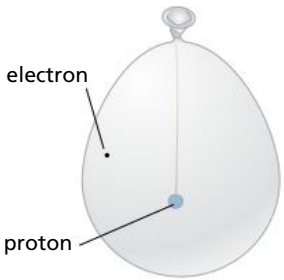
ISBN 978 1 4202 3246 2

INQUIRY 3 Isotope models

You will need: plasticine (two different colours), cotton thread, round white balloons

1 Make small balls from two different colours of plasticine to represent protons and neutrons.

2 Make a model of hydrogen-1 by hanging a proton inside a balloon as shown. Put a small dot on the balloon to represent the electron.



A model of hydrogen-1

3 Also make models of hydrogen-2 and hydrogen-3.
- What is the difference between the three isotopes of hydrogen?

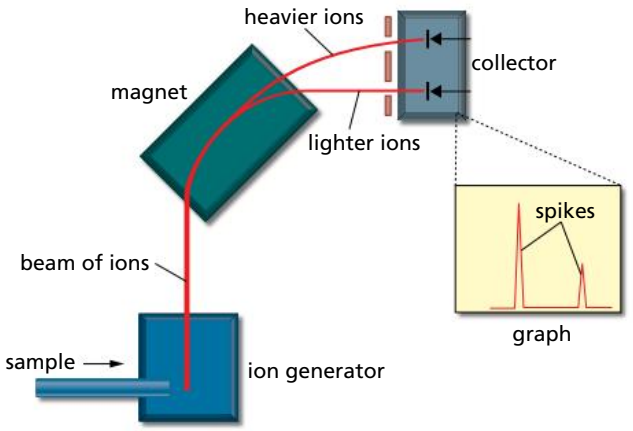
4 Using the information in the table on page 31, make models of the two isotopes of carbon, and the atoms of nitrogen and oxygen. Remember that as the atomic number increases, so does the size of the atom.

Identifying atoms

Scientists have developed an instrument called a *mass spectrometer*. It measures the masses of individual atoms and isotopes and allows scientists to identify them. It can also be used to identify molecules.

Inside the mass spectrometer the sample to be tested is converted into a high-speed beam of charged particles (ions). This beam is then bent by a magnetic field. The lighter particles are bent more than the heavier ones. To understand this, imagine a cricket ball and a table tennis ball travelling past you. If you squirt water from a hose at them you will be able to move the table tennis ball from its path much more easily than the cricket ball. This is because it is lighter. In this way the ions in the mass spectrometer are separated and then detected in the collector. The results are reported as a graph as shown top right, with spikes for each ion.

Mass spectrometers have many different uses. They are widely used in forensics to identify the atoms in materials collected at crime scenes. They are also used in drug testing and in searching for weapons of mass destruction, by taking samples from the environment.



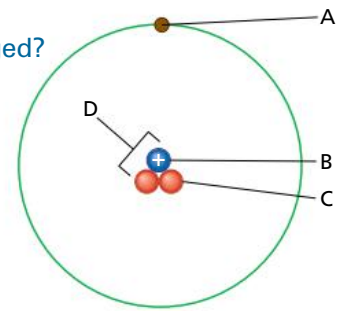
How a mass spectrometer works

Over to you

1 What makes one atom different from another?

2 Name the three subatomic particles.

3 Which of the three subatomic particles:
- **a** are in the nucleus?
- **b** moves rapidly around the nucleus?
- **c** is the smallest?
- **d** is positively charged?
- **e** is negatively charged?
- **f** is neutral?



4 Copy the diagram of a tritium atom on the right and add labels for A, B, C and D.

5 Imagine that you have shrunk to a size smaller than that of an atom. At this size you have 15 minutes to wander around inside a gold atom. It has an atomic number of 79 and a mass number of 197. Describe what you see.

6 Why did Rutherford change Thomson's model of the atom?

7 Two atoms both have 10 neutrons in their nucleus. One has 8 protons, the other has 9. Are they isotopes? Why or why not?

8 Only one isotope of hydrogen is radioactive. Predict which one it is and give a reason for your prediction.

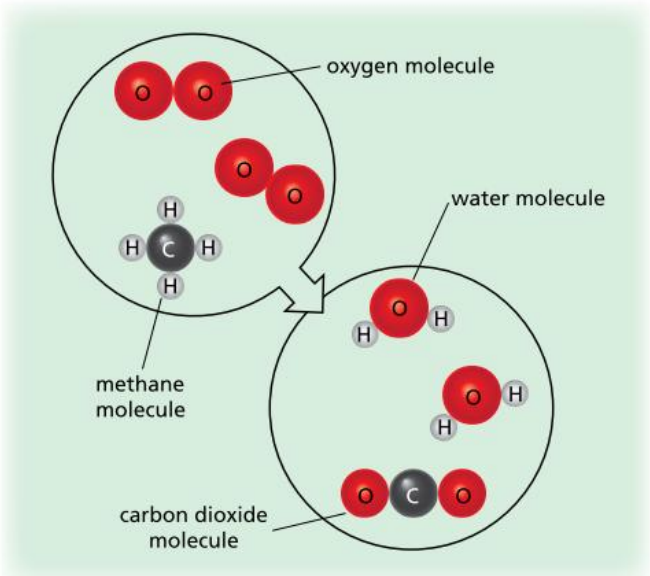
9 Sir Isaac Newton once said 'If I have been able to see further than others, it is because I stood on the shoulders of giants.' Write a paragraph using the history of the atom to explain what he meant.

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2.2 Splitting the atom

Chemical reactions

To understand nuclear reactions you must first understand chemical reactions. The diagram below is a representation of the chemical reaction that occurs when methane (natural gas) burns in air. Methane molecules (CH_4) react with oxygen molecules (O_2) from the air to form carbon dioxide (CO_2) and water molecules (H_2O). Count the number of carbon, hydrogen and oxygen atoms before and after the reaction. What do you notice?



Conservation of mass

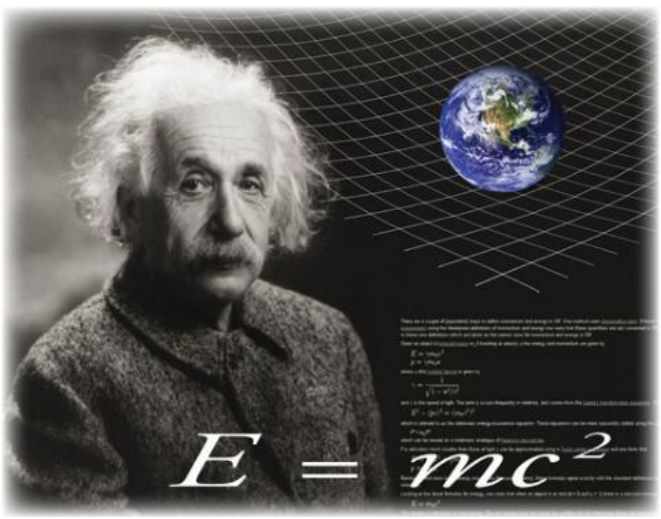
All the atoms present before the chemical reaction are still there after the reaction. No atoms are destroyed and no new ones are formed. In other words, the atoms are *conserved*. The molecules break apart and rearrange themselves to form new molecules, but they are all still there. The oxygen atoms form chemical bonds with carbon and hydrogen atoms by sharing their electrons, but the nuclei of the atoms are not affected. Two new substances (carbon dioxide and water) are formed, but no new elements—that is, no new atoms. Scientists have found this is true for all chemical reactions, so they call it the law of **conservation of mass**. For example, when paper burns, no atoms are lost. Some of the atoms that were in the paper are in the ashes that are left. The rest are in the smoke and invisible gases released into the air.

Nuclear reactions

In this section you will learn about **nuclear reactions**. For example, an atom of plutonium-238 has 94 protons in its nucleus and 144 neutrons, giving it a mass number of 238 (see page 31). Plutonium-238 is a synthetic element which is radioactive, because its nucleus is very unstable. As a result, two of the protons and two of the neutrons break off to form a totally different atom—helium, which has 2 protons and 2 neutrons in its nucleus. What remains is no longer plutonium-238, because it has only 92 protons. It is the element uranium. This nuclear reaction can be represented as follows:

$$^{238}_{94}\mathrm{Pu} \rightarrow {}^{234}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$$

The top numbers show the total number of protons and neutrons in the nuclei. The bottom numbers show the number of protons, which determine which element it is. You will notice that the numbers of neutrons and protons (and electrons) are the same on both sides of the equation. However the combined mass of the two atoms on the right is very slightly less than the mass of the original plutonium atom—so mass has been lost. This never happens in a chemical reaction. It only occurs in nuclear reactions where the nuclei are involved in the reaction. Scientists have found that the mass lost in a nuclear reaction is converted directly into energy, according to Albert Einstein's famous equation $E = mc^2$.



In this equation **c** is the velocity of light—a very large number—so a tiny loss of mass in a nuclear reaction produces a huge amount of energy. For example, a loss of 1 gram produces 90 million megajoules—enough energy to meet the needs of a city about the size of Cairns for a day!

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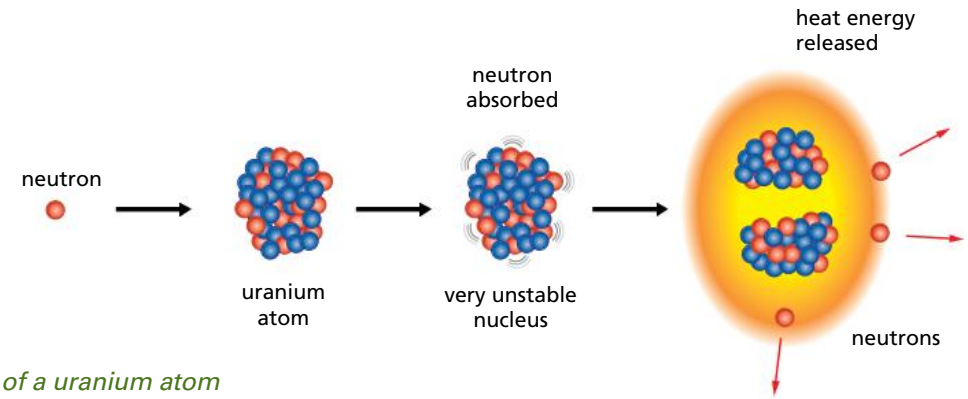
Chain reactions

In a chemical reaction atoms are simply rearranged. The atoms combine to form molecules or the molecules break up into atoms, but one atom can't be changed into a different one. This would mean changing the nucleus of the atom. However, all this changed in 1919. Ernest Rutherford fired nuclei of helium atoms at nitrogen atoms and occasionally oxygen atoms were produced. This was a nuclear reaction because it involved changes to the nuclei of the atoms. The nucleus of the nitrogen atom had gained a proton (and a neutron) to become an oxygen atom. This discovery caused much excitement among scientists. It seemed that the dream of the ancient chemists of converting common metals into gold might come true.

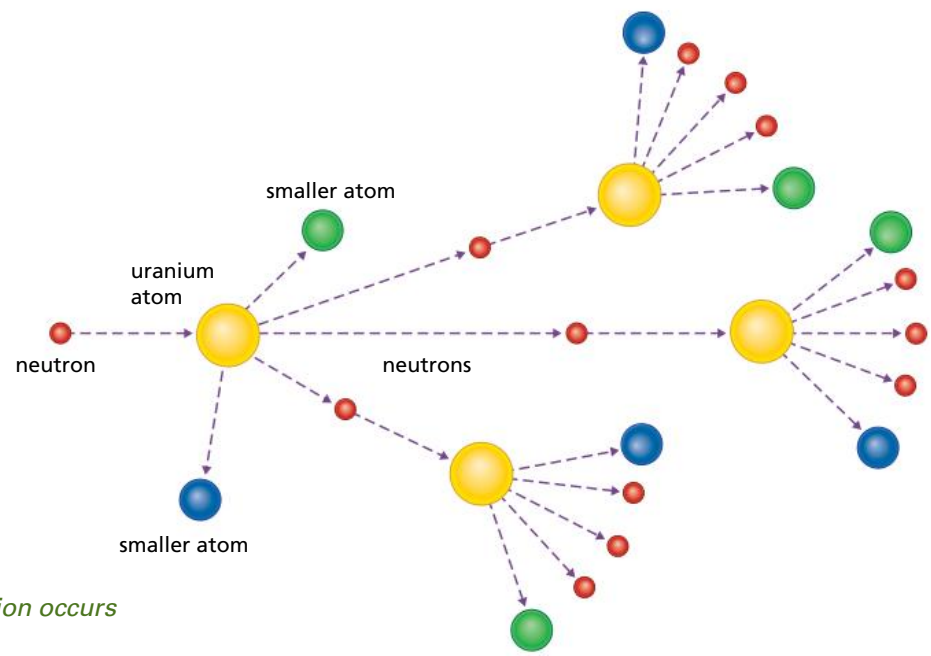
When neutrons were discovered in 1932, scientists used them to bombard other atoms in the hope of causing more nuclear reactions. At the time, uranium was the largest atom known, and scientists were trying to make larger atoms by bombarding it with neutrons. Eventually they were successful and made completely new elements such as plutonium and americium. However, they also discovered that the nuclei of some isotopes could be split into two smaller nuclei. This process was called **nuclear fission**. Fission simply means splitting into parts.

When a neutron collides with a uranium-235 atom, the uranium atom becomes extremely unstable. It quickly splits into two smaller atoms and three or four neutrons, and releases a huge amount of energy.

The neutrons released can bombard other uranium nuclei, which in turn produce more neutrons. These can bombard even more nuclei, and so on. This is called a **chain reaction**. Huge quantities of energy can be released in a fraction of a second. If the chain reaction is not controlled there is a nuclear explosion. If the chain reaction is controlled you can generate electricity in a nuclear power station.



Nuclear fission of a uranium atom



How a chain reaction occurs

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INQUIRY 4 **Chain reaction**

Part A: Dominoes

You will need: a set of dominoes to model what happens in a chain reaction

1 Set up the dominoes so that each domino that falls will knock over two others. The more dominoes you use, the more dramatic the effect will be.

- Once you knock over the lead domino, can you stop the chain reaction?
- Would you say this was a controlled chain reaction or an uncontrolled one? Why?

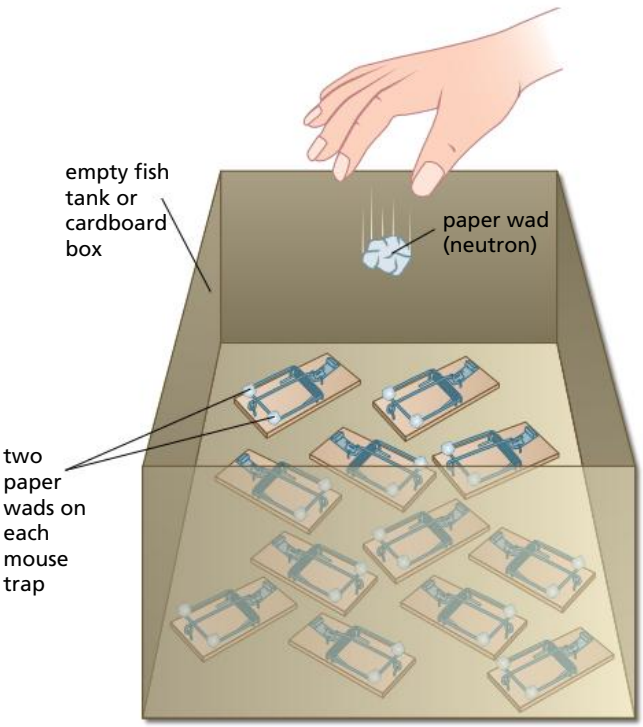
2 Set up the dominoes again. This time arrange them so that when they fall, some knock over two dominoes, some knock over one, and some don't knock any over.

- What happens this time? Is this a controlled chain reaction or an uncontrolled one? Why?
- Of the two setups, which is most like what happens when a nuclear bomb explodes? Which is like what happens in a nuclear power station?

Part B: Mouse traps

Another way to model a chain reaction is to use a box full of mouse traps as set up by your teacher.

- What do the mouse traps represent?
- What do the paper wads represent?



Nuclear power stations

A nuclear chain reaction can occur very quickly if it is not controlled. This is what happens in a nuclear bomb and huge amounts of energy are released in a fraction of a second. In a power station the reaction is carefully controlled, so that the energy is released at a steady rate.

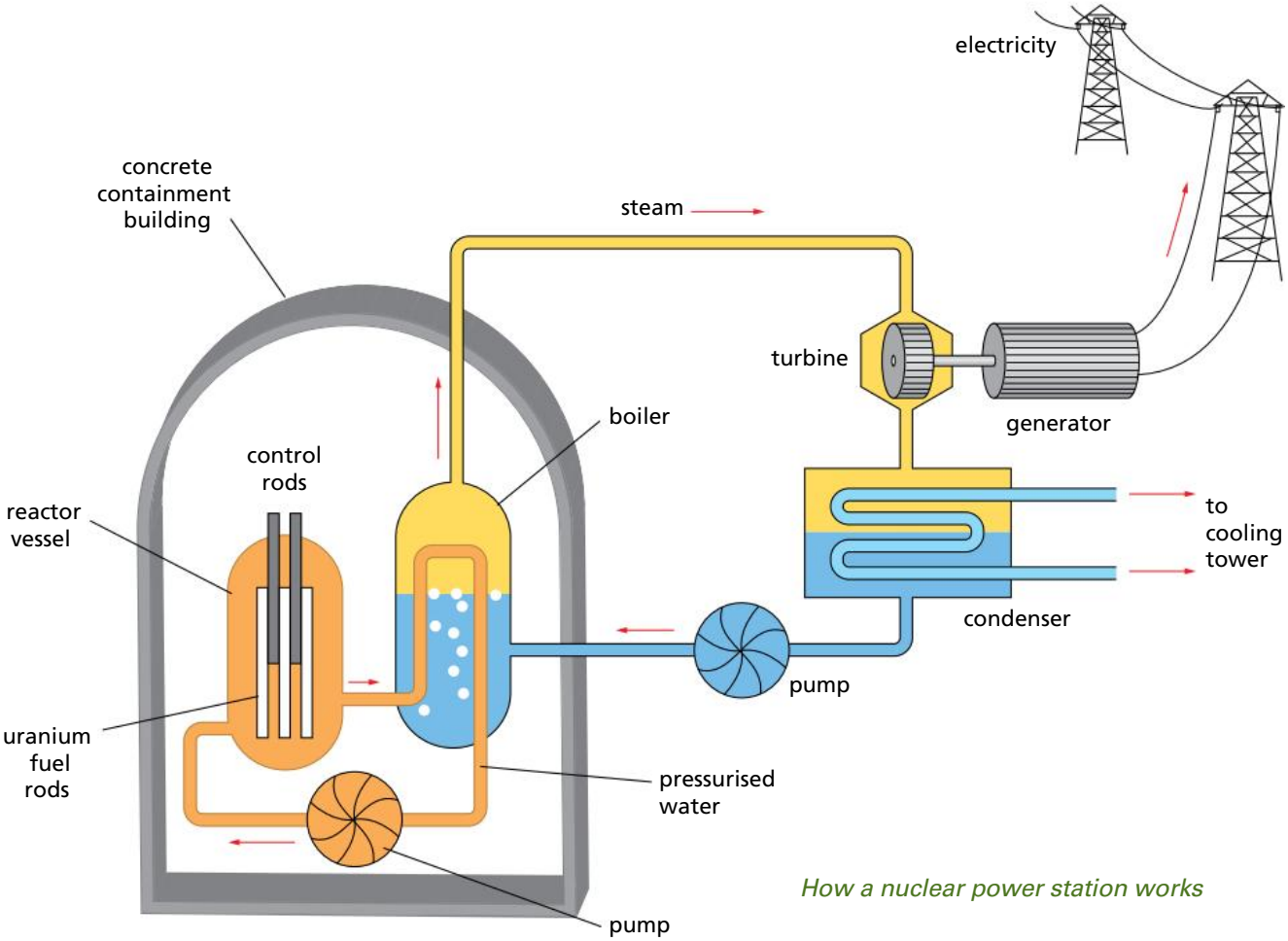
The central part of a nuclear power station is the **nuclear reactor**, which contains the uranium fuel. (See the diagram on the next page.) The reactor has *control rods*, made from a material that absorbs neutrons. These control rods can be moved in and out of the *core* of the reactor. When they are pushed into the reactor they absorb a lot of neutrons, and this stops the chain reaction. When they are pulled out, fewer neutrons are absorbed. As a result there are more neutrons available, and the chain reaction speeds up. So, by moving the control rods in and out, the chain reaction can be controlled.

The heat produced in the reactor is taken away by the coolant, which is usually pressurised water. This heat is used to boil water and produce steam. The steam then spins turbines that are connected to electric generators. During the fission reaction, dangerously radioactive materials are produced. The thick concrete containment building around the reactor stops the radiation from escaping.

There are two main isotopes of uranium—uranium-235 and uranium-238. Only uranium-235 atoms will split, but uranium ore contains less than 1% of this isotope. Scientists have solved this problem by removing some of the U-238 using a centrifuge to produce *enriched uranium* (about 3% U-235) to use in nuclear reactors. The uranium used in nuclear bombs must be enriched even further (at least 20% U-235).

Some ships and submarines are nuclear-powered and work in much the same way as a nuclear power station. The ships don't need to carry a lot of fuel oil as normal ships do, and can keep operating for several months without refuelling.

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How a nuclear power station works

Nuclear fusion

There is a second type of nuclear reaction called **nuclear fusion**, which is the reaction that powers the sun and other stars. It occurs when two nuclei of deuterium or tritium (isotopes of hydrogen) are brought together or *fused*. The process releases huge amounts of energy, much more than nuclear fission does.

However fusion needs enormous temperatures to get it going—around 100 000 000°C. At this temperature matter is not a solid, a liquid or a gas. It is in a fourth state of matter called **plasma**—an ionised gas consisting of fast-moving electrons and positive ions. The major problem is what sort of container to put the plasma in, since no material known can stand these temperatures. So scientists have been experimenting with 'magnetic bottles', in which the plasma is contained inside invisible magnetic fields.

So far, scientists have only been able to produce fusion for a few seconds. Much more research and development will be necessary before fusion power stations are possible. The promising thing about nuclear fusion is that it produces less radioactive waste than nuclear fission. Also, there is an unlimited supply of the fuel needed since deuterium (heavy hydrogen) can be extracted from seawater.

Nuclear weapons

To make a fission bomb there must be enough uranium or plutonium to keep the chain reaction going. This is called the *critical mass*. There must also be enough fast-moving neutrons to start the reaction. There are two explosions which occur. The first explosion is that of a conventional explosive, which forces two masses of uranium or plutonium together to make a critical mass. This explosion triggers off the chain reaction which causes the nuclear explosion. The first atomic bomb dropped on Japan was like this.

A fusion bomb is more powerful than a fission bomb. It is also called a hydrogen or thermonuclear bomb. It contains a fission bomb that creates the enormous temperatures needed to trigger the fusion bomb.

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SCIENTISTS AT WORK

Lise Meitner (1878–1968)

Lise Meitner (LEEZ-a MITE-ner) was born in Vienna, Austria, in 1878. She was one of eight children and her family was Jewish. She was a shy girl. At that time girls didn't go to high school, but her parents paid for a personal tutor. She did well at maths and science and loved music. She went on to university, even though women at the time didn't do this. Lectures bored her but the laboratory fascinated her, so she decided to study physics.

Meitner started experimenting with radioactive elements and for 30 years worked with Otto Hahn in Berlin in Germany. In 1917 she and Hahn discovered a new element called protactinium. They were also hoping to discover an element heavier than uranium.

In 1938 Hitler took over Austria and Meitner was forced to flee from Germany into Sweden. This cut her off from her laboratory and the scientists she had been working with. However she kept in touch by mail. Hahn and Fritz Strassman continued the experiments they had begun earlier with Meitner—bombarding uranium with neutrons. To their surprise they found that the products of the nuclear reactions were lighter than uranium, not heavier.

Hahn wrote to Meitner in Sweden saying 'it can't really break up into barium … try to think of some other possible explanation'. While in Denmark visiting her nephew Otto Frisch for the Christmas holidays, she and Frisch proved that the splitting of the uranium atom was theoretically possible. They published their findings and called the process 'fission', a term used in biology for the splitting of a cell.

Hahn and Strassman showed by experiment that Meitner was correct. Hahn published his findings without listing Meitner as a co-author, even though he had worked with her on fission for 30 years. In 1944 he was awarded the Nobel Prize for Chemistry; Meitner missed out. Hahn said he couldn't give credit to Meitner because of the political situation. However, in later years Hahn never fully acknowledged the part that Meitner played in the discovery.

Meitner never complained about not getting the Nobel Prize. She refused to work on the project to develop an atom bomb and did not like being called 'the mother of the atom bomb'. When Hollywood wanted to make a movie about her, she said that she 'would rather walk the length of Broadway in the nude than see herself in a movie'.

In 1997 Lise Meitner was rewarded with a permanent place in the periodic table. The synthetic element with atomic number 109 was called meitnerium (mite-NEAR-ee-um) after her.



Lise Meitner

Over to you

1. How are nuclear reactions different from chemical reactions?
2. Explain in your own words the law of conservation of matter.
3. What is the difference between fission and fusion? Which produces more energy?
4. Which subatomic particles produced during nuclear fission are capable of causing a chain reaction?
5. What is used for fuel in a nuclear reactor?
6. Why is a nuclear reactor enclosed in concrete?
7. Use the diagram on the previous page to explain in your own words how a nuclear power station works.
8. **a** What is the function of the control rods in a nuclear reactor?
   b What would happen to a nuclear reactor if the control rods were pulled out and then for some reason could not be pushed back in?
9. Why did Lise Meitner have to flee from Germany in 1938?
10. Why do you think Meitner wasn't awarded the Nobel Prize with Otto Hahn?

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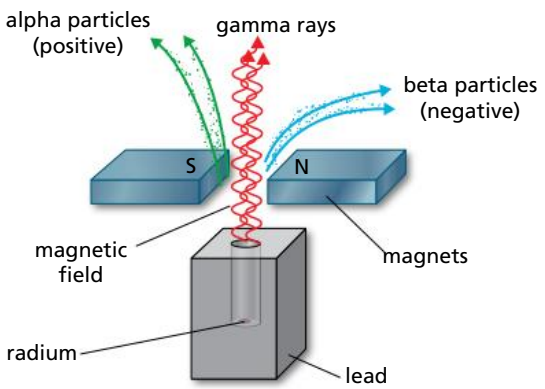
2.3 Radioactivity

You probably know that radioactivity means danger, but what exactly is radioactivity?

Uranium was discovered in 1896, a few years after the planet Uranus was discovered. Henri Becquerel, a French scientist, placed some uranium ore in a dark drawer with some sealed photographic plates. Later he found that the plates were foggy and hazy. To explain his observations he inferred that the uranium must have given off a type of radiation that could pass through the film wrappings and affect the film. He had discovered radioactivity.

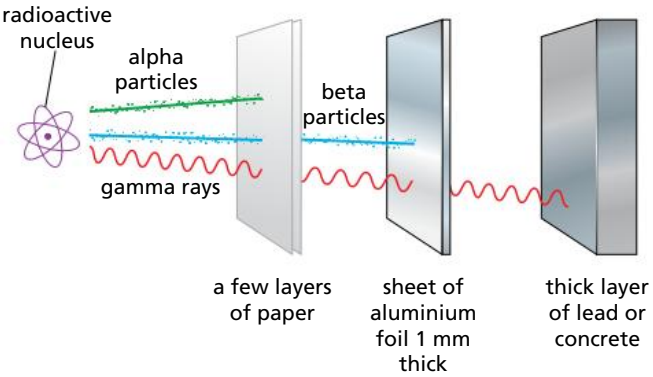
Becquerel knew Marie Curie and her husband Pierre, and he suggested that they follow up his findings. The Curies found that all uranium ores were radioactive. They also discovered two more radioactive elements—radium and polonium.

Ernest Rutherford investigated radioactivity further. He put some radium in a hole in a block of lead to form a beam of radiation. He then put magnets near the beam as shown below. He found that part of the beam did not bend, while two other parts of the beam bent in opposite directions. From this he inferred that the two bent beams had opposite charges. Also, the negative beam was bent more than the positive beam, so he inferred that the particles in it were lighter than those in the positive beam. The beam that was not affected by the magnetic field he inferred had no charge.



Types of radiation

From Rutherford's experiment above we know that radioactivity is made up of three different types of radiation. **Alpha particles** are made up of two protons and two neutrons, so they are really helium nuclei. They have a positive charge and move at speeds of up to one-tenth the speed of light. They travel in air for only a few centimetres and can be stopped by the thickness of a sheet or two of paper.

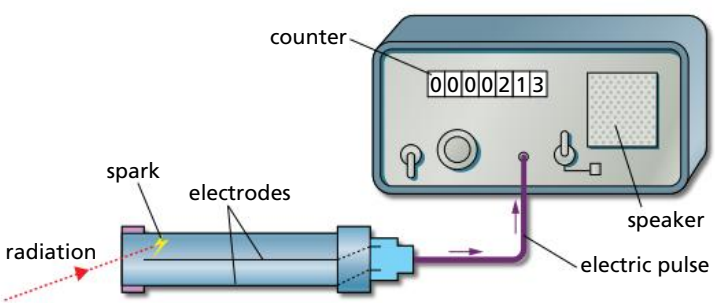


Beta particles are high-speed electrons, with a negative charge. They are not the electrons that surround the nucleus of an atom. Rather, they are produced by the breakdown of neutrons in the nucleus. Beta particles can travel a few metres through air, but are stopped by objects such as a sheet of aluminium or a centimetre of wood. They move at speeds up to nine-tenths the speed of light.

Gamma rays are not particles but a special type of **electromagnetic radiation**, like light, UV and X-rays. They have very high energy and can travel kilometres through air. They can be stopped by objects such as thick concrete blocks or 2–3 cm of lead. Gamma rays are often released with alpha or beta particles. Like all electromagnetic radiation, gamma rays move at the speed of light.

Detecting radiation

To detect radioactivity you can use a *Geiger counter*. It consists of a glass tube containing a gas at low pressure. Inside the tube are two metal electrodes with a high voltage between them. When an alpha or beta particle passes through the tube it knocks electrons out of some of the gas atoms. Because of the high voltage, a short 'spark' of electric current flows between the electrodes. This electric pulse is sent to a counter, where it registers as a count or a click. If the counter clicks rapidly it means there is a large amount of radioactivity present.



How a Geiger counter works

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INVESTIGATION

1 Using a Geiger counter

Aim

To use a Geiger counter to measure background radiation.

Risk assessment and planning

Read through the investigation and prepare a data table in which to record your results.

Apparatus

- Geiger counter and detector
- white sand
- black mineral sand
- piece of granite

Method

1. Connect the detector to the Geiger counter and switch it on.
2. Find out how to read the counter. If possible switch on the audible 'click' so you can hear the count.
3. Make sure the radioactive sources are well away from the detector.
4. Measure the *background radiation* in the room. To do this, record the count after 1 minute. Do this three times and calculate the *average* count.
5. Place a sample of white sand 1 cm away from the detector. Measure and record the radiation as before.
6. Repeat for the mineral sand and the granite.

Conclusion

1. What is the background radiation in your classroom?
2. Is the radiation higher near sand or granite?

INQUIRY

5 Radioactive sources

Jackiaya used a Geiger counter to measure the radiation 1 cm away from three different radioactive sources. He also measured the radiation when he placed sheets of various materials between the source and the detector of the Geiger counter. He then repeated his measurements with two unknown sources.

All his results are counts per minute, and he found the background radiation at 1 cm to be 20 counts/min.

Source	Po-210	Sr-90	Co-60	A	B
Radiation type	alpha	beta	gamma		
No shielding	198	5152	2119	523	2728
2 sheets of paper	28	4796	2092	461	2492
1 sheet of plastic	26	2704	2046	210	969
1 sheet of aluminium	23	2137	1993	156	635
1 sheet of lead	20	22	1773	80	22

1. Which source was the most radioactive?
2. Which type of shielding was the most effective at stopping radiation?
3. Did the piece of lead stop all the radiation from the Po-210 source?
4. Suggest why the piece of lead didn't stop all the gamma radiation.
5. Use Jackiaya's data to infer which type of radiation was released by the two unknowns—A and B. Explain your answers fully.

Radioactive decay

If an isotope has an unstable nucleus, it will break down or *decay* to a more stable nucleus. When this happens it will emit radiation in the form of alpha particles, beta particles or gamma rays.

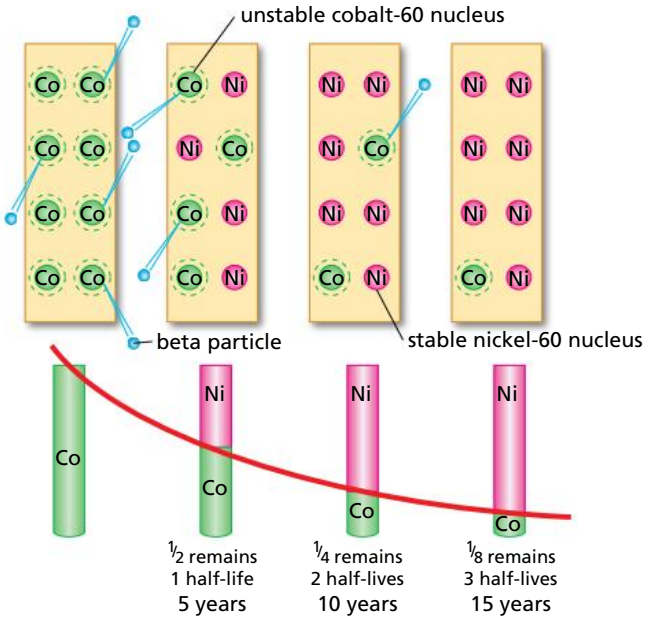
Just as it is impossible to predict when someone will win Lotto, it is impossible to say when a particular nucleus will decay. It could decay in the next second, or it could remain unchanged for the next 500 years. The decay process is random. However, one aspect of radioactive decay is predictable and it is called the **half-life** of an isotope. This is the time taken for half of the isotope's nuclei to decay. No matter how much of the isotope there is, it always takes the same time for half of its nuclei to decay.

Half-lives can range from more than a billion years for some isotopes to less than a billionth of a second for others. For example, the half-life of radioactive cobalt-60 is about 5 years. The radioactive cobalt-60 nucleus gives off a beta particle and in the process changes to a different element—nickel-60.

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This means that after one half-life (5 years), cobalt's radioactivity is only a half of what it was to start with. After two half-lives (10 years) only a quarter of its radioactivity remains. After three half-lives (15 years) only an eighth of its radioactivity remains.

As a radioisotope decays, the amount of radiation emitted decreases, and fewer unstable nuclei remain. Isotopes with short half-lives emit more radiation, but their radioactivity dies away more quickly.



How radioactive cobalt changes to nickel

Radioactive dating

Cosmic radiation from space is constantly bombarding our atmosphere. When it hits nitrogen atoms it can change them into radioactive carbon-14, called *radiocarbon*. These carbon-14 atoms combine with oxygen to form carbon dioxide ($C + O_2 \rightarrow CO_2$).

This radioactive CO_2 is taken in by green plants such as trees, along with normal CO_2 containing carbon-12 atoms. During photosynthesis the CO_2 is converted into compounds in the tree's tissues. When the tree dies the radiocarbon gradually decays to nitrogen-14. So the amount of carbon-14 in the wood slowly decreases.

After about 5600 years there are only half as many C-14 atoms as there were when the plant died. So, by measuring how much C-14 there is in an object, you can estimate how long ago the plant from which it was made was alive. The less C-14 compared with C-12 there is, the older the object.

Radiocarbon dating is useful for finding the age of such things as wood, bones, shells and the things left by early humans, for example the Dead Sea scrolls (about 2000 years old). In 1988 radiocarbon dating was used to date the shroud of Turin. This ancient piece of cloth shows marks which some people believe were made by Christ's body after the crucifixion. However, it was found to be only 500–600, not 2000 years old.

After about 50 000 years the amount of radiocarbon becomes too small to measure accurately, so other radioisotopes are used. For example, all rocks contain small amounts of radioactive elements such as uranium and potassium. These have longer half-lives than carbon-14 and can be used to estimate the ages of rocks and the fossils they contain.

INQUIRY 6 Radioactive decay model

We don't know when a particular atom in a radioisotope will decay, but we do know that half of the atoms will decay in a certain time. This is like tossing a coin. You don't know whether it will be heads or tails, but if you toss it 100 times you would expect about 50 heads and 50 tails.

You will need: 100 coins, or plastic counters with a dot on one side, container with lid

1. Put 100 coins or counters in the container and mix them thoroughly.
2. Tip the coins or counters onto the bench and remove the heads or the counters with dots facing up. These represent the nuclei that have decayed after one half-life.
3. Count and collect the remaining coins. These represent the radioactive atoms remaining. Record this number in a table like this:

Number of half-lives	Radioactive nuclei remaining
0	100
1	
2	

4. Repeat steps 1–3 six times, recording the number of tails or counters with no dots left each time.
5. Plot your results with time in half-lives on the x-axis and radioactive nuclei remaining on the y-axis. Draw a curved line of best fit through the plotted points.
   - How does the number of radioactive nuclei remaining change with time?
   - If you started with 1000 radioactive nuclei, how many would you expect to have left after 6 half-lives? Explain your prediction.

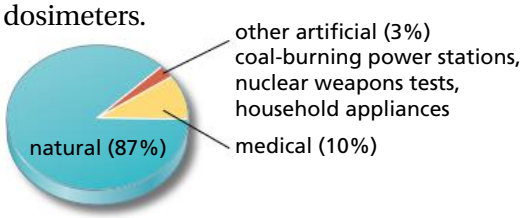
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Radiation and you

There are many different types of radiation around you, but it is only the high-energy radiation that is harmful. Examples are UV radiation, X-rays, gamma rays and cosmic rays (from space). This radiation can cause cancer and damage your reproductive cells, putting your future children at risk. The effects of radiation on your body depend on how much radiation you receive.

Most of the harmful radiation comes from natural background radioactivity in the Earth, mainly from the radioactive uranium and thorium in rocks. These decay to release a radioactive gas called radon into the air you breathe. You also receive radiation from cosmic rays from space and from the natural radiation of your food and drink.

You cannot do anything about the natural radiation you receive, but it is obviously important to keep the radiation from medical and other artificial sources to a minimum. We each receive a dose of about 2 millisieverts every year from natural radiation. The *sievert* is a unit used for measuring radiation. At present there is an international guideline that no member of the public should receive more than 1 millisievert of artificial radiation per year. A single chest X-ray results in a dose of about 0.1 millisieverts. Researchers, hospital staff and workers in nuclear power stations wear special detectors called dosimeters. These measure the amount of radioactivity they receive.



Sources of radiation in Australia

Over to you

1 Copy and complete this table:

Type of radiation	What is it?	Distance travelled in air	Can be stopped by:
alpha beta gamma	helium nuclei		

2 Actinium-228 decays by emitting beta particles, and has a half-life of 6 hours. If you have 100 g of actinium-228 now, how much will be left in:

a 6 hours? **b** 12 hours? **c** 24 hours?

3 You have 64 g of a radioisotope with a half-life of 5 days. How much will be left after 5 days? After 10 days? How many days will it take for the mass to decrease to 1 g? Show this information on a graph.

4 If the half-life of carbon-14 is 5600 years, about what fraction of the original radioactive carbon-14 would you expect to find in:

a an Aboriginal boomerang 11 000 years old?

b a human skull 23 000 years old?

5 The graph below shows the radioactive decay curve for a certain radioisotope.



a What is the half-life of the radioisotope?

b How long did it take for the radioactivity to fall below 50 counts/min?

INQUIRY 7 Fukushima disaster

There have been various accidents in nuclear power stations, but a recent one was at Fukushima in Japan in 2011. There was a meltdown in three reactors and radioactive material was released into the environment.

Use the internet and other resources to find out as much as you can about the Fukushima disaster. Write a report. In your report you should answer these questions:

- What caused the accident?
- What is a meltdown in a nuclear reactor?
- What radioisotopes were released into the environment? What were their half-lives?
- What was done to reduce the loss of life and to clean up the disaster area?
- What short-term and long-term effects did the radiation have on people in the Fukushima area?

When writing your report use several different sources, not just one. Use your own words rather than copying material. And make the report interesting by using photos, maps and diagrams where possible.

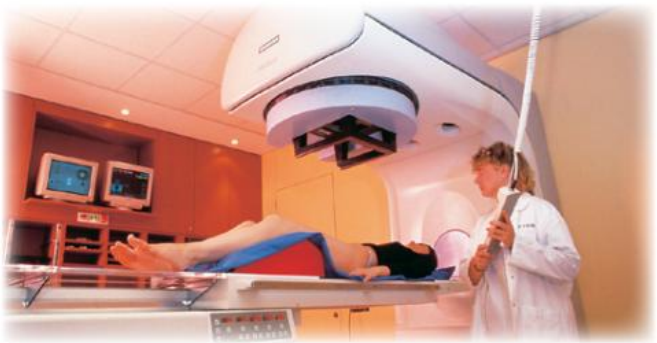
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2.4 Using radioisotopes

Radioisotopes are commonly made by placing stable isotopes into a nuclear reactor, where they are bombarded by neutrons. In Australia, radioisotopes are made at the Lucas Heights nuclear reactor in Sydney. Radioisotopes can also be made in a *cyclotron*. This device accelerates charged particles to very high speeds. These particles hit a target of specially prepared material in which nuclear reactions occur and some atoms become radioactive.

Nuclear medicine

Alpha, beta and gamma radiation is sometimes called ionising radiation because it can ionise atoms and molecules, that is, give them an electric charge. These ions are more likely to become involved in chemical reactions. In the body, these ions may cause chemical reactions that destroy cells, or they may cause uncontrolled cell growth—cancer. However, cancer cells are more sensitive to radiation than normal cells and so radiation is often used to treat cancer. In *radiotherapy*, a radioisotope (usually cobalt-60) is placed in a shielded box with an opening through which a beam of gamma rays emerges. The beam is aimed at the area where the cancer is, and the machine is rotated. This ensures that the cancer cells receive a large dose, killing most of them, while the surrounding healthy cells receive only a small dose.



A patient undergoes radiotherapy

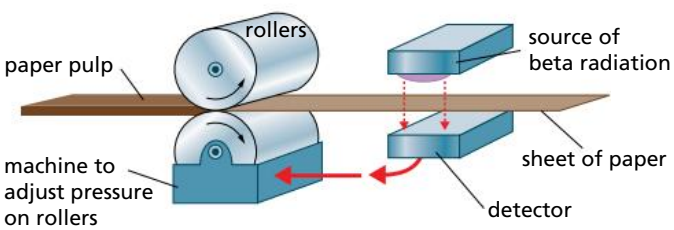
Radioisotopes with short half-lives can also be used to diagnose the condition of internal organs, blood vessels and bones. Radioactive *tracers* that emit gamma rays are swallowed or injected, and these tend to collect in particular parts of the body. They can then be detected by a gamma camera outside the body, which converts the gamma rays to an image.

An important technique in nuclear medicine is called PET (positron emission tomography). Radioisotopes such as carbon-11, nitrogen-13 or oxygen-15 are injected or inhaled into the body. These radioisotopes emit *positrons*, which are like electrons except that they have a positive charge. When a positron meets an electron in an atom in the body tissue, the particles destroy each other. In the process two gamma rays are created, travelling in opposite directions. An array of detectors around the patient detects these gamma rays and feeds the information into a computer. Here the exact position of the nucleus that emitted the positron can be calculated. By combining the information from many separate emissions, the computer builds up a picture of a slice of the patient's body.

Radioisotopes in industry

Many industrial problems can be solved using radioisotopes. For example, small leaks in complicated pipe systems can be traced. You simply add the radioisotope to the liquid in the pipe and follow its movement with a radiation detector.

When paper is manufactured it is important to make it the correct thickness. Beta radiation is passed through the paper and detected on the other side. The thicker the sheet, the less radiation passes through it. The detector can be linked to the rollers to automatically control the thickness of the paper. If the amount of radiation passing through the paper decreases, the rollers move closer together to make a thinner sheet. A beta source such as strontium-90 is usually used. For plastic or metal sheets, a gamma source is used because its radiation can pass through these materials.

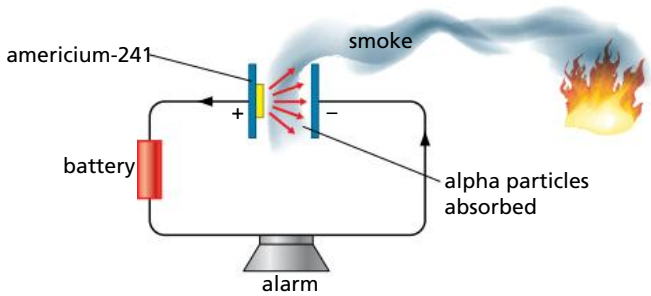


Radioisotopes are also used to check whether containers on a production line have been correctly filled. The radioisotope is placed so that if the container is full no radiation passes through. If the container is empty or not full, the radiation passes through to a detector which sets off an automatic mechanism to reject the faulty container.

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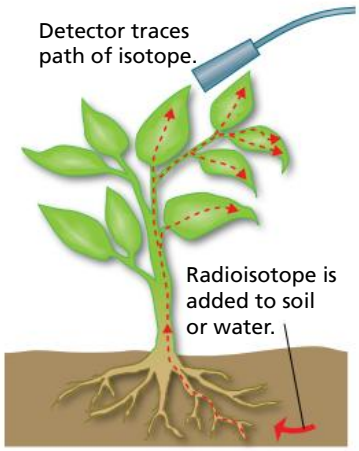
Smoke detectors

Most homes have smoke detectors installed. These contain a small amount of americium-241, a synthetic radioisotope made in nuclear reactors. Alpha particles emitted by the americium ionise the air and create a small electric current that stops the alarm from sounding. If smoke enters the detector it absorbs the alpha particles and interrupts the current, setting off the alarm.



Food and agriculture

To investigate the effect of fertiliser on plants, the fertiliser is 'labelled' with a radioisotope and injected into the soil around the plant. The plant absorbs the fertiliser and its path in the plant can be traced by a detector. In this way you can find out how plants use fertilisers and which fertiliser is the best to use.



Another use of radioisotopes is the control of insects without using chemical insecticides. The insects are sterilised with radiation before they hatch. They are then released into the infected area. When they mate with females, no offspring are produced. In this way the insect pests in the area can be drastically reduced.

Radiation is widely used to sterilise medical and surgical equipment by killing all bacteria and other micro-organisms so that they cannot infect patients. For example, disposable syringes are sealed in plastic and the package is then exposed to radiation with gamma rays from a cobalt-60 source. This process is called *irradiation*.

Irradiation can also be used to preserve food, because it kills the bacteria that cause the food to spoil. Food that has been irradiated keeps longer than food that hasn't.

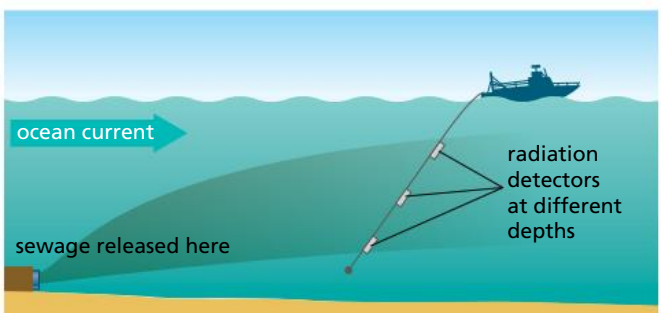
When food is irradiated it does not become radioactive, and on their trips into space astronauts eat food preserved by irradiation. It has been suggested that our food be irradiated to make it last longer. However, the radiation may destroy vitamins in the food and produce unwanted chemicals. For this reason many people are at present not convinced that food irradiation is a good idea.



Protesters outside a food irradiation plant

Environmental monitoring

Radioisotopes can be used to monitor the movement of materials in the environment. For example, radioactive gold-198 is used to monitor the flow of sewage from pipes off the coast near Sydney. The movement of the radioisotope is easily traced by using a radiation detector, as shown.



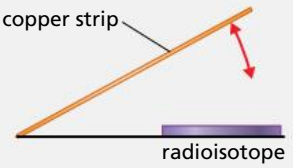
Radioisotopes can also be used to track the movement of sand and silt. Suppose the sand along a beach is disappearing and you want to know where it is going. You simply add a small amount of radioactive tracer to the sand and follow its path with a detector.

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INQUIRY 8 Atomic battery

Read the following information and answer the questions below.

A team of researchers at Cornell University in the USA have invented an atomic battery. It consists of a small strip of copper 2 cm long, 1 mm wide and razor-thin. This is attached to a thin film of the radioisotope silver-63.



As the isotope decays it emits beta particles (electrons). These electrons collect on the copper strip, giving it a negative charge. Because the isotope loses electrons it becomes positively charged. As a result there is an electrostatic attraction between the copper strip and the isotope film. As this attraction increases, the copper strip bends towards the isotope. When it gets close enough a tiny electric spark jumps from the copper to the isotope and the charges cancel each other out. The copper strip then springs back up and the whole process starts again. It is like one of those novelty toy birds that dips its beak into a glass of water over and over again.

Silver-63 has a half-life of over 100 years, so it should be able to power the battery for about 50 years. The researchers are now building and testing practical devices using the atomic battery. The researchers say these devices could be made as small as one cubic millimetre.

1 Draw a diagram or series of diagrams showing how you think the atomic battery works.
2 What advantages does the atomic battery have over normal batteries?
3 Suggest ways in which the atomic battery could be used.
4 Given that the atomic battery emits beta particles, would it be safe for use in medical implants such as heart pacemakers? Explain.

Forensic analysis

By bombarding a sample with neutrons in a nuclear reactor, the atoms in the sample can be made radioactive and identified. In one famous case forensic scientists used this technique to investigate a few strands of Napoleon Bonaparte's hair, 140 years after he died. They found arsenic in the last few centimetres of each hair. From this they inferred that he may have been poisoned. However, he may have taken arsenic as a medicine, or he may have absorbed arsenic from the wallpaper in his house.

This technique is used in forensic analysis to analyse material gathered at crime scenes. For example, residue from the skin of a person believed to have fired a gun can be analysed for the presence of metals such as lead.

Over to you

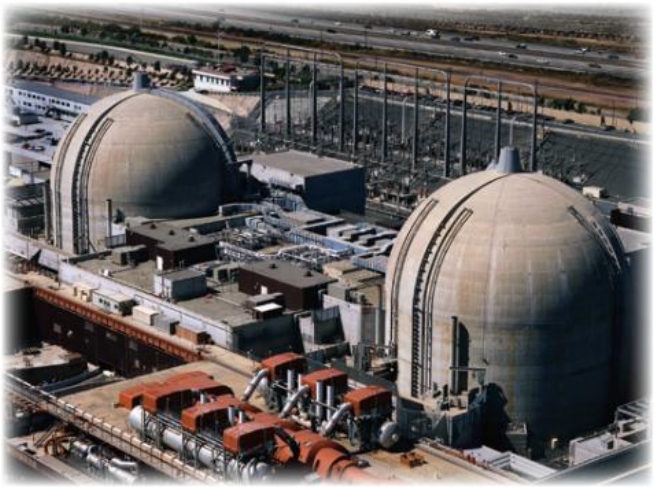
1 Would an alpha particle emitter be suitable for measuring the thickness of cardboard in a factory manufacturing cardboard boxes? Explain.
2 **a** What is the danger of using radioisotopes to kill cancer cells?
b Why do you think gamma radiation is used to treat cancers inside the body, but beta radiation is used to treat skin cancers?
3 To treat a patient with a cancerous tumour, a doctor chooses strontium-90, a beta source with a half-life of 28 years. Should he inject the patient with this or should he use it externally? Explain your answer.
4 Why is gamma radiation rather than beta radiation used for sterilising dressings?
5 A mining operation is proposed upstream from a town. The residents want to know if any of the waste products from the mine could reach the town. How could they use a radioisotope to check this?
6 The manager of a cornflakes factory wants to make sure the packets are filled to the correct level. Draw a labelled diagram showing how this could be done using a radioisotope.
7 The photo below shows how radioisotopes for use in medicine and industry are packaged for transport by air from Sydney to other parts of Australia. Describe the safety features.



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2.5 The nuclear debate

The population of the world increases by about 1.3% each year, and the electricity used increases by about the same amount. At present 38% of this electricity is generated in coal-burning power stations and 17% in nuclear power stations. There are about 440 nuclear power stations in 35 countries around the world.



A nuclear power station in the USA—note the two concrete containment buildings.

Advantages of nuclear power

A typical coal-burning power station uses almost 3.2 million tonnes of black coal a year. A nuclear power station of the same capacity uses only about 27 tonnes of enriched uranium, produced from about 60 000 tonnes of uranium ore. Increased use of nuclear power would considerably reduce our use of valuable fossil fuels.

A typical coal-burning power station produces about 7 million tonnes of carbon dioxide each year. However, increasing levels of carbon dioxide in our atmosphere may lead to global warming and climate change, due to the greenhouse effect. By contrast, nuclear power stations do not produce any carbon dioxide. So greater use of nuclear power would considerably reduce the emission of greenhouse gases. It is estimated that if the electricity produced worldwide by nuclear power stations was generated instead by burning coal, an extra 2400 million tonnes of carbon dioxide would be released into the atmosphere each year.

A coal-burning power station also produces an estimated 200 000 tonnes of sulfur dioxide each year, and this can lead to acid rain. So this is yet another advantage of nuclear power, which produces no sulfur dioxide.

Finally, a coal-burning power station produces 200 000 tonnes of solids each year, mainly ash. This ash contains several hundred tonnes of toxic heavy metals, including arsenic, cadmium and lead, which remain in the environment. The burning of coal also releases radioactive heavy metals (including uranium and thorium). The burning of natural gas releases radioactive radon gas. The amount of radioactivity released is very small compared to the level of natural background radiation, but it is often greater than that from nuclear power stations.

INQUIRY 9 Nuclear energy production

The table shows the total nuclear energy produced in the world from 1978 to 2011

Nuclear energy production (million tonnes of oil equivalent)

Year	Production	Year	Production
1978	140	1996	545
1981	189	1999	571
1984	282	2002	611
1987	393	2005	627
1990	453	2008	619
1993	495	2011	599

1. Display the data on a line graph. You will be predicting up to the year 2025, so think carefully about the units for the axes. Draw a curved line of best fit through the plotted points.
2. Write a short description of how the use of nuclear energy changed from 1978 to 2011.
   - When did nuclear energy production reach its peak?
3. Use your graph to estimate or predict the nuclear energy production in 2000, 2015 and 2025.
4. Compare your predictions with those of other people. Mark the range of predictions for 2025 on your graph. Why do the predictions vary?
5. Discuss the use of nuclear power with others. List factors that you think may increase or decrease the use of nuclear energy over the next 25 years.
6. Try to reach a consensus on a prediction for the year 2025. Add this to your graph and label it.

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Disadvantages of nuclear power

Nuclear power stations have a good safety record, but there have been a number of serious accidents. The worst of these was at Chernobyl in Ukraine in 1986, and a more recent accident occurred at Fukushima in Japan in 2011 (see Inquiry 7 on page 41).

The world's nuclear power stations produce about 14 000 tonnes of radioactive waste each year. About a third of this is reprocessed and used again, but the other two-thirds has to be stored. The first step in handling these radioactive wastes is simply to let them sit for several months in shielded containers. Substances with short half-lives decay enough to become safe during this time. But substances with longer half-lives must be stored for hundreds, perhaps thousands of years and not allowed to escape into the environment.

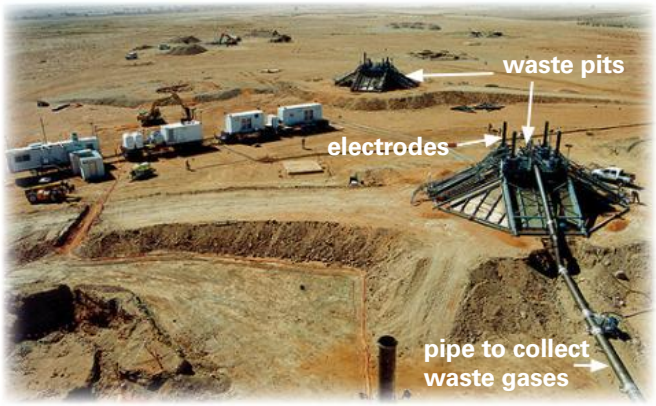
For many years low-level wastes were mixed with concrete, put into drums and then dumped at sea. This method of disposal has now been banned, because some drums started to leak. High-level wastes are presently stored under water in stainless steel tanks inside concrete vaults lined with stainless steel. The water absorbs the radiation and must be cooled to remove the heat produced. However, none of the nuclear wastes produced in the USA over the last 45 years has been *permanently* disposed of.

Scientists are investigating various methods for future long-term storage of nuclear wastes. One idea is to solidify the wastes in glass or ceramic capsules. In 1978 Professor Ted Ringwood of the Australian National University in Canberra worked out a way of mixing the waste with three different minerals under high pressure and temperature to form a synthetic rock called Synroc. The capsules produced in this way would be placed in metal containers and stored in deep underground caverns. The area where the waste is buried, however, needs to be free from earthquakes. And can we be absolutely sure of what will happen to the wastes over the next thousand years or so?

PROBLEM SOLVING

Have you prepared and presented your speech on the nuclear debate? You may be able to use the advantages and disadvantages of nuclear power from this section.

In 1984 Australian scientists measured radiation levels at Maralinga in South Australia, where the British tested nuclear weapons in 1956 and 1957. The levels were 10 times higher than expected, so in 2000 the site was cleaned up. The waste was not removed but melted into huge glassy masses. This was done by putting four huge graphite electrodes into the waste pits and passing a very large electric current through them, as shown in the photo. Only time will tell whether this site is now safe.



Cleaning up the radioactive wastes at Maralinga

When nuclear waste is transported it is put in special flasks designed to survive any possible accident. The safety of these flasks was demonstrated by crashing a train into one of them at 160 km/h. The flask survived the crash without leaking. However, there have been accidents. For example in 1994 trucks carried 10 000 drums of low-level radioactive waste through NSW, Victoria and South Australia to a temporary storage site at Woomera. One of the loads spilled and a specialised cleanup operation was necessary. There is also the risk that nuclear material could be lost during transport or stolen and used by terrorists to make nuclear weapons.

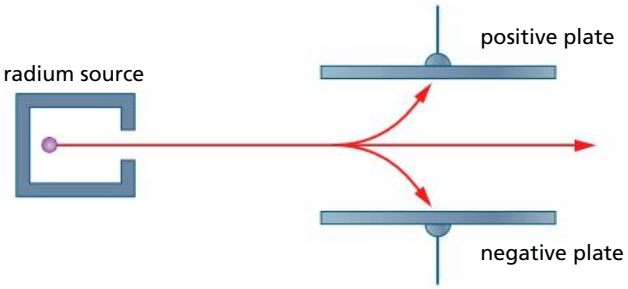


Testing the safety of a radioactive waste container

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THINKING SKILLS

1 An electric field is set up between two charged plates as shown and the alpha, beta and gamma radiation from a radioactive radium source passes into the electric field. Some of the radiation is attracted to the positive plate, some to the negative plate and some is unaffected and passes straight through.



a Which type of radiation is attracted to the positive plate? Explain your answer.

b Which radiation is attracted to the negative plate? Why?

c Which radiation passes through the electric field unaffected? Why?

2 What are the advantages and disadvantages of using a nuclear reactor to power a spaceship?

3 Sources of alpha particles are not usually regarded as dangerous unless they are breathed in or taken in with food. Why is this?

4 Suggest a way of storing a radioisotope that emits only alpha and beta particles.

5 You have designed a building that is radiation-proof. How could you test that it works?

6 Explain how both of the following statements can be true:

- Nuclear fusion has not been used as an energy source on Earth.
- Nuclear fusion is the most important energy source on Earth.

7 How can the use of nuclear power help avoid global warming?

8 Given the choice, would you prefer to live near a coal-burning power station or a nuclear power station? Explain your answer.

9 The radioactivity count rate for a sample of a radioisotope fell from 800 to 100 counts/min in 15 hours. What is the half-life of the radioisotope? Explain your working.

10 The table below shows the radiation count from a radioisotope over a period of 40 minutes:

Time (min)	0	5	10	15	20	25	30	35	40
Count	152	115	87	66	50	38	29	22	17

a Plot a line graph to display the data.

b How long does it take for the count to drop from 120 to 60 counts?

c How long does it take for the count to drop from 60 to 30 counts?

d What is the half-life of the radioisotope?

e Predict how long it would take for the count to reach 10.

11 How could an agricultural researcher use a radioisotope to find out whether most of the fertiliser spread on a paddock is ending up in the food the cattle eat or whether it is being washed into a creek and wasted?

12 When a giant star explodes, its core collapses to form a neutron star. A matchbox full of material from a neutron star would have a mass of millions of tonnes. Use what you learnt in Section 2.1 about atoms to explain this incredibly high density.

13 Imagine a friend of yours is applying for a job in the nuclear industry. Write a letter to him or her explaining the dangers and benefits of radiation.

14 Australia's only nuclear reactor is at Lucas Heights in Sydney. Use internet research to find out:

a what it is used for

b whether there are any safety concerns.

15 Use internet research to answer these questions about nuclear power stations:

- How are they built?
- What are fuel rods and control rods?
- How is the reactor kept cool?
- How is electricity generated?
- What safety features are there?

Use materials such as cardboard, wire and papier-mâché to build a model that incorporates the information you have found. Label all the parts of your model.

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 Atoms are composed of a positively charged _____ surrounded by negatively charged _____. Inside the nucleus are _____ (positive charge) and neutrons (no charge).

2 Isotopes are atoms that have the same number of protons and electrons, but different numbers of _____.

3 In _____ reactions, no mass is gained or lost (conservation of matter), but in nuclear reactions mass is converted into _____ ($E = mc^2$).

4 Nuclear energy is produced by splitting the nuclei of large atoms such as uranium-235. This is called nuclear _____.

5 Nuclear _____ occurs when small atoms such as hydrogen join together. This process occurs in the _____ and produces huge amounts of energy.

6 _____ materials are those in which the nucleus of the atom breaks down and radiation is given off. There are three types of radiation: alpha and beta _____ and _____ radiation.

7 The rate at which the radiation is given off is measured by the _____. This is the time taken for half of the _____ in a sample to decay.

8 Isotopes that are radioactive are called _____. They have many uses, especially in _____, industry and radioactive dating.

atoms
chemical
electrons
energy
fission
fusion
gamma
half-life
medicine
neutrons
nucleus
particles
protons
radioactive
radioisotopes
sun

Self-management



True or false?

Which of the following are true and which are false? Rewrite the ones that are false to make them true. All the answers are in the chapter.

1 The nucleus of an atom contains protons, neutrons and electrons.

2 The number of protons in the nucleus is always the same as the number of neutrons.

3 Electrons are much smaller than protons and neutrons.

4 Gamma rays can be used to kill cancer cells.

5 In a nuclear reactor, one atom can change to a different atom.

6 Lise Meitner received a Nobel Prize for Chemistry in 1944.

7 Nuclear power stations do not produce greenhouse gases.

8 Radioisotopes with short half-lives emit more radiation than those with longer half-lives, but their radioactivity dies away more quickly.

9 Radioactive wastes lose their radioactivity after being buried for about 50 years.

10 The Chernobyl disaster occurred in the USA in 1986.

11 The reason there are no nuclear power stations in Australia is because we have no reserves of uranium.

12 We receive much more radiation from natural sources than from artificial ones.

Now it's your turn. Search through the chapter and write three statements like those above that are true and three that are false. Try them out on your classmates.

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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 If an atom has 9 protons and 11 neutrons then the number of electrons around the nucleus is:

A 2
B 9
C 11
D 20

2 What happens when an unstable nucleus breaks down?

A Electrons are forced into the nucleus.
B Particles and energy leave the nucleus.
C Two nuclei join together.
D Huge amounts of energy are needed.

3 The half-life of a radioisotope is:

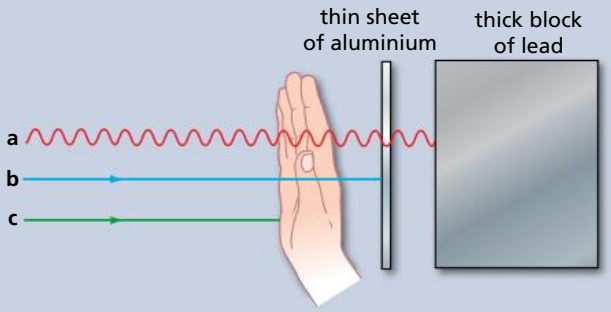
A the time it takes for half of it to decay
B the time before it starts to give off radiation
C when it has only half of its life left
D the same for all radioisotopes

4 A common use for the carbon-14 radioisotope is:

A cancer therapy
B detecting thyroid disease
C as a fuel in nuclear power stations
D finding the age of ancient objects

5 Name the particles that are found in an atom. State what their charge is and where they are found in the atom.

6 Name the three types of radiation shown in the diagram below.



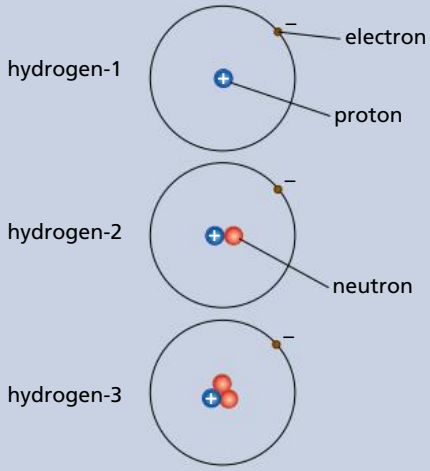
How far radiation can penetrate

7 **a** What is the difference between nuclear fission and nuclear fusion?

b Why has it been possible to use both fission and fusion in bombs, but only fission for peacetime purposes?

8 Hydrogen has three different isotopes as shown.

a What do the numbers 1, 2 and 3 indicate?
b How are the three isotopes similar?
c How are they different?
d Which isotope would you expect to be radioactive? Why?



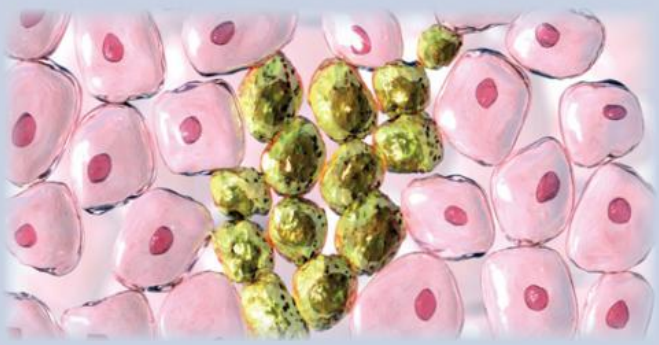
9 Name two similarities between nuclear power stations and coal-burning power stations. Name two differences.

10 A barium isotope has a half-life of 6 minutes. If there are 800 g of barium now, how much will there be in half an hour from now?

11 Ming said 'It's OK for Australia to mine and sell uranium overseas, provided we don't build nuclear power stations here or use our uranium to build nuclear weapons'. Is this a reasonable view to hold? How would you answer him?

12 Radiation is more destructive to cells that are dividing and growing rapidly than it is to normal cells.

a How can this be an advantage?
b How can it be a problem?



Cancer cells (yellow) invading normal cells

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3



Health and nutrition

By the end of this chapter you will be able to …

Knowledge and Understanding

- explain how the digestive system provides cells with the requirements for life (LW1b)

Skills–Working Scientifically

- describe the purpose of an investigation (5.1a)
- explain the need for an experimental control (5.2e)
- identify the equipment and materials needed to perform various experiments (5.3a)
- assess risks associated with laboratory experimentation (5.3d)
- construct an appropriate data table to record the results of an experiment (6e)

LITERACY FOCUS

absorbed
antioxidant
appendix
basal metabolic rate
cholesterol
deficiency disease
diarrhoea
digest
duodenum
faeces
minerals
obesity
oesophagus
peristalsis
phloem
saliva
vascular plants
villi
vitamins
xylem

Focus for learning

The nutritional facts about a Big Mac are presented below. Do you know what all these mean and what your body does with this food when it is eaten? You will explore these details in this chapter.

Nutritional facts of a Big Mac (215 g)
kilojoules: 2060 kilojoules from fat: 1024

Food substance		Vitamin or element daily requirement	
total fat	27 g	vitamin A	6%
saturated fat	11 g	vitamin B	6%
cholesterol	85 mg	calcium	30%
total carbohydrate	35 g	iron	25%
dietary fibre	3 g	sodium	42%
sugars	6 g		
protein	25 g		

The standard unit used to measure the energy value of food is the kilojoule (kJ). However, calories are often used. One calorie is about 4.2 kJ.

PROBLEM SOLVING

Nutrition

1 Find the nutritional facts for your favourite food. Look on the box or packaging, in *Choice* magazine or food tables in your food science classes. You could also try nutritiondata.self.com.

2 Draw a labelled diagram of the human digestive system on a large piece of paper. Indicate on your diagram where the different nutritional parts of your favourite food are digested.

3 State whether your food is an energy-dense or nutrient-dense food.

The rest of the chapter will help you with this problem.

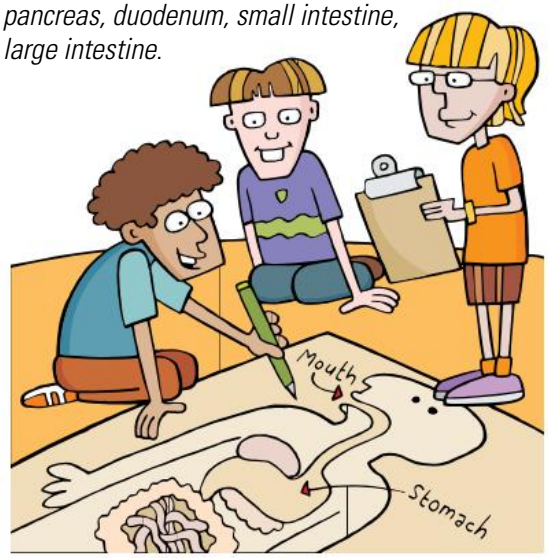
INQUIRY 1

Your digestive system

The organs in your digestive system digest or break down food so it can be used by your body. Do you know where these organs are found?

Part A: What do you know?

1 In groups of three, draw a body outline on a large piece of butcher's paper. Draw and label any parts of the digestive system that you know. The following words may help you: *oesophagus, stomach, pancreas, duodenum, small intestine, large intestine.*



2 How does your diagram compare with the diagram of the digestive system on the next page? How many organs did you put in the right place? How many were incorrectly placed?

3 Write what you know about each organ on your diagram.

4 Explain how you think food gets out of your digestive system and into your body cells.

Part B: Digesting a Big Mac

1 With coloured pens indicate the organs in which you think each of the different nutritional parts of a Big Mac are digested.

2 An adult should eat about 8000 kJ per day. How many kilojoules are there in a Big Mac?

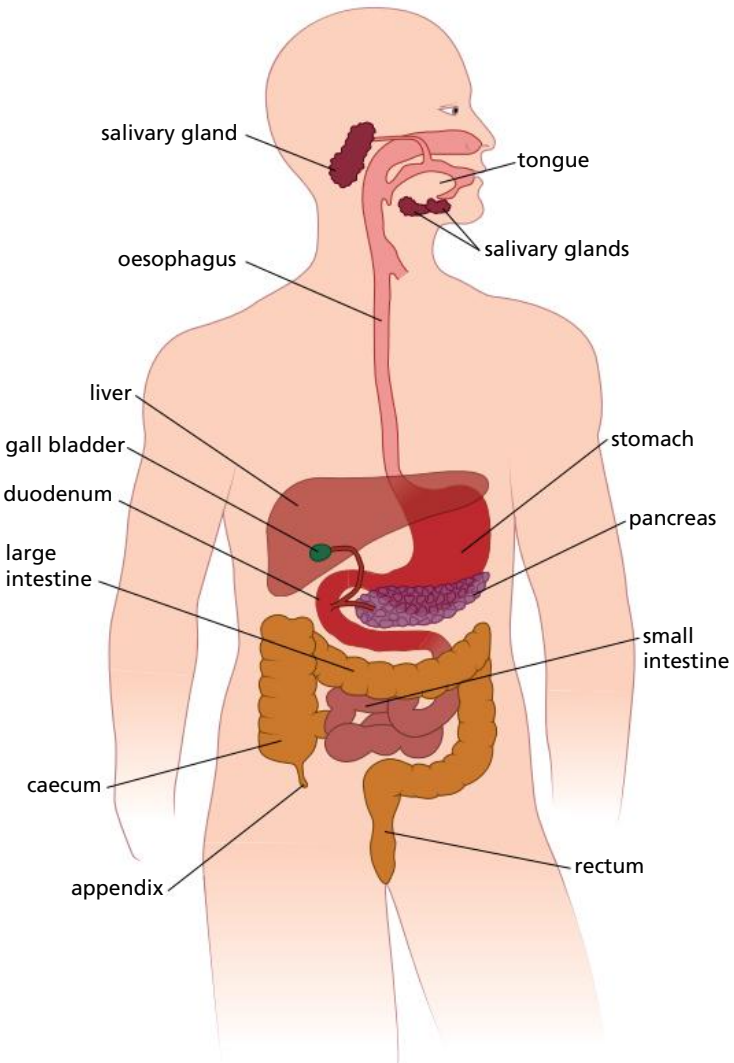
3 Would a person be healthy if they ate foods like a Big Mac all the time? Explain.

Keep your work in this section so that you can review your ideas later in the chapter.

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3.1 Digestion

Animals are unable to make their own food, as plants do, so they must eat other organisms to obtain the nutrients or substances they need to survive. When food is eaten, most of it cannot be used by the body as it is. The food must be broken down to simpler substances that can be taken into and used by body cells. Think about that Big Mac. The proteins, carbohydrates and fats in it contain complex molecules made up of simpler building blocks. **Proteins** are made up of amino acids. **Carbohydrates** are made up of simple sugars, such as glucose. **Fats** and oils are made up of fatty acids and glycerol. It is the role of the digestive system to break down these complex substances into their simpler building blocks.



Mouth

Digestion starts in the mouth. Here food is broken down by chewing. This is referred to as mechanical or physical digestion. Large pieces of food are ground up into smaller pieces. This increases the surface area of the food on which saliva can work, and allows the food to be swallowed easily.

Saliva is produced by the salivary glands in the mouth. It contains *salivary amylase* (AM-ill-aze). This is one of many different digestive enzymes found in the digestive system. An enzyme speeds up the rate of a reaction, without being used up itself, so it can be used again and again. The action of digestive enzymes splits large food molecules into smaller ones. Amylases such as salivary amylase break down starch to maltose, a sugar containing two units of glucose. Enzymes that break down proteins to amino acids are called *proteases* (PRO-tee-azes). *Lipases* (LIE-pazes) break down fats and oils to fatty acids and glycerol.

The tongue mixes the food with salivary amylase and rolls it into a ball ready to be swallowed. As this happens the entrance to the nasal cavity is sealed. A flap of skin called the *epiglottis* covers the entrance to the trachea or windpipe so that the food passes into the oesophagus and not the lungs.

Oesophagus

The tube leading from the mouth to the stomach is called the **oesophagus** (uh-SOF-a-gus). It is lined with muscles that contract behind the food and relax in front of it. This pushes the ball of food down into the stomach. These muscular contractions are called **peristalsis** (per-i-STAL-sis). They occur in all parts of the digestive tract, which is the name of the series of digestive organs joined together.

Stomach

A ring of muscle surrounds the entrance to the stomach. It is called a *sphincter* muscle. Once food enters the stomach, this muscle contracts, sealing off the oesophagus and preventing food moving backwards. The stomach is a sack-like bag with muscular walls. The movement of the muscular walls churns the food in the stomach and mixes it with gastric juice, which contains the enzymes *pepsin* and *rennin*. Both pepsin and rennin break down proteins. Rennin makes milk more solid so it stays in the stomach for longer. This is important for babies

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because most liquids move through the stomach after about 10 minutes, so with rennin present, the milk can be properly digested.

Gastric juice also contains hydrochloric acid, which is needed for these enzymes to work. The walls of the stomach are not corroded by the acid because glands in the walls of the stomach secrete mucus, which coats and protects them.

When food leaves the stomach it is a soupy liquid called *chyme*. Another sphincter muscle, at the base of the stomach, opens to allow the chyme to move into the duodenum. It takes about 6 hours for an average meal to pass through the stomach. Some fats can remain in the stomach for 30 hours.

Duodenum

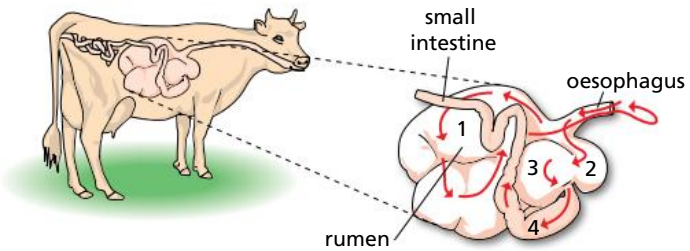
The **duodenum** (du-o-DEE-num) is the first 30 cm of the small intestine. Here, bile and pancreatic juice continue digestion. Bile is a greenish-yellow fluid made in the liver. It is stored in the *gall bladder*, which is found on the surface of the liver and empties into the duodenum through the bile duct. It contains bile salts, which turn fats and oils into tiny droplets (an emulsion). This provides a larger surface area for *pancreatic lipase* to work on. This enzyme is produced by the *pancreas* and breaks down fats and oils to fatty acids and glycerol. Bile also contains sodium hydrogen carbonate (baking soda), which neutralises the acidic chyme, so that the enzymes in the small intestine can work. Bile salts convert vitamins A, D, E and K, as well as cholesterol, into forms that can be used by the body. Vitamins are essential substances that your body needs to be healthy. Cholesterol is a substance found in your blood and brain. It is an important part of membranes in animals.

As well as lipase, the pancreas also produces *pancreatic protease*, which continues the digestion of proteins. It also contains *pancreatic amylase*, which breaks down starch to maltose and glucose.

Digestion in other animals

Not all animals have the same digestive system as humans. For example, cows are called ruminants and have a four-chambered stomach.

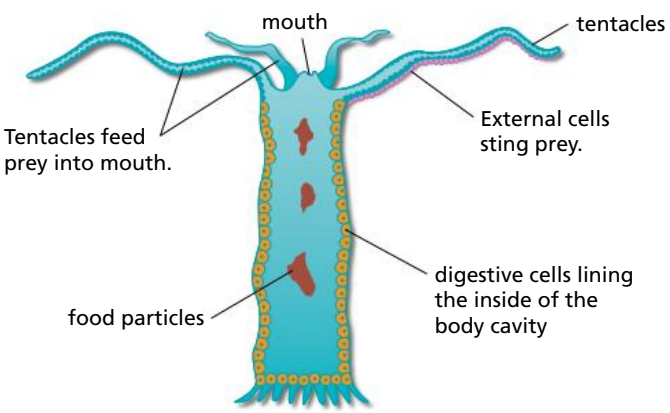
Food is swallowed into chambers 1 and 2, where bacteria cause the food to ferment, and the cellulose in plant cell walls is broken down. Chamber 1, called the *rumen*, is a storage chamber for unchewed food. The food is then shaped into balls and *regurgitated* or passed back to the mouth for chewing. The food is swallowed again and this time completes its passage through chamber 2 again and then chambers 3 and 4 as fluid and fine particles.



Cows also have a 50-metre-long intestine to continue breaking down cellulose. By comparison, your small intestine is only about 8 metres long. Herbivores (animals that eat plant material) often have a large **appendix**. This is a small finger-like extension of the *caecum* (SEE-cum)—a small sac that is connected to the large intestine. The bacteria in the appendix continue the digestion of cellulose. Your appendix has no digestive function. It can sometimes become infected and may need to be removed.

In birds, food moves from the stomach to a gizzard before going to the intestine. The gizzard is quite muscular and contains rocks and grit. These help to grind up the food, since birds don't have teeth.

Some animals like the hydra have a body that is a single tube with one opening that acts as a mouth and an anus. A hydra stings its prey with tentacles which then push the prey into its mouth. Cells lining the internal walls of the body produce enzymes that digest the prey and absorb (take in) small food particles. The hydra then contracts its body to thrust any wastes out of its mouth.



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INVESTIGATION

1 Enzyme action

Aim

To design an experiment to test one of the following hypotheses:

A An enzyme is affected by temperature.

B An enzyme is affected by pH.

C An enzyme only works on one particular substance.

D The amount of enzyme affects how quickly a reaction takes place.

E The amount of food present affects how quickly a reaction takes place.

F Churning (stirring) the food causes an enzyme reaction to occur faster.

You will use junket tablets, which are used to solidify milk to make desserts. Junket tablets contain the enzyme rennin.

Risk assessment and planning

1 Hypothesis A or B requires the use of a Bunsen burner or acids and bases. What safety precautions will be necessary?

2 How should you dispose of the junket once it is made so that it doesn't make the the sink smell?

Apparatus

- junket tablets
- full-cream milk
- stirring rod
- assorted beakers
- thermometers
- Bunsen burner equipment
- different acid and base solutions (only for hypothesis B)
- different types of milk, e.g. skim, soy, UHT, and various other liquids (hypothesis C)

Method

Part A

Follow the instructions on the packet to make junket using full-cream milk.

- How long did it take for the junket to solidify the milk?
- What temperature was the milk?
- How much junket did you use?
- How much milk did you use?
- Did you stir it?

✻ Record the answers to these questions in your notebook.

Part B

The junket you just made is the control or the point of comparison for your own experiment. You will now vary the way the junket is made to test your chosen hypothesis. The apparatus in this practical has been provided for you. What are you going to do? How are you going to make your experiment a fair test?

Results

Was your hypothesis correct? Explain why or why not.

Discussion

1 Which variable were you testing?

2 Was your experiment a fair test? Which variables did you control or keep constant?

3 What could be done to improve the experiment?

Conclusion

Report your findings in a two-minute presentation to the class.

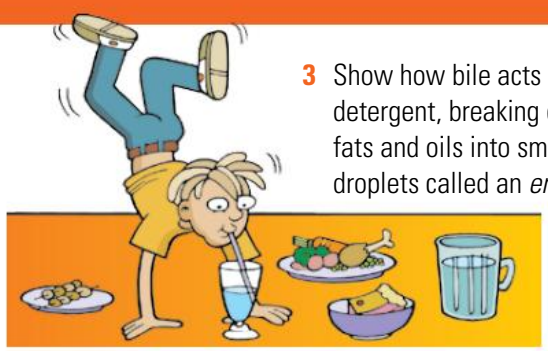
INQUIRY

2 Digestion show and tell

Collect your own equipment using materials in your home to demonstrate one of the following:

1 Show how muscles contract behind a ball of food and relax in front of it to push the food along the digestive tract. Hint: Could your hands be the muscles?

2 Show if your body position makes a difference to whether you can swallow food or drink water.



3 Show how bile acts like a detergent, breaking down fats and oils into smaller droplets called an *emulsion*.

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INQUIRY 3

Summary table

Copy this table to make a summary of the digestive system so far. Complete any missing boxes. Leave room in your notebook for more rows to be added to your table in the next section.

Organ	Activity	Substance produced	Result
mouth		saliva containing salivary amylase	Teeth and tongue carry out mechanical digestion, breaking the food down to smaller pieces. Starch digestion starts in the mouth.
oesophagus	Food moves to the stomach by the action of peristalsis.	Nothing is produced.	
stomach		pepsin rennin hydrochloric acid mucus	
duodenum		Nothing is produced, but it receives substances from other areas.	
pancreas			Continues the breakdown of starch.
		pancreatic proteases	
		pancreatic lipases	
gall bladder	Bile is stored here and then carried through the bile duct to the duodenum.	Nothing is produced.	

SCIENTISTS AT WORK

Dr Chris McSweeney

Dr Chris McSweeney is a senior research scientist with CSIRO at the University of Queensland. He is researching how bacteria can more effectively digest plant cell walls (fibre).

There are 100 million sheep and 20 million cattle in Australia, which eat about 1.5 million tonnes of fibre each day. Half of the fibre is not digested properly, and forms dung and methane. The methane produced contributes to greenhouse gases, so improving the fibre digestion of cattle and sheep could improve the environment.

Chris has been looking at ways to genetically alter the rumen bacteria so that they break down plant cell walls more effectively. This would provide ruminants with more nutrients than they would normally receive from the food they eat, and therefore reduce the amount of food they need. This could save the livestock industry $180 million each year.

Chris spent many holidays on sheep properties in Queensland and developed an interest in rural life and rural animals. A friend convinced him to study veterinary science at university, and after completing his degree he worked at a large animal practice for two years. Chris then decided to study for his PhD and developed practical ways to treat livestock poisoned after eating toxic plants.

Chris enjoys what he does. He gets to work with talented people, and travel around the world meeting other scientists. His work is challenging because he is solving problems faced by the livestock industry today.



Dr Chris McSweeney samples the rumen from an African antelope.

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SKILL

Group work

Not everyone in a group works in the same way. For example, some sit back and let others complete the task, some get lost in discussion and never finish the task, and some take over, not listening to others. To solve these problems it is often good for each person to have a role to perform, and to rotate these roles each time group work is suggested.

Suggested group roles

- *Timekeeper:* reminds the group of the time, so that all of the task can be completed.
- *Reporter:* summarises the group's ideas and presents them to the class or group.
- *Recorder:* writes down all the group's ideas.
- *Task controller:* reminds the group of the tasks that still need to be done.
- *Participant controller:* prevents one person taking over and ensures everyone is able to have their say without being interrupted.
- *Encourager:* tries to make positive statements about group members' comments, so that all participants feel their efforts are valued.

The number of roles will vary depending on the size of the group:

3 person group: timekeeper, recorder, reporter

4 person group: add a task controller to the above

5 person group: add a participant controller

6 person group: add an encourager.

1 As a group of 4 you will spend one lesson only in the library researching possible problems that can occur with the digestive system. The possible problems you could be given to research by your teacher include: appendicitis, diverticulitis, gallstones, gastric ulcers, gastritis, gastroenteritis, food poisoning, mumps, heartburn, cancer of the oesophagus, stomach or bowel

2 After researching, report back to the class on your findings. It is not always easy to pay attention when a group or person is presenting their information. To make sure you are attentive, complete the following in point form for each group.

a List three pieces of information that were mentioned.

b List one interesting thing that you have found out but which you did not know at the start.

c How well do you think the group completed the task set? Give them a mark out of 5 as follows:

Not completed 1

Poor 2

Satisfactory 3

Better than most 4

Outstanding 5

d Assess yourself during the presentation by answering the questions below.

Did you:

- listen quietly to the group?
- not talk to others while the group was presenting their work?
- make eye contact with the group members?
- smile and encourage the group to present their work?
- ask any questions of the group? How many?

Over to you

1 What is digestion and why is it necessary in your body?

2 What are carbohydrates, proteins and fats broken down to?

3 What are enzymes and why are they needed in the digestive system? What are amylases, lipases and proteases?

4 Explain whether you think plants would need to carry out digestion.

5 What is bile and why is it needed in your body?

6 List three adaptations that herbivores have to digest cellulose in their food. Are these adaptations structural, functional or behavioural? Explain.

PROBLEM SOLVING

You should now be able to draw a labelled diagram of the digestive system. You should also be able to indicate where substances such as carbohydrates, proteins and fats are broken down along the digestive tract.

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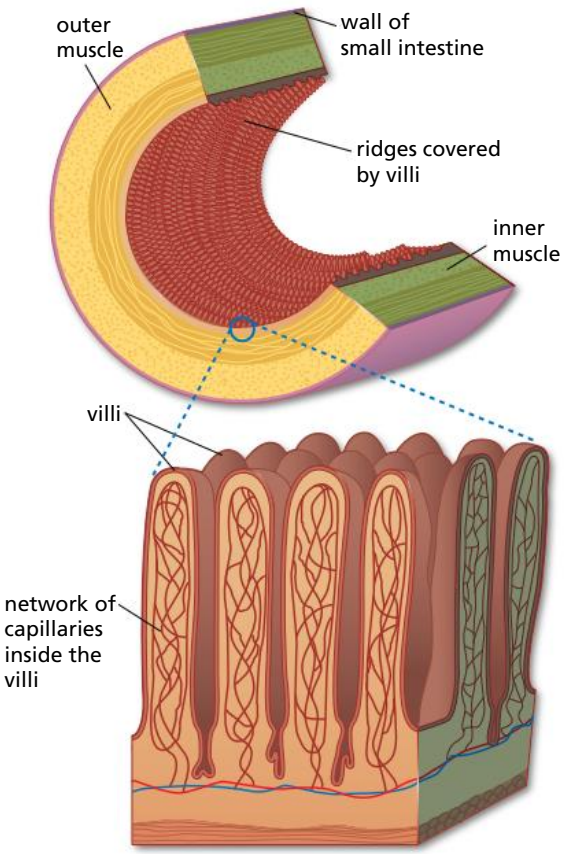
3.2 Small and large intestines

After the food has moved though the duodenum, digestion continues in the small intestine. There, several enzymes complete the breakdown of proteins to amino acids. Other enzymes complete the digestion of carbohydrates to sugars such as glucose. Finally, several lipases complete the digestion of fat. At this stage, the broken-down food is in a form that allows it to be **absorbed** or taken into the bloodstream through the walls of the small intestine. In this way the digestive system is connected to the circulatory system.

Villi

The walls of the small intestine are lined with finger-like projections called **villi** (singular villus).

The villi increase the surface area of the small intestine walls so that more food substances can be absorbed. Villi are only about 1 mm long. However there are about 5 million villi in the small intestine, providing about 30 m^2 (square metres) of surface area where absorption can occur.



The thin walls of each villus enclose a network of capillaries. Food substances move into the cells that line the walls of the villi and then pass into the capillaries. Contractions of the villi help this movement. The capillaries then empty into a vein that links to the rest of the bloodstream.

Food substances are carried in the plasma of the bloodstream to the cells. Glucose from carbohydrates moves into the body cells where it is used in respiration. It reacts with oxygen to produce water, carbon dioxide and energy. Broken-down fats are used to make cell membranes and various cell structures. Any leftover fats are also used in respiration or stored as fat in body tissue. Amino acids from proteins enter the cells and are reassembled to produce the various proteins such as enzymes needed for cellular activities.

If there are more food substances than the body can use, they are carried to the liver to be stored. A small amount of glucose can be stored as glycogen. A glycogen molecule is made up of many glucose molecules joined together. Any excess glucose is converted to fat. Beneath your skin and around most organs are fat cells that can store fat inside them. Fat not used by the body is stored in these cells. Amino acids that are not used are broken down by the liver (see the next chapter).

The large intestine

The material that ends up in the large intestine is made up of cellulose, plant fibres, mucus and lots of water. Most of the water is reabsorbed by the large intestine. If this material passes through the large intestine too quickly and not enough water is removed, diarrhoea (die-oh-REE- a) can occur. If there is not enough fibre in the large intestine to stimulate peristalsis, constipation can occur.

The large intestine also removes elements such as calcium and iron that may be in too high a concentration. It also removes bile salts. The bile salts are taken back to the liver for re-use. The remaining material is called **faeces** (FEE-seas). It passes into the last part of the large intestine called the *rectum*, where it is stored before passing out of the *anus*.

A healthy large intestine contains large amounts of bacteria—about half the mass of the faeces. The faeces also contain pigments that result from the breakdown of red blood cells in the liver. These pigments make the faeces brown.

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INVESTIGATION

2 Small intestine model

Aim

To model how molecules are absorbed from the small intestine into the bloodstream.

Risk assessment and planning

1 Read the list of apparatus you will be using for this investigation. Discuss with your teacher whether there are any chemicals that are caustic or could stain your fingers. Which chemicals need special disposal?

2 You will be using cellulose tubing, which acts like the wall of the small intestine. You will then determine whether glucose, protein or starch molecules are able to pass through the tubing. Which of these are complex molecules? Which are simple molecules? Predict which molecules are likely to pass through the cellulose tubing.

Apparatus

- cellulose tubing cut into three equal lengths of 20 cm
- 10% glucose solution
- starch solution
- 10% gelatine solution (protein)
- iodine solution in a dropping bottle
- glucose test tape
- protein test tape: Albustix or Uristix
- 3 × 500 mL beakers
- 3 plastic bread-bag clips
- 3 pencils
- distilled water
- filter funnel
- 3 paperclips

Method

Part A

1 Pour a small amount of distilled water into a beaker. Test this water with the glucose test tape first, then with the protein test tape and finally with a drop of iodine. (Remember iodine turns starch blue-black.) Empty the beaker and wash it out.

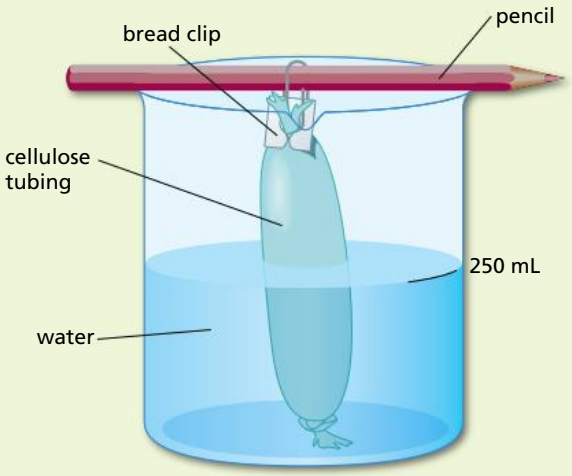
2 Tie a knot in one end of each piece of cellulose tubing. Hold the other end under running water and roll the tubing between your fingers and thumb to open the tubing and form a tube.

3 Using a clean filter funnel, almost fill one of the tubes with glucose solution so that you can seal the tube using a plastic bread clip without glucose overflowing.

4 Fill the other two tubes in the same way, one with starch solution and the other with gelatine solution.

5 Add 250 mL of distilled water to each of the three 500 mL beakers.

6 Into one beaker place the cellulose tubing filled with glucose. Slip a paperclip through the bread clip and loop it over a pencil to hold the tubing in the beaker as pictured.



7 Place the tubing filled with starch and the tubing filled with gelatine into separate beakers of distilled water in the same way.

8 After half an hour test the distilled water in each beaker as you did in step 1. Repeat this after 24 hours. Record your findings.

Results

1 Were your predictions correct? Which molecules were small enough to pass through the cellulose tubing, and was this what you expected?

2 What variable were you testing?

3 What variables did you control?

Conclusion

How does the cellulose tubing act like the small intestine? Why does most food need to be digested before reaching the small intestine?

Part B

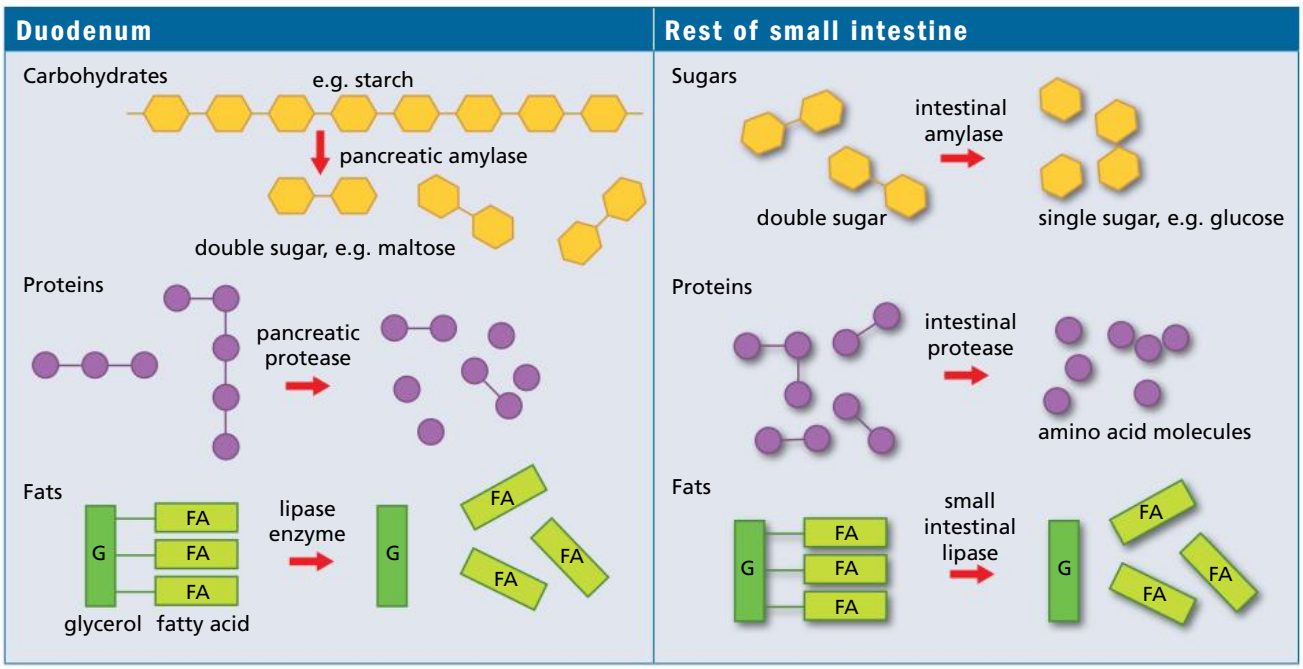
Do different liquids, for example orange juice or milk, need to be digested before passing through the wall of the small intestine? Design an experiment to find out.

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INQUIRY

4 Modelling molecules

The following diagrams show the action of protease, amylase and lipase in the duodenum and the rest of the small intestine. Look at the diagrams and explain the similarities and differences between these two organs.



INVESTIGATION

3 Your own design

Choose one of the following.

A Design an activity to show how a folded surface has a greater area than a flat one.

B Design an experiment to show how the shape of the surface of the intestines affects the absorption rate of nutrients. For example you could cut agar jelly stained with phenolphthalein into the shape of villi and compare its absorption rate with the absorption rate of other shapes. (Phenolphthalein changes colour when it comes in contact with acid.)

C Design an experiment to show how rocks and grit in the gizzard of a bird help to break down food.

D Design an experiment to show whether teeth are more effective than rocks and grit in breaking down food into smaller pieces. Link your findings to the types of food eaten by birds and humans.

E Observe a rat dissection carried out by your teacher, and describe and draw its digestive system. Describe similarities and differences between the rat and human digestive systems.

Over to you

1. Add the following organs to your table in Inquiry 3, then complete the relevant columns:
   small intestine, large intestine, appendix, rectum, anus
2. Describe the structure of villi in your own words. Why do villi help absorb nutrients from the digestive system more effectively than a smooth tube does?
3. What happens to the breakdown products of proteins, carbohydrates and fats when they leave the small intestine?
4. Describe the difference between the:
   a duodenum and the small intestine
   b small intestine and the large intestine.
5. How is the digestive system linked to the circulatory system?
6. Why is it important to eat lots of fibre in your diet?
7. A Big Mac contains 85 mg of cholesterol. Find out more about this fat and why you should limit the amount of cholesterol in your food. Find out what fats you should eat and in what foods they are found.

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3.3 Plant food

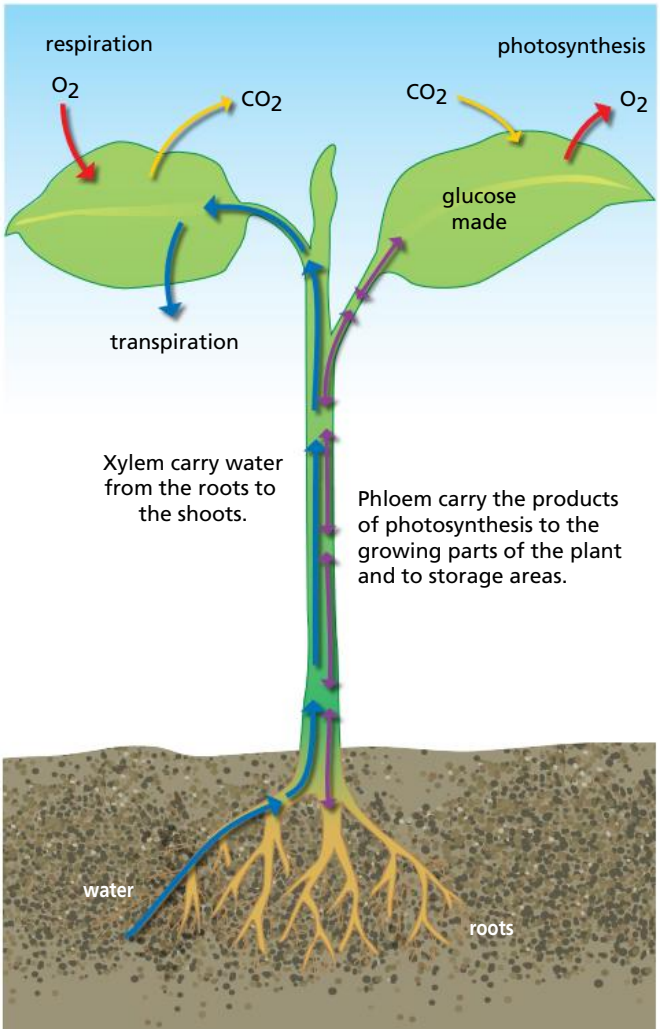
Let's summarise what you know so far. You are an animal and, like other animals, you must eat other organisms to survive. You have a digestive system to break down the food you eat into a form that can be used by your body and taken into your cells. Carbohydrates, proteins and fats are major nutrients that must be eaten daily. This ensures that your body has the basic building blocks of glucose, amino acids, fatty acids and glycerol for your cells to function. These substances are used by your cells in chemical reactions such as respiration. In this reaction, oxygen and glucose combine to produce water, carbon dioxide and energy. The building blocks are also re-assembled to make other materials your body needs. For example your body builds tissues, organs and enzymes from proteins. These are all assembled from the building blocks provided by digestion.

Your digestive system is connected to your circulatory system so that the food substances digested can be transported around your body to the liver and to body cells to be used.

Moving plant food

Most plants do not eat other living things to meet their food requirements, so they don't need a digestive system. Instead they carry out photosynthesis. In the presence of light, they convert carbon dioxide and water to glucose and oxygen. Plants use the substances made during photosynthesis to make new materials and also to carry out respiration. Some of the products of photosynthesis are stored or used for growth. This means that the materials made in the leaves of plants must be transported to other areas.

Plants do not have a bloodstream to move nutrients to cells. Some plants such as flowering plants and conifers have a system of tubes running through their bodies to carry nutrients around. These plants are called **vascular plants**. One series of tubes, called **phloem** (FLO-em), connect the leaves to the growing parts of a plant and to storage areas. These tubes are formed by cells that lie end to end. The sugar made during photosynthesis is able to move downwards to the growing tips of the roots through these tubes or upwards from the leaves to the buds, new leaves, flowers and fruit. Phloem in the stem allow transport of sugars in both directions.



Moving water

For photosynthesis and respiration to occur in plants, water is needed. A series of tubes called **xylem** run from the roots to the leaves of a plant to allow the movement of water. Like phloem tubes, xylem tubes are made up of a series of cells lying end to end. The difference between the two is that phloem tubes contain cells with living cytoplasm, whereas the cells in xylem tubes are dead in the middle and therefore hollow. The walls of the cells that remain contain lignin. This is a hard woody substance that supports the plant just as your skeleton supports you. This is why vascular plants are also called woody plants.

Water is taken in from the soil by small narrow tubes called root hairs, which grow from a root. Some plants can have 14 billion root hairs in their root system, penetrating a huge area of the soil. The root hairs increase the surface area available to a plant to absorb water.

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Root hairs take up water in a plant.

From the roots the water moves up the plant through the stem to the leaves. Water is lost from a plant by evaporation from the leaf surface. This is called **transpiration**. As water is lost, more water is drawn into the cells underneath. This draws water from the stem, which in turn draws water from the roots by capillary action, and so water moves up through the plant.

Water moves into a cell and causes it to swell. The water inside the cell pushes against the cell wall, making it firm. There is a limit to how much water can fit into a cell. The cell stops taking in water when it is full, and is then said to be *turgid*. In some plants, the amount of water in the cells is important to the support of the plant. If water is not replaced by the roots when it is lost from the leaves, plant cells start to lose their firmness and the plant wilts. For example, impatiens (common garden plants) rely on water in their cells to stay upright. Without water to support them, they soon fall over.

Water movement through a plant is affected by how quickly evaporation occurs from the leaf surface. If the air is very humid, water does not evaporate quickly. On hot days and on windy days evaporation rates increase. This is why on hot, dry, windy days it is important to water your garden plants.

INVESTIGATION

4 Examining plants

Choose one of the following to investigate.

A Examine the roots and root hairs of different plants under a microscope. Are these structures the same in all plants? Try to explain any differences you find.

B Design an experiment to show whether root hairs are needed by a plant to survive. For example you could remove the root hairs from one plant and compare it to a plant with its root hairs intact.

C Transpiration is affected by humidity, temperature and wind. Design an experiment to show how one of these factors affects how much water is taken up by plant roots.

D Use a microscope to examine the cells of impatiens that have been kept in water and those that have been kept without water. How turgid are the cells in each case?

Over to you

1. What do plants do with the products of photosynthesis?
2. How do the cells of plants get the nutrients they need from photosynthesis?
3. How do plants take in water and how is water transported through a plant?
4. Why do you think plants have root hairs?
5. In which conditions would you expect the rate of transpiration to be the greatest? Give reasons for your answer:
   - **A** wet and windy
   - **B** hot and humid (high moisture in the air)
   - **C** dry, very hot and little wind
   - **D** dry, very hot and windy
6. Would you expect seaweed (algae) to contain xylem and phloem vessels? Explain your answer.
7. In 1648 an experiment was performed in which a tree was placed in 91 kg of soil and the tree allowed to grow for 5 years, with only rainwater or distilled water added to it. After 5 years the soil was weighed again and was almost 91 kg, the same weight as before. However the tree had increased in mass by 77 kg. What had caused this increase in mass?

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3.4 Vitamins and minerals

The building blocks obtained from food are used to provide energy, repair and replace cells, and build new body tissue for growth. (See the table at the bottom of the page.)

Every part of your body has been assembled from the food you eat. For example, proteins are split into individual amino acids by your digestive system. Your cells then reassemble these in different sequences to make the new proteins your body needs. Different sequences of amino acids make different proteins.

As an animal you need water. The chemical reactions that occur in your body cannot take place without it. Oxygen is also essential because it is needed for respiration. However, there are other nutrients that are needed by your body on a daily basis, for example the minerals containing the elements calcium, iron and sodium.

Minerals

Minerals are naturally occurring chemical compounds. They are the building blocks of rocks. They are also found in food but, unlike carbohydrates and fats, they are not used for energy. Minerals contain about 15 elements that your body needs for good health. Each element carries out an essential function. For example, calcium is needed for your muscles to work properly. Some other examples are listed on the right.

PROBLEM SOLVING

Listed in the nutritional facts of a Big Mac are nutrients such as carbohydrates, proteins and fats, as well as vitamins A and B, calcium, iron and sodium.

1. Use the tables on this page and the next to find out what these nutrients are and what each does in your body.
2. From reading the tables, what is an energy-dense food?
3. Which nutrients are energy-dense? How much of these nutrients are found in a Big Mac?

Element	What it does in the body
calcium: milk and dairy foods	Makes up bones and teeth. Without it, bones can break easily.
iron: red meat, poultry, fish, green leafy vegetables	Found in haemoglobin in red blood cells and transports oxygen around the body.
copper: nuts, potatoes, cereals	Needed for growth and to enable iron to be used in the body.
iodine: seafood, dairy products, iodised table salt	Needed so that the thyroid gland can work correctly. This gland controls the rate of body metabolism (see next chapter).
sodium (as sodium chloride): salt, processed foods	Needed for blood plasma, digestion and the correct functioning of nerves. Controls the balance of fluid in our bodies.

Type of food	What it is made of	What it does in the body
carbohydrates: sugar and foods with sugar in them, e.g. bread, pasta, rice, potatoes and cellulose (found in fruits, vegetables and cereals)	• Made up of carbon, hydrogen and oxygen. • Simplest carbohydrate is glucose ($C_6H_{12}O_6$), one type of simple sugar; other sugars are made from simple sugars e.g. two simple sugars together make sucrose ($C_{12}H_{22}O_{11}$) or maltose. • Starch is a polymer chain of simple sugars.	• The main energy source for the body. • Converted to glucose which is then used in respiration. • Stored in small amounts in the liver and muscles as glycogen, with the excess stored as fat.
proteins: meat, milk, eggs, fish, cheese, nuts	• Made up of nitrogen, carbon, hydrogen and oxygen. • Simplest units of proteins are amino acids. • About 20 different types of amino acids, eight of which are *essential* in your diet, as they cannot be made by the body. • Function of the protein determined by how the different amino acids are linked together.	• Used to make body tissues, organs and enzymes. • Used to provide energy only when the reserves of carbohydrates, fats and oils are used up. • Have millions of functions in the body. • Green plants can make their own amino acids but animals can only make some.
fats and oils: butter, margarine, sunflower oil, olive oil, canola oil. (A fat is solid at room temperature, but oils are not.)	• Made up of carbon and hydrogen, with small amounts of oxygen. • Simplest are made up of fatty acids linked to glycerol.	• A high source of energy called an energy-dense food; a small amount can be stored in the body and can release a large amount of energy. • Harder to digest than other foods. • Stored in the skin, around the heart and kidneys, and around muscles. • Insulates the body when stored under the skin.

Nutrients and their functions

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Vitamins

Vitamins are not made by your body. They must be obtained from food. They are a group of chemicals that come from living things. Like minerals, they are not used for energy, but each has a special job to perform. Without vitamins, the chemical reactions in your body could not take place. For example the B group vitamins control the reactions that allow energy to be released from the nutrients in food. Without vitamins you will become ill. For example, a lack of vitamin C causes a disease called scurvy, which causes gum problems, loss of teeth, and wounds that don't heal. Scurvy is called a **deficiency disease** because it is caused by the lack of an essential body substance.



Thiamine and Riboflavin?

Vitamins and food sources	What it does in the body
A red meat and dairy products, egg yolks, fish, liver, yellow vegetables (Beta-carotene is found in orange and green leafy vegetables.)	• Needed for growth and for healthy eyes. Without it a person can have poor night vision, dry eyes and blindness. • Needed for a healthy immune and reproductive system. • Beta-carotene can be converted to vitamin A. It is also part of a group of vitamins called *antioxidants*. These are vitamins that protect you from substances made when oxygen is used by your body. They are important because they protect the body from cancer, ageing and cardiovascular disease.
B1 milk, pork, liver, heart, kidneys, green leafy vegetables (e.g. broccoli), sweet corn, beans, vegemite, brown rice, added to baking flour	There are 12 different substances that make up the B group vitamins. B1 (thiamine) is needed for respiration and without it stunted growth can occur. Without B1, a disease called beri-beri can occur where the limbs become paralysed; vitamin B1 also protects the heart and nervous system.
B2 milk, dairy products, eggs, meat, vegemite	B2 (riboflavin) is needed for respiration, and without it stunted growth can occur. B2 is also needed for other B group vitamins to work.
B3 meat, fish, seafood, nuts	B3 (niacin) is needed for the proper functioning of the nervous system. It helps other vitamins work. It is also needed for your skin and digestive system.
C (ascorbic acid): raw fruit, green vegetables, citrus fruits such as lemons, fresh fruit juice, capsicum, tomatoes, broccoli, potatoes	• Used to make a protein called collagen which is needed for healthy bones, blood, skin, teeth and gums. Lack of vitamin C causes scurvy. This disease produces bleeding gums, bleeding at the joints, and wounds that don't heal. • Vitamin C is also an antioxidant.
D sunlight, some fish, dairy products and meat, added to many foods The skin makes vitamin D in sunlight.	• Necessary for calcium and phosphorus to be used by the body. • It is needed for bone development, and soft, weak bones occur without it. This is called rickets in young children. Rickets can be prevented by being in sunlight, because the skin makes vitamin D in sunlight. • Helps the body make insulin.
E green leafy vegetables, whole grains, vegetable oils	• An antioxidant. Needed for muscle maintenance, healthy liver, nerve function and male fertility. • It also prevents the destruction of red blood cells. A deficiency in infants can cause anaemia.
K This vitamin is made by 'good' bacteria in the digestive tract.	Needed for blood clotting. Without it slow blood clotting and internal bleeding occur.
Folic acid (folate): green vegetables, wholegrain bread, vegemite, liver, oranges, nuts and beans	Needed for: • red blood cell production and for making DNA • the nervous system to work properly • the healthy development of a baby before birth.

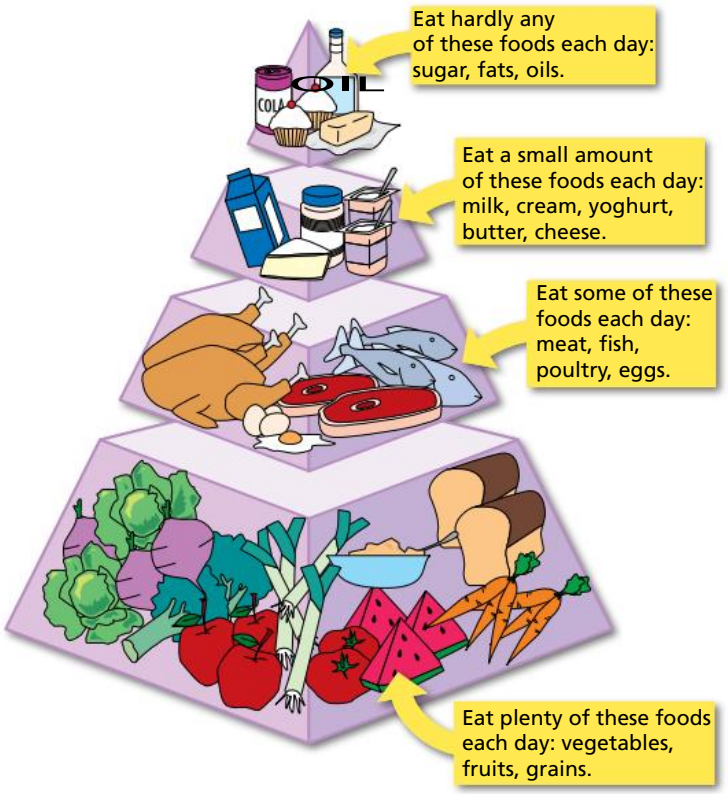
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Fibre

You also need *fibre* in your diet for good health. Fibre is sometimes called roughage. It is made up of plant material and cellulose from plant cell walls that cannot be broken down by your digestive system. It is important because large amounts of fibre are necessary for peristalsis. When peristalsis doesn't work properly, constipation occurs.

Keeping healthy

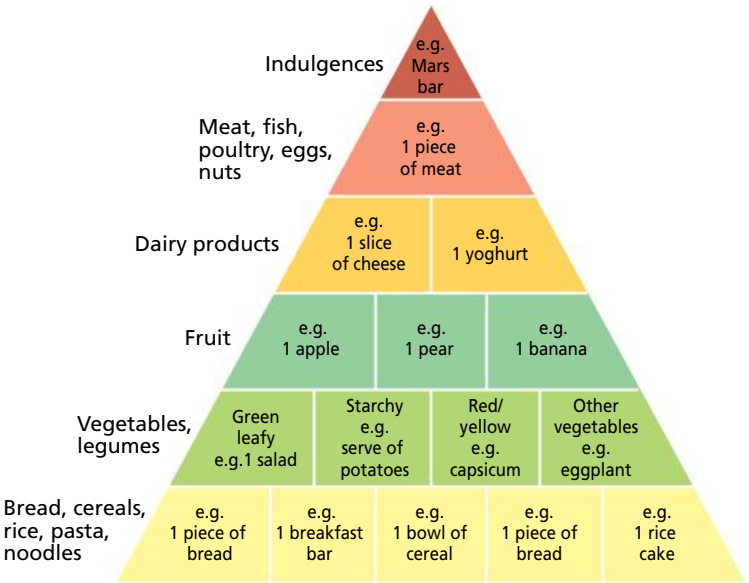
To ensure you get all the substances you need to be healthy, you should follow the healthy food pyramid each day.



Energy in food

Respiration provides you with energy. The chemical energy stored in food is released during respiration in your cells and used to keep your body functioning. For example, energy is needed to make your muscles move, or to send messages via your nervous system to your brain. As these energy changes occur, heat is released, which is why your body is warm.

The average woman needs between 6480 and 7980 kilojoules each day. The average man needs between 8485 and 9990 kilojoules each day. The food and nutrition plan (top right) can be used to plan and record daily food intake. Every time you eat a serving of each food category, for example one apple, a piece of bread or a small bowl of cereal, you tick the box inside the pyramid. Extra servings are indicated by ticking outside the pyramid for each food category. You will use this table in Inquiry 5.



Food and nutrition plan for an adult

Minerals and vitamins in plants

Plants also need vitamins and minerals to be healthy. They are able to make their own vitamins; however, they must take up minerals from the soil. Some minerals are needed in large quantities, for example, those containing the elements nitrogen, calcium, phosphorus, sulfur, magnesium and potassium. Without nitrogen a plant may have a weak stem and small roots. Dead spots on yellow leaves can indicate that a plant needs potassium. Yellowing lower leaves can indicate that the plant needs magnesium.

Plants need other minerals in only very tiny amounts, for example those that contain the elements copper, zinc, boron, chlorine, manganese and molybdenum. These elements are called *trace elements*. For example white leaves on the upper part of a plant can be a result of insufficient iron.

Once a mineral is taken into a plant, it is used to make other compounds that the plant needs. For example nitrogen and sulfur are taken in as nitrate and sulfate compounds through the roots. With these compounds and the carbohydrates made in photosynthesis, plants can make all the amino acids they need to assemble proteins and survive. These minerals are transported to the areas that need them, or they are stored in the plant.

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INVESTIGATION

5 Mineral deficiencies

Aim

To examine the development of plants in different nutrient solutions.

Risk assessment and planning

1 Read through this investigation and identify any possible risks.

2 Draw a data table to record your results over a 4 week period.

Apparatus

- distilled water
- Solution 1: calcium nitrate (236 g per L)
- Solution 2: potassium nitrate (101 g per L)
- Solution 3: potassium hydrogen phosphate (14 g per L)
- Solution 4: magnesium sulfate (246 g per L)
- Solution 5: iron tartrate (41 g per L)
- Solution 6: sodium nitrate (85 g per L)
- Solution 7: sodium sulfate (142 g per L)
- Solution 8: calcium chloride (112 g per L)
- Solution 9: potassium chloride (79 g per L)
- 6 small plastic yoghurt containers with a hole in the middle of the lid
- cotton wool
- 6 tomato seedlings

Method

1 Set up 6 tomato seedlings as pictured, using the following solutions:

Seedling 1 Full nutrient solution. To make up a full nutrient solution, add the following to a litre of water:
- 10 mL of solutions 1, 2 and 3
- 4 mL of solution 4
- 2 mL of solution 5

Seedling 2 No calcium
Add the following to a litre of water:
- 10 mL of solutions 2 and 3
- 4 mL of solution 4
- 2 mL of solution 5

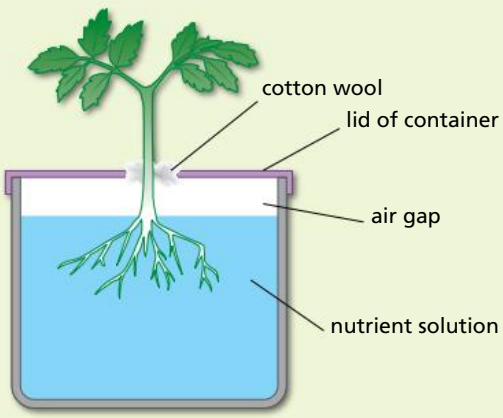
Seedling 3 No phosphorus
Add the following to a litre of water:
- 10 mL of solutions 1 and 2
- 4 mL of solution 4
- 2 mL of solution 5
- 1 mL of solution 9

Seedling 4 No nitrogen
Add the following to a litre of water:
- 10 mL of solution 3
- 4 mL of solution 4
- 2 mL of solution 5
- 10 mL of solutions 8 and 9

Seedling 5 No magnesium
Add the following to a litre of water:
- 10 mL of solutions 1, 2 and 3
- 2 mL of solution 5
- 4 mL of solution 7

Seedling 6 Distilled water

2 Record the increase in height and in the number of leaves, and any changes to the colour of the leaves of the seedlings over a 4 week period.



Results

1 What happened to each of the seedlings over the 4 week period? Draw a graph of your findings.

2 Did any seedlings start to show mineral deficiencies? How do you know?

3 What was the variable you were testing in this practical?

4 Which minerals did you test? Do they contain trace elements or are they needed in larger quantities by plants?

5 What variables did you need to control to be able to compare the seedlings?

6 Why did you grow one of the plants in distilled water?

7 You used nutrient solutions instead of soil. Suggest a reason for this.

Conclusion

Summarise what you found in this investigation.

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INQUIRY 5 Your energy needs

1 Calculate your own energy needs using the following table as a guide.

a First, find the number of kilojoules or calories needed for someone your age.

	Females (average height 162 cm)		Males (average height 172 cm)	
Age	kilojoules	calories	kilojoules	calories
14–22	7900	1900	10900	2600
23–50	7500	1800	9600	2300
51–65	7100	1700	8400	2000

b For every 4 cm you are above the height listed in the table, add 420 kJ or 100 calories. Subtract this amount for every 4 cm you are under the average height listed.

c If you do hardly any exercise, subtract 840 kJ or 200 calories. If you do some exercise, add 2100 kJ or 500 calories. If you are extremely active, add 4200 kJ (1000 calories).

2 Work out the serves of each food category you need to eat each day.

kilojoules	6000–6500	6501–7000	7001–7500	7501–8000	8001–8500+
calories	1430–1550	1551–1670	1671–1790	1791–1910	1911–2030+
Meat	1 serve	1	1	1	1
Dairy products (low fat for adults)	2 serves	2	2	2	2
Fruits	3 serves	3	3	3	3
Vegetables	4 serves	4	4	4	4
Cereals	5 serves	6	7	8	9
Fats	30 g	36 g	42 g	48 g	57 g
Extras	0 serves	0–2	2	2	2

3 Draw your own food and nutrition plan (see page 64) that meets your energy needs. As a teenager you need to add an extra serve of meat and dairy products (not low fat) and have 9–12 cereal serves.

4 Use the plan you have drawn to keep a record of the number of serves of each food category you eat every day for five days. You will need a new food and nutrition plan for each day.

5 Do you have a healthy diet? Are you eating the wrong types of food or not eating foods that you should be eating? Explain what you need to do to improve your eating habits.

INQUIRY 6 Food tests

1 Test the foods below for the presence of carbohydrates (starch and sugar), proteins, oils and fats.

starch: potatoes, bread, rice

sugar: fruit, soft drink

protein: egg white, cheese

oils and fats: butter, margarine

2 Test unknown foods as well.

To test for starch, use iodine. To test for glucose and protein, use glucose sticks and Albustix. Oils and fats leave a grease stain on brown paper. Solid foods need to be ground up with a mortar and pestle and then mixed with distilled water before being tested.

Over to you

1 A person eating a diet made of up of only carbohydrates will die. Explain why.

2 You are going to take part in the next Survivor TV series in which you must survive 40 days and carry as little food as possible. What foods would you take with you and why?

3 Linoleic acid is an essential fatty acid. Use a dictionary to help you explain what this means.

4 In the 1800s British sailors were called 'Limeys' because they were given lime and lemon juice during long sea voyages, as they could not obtain fresh fruit. What deficiency disease did this prevent? What was in the juice that prevented the disease?



5 Vitamin K is usually made by 'good' bacteria in the digestive tract. What could happen to your body if you were ill and needed to take large quantities of antibiotics that kill bacteria?

6 In 1896 a Dutch doctor discovered that chickens that were only fed processed rice (rice with the husks removed) developed a disease called beri-beri. He cured the chickens by feeding them unprocessed rice. He concluded that there must be a germ (bacteria) in the husks that the chickens needed. Was the doctor correct? What additional information could you give the doctor today to help him cure the chickens?

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3.5 Healthy eating

You may be surprised to know that Australia is one of the fattest nations in the world, not far behind the USA, and that the average weight of Australians is increasing. To determine whether you have a healthy weight, you need to work out your body mass index or BMI and your waist/hip ratio.

Body mass index (BMI)

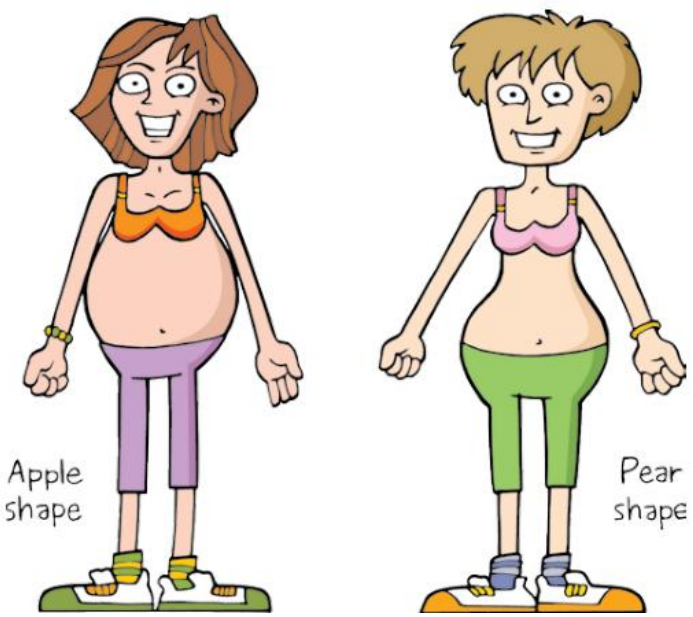
This tells you the percentage of fat in your body. First measure your mass in kilograms. Then measure your height in metres and square it. Divide your mass by this figure. For example, if a girl was 1.74 m tall and weighed 65 kg, the calculation would be:

$$\frac{65}{1.74 \times 1.74} = 21.5$$

A BMI of 18–24 is healthy. A BMI of 17 or less is considered to be underweight. A BMI of 25 or more is considered to be overweight. Over 30 is considered to be obese (excessively fat).

Waist/hip ratio

This ratio shows where the fat is stored in your body. Divide your waist measurement in centimetres by your hip measurement in centimetres. To be healthy, this ratio should be 0.80 or less for women and 0.90 or less for men.



A person with a high waist/hip ratio (apple shape) has a greater chance of having health problems than a person with a low waist/hip ratio (pear shape).

A person who is overweight or obese is more likely to develop heart disease, or to have a heart attack or stroke. They are also more likely to suffer from high blood pressure and to develop diabetes. Obesity has also been linked to breast cancer and cancer of the uterus.

Obesity

People become overweight or obese when they eat more food than they use for energy. The excess food and the energy contained in it are stored first as glycogen in the liver (see Chapter 4) or as fat in body tissue. It is far easier for the body to store the excess as fat. The body stores fat when fat is eaten or when too much food is eaten and not used, for example when there is little activity or exercise. Sugary drinks and alcoholic drinks provide high amounts of energy and are stored as fat if the energy in them is not used. Alcohol contains 29 kJ of energy per gram, and heavy drinkers are often overweight because they don't use up the energy contained in all the alcohol they drink.

The rate at which respiration occurs in your body when you are at rest is called your *basal metabolic rate*, or the lowest amount of energy needed by your body to keep it working. This rate is less if a person doesn't exercise or if a person has very little muscle in their body (because muscles use up energy). It is also less if a person skips meals, stops eating carbohydrates or eats less food. This is because the body tries to use less energy in response to less food.

You can prevent stored fat by reducing the amount of fat you eat. Fats are energy-dense foods. They provide 37 kJ of energy per gram, whereas carbohydrates and proteins provide only 16 kJ of energy per gram. So you have far more energy to burn off from eating fats than from eating carbohydrates. Fats are also nutrient-low foods. So, eating large amounts of fats will mean that you miss out on essential nutrients from the food you should be eating. Having regular, small meals will prevent your body storing fat to survive periods of starvation. Increasing your fitness and muscle mass will use up more energy.

The best way to maintain a healthy weight is to reduce the amount of fat in your diet, not drink alcohol, never skip meals, exercise every day and follow the healthy eating pyramid. Diets in which people don't eat certain food groups and skip meals are not healthy.

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INQUIRY 7 Why are Australians getting fatter?

1 The Women's Health Organisation has listed the following reasons why Australians are getting fatter. In a group, rank these in order from most important to least important. Explain your order.
   - a Busy lifestyles mean people rely on convenience foods or takeaway foods more so now than in the past.
   - b On average, people eat three takeaway meals per week.
   - c Convenience foods are often high in fat and sugar, and low in important nutrients.
   - d People spend more leisure time watching TV, using the computer and playing video games, which require no exercise.
   - e The hours of work have increased, so people spend less time at leisure.
   - f People eat larger serves of takeaway foods because foods are sold as 'combos', so they eat more than they would normally.
   - g 'Upsizing' is used to sell food. For example you can buy a king-size bag of potato chips for the same price as a normal bag.
   - h The use of the car means less energy is spent walking or getting around.
   - i Temporary fad diets mean people slow down their basal metabolic rate, then increase in weight when they stop dieting.
2 Add to the list any other reasons you can think of that have not been included here.
3 Present 10 things you could do every day to help avoid obesity.

Over to you

1 What is the difference between body mass index and waist/hip ratio?
2 What is meant by basal metabolic rate? What causes this to slow down?
3 How can you maintain a healthy weight?
4 What diseases are you more likely to get if you are overweight or obese?
5 A girlfriend of yours says that she diets and diets, but doesn't get any thinner. What advice would you give her?

INQUIRY 8 Body image

How you view and feel about your body is called your body image. Only one in five women likes her body or has a positive body image. Ninety per cent of Australian women have dieted at least once in their lives. Dieting is increasing for both men and women.

Part A

1 Do you have a positive body image or a negative body image? Explain.
2 A negative body image is said to be caused by:
   - a peer pressure to look thin
   - b media and advertising promoting thin bodies
   - c magazines promoting fad diets
   - d judging people by their body shape and size
   - e health campaigns to lose weight
   - f dieting parents.

In groups of three, discuss whether you agree or disagree with these reasons. At the end of the discussion, present a list of three reasons that you think are the most important in promoting a negative body image. Suggest ways of developing a positive image.

Part B

1 By yourself, predict your body mass index on a scale from 10 to 40. Remember, 18–24 is a normal healthy BMI.
2 Predict your waist/hip ratio on a scale from 0 to 1. Remember a healthy ratio is 0.8 for women and 0.9 for men.
3 Now measure your height, mass, waist and hips. Calculate your BMI and waist/hip ratio as shown on the previous page.
4 How accurate were you in predicting your BMI and your waist/hip ratio? Did you have a different image of your body from that indicated by these calculations?

PROBLEM SOLVING

You should now be able to complete all sections of the chapter problem. Make sure to ask your teacher if there are any parts you still can't complete. It would be a good idea to get your teacher to read through a rough copy of your work.

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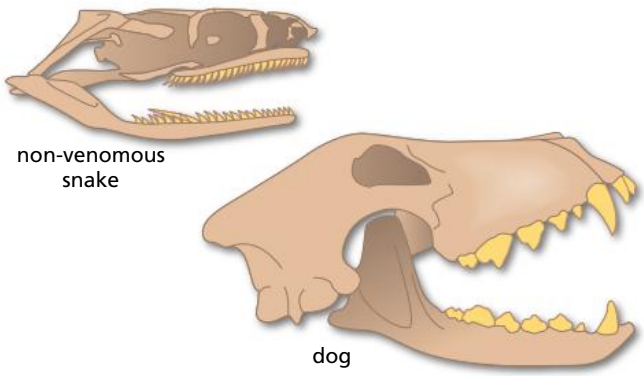
THINKING SKILLS

1 The appendix used to have a function in digestion. What do you think it was used for? Why don't you think it is of use in people today?

2 Would you agree or disagree with the following statement? Give reasons for your answer. *Food does not enter the body until it moves across the walls of the small intestine.*

3 Why do you think dog saliva contains no salivary amylase?

4 Dogs and cats have very long canines, which are the long pointed teeth you can see in your mouth when you smile. These teeth are for tearing flesh. Snakes have teeth that are very thin and long, that curve towards the back of the mouth. Some herbivores have no canines at all, but molars with ridges on them. Explain why you think these different animals have different teeth.



5 Given that the walls of the digestive tract are made of protein, why aren't they digested by enzymes such as pepsin? Find out what an ulcer is and what happens to the lining of the stomach when this occurs.

6 Lactase is an enzyme that splits lactose, a sugar, into a simpler form (glucose).

a Lactose-free milk contains lactase and the milk is very sweet. Suggest why this milk is sweeter than normal milk.

b Adult mammals do not rely on milk as their source of food as babies do, so they start to lose the enzyme lactase as they grow older. Some groups of people such as Europeans continue to produce lactase, while other groups don't. Those who don't are said to be lactose-intolerant and often are bloated and get diarrhoea if they drink milk. Find out if there are any people in your class who are lactose-intolerant. How does milk with lactase in it help these people?

7 Find out what gallstones are and what causes them.

8 Acid in the stomach is needed for pepsin to work. As bones dissolve in acid, scientists believe that an acid stomach is an adaptation for animals feeding on bones. Would you expect to find pepsin and acid in the stomach of a herbivore? Explain.

9 The body can store only small amounts of carbohydrates as glycogen, and converts the rest to fat. Predict what would happen if a person went on a diet eating only carbohydrates. Why is a diet like this not advisable?

10 What is in breakfast bars? The best breakfast bar you can eat is one that is low in fat, low in sugar and high in fibre. Carry out a survey of different breakfast bars and say which you think is the healthiest and why.

11 If taken in excess, some vitamin and mineral supplements can be dangerous. For example vitamin A can cause liver damage. Find out the recommended daily amounts of the vitamins listed in the table on page 63.

12 The ileum and the colon are parts of the digestive system. Find out what they are.

13 Investigate the structure of teeth. What are premolars, molars, incisors and canine teeth? What are the different functions of these teeth?

14 Underweight people suffer health problems just as overweight people do. Find out what health problems they have.

15 Kwashiorkor, goitre, pellagra, xerophthalmia and pernicious anaemia are all deficiency diseases. Find out how to pronounce these diseases, what causes them, and how they can be avoided.

16 Investigate the different preservatives that are added to foods. Find out why they are added.

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 Food is broken down to simpler substances that can be used by body cells. This process is called _____.

2 _____ split large food molecules into smaller ones. _____ break down carbohydrates to glucose. _____ break down proteins to amino acids, and _____ break down fats and oils to fatty acids and glycerol.

3 There are a number of organs that make up the digestive system. For example, the _____ links the mouth to the stomach. Food moves along the digestive tract by _____.

4 The walls of the small intestine are lined with _____ to allow small food particles to move into the bloodstream.

5 The products of digestion are used for chemical reactions in your cells and to make other materials your body needs, e.g. for _____.

6 Plants carry out photosynthesis to make food. Some plants have a series of tubes called _____ that carry the products of photosynthesis to the cells that need them. _____ tubes carry water up from the roots.

7 _____ and _____ are found in the food you eat and are necessary for good health. Each carries out an essential function.

amylases
digestion
enzymes
growth
lipases
minerals
oesophagus
peristalsis
phloem
proteases
villi
vitamins
xylem

Self-management

1 Your work in Inquiry 1 was based on what you knew at the time. Review this work. Which questions did you answer incorrectly? What do you now know that you didn't know when you started the chapter? Correct anything that you had wrong.

2 It is always important to review the work that you do, especially to prepare for a test or exam. The steps below will help you review this chapter and can be used in any subject at any time to help you review what you have learnt.

a Read through your notebook. Have you written down your work in date order? Have you been sick and missed work? Do you have all the handouts given to you by the teacher? Check your notebook with a partner and update your work before continuing.

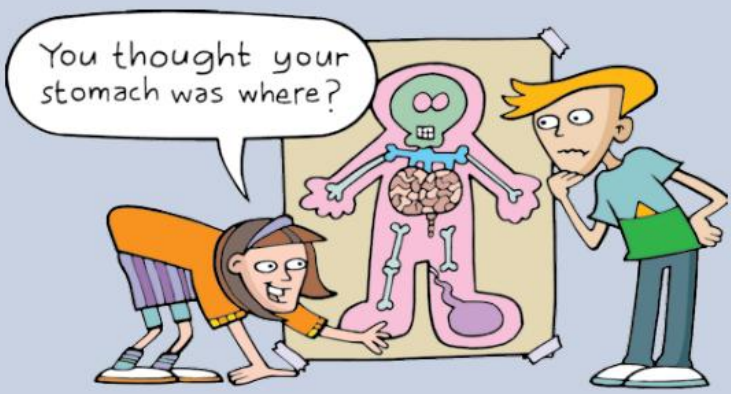
b Read through all the homework you were given to complete. Finish anything you didn't do. Highlight any questions you cannot do.

c List all the words in bold in the chapter and write down their meanings. Highlight any words in your notebook that you don't understand.

d What things can you do? List these. For example: *I can label a diagram of the digestive system and describe what each organ does.*

e What do you have problems with? List these. For example: *I don't know what peristalsis is.*

f Ask your teacher to go over the words you don't understand, any homework you couldn't do, and the things that you are having problems with.



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Checkpoint

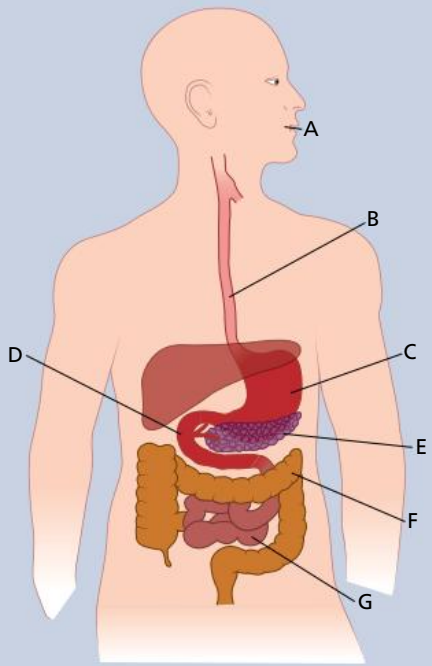
Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 Match the following words with their meanings:
villi, digestion, absorption, peristalsis, deficiency disease

- **a** The muscular movement of food along the digestive tract
- **b** Lack of a particular nutrient, causing a disease in the body
- **c** The taking in of nutrients by the body from the small intestine
- **d** Finger-like extensions that cover the walls of the small intestine
- **e** The breakdown of larger food molecules into smaller molecules that can be absorbed by the body

2 Label the following diagram.



3 Give the letter corresponding to the correct part from the diagram above to show where you would expect to find:

- **a** faeces
- **b** pepsin
- **c** salivary amylase
- **d** pancreatic enzymes acting on food

4 Explain why plants do not need a digestive system.

5 Four boxes in the following table have been incorrectly placed. Which boxes are they and where should they be?

Organ	Activity	Substance produced
Box 1 mouth	**Box 2** Food moves down to the stomach by the action of peristalsis.	**Box 3** pepsin
Box 4 oesophagus	**Box 5** The food is churned, mixed with saliva and rolled into a ball.	**Box 6** Nothing is produced.
Box 7 stomach	**Box 8** The food is churned and mixed with acid and enzymes. The breakdown of proteins starts here.	**Box 9** salivary amylase
		Box 10 rennin
		Box 11 hydrochloric acid
		Box 12 mucus
Box 13 duodenum	**Box 14** Bile is secreted into the duodenum to break down fats. Pancreatic enzymes continue digestion.	**Box 15** Does not produce anything, but it receives substances from other areas.

6 Alexander was overweight and needed to go on a diet. He did not want to exercise so he altered his food intake instead. He decided he would skip breakfast and avoid carbohydrates altogether. He loved takeaway foods, but he knew they were high in fat, so he thought that if he had a takeaway meal it would be his only meal for the day. Alexander found that he was hungry, but not losing a lot of weight. Why?

7 The photo shows the wall of one part of the digestive tract. Which part is it and why do you think so?



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4



Body balance

By the end of this chapter you will be able to …

Knowledge and Understanding

- describe some examples of how multicellular organisms respond to changes in their environment (LW1a)
- outline how the nervous and endocrine systems work together to maintain humans as functioning organisms (LW1d)

Skills–Working Scientifically

- use laboratory equipment to safely dissect a kidney (6b)
- assess the effectiveness of an experiment and whether its design could be improved (6f)
- research drugs and suggest ways to convince people to say 'No' to them (7.1c)
- suggest a range of possible solutions to an identified problem (8a)

LITERACY FOCUS

auxin
axon
central nervous system
effectors
endocrine glands
endocrine system
excretion
glycogen
homeostasis
hormones
metabolism
motor neuron
pituitary gland
receptors
sensory neuron
stimulants
synapse
ureter
urethra
urine

Focus for learning

A recent survey showed that 40% of Year 7 students had drunk alcohol, and 6% had smoked marijuana. By Year 11 these figures were 88% and 42% respectively. It was also found that 50% of Year 7 students had smoked cigarettes, 35% used pain killers weekly and 1% had tried illegal drugs. These are frightening statistics.

Drugs alter the way your body or mind works. They can cause death and many are illegal. They destroy families and relationships. A drug taker is at risk of unsafe and unplanned sex, dying in a car accident, and contracting HIV and hepatitis through needle sharing.

Drug taking can lead to *tolerance* so that a person needs more and more of a drug to get the same feeling as before. It can then lead to *physical dependency* so that the body gets so used to having a drug present it cannot function without it. Finally, it can lead to *psychological dependency*, where a person's emotions and thoughts are altered to the point where they cannot stop taking the drug.

Drug types

Psychoactive drugs affect the nervous system and alter a person's mood, behaviour and judgement. Psychoactive drugs can be:

- *stimulants* like caffeine or nicotine. These are called 'uppers' and they increase brain activity and speed up the way in which nerves work.
- *depressants* like alcohol. These are called 'downers' and are the opposite of stimulants.
- *hallucinogens* like LSD. These make a person 'see' things or imagine a world that isn't real.
- *other drugs* that are a mixture of the above three groups. For example cannabis is initially an 'upper'. It then causes hallucinations.

This chapter looks at how a normal balance is maintained inside your body and how drugs affect this.

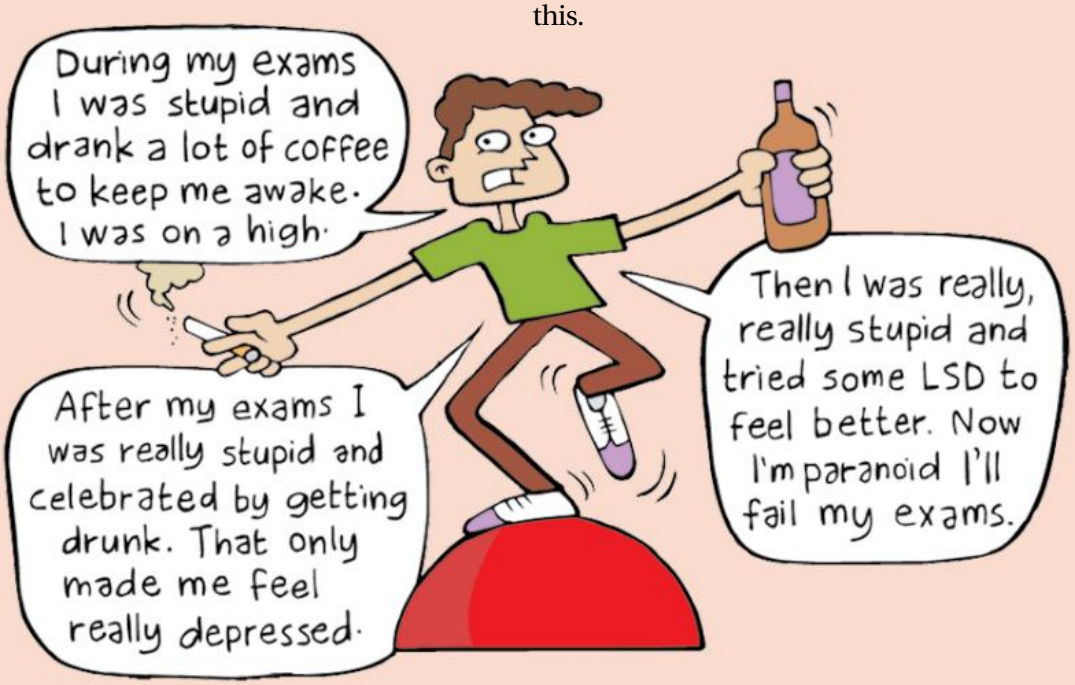
PROBLEM SOLVING

No drugs

Your task is to convince the school community to say 'No' to drugs. This can be in the form of a poster, role-play, the school magazine, a newspaper article or a library display. In this you must:

1. Research one drug and explain how it affects the normal balance inside your body.
2. Explain 'cool' ways to say 'No' to drugs.

Inquiry 2 on page 75 will get you started, and the rest of the chapter will help you with your problem.



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4.1 Balance in the body

Regulation

Organs such as the liver and the kidneys carry out *regulation* inside your body. This means they keep the concentration and composition of your body fluids constant. Another name for this is **homeostasis** (ho-me-o-STAY-sis). Drugs such as alcohol, inhalants and amphetamines (see Inquiry 2) affect these organs. Death can occur because the internal balance is altered and the body cannot work as it should. The role of the liver and kidneys in maintaining balance in the body is outlined here.

Regulation of blood sugar (glucose)

If there is too much glucose in the blood, the liver converts it into a carbohydrate called **glycogen**. When the concentration of blood glucose falls, the liver converts the glycogen back to glucose again. If the glucose reaches too high a concentration in the body it is removed by the kidneys.

Removal of amino acids

Amino acids (building blocks of proteins) cannot be stored in the body for long periods of time. Excess amino acids are converted to glucose or glycogen. In this process, the element nitrogen is removed from the amino acid. This forms ammonia, which is very toxic. To get rid of the ammonia it is converted to urea and removed from the body by the kidneys.

Regulation of the blood

The liver destroys red blood cells. As it does, the iron from the haemoglobin in the red blood cells is stored. The liver also produces many proteins that are found in plasma. One of these is fibrinogen, which is needed for blood clotting.

Removal of poisonous substances

The liver breaks down chemical compounds such as alcohol that are harmful to the body. The breakdown products can then be removed by the kidneys. For example, alcohol (ethanol) is broken down to acetaldehyde by the liver, then to acetic acid and finally to carbon dioxide and water. The liver also removes chemical compounds such as hormones normally found in the body. (See Section 4.4.)

Fats and bile

The liver produces bile salts which are needed for the breakdown and absorption of fats from the digestive system. The liver also regulates the use of fats in the body.

Coordination

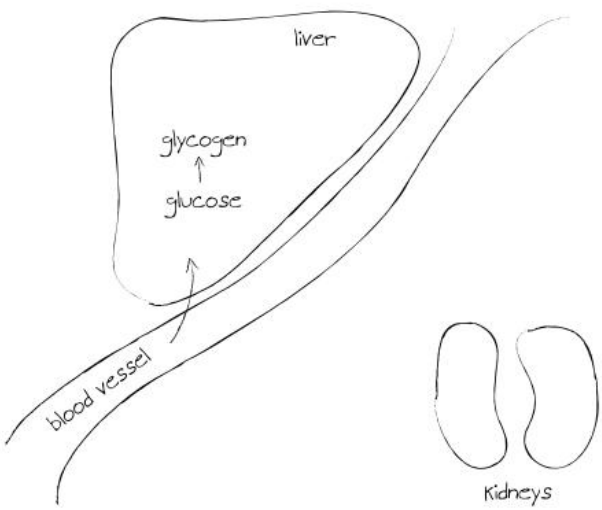
All the systems of the body need to work in the right way, at the right time and in union with one another. This *coordination* of the body is carried out by two systems: the nervous system and the endocrine system. The nervous system is made up of a network of nerves that link to the spinal cord and the brain. The endocrine system is made up of different glands in the body that produce chemical messengers called **hormones**, which act on certain body organs. The endocrine system is also involved in maintaining homeostasis.

Drugs affect the nervous system by speeding it up (stimulants) or slowing it down (depressants). Some drugs can also cause brain damage.

INQUIRY 1 Functions of the liver

You will need: butcher's paper, coloured marker pens

1. Form groups of three.
2. Draw a large liver, blood vessel and kidneys on the butcher's paper. The diagram below will help you.
3. Using the information on this page, add labels to your diagram to show what goes into and out of the liver from the blood.
4. Also show how the kidneys are linked to the functions of the liver.
5. Swap your completed diagram with another group. Add anything you think is missing in a different coloured pen and then pass it back to the other group.



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INQUIRY 2 Drugs

Read the table below and then answer the questions on the next page.

Drug	Drug group and ingredients	Short-term effects	Long-term effects
alcohol	depressant made by the action of yeast on sugar (fermentation) to produce ethanol	• feeling happy, confident, relaxed • loss of inhibitions (don't care what people think of you) • confusion, loss of coordination • nausea, vomiting, headaches	• tolerance and dependency • hepatitis, cirrhosis and liver cancer • high blood pressure, enlarged heart • loss of memory, confusion, brain injury
cannabis (marijuana, pot, grass, weed, yandi, hash, reefer, joint)	belongs to 'other' group (refer to page 73)	• a feeling of being 'high' and loss of inhibitions, becoming sleepy • loss of memory and coordination • anxiety, panic and confusion • hallucinations, vomiting and blackouts	• tolerance and dependency (both types) • loss of motivation, concentration, memory and the ability to learn • loss of menstrual cycle in women, low sperm count in men, loss of sex drive
amphetamines (speed, whizz, go-ee, ice, crystal meth, meth)	stimulant, many different drugs, pure or impure (mixed with other substances, e.g. sugar, ephedrine)	• a feeling of confidence and energy • increased heart rate, breathing rate and blood pressure, enlarged pupils • inability to sleep, loss of appetite, restlessness, shaking, headaches • anxiety, panic, hostility, dizziness	• tolerance and dependency (both types) • malnutrition because users don't eat, leading to a reduced resistance to viruses • violence and emotional problems • impure form can cause collapsed veins, damage to the heart, liver, lungs and brain
heroin (horse, hammer, H, dope, smack)	depressant, mixture of codeine and morphine, pure or impure (mixed with sugar and speed)	• feeling of wellbeing and pleasure • shallow and slow breathing, decreased heart rate • lack of balance and coordination • nausea, vomiting and sleepiness • pinpoint-sized pupils and cold skin	• tolerance and dependency (both types) • loss of appetite leading to malnutrition and greater risk of developing infections • loss of menstrual cycle and infertility in women, men cannot have an erection • heart and lung problems
tobacco	stimulant, nicotine, acetone, hydrogen cyanide, arsenic, ammonia, DDT, naphthalene	• increased heart rate and blood pressure, increased brain and nervous system activity • bad breath, nausea and coughing • breathing difficulties	• cancer of the mouth, throat, larynx, lung, pancreas, kidney, stomach, cervix • high blood pressure, heart and circulation problems • emphysema and chronic bronchitis
inhalants (glue-sniffing, chroming)	stimulant	• a feeling of being 'high' and loss of inhibitions, followed by drowsiness • blackouts, cramps • vomiting, diarrhoea, nosebleeds • flu-like symptoms, e.g. runny nose	• tolerance and dependency (both types) • seizures, coma and heart failure • damage to the brain, kidneys, nervous system and liver • blood production affected
ecstasy (XTC, E, pills, Ex, eccy)	belongs to 'other' group (refer to page 73)	• feeling of confidence, tranquillity, 'love' followed by jaw clenching, teeth grinding, nausea • dry throat and mouth, loss of appetite	• convulsions, vomiting, floating sensations • brain damage, depression, anxiety • the undesirable effects of this drug mean that people do not use ecstasy for long periods of time
psychedelics, LSD, magic mushrooms	hallucinogens	• mind altering, distorted self-awareness and feeling of wellbeing • nausea, chills, shaking, panic • rapid heart rate, increased blood pressure, dilated pupils	• tolerance and psychological dependence • flashbacks (hallucinations return) • impaired memory and concentration • increased risk of mental disorders
cocaine (coke, Charlie, blow, C, pepsi)	stimulant, cocaine hydrochloride, can be pure or impure	• feeling of wellbeing, alertness, energy and increased heart rate • aggression, agitation and panic • loss of coordination, vomiting	• dependency (both types) • nose eaten away through snorting coke • reduced hunger, thirst and sleep • heart attack

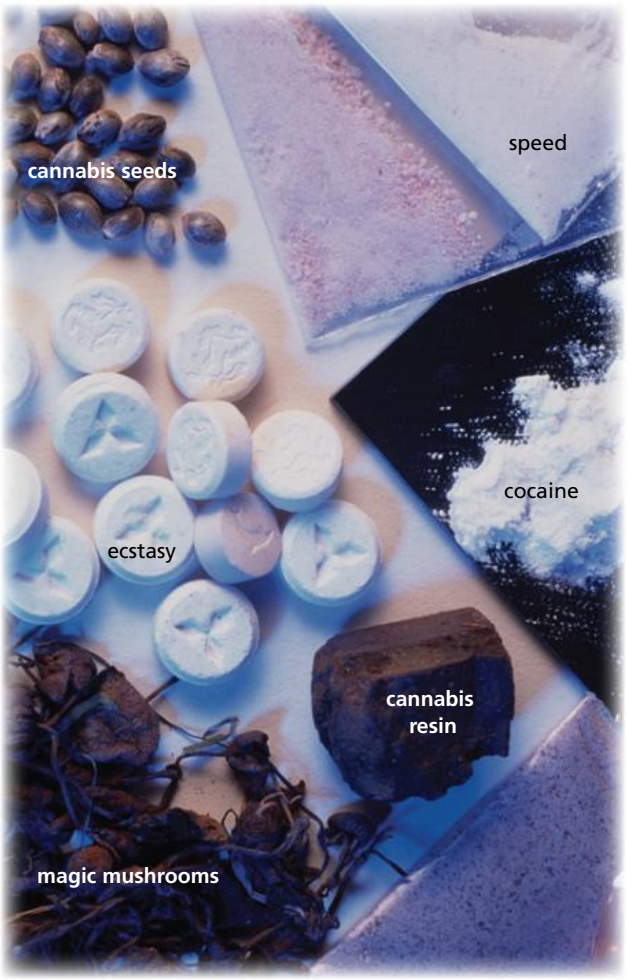
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INQUIRY 2 continued

1 List the words in the table that you don't know, and find out what these words mean.
2 What is the difference between a stimulant, a depressant and a hallucinogenic drug? Give an example of each.
3 What does the drug group 'other' mean? Give an example of a drug in this group.
4 What does dependency mean? What is the difference between physical and psychological dependency? Give an example of a drug that causes each type.
5 When a person has a drug dependency and they stop taking the drug, they have withdrawal symptoms. Find out what withdrawal symptoms are. Why do you think this happens?
6 Which of the drugs listed in the table are legal drugs? Which are illegal?
7 Find out what the legal consequences are for possessing, selling and using illegal drugs.
8 It has been said that the negative effects of taking drugs far outweigh the positive effects. Would you agree or disagree with this statement? Explain.
9 Before you commenced this chapter, would you have considered taking drugs? Explain. Has what you have read so far changed your thinking? Give reasons for your answer.
10 Three reasons why young people take drugs are:
- to look cool, be more confident and less inhibited at parties or in social settings
- to escape boredom, stress and their life in general
- to see what drugs are like.

In groups of three, explain whether you agree or disagree with the reasons above. Write your own list of reasons to explain why young people take drugs.

11 How could you use the information in the table on the previous page to convince another student in the class to stop taking drugs?
12 Only some of the short- and long-term effects of taking drugs are listed in the table. Use the internet to find out more about these drugs.



Over to you

1 What does homeostasis mean?
2 Explain how each of the following helps to maintain a constant internal body environment.
- **a** The bloodstream carries oxygen to the cells and carries the products of their activities away.
- **b** Blood vessels in the skin can dilate (enlarge) or constrict (shrink).
- **c** The lungs remove carbon dioxide.
- **d** The kidneys remove excess water and harmful substances such as urea from the body.
- **e** The kidneys remove substances such as glucose, if the concentrations of these substances become too high in the body.

3 It takes the liver about an hour to break down a standard glass of beer. Suppose a person has 10 beers between 8 pm and midnight. Could they still have alcohol in their system when they leave for work at 5 am the next morning? Explain your answer.

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4.2 The excretory system

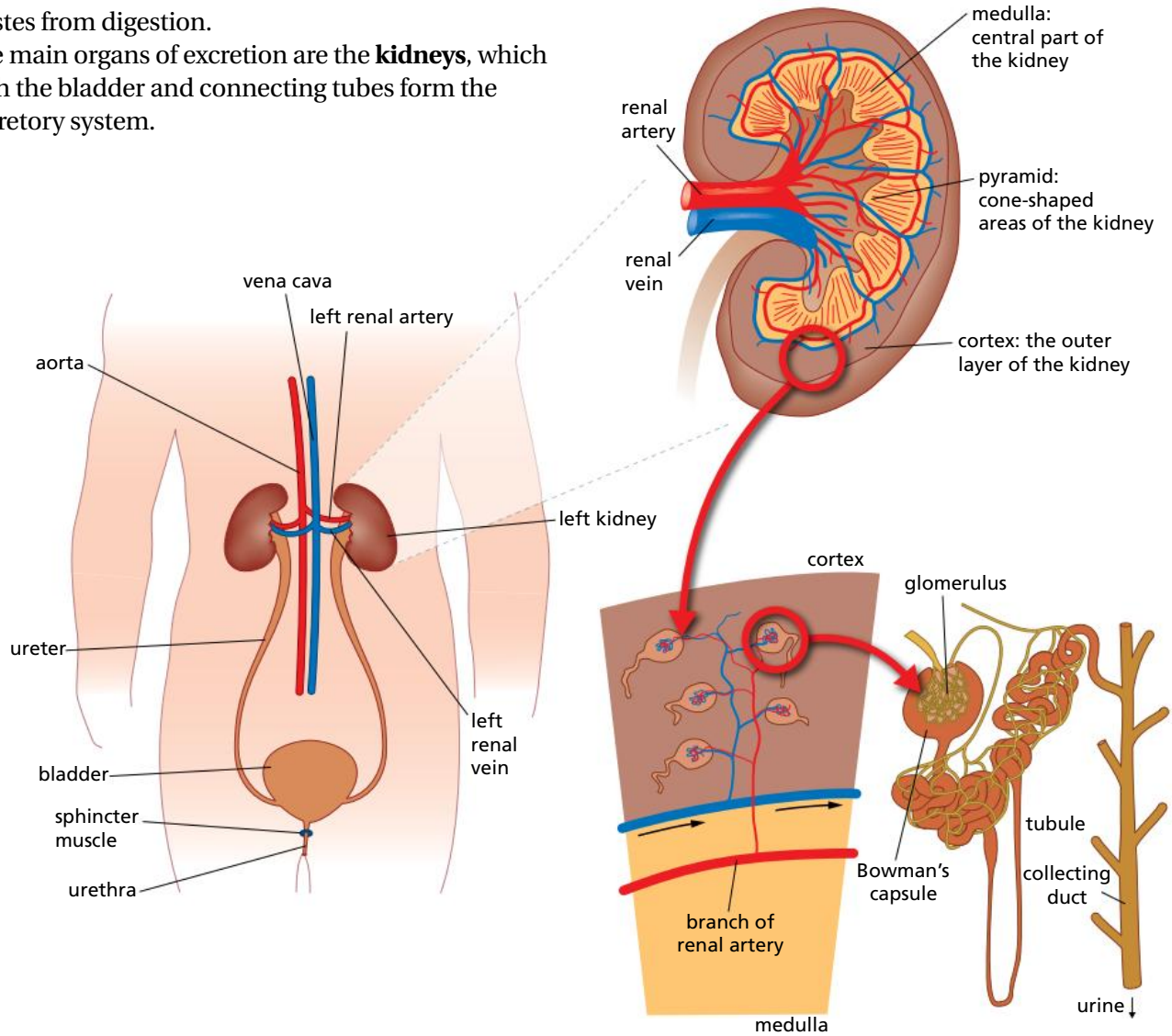
Excretion is the removal of unwanted substances made by your cells. Some of these substances are carbon dioxide, excess water, urea from the breakdown of amino acids, and glucose. They are removed if their levels reach too high a concentration in the body. These unwanted substances are made in chemical reactions that take place inside your cells. One such reaction is respiration, which converts oxygen and glucose to carbon dioxide, water and energy. The term used to describe all the chemical reactions that take place in your body cells is called **metabolism**. Excretion is the removal of wastes from cell metabolism. It is not the same as removal of wastes from digestion.

The main organs of excretion are the **kidneys**, which with the bladder and connecting tubes form the excretory system.

The kidneys

The role of the kidneys is to filter your blood. The renal arteries carry blood from the body to the kidneys. In each kidney the renal artery branches into smaller and smaller blood vessels until it reaches a *glomerulus* (glo-MER-u-lus) (plural *glomeruli*), which is a ball of capillaries. Each glomerulus is surrounded by a cup-shaped structure called the *Bowman's capsule*.

Fluid in blood that needs filtering flows out of the glomerulus and into the Bowman's capsule. Blood cells and large protein molecules remain in the blood and do not pass into the Bowman's capsule.



The excretory system, with a kidney enlarged to show the internal structure of the cortex

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The fluid that enters the Bowman's capsule contains glucose, amino acids, water, vitamins and minerals. These substances pass into the kidney tubule, which is a 3 cm long tube surrounded by a network of capillaries. Substances such as glucose and amino acids that are needed by the body are *reabsorbed* (taken out of the fluid) by the cells that line the tubule walls, and pass back into the blood through capillaries around each tubule. There are about a million individual kidney tubules.

The leftover liquid is called **urine**. It contains urea and any unwanted substances. Your body is able to determine which substances are needed and which are not. If you drink more water than your body needs, you will produce a lot of urine. If you drink very little, the body will reabsorb as much water as it can.

The composition of urine is shown in the table below. Normally substances such as glucose, amino acids, vitamins and minerals that are needed by the body are reabsorbed, leaving very little of these substances in urine. If high levels of these are found in urine it may mean the kidneys are not working properly.

Substance	Amount in urine per day
glucose	trace
sodium salts	6 g
potassium salts	2 g
calcium salts	0.2 g
urea	35 g
water	1.5 L

Urine flows from each kidney tubule into a collecting duct that drains into a tube called the **ureter**. Muscular contractions of the ureter wall ensure that urine is continuously moved into a collecting sac called the *bladder*. As it fills, the bladder stretches, triggering nerves to send a message to let your brain know that your bladder is full and needs emptying.

From the bladder there is a tube called the **urethra** that is sealed by a sphincter muscle. When you need to, you can relax this muscle so that urine flows from the bladder, down the urethra and out of your body.

It takes only five minutes to filter all the blood in the body through the kidneys. On average, about 1.5 litres of urine is produced each day, although this varies, depending on how much water you drink.

Excretion in other animals

Most animals have to get rid of wastes such as urea from their bodies. Amphibians excrete urea, whereas birds, reptiles, insects and snails excrete uric acid. The advantage of this is that uric acid requires little or no water to be excreted, so the animal can get rid of its waste without losing too much water.

Some animals, for example birds, have no bladder. Instead the ureters empty straight into the *cloaca* (clo-ACHE-a). This is a chamber or cavity that is shared by the excretory, digestive and reproductive systems. Substances from all these systems move through it. The urine leaves the cloaca and moves to the large intestine, where water can be reabsorbed. Urine is excreted as uric acid, together with faeces from the digestive system. Snakes have a similar excretory system.

In frogs, the ureters drain urine into the bladder, which empties into the cloaca. When a frog is in water, it filters lots of blood and reabsorbs very little water. On land, the frog reduces blood flow and adjusts the rate of filtration to conserve water. It can also store water in its bladder and reabsorb it when water is scarce. A frog can also force water from its bladder as a defence against predators.

Some mammals such as monotremes also have a cloaca. In fact these mammals get their name from this. The term 'mono' means one and 'treme' comes from the Greek word *trema* meaning hole. So monotreme means one hole.



A baby echidna positioned to show its cloaca

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INVESTIGATION

1 Kidney dissection

Aim

To examine a sheep's kidney.

Risk assessment and planning

Read through the investigation and discuss these questions with your teacher before starting.

1 What safety precautions are necessary when handling dead organs, to safeguard yourself and others?
2 How should dissected tissue be disposed of?
3 How should the laboratory and any equipment used be cleaned?

Apparatus

- sheep's kidney
- newspaper
- plastic bags
- disinfectant
- dissecting equipment
- cutting board
- laboratory coat or apron
- disposable gloves
- ruler
- microscope
- prepared slides of kidney tissue

Method

Part A

1 Lay some newspaper on the bench and place the cutting board on top of it.
2 Put the sheep's kidney on the cutting board.
3 Before you cut the kidney examine it on the outside.
   a What does the kidney look like? Describe its shape and colour.
   b What does it feel like (through the gloves)?
   c Measure the kidney's dimensions and make a sketch of it, including any tubes and blood vessels you can see. You may need to remove any fat around the kidney to do this.
4 Now cut the kidney in half as shown in the photo top right.
5 Draw the kidney as it appears now. Use the diagram on page 77 to label the parts of the kidney.
6 What colours are the cortex, the medulla and the pyramid? Use the diagram on page 77 to describe the structures that are found in each of these areas.



Part B

1 Review with your teacher how to use a microscope and draw microscope specimens.
2 Examine prepared slides of different kidney tissues. Draw and describe what you see.

Results

Present your drawings and descriptions of the kidney.

Conclusion

Write a brief summary about the sheep's kidney. Explain whether the kidney dissection was what you expected and what you have learnt from the dissection.

You could use the internet to find a 'virtual' dissection of a frog. Use a search engine and type in 'frog dissection'. Look at its excretory system and compare it to the excretory systems you have studied in this section.

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SCIENTISTS AT WORK

Liver and kidney transplants

Using drugs can cause damage to the liver and the kidneys. For example, alcohol causes *cirrhosis* or scarring on the liver, and tobacco can cause kidney cancer. Needle sharing can result in hepatitis C, and this may cause liver failure (when the liver stops working completely).

In some cases, a liver transplant can be performed. In a transplant a healthy liver is taken from a person who has recently died and placed into the person who needs it. Seventy-five per cent of people who receive a new liver survive more than three years. The problems with liver transplants are:

- finding a new organ
- rejection of the organ because the patient's body sees it as 'foreign'
- life-long drug taking to stop the body rejecting the new organ
- the cost of the transplant.

It is possible to live with just one kidney, so a new kidney can come either from a living person or from a person who has recently died. *Dialysis* is used to keep someone waiting for a kidney transplant alive. This is where a machine does the work of the kidneys. Blood from the patient's artery enters the machine and runs through tubes that remove wastes from the blood. The blood then returns to the patient through a vein. Dialysis is needed three times a week.

New technology

Scientists have been able to grow organs that act and function like kidneys, from cow embryo cells. If human embryos could be used, then it could be possible to grow organs for people who need transplants. The genetic information of the patient could be inserted into a human embryo cell. When a new organ grows from the cell, it would be very similar to the tissues of the patient and therefore less likely to be rejected. The human embryo would be destroyed in the process, so there are ethical issues concerning the use of human embryos in this way.

The use of pig organs in humans is also being investigated. Pig cells contain a gene that causes the human body to reject them, but scientists have found a way to remove this gene. However, the issue of transferring pig viruses to humans is a concern to many people.

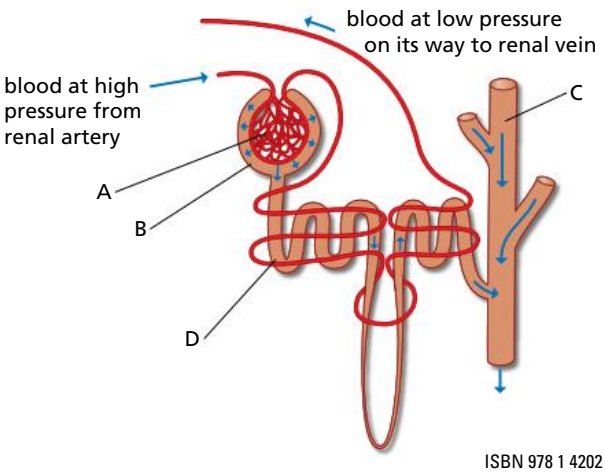


Pig parts for humans? Do you think this should be done?

Doctors have also replaced a patient's liver with a piece of liver cut from a live liver donor. The liver piece can grow new cells and replace itself. So after some weeks, both the patient and the donor have a fully functioning liver again. However, there is a small chance of the donor dying, because an infection can occur when their liver is cut.

Over to you

1. What is excretion?
2. Label the four parts indicated on the diagram on the right and explain what each part does.
3. A test result showed blood in a patient's urine. Is this normal? Explain.
4. Explain whether you think plants carry out excretion.



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INQUIRY

3 Who gets the liver?

1 Draw up a table with the following headings.

Strengths	Weaknesses	Action	Possibilities

2 Under the heading 'Strengths' write all the points that you can think of in favour of the use of the new liver and kidney technology described on the previous page.

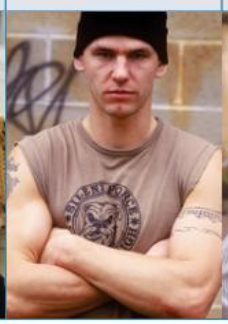
3 Under the heading 'Weaknesses' write all the points *against* the use of this new technology.

4 In the 'Action' column, explain how the weaknesses can be turned into strengths.

5 Finally, explain what the possibilities are for the future in the 'Possibilities' column.

6 In Australia, one person dies each day waiting for an organ transplant. Imagine you are a doctor with six patients waiting for a transplant as shown in the table below. There are only two livers available. In groups of five, see if you can reach a consensus on who should get a new liver. You will need to justify your decision, that is, give detailed reasons for it.

- Compare your group's decision with those of other groups in the class. What were the similarities and differences between groups?
- The decision you made is based on ethics, or the values you hold. What values influenced your decision?
- How do you think a patient who didn't get a new liver would view the new technology available?

Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
A 40-year-old single woman with no other medical problems	A 33-year-old man with one year left to serve on a 5 year armed robbery conviction	A 5-year-old Vietnamese boy who has recently arrived in Australia	A 55-year-old father of four who has no other medical problems	A 12-year-old child with Down syndrome	A 32-year-old mother of a 6-month-old child with no other medical problems
					

INVESTIGATION

2 Investigating urine

You will need: small plastic vial, urine test strips for glucose, protein and blood (available at pharmacies)

1 Your teacher will give those students who wish to test their urine a small plastic vial to collect a urine sample.

2 Dip each test strip into your urine sample and compare the colour change on the strip with the colour chart provided.

3 Would you expect to find glucose, protein and blood in your urine? Why or why not?

4 Design an experiment to test one of the following hypotheses:

- **a** Drinking large amounts of water will produce large amounts of urine.
- **b** The level of glucose in urine remains constant no matter how much sugar is eaten in a day.
- **c** There will be no protein present in urine no matter how much protein is eaten in a day.
- **d** When water is lost from the body through sweating, less water is lost in urine.

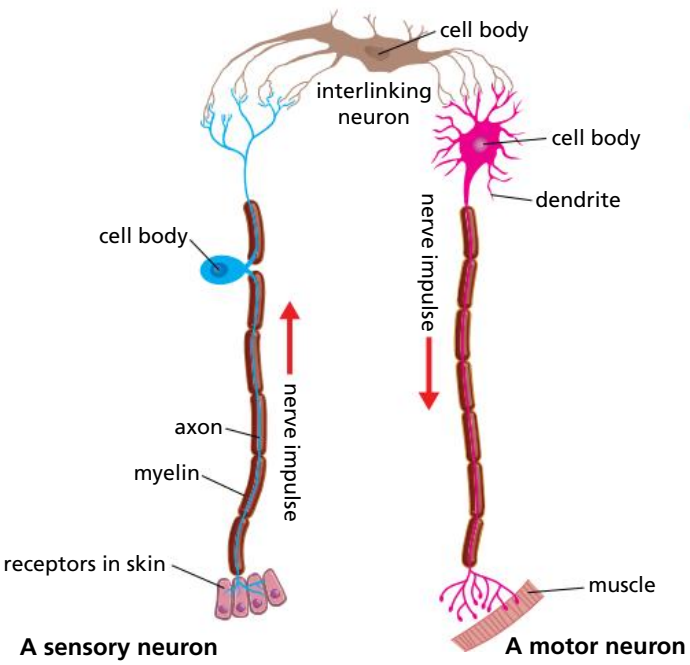
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4.3 The nervous system

Responding to a stimulus

You are lying in bed asleep and the alarm goes off. You quickly roll over and turn it off. The alarm is a *stimulus*, or something that makes you take action. Your ears are the **receptors**. The sound is transmitted as nerve impulses along the auditory nerve to your brain. Your brain works out what is happening and sends a message, via the nerves, to the muscles in your arm and hand. The muscles are the **effectors**. They carry out a *response* or reaction to the nerve impulse they receive. It may take only a couple of milliseconds for a response to occur, because nerve impulses can move at almost 100 m/s through nerve cells.

A nerve cell is called a **neuron** (NEW-ron) and there are different types of neurons in the body. **Sensory neurons** lead away from receptors and **motor neurons** lead towards effectors. In neurons, the *cell body* is the nucleus and the cytoplasm surrounding it. Branching fibres of cytoplasm called *dendrites* receive impulses from the axons of other neurons. An **axon**, also called a nerve fibre, usually carries impulses away from the cell body. The axons of many neurons are surrounded by *myelin*, which is a fatty layer. An axon can be up to 2 m long. Sensory neurons carry information from receptor cells (e.g. pain receptors in the skin), along the axon to the cell body. In motor neurons, dendrites carry the information to the cell body.



A sensory neuron A motor neuron

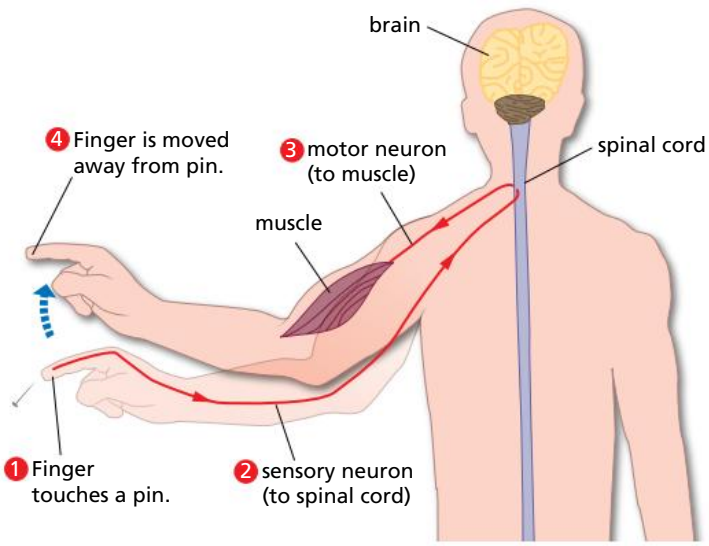
Sensory and motor nerves

A bundle of nerve fibres is called a nerve. One nerve may contain thousands of fibres working separately from each other. A nerve can be made up of sensory neurons and motor neurons, with nerve impulses travelling in both directions. When you turn off the alarm, the nerve pathway is something like this:

stimulus (alarm) → **receptor** (ears) → **sensory neuron** (auditory nerve) → **brain** → **motor neuron** → **effector** (muscles) → **response** (alarm switched off)

Reflex action

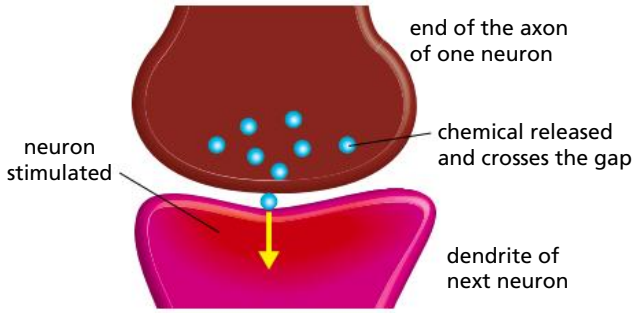
A reflex action has a very simple pathway in which a receptor-sensory neuron is linked to a motor neuron and effector, without going via the brain. For example, if you put your finger on a pin, a reflex action allows you to lift your finger off the pin immediately, before waiting for a response from the brain. This way you can get a quick response and have less damage to the body.



Synapses

Neurons are not connected to one another. There is a space between them called a **synapse** (SIN-apse). When an impulse reaches a synapse, a chemical crosses the gap and stimulates the next neuron to continue the impulse. This is a one-way movement. The chemical is shut off after the impulse is passed along. Drugs such as tranquillisers block the release of this chemical in the brain. This slows down brain functions. Amphetamines work in the opposite way.

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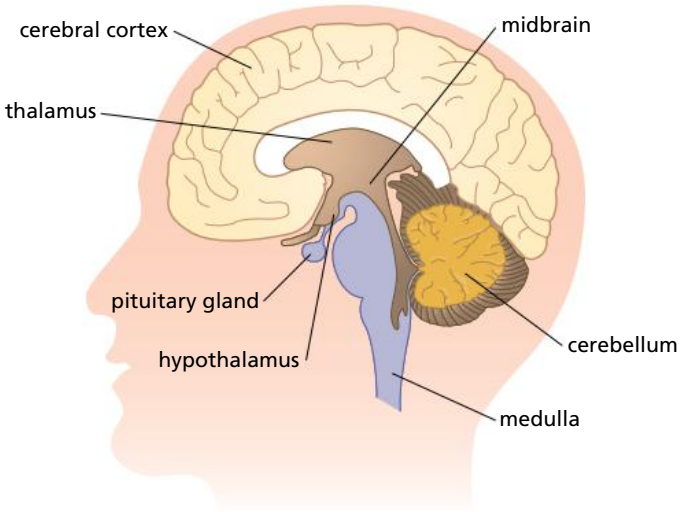
How a synapse works

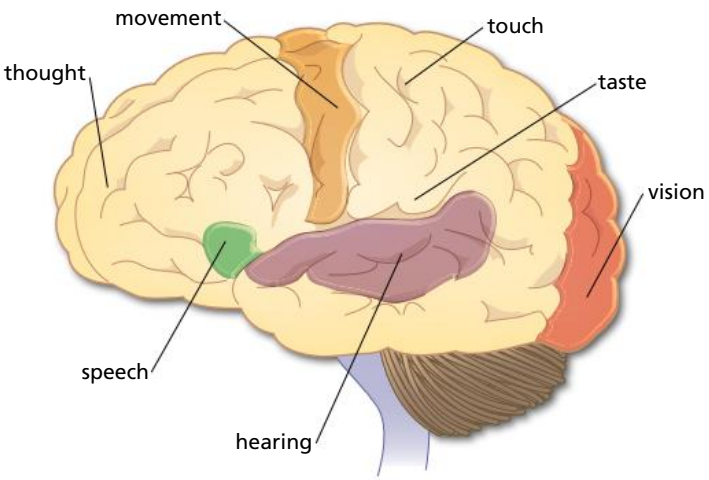
The central nervous system

Some nerves connect to the brain and some nerves connect to the spinal cord. The brain and spinal cord together form the **central nervous system**. It is the control centre of the body. You are aware of what is happening to your body because information is sent to your brain, which is made up of 10 to 50 thousand million neurons. The different parts of the brain and their functions are outlined in the table below and diagrams right.

Your brain can also control parts of your body without you thinking about it. For example your heart and blood vessels, the muscles in the walls of your digestive system, your glands, and your respiratory, excretory and reproductive systems are all controlled in this way.

Part of the brain	Function
cerebral cortex	made up of the cerebrum (divided into two hemispheres); covered with a thick, folded layer called the cortex; controls sensory and motor functions and memory
cerebellum	responsible for balance, coordination, posture and fine movement
medulla	controls breathing, respiration rate, swallowing, sneezing, coughing and vomiting
hypothalamus	floor of the brain; controls sleeping, eating, drinking, speech, body temperature, some emotions and water balance; links the nervous system with the endocrine system; produces some hormones
thalamus	contains neurons that link it to the medulla and midbrain; has pathways to the cortex and spinal cord; activates the rest of the brain when a stimulus is received





The top diagram shows the parts of the brain listed in the table. The bottom diagram shows different parts of the cerebral cortex and their functions.

The nervous systems of other animals

There are many different types of nervous systems in animals. Some animals, such as hydra, have nerve cells that spread throughout their bodies like a net. Impulses can move in any direction from wherever the stimulus occurs. The stronger the stimulus, the more it spreads throughout the nerve network.

A bird brain is different from a human brain. In birds the part of the brain that controls instincts such as flying, feeding and reproduction is larger. The midbrain, which controls sight, is well developed in birds. However the part that controls smell is small, because birds do not rely on this sense to survive.

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INQUIRY 4 Test your nervous system

You will need: soft toy ball, small torch

What you call a reflex is created by a reflex action in your body. A reflex protects your body without you thinking about it.

1. Sit on the edge of the table with your legs crossed. Both legs should hang freely.
2. Have a partner strike your leg below the knee, using the side of their hand. What happens? How can you explain this?
3. Stand behind a window with your partner on the other side of the window, facing you. Gently throw a soft toy ball at the window. Does your partner blink? Explain why this reflex occurs.
4. Have your partner close their eyes for 1 minute. When they open their eyes shine a torch light into one of them. What happens to the pupil of this eye compared with the other eye? How can you explain this?

INQUIRY 5 Tickle yourself

When you try to tickle yourself the cerebellum is activated. It helps coordinate movement and tells the body what you are about to do. If you are tickled by somebody else, the brain has no early warning system, and so it responds to the tickle.

1. Try tickling yourself on the back of your neck, below your ribs and on the inside of your arm.
2. Now get a partner to tickle you in the same places.
3. What differences do you notice and how can you explain them?
4. Why is it important for your body to be able to distinguish between an external stimulus and one that you have caused yourself?



INQUIRY 6 Looking at nerves

You will need: prepared slides of sensory nerve tissue, motor nerve tissue, brain tissue and spinal cord tissue

Examine the different slides that you have been given. Draw and describe what you see.

Over to you

1. Why do animals need a nervous system?
2. What is the difference between a sensory neuron and a motor neuron? Explain.
3. Why does a reflex action bypass the brain? Give an example of when this would occur.
4. What is a synapse?
5. Stimulants increase the release of the chemical that crosses the synapse, and depressants decrease the release of this chemical. What effect does this have on the body?
6. Which part of the brain is likely to control anger? Explain.
7. Barbiturates or sleeping tablets like those taken by Marilyn Monroe (see Chapter 10) block the thalamus from working. What effect does this have on the brain? If this area of the brain is destroyed, a person falls into a coma. Why do you think this happens?
8. The part of the thalamus that activates the rest of the brain when it receives a stimulus can increase some stimuli and block others. It acts like a filter, letting the brain react to only some stimuli. What stimuli would occur to which there is no need to react? Why do you think this filtering system is necessary?

PROBLEM SOLVING

Remember that you must research a drug and explain how it affects the normal internal balance of your body.

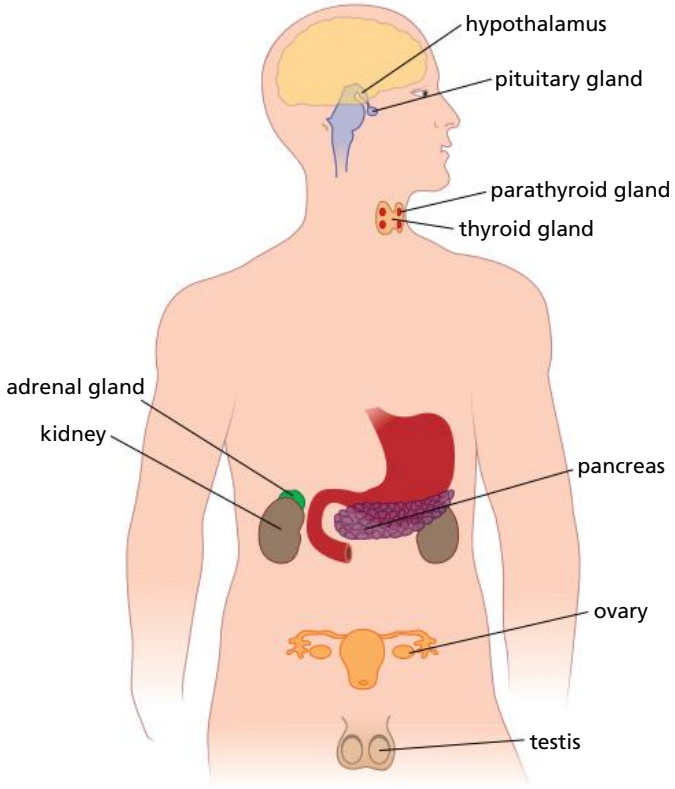
- Find out how the drug you are researching affects the nervous system. For example, is it a stimulant or a depressant, and what does this do to the nervous system?
- Find out how the drug you have chosen affects the liver and the kidneys.
- Does the drug you are researching have any long-term effects on the nervous system, liver or kidneys?

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4.4 The endocrine system

A **gland** is an organ that produces a useful substance that is used somewhere in the body. The release of useful substances is called *secretion*. There are different types of glands. Some glands, such as the salivary glands in the mouth, and the pancreas, secrete their substances through ducts or tubes that empty directly into where they are needed. Other glands, called **endocrine glands**, have no ducts at all. They secrete chemicals called hormones into the bloodstream. The hormones travel around in the blood causing changes to target tissue in the body. A target tissue is the part of the body that the hormone affects. Together these ductless glands make up the **endocrine system**. The major organs in this system are shown in the diagram. Some of the functions of these organs are described in the table below.

Nerve impulses produce a short, quick response in the body. Hormones are produced in tiny amounts and affect the body more slowly. However, the effects are long-lasting.



Endocrine gland	Hormone	Target tissue	Main effects
hypothalamus	vasopressin	kidneys	controls water loss from the kidneys
pituitary	thyroid-stimulating hormone	thyroid	alters the rate of thyroxine released from the thyroid
	antidiuretic hormone	kidneys	reduces the amount of water reabsorbed from the kidneys
	pituitary growth hormone	bones, muscles	controls the size of bones and stimulates muscle growth
thyroid	thyroxine	body cells	affects the rate of body metabolism, affects physical and mental development
	calcitonin	blood	decreases the amount of calcium in the blood
parathyroid (found on top of the thyroid)	parathyroid hormone	blood	increases the amount of calcium in the blood
pancreas (islets of Langerhans)	insulin	liver, most cells	reduces the level of glucose in the blood and increases the production of glycogen
	glucagon	liver	increases the level of glucose in the blood, glycogen is broken down
adrenal glands (on top of the kidneys)	adrenalin	body cells	increases the metabolism of the body to fight or run, e.g. heart rate increases
ovary	progesterone	uterus	causes thickening of uterus walls
	oestrogen	body cells	causes female sexual characteristics to develop
testes	testosterone	male reproductive system, body cells	causes sperm to be produced, and the development of male sexual characteristics

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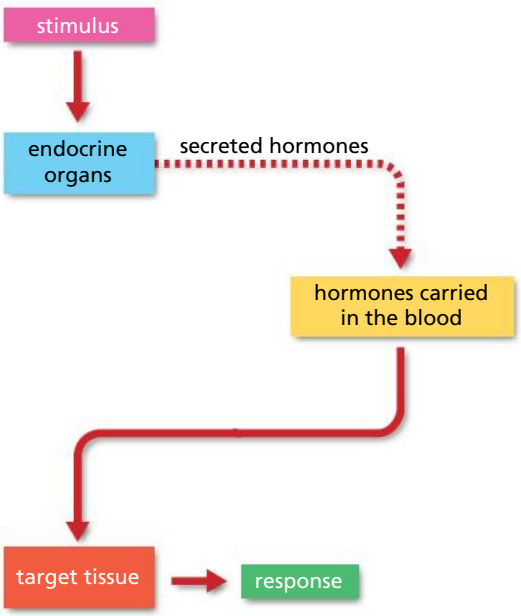
SKILL

Interpreting diagrams

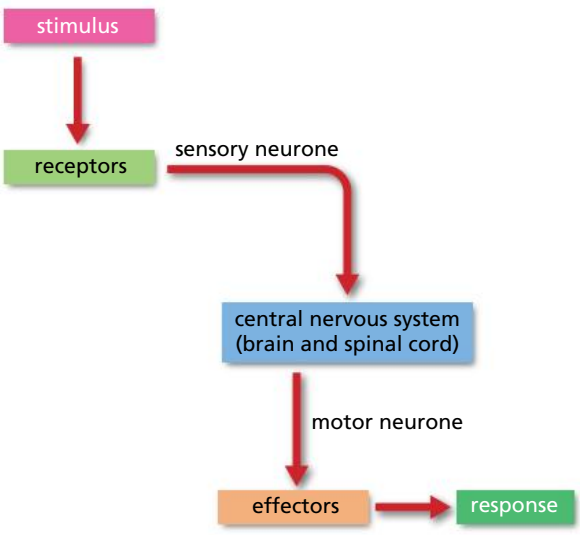
It is possible to explain and compare body systems by using diagrams. If you are asked to interpret a diagram, find the meanings of any words you don't know and make sure you study the diagram thoroughly before answering any questions.

1 The following two diagrams explain and compare the endocrine and nervous systems. Look at these diagrams and then answer the questions.

A Endocrine system



B Nervous system



a What is the difference between a stimulus and a response?

b For diagram A, what does 'secreted hormones' mean? What is 'target tissue'?

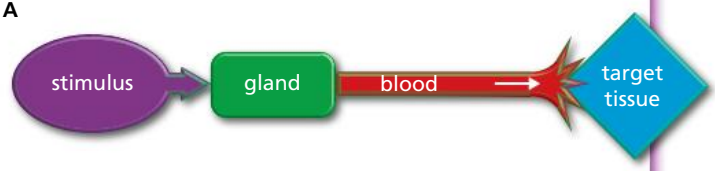
c For diagram B, what are receptors and what are effectors? Give an example of each.

d Why is a dotted line used in diagram A, but not in diagram B?

e What are three differences between the two systems? Are there any similarities? Explain.

2 Look at the three diagrams below.

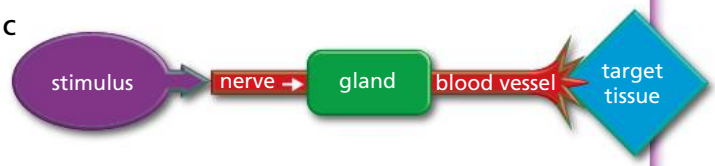
A



B



C



a Explain diagrams A and B. Do you think these diagrams adequately represent each system? Explain.

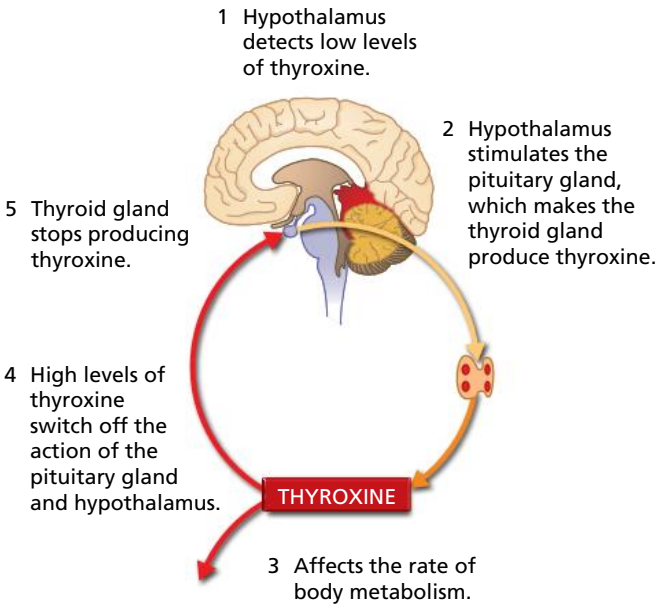
b Draw your own diagram to represent each system.

c If you are ever put in a situation in which you are in danger and need to fight or run for your life, your body releases adrenalin. The effect of this hormone is described in the table on the previous page. Which of the models above would best describe a situation where you realise you are in danger and need to run for your life? Explain.

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Feedback mechanisms

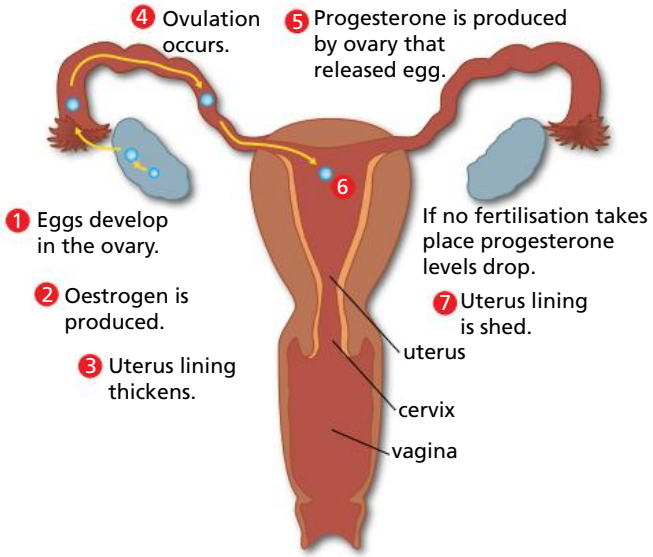
Glands in the endocrine system control other endocrine organs and how the body functions, using *feedback mechanisms*. This is where information that is sent out in a system returns to the same source, providing information (feeding back) to the source about what is going on in the system. This then affects the outputs of the system. For example, the hypothalamus and the pituitary gland in the brain monitor the levels of thyroxine in the body. The thyroid gland produces thyroxine, as shown in the diagram below.



The menstrual cycle

Progesterone and oestrogen are two hormones that control the menstrual cycle. At the beginning of this cycle the lining of the uterus is thin. As eggs start to develop in the ovary, oestrogen is produced, causing the lining of the uterus to thicken. When one egg has developed fully, it is released from the ovary and this is called *ovulation*. The part of the ovary that released the egg then produces progesterone. This hormone prepares the uterus to accept the egg if it is fertilised (joined with a sperm). About 11 days after ovulation, if the egg is not fertilised, progesterone production falls and the lining of the uterus is shed. This is commonly called 'having a period'. The hypothalamus in the brain detects the falling levels of progesterone. It activates the pituitary gland to produce a hormone to start the development of eggs in the ovaries again. The cycle is then repeated.

The contraceptive pill contains synthetic compounds that prevent the release of hormones needed for eggs to develop and ovulation to occur.



INQUIRY 7 Writing a poem

Here is the start of the poem that describes the differences between the endocrine and nervous systems. Add two more verses to finish it.

In the nervous system, messages are fast.
They skip along a neuron and across a synapse.
In the endocrine system, messages are slow.
Hormones are messengers, from glands they go.

Over to you

1. What is an endocrine gland and how is it different from other glands in the body?
2. Explain how the changes produced by adrenalin help the body face danger.
3. Name the hormones that control:
   - **a** the rate of body metabolism
   - **b** the menstrual cycle
   - **c** the development of sexual characteristics in males.
4. Draw two overlapping circles. In one circle write down all the points you know about the nervous system. In the other circle write down what you know about the endocrine system. In the overlapping parts of the circle note any points about the nervous and endocrine systems that are the same.

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4.5 Plant hormones

Plants also regulate and control growth with hormones. These hormones are produced by new leaves, shoots, roots, developing seeds, and fruit.

Auxins

Auxin comes from the Greek word *auxe* meaning 'to increase'. It describes a group of plant hormones that are made in the growing tip of shoots and roots. As a shoot grows, it releases auxins that move down the shoot, causing the cells underneath the tip to *elongate* (get longer). This increases the length of the stem. It is possible to make plant cuttings grow roots by dipping them in hormone powder that contains auxins.

The growing bud at the top of a plant stem produces other auxins that stop the growth of buds at the sides of the stem. This makes sure the plant grows upwards.

Auxins also cause the shoot to bend towards light. This is called *phototropism*, from the Greek words *photo* meaning light and *trope* meaning to turn. Charles Darwin in 1880 was one of the first people to investigate phototropism, by covering the growing tip of grass seedlings with tiny black caps. The covered tips did not turn towards the light. So Darwin suggested that the tip detected the light and transmitted something to other parts of the stem, causing it to bend. It is now known that auxins cause this to happen.

Plant shoots and roots respond to gravity. Auxins cause shoots to bend upwards or away from the effect of gravity, and cause root tips to bend downwards. This is called *geotropism* or turning caused by gravity.

Auxins start fruit development in fertilised flowers, and the seeds inside the fruit also release auxins to continue the growth of the fruit.

In deciduous plants (those that lose their leaves in winter), auxins are produced in the growing leaves. When auxin levels decrease, the leaves fall from the trees.

Gibberellins

Gibberellins (jib-er-EL-ins) are another group of plant hormones that cause growth. When added to dwarf plants, gibberellins cause rapid stem growth. This can be seen in plants such as cabbages. When buds stop developing in winter and seeds don't grow, this is called *dormancy*. Gibberellins break the dormancy of buds and seeds in some plants, causing them to grow. They also cause some plants to flower.



A normal bunch of grapes (top) and one treated with gibberellins (below)

Cytokinins

Cytokinins (site-oh-KYE-nins) help cell division in plants. They seem to work together with auxins to determine what role a plant cell will perform. Buds form when there are more cytokinins than auxins present. Roots develop when there are more auxins than cytokinins.

Auxins, gibberellins and cytokinins promote growth in plants. There are also hormones that do the opposite. For example, abscisic acid causes seeds and buds to become dormant ready for winter. A similar thing happens in your body. For example insulin *reduces* the level of glucose in the blood, whereas glucagon *increases* it. The balance of these hormones helps maintain control in the body.

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Ethylene

Fruit ripens because of the hormone ethylene. When a fruit reaches its right size, ethylene increases the chemical reactions that occur in the fruit, producing large amounts of carbon dioxide, and the process of ripening begins. Ethylene can also start buds and seeds growing after winter, and produces flowering in some plants. It can also cause growth in stems and roots.

It is often stated that one over-ripe apple can make the whole barrel go bad. This is because a ripe piece of fruit gives off ethylene gas and causes the other fruit around it to ripen faster.

How plants flower

Most plants will only flower if day and night are a certain length. Some plants, such as petunias, need short nights and long days to flower. Other plants, such as chrysanthemums and poinsettias, flower after long nights and short days. Some plants, such as dandelions, carnations and sunflowers, can flower in either condition. It is believed that a hormone produced in the leaves of plants moves to the buds and causes them to produce flowers when the day/night length is right. Scientists infer that plants must be able to detect light differences in order to flower.



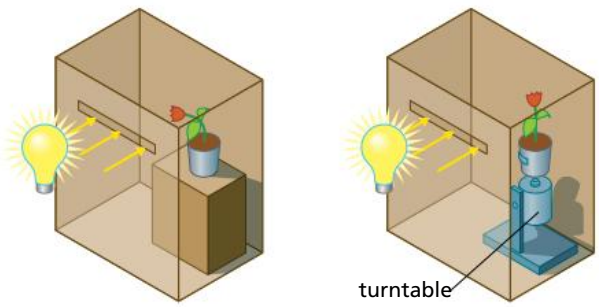
The poinsettia needs short days and long nights to flower. In Australia these striking red and green plants are grown commercially in a controlled environment so that they flower at Christmas.

INQUIRY 8 **Plant responses**

As a group, read the following information and answer the questions below.

Experiment 1

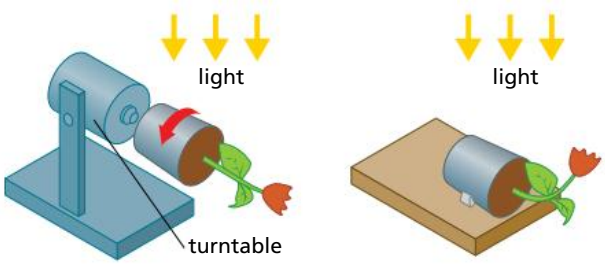
Two identical seedlings of similar height and number of leaves were placed in boxes as pictured. The only light entering the boxes came from slits cut in the sides. One of the seedlings was placed in the corner of the box. The other was placed on a turntable that rotated four times per hour. The stationary seedling bent towards the light. The rotating seedling grew straight up.



1. Would you have expected these results? Explain.
2. What is the word used to describe bending towards light? How does this happen?
3. What was being tested in this experiment?
4. What variables were controlled to make the experiment a fair test?

Experiment 2

Two identical seedlings of similar height and number of leaves were placed on their sides as pictured. One of the seedlings was placed on a turntable that rotated four times per hour. The stationary seedling bent towards the light above it, but the rotating seedling grew straight.



1. What was the aim of this experiment?
2. Explain whether the results were expected.
3. What was tested and which variables were controlled?

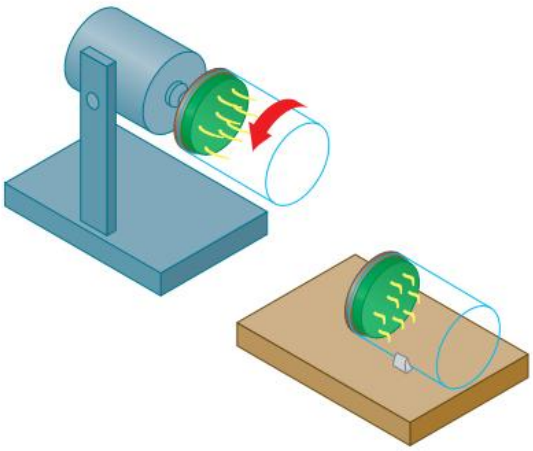
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INQUIRY

8 continued

Experiment 3

Bean seeds that had started to grow roots were pinned to pieces of floral foam (green material used by florists) and placed in jars on their side as shown. One of the jars was attached to a turntable that rotated four times per hour. The stationary bean roots bent downwards. The rotating bean roots didn't bend.



1 Explain whether the results were expected.
2 What was tested and which variables were controlled?
3 What is Experiment 3 testing that is different from Experiment 2?

Over to you

1 List one major function that auxins play in regulating the growth of plants. Do the same for gibberellins and cytokinins.
2 Why do plants need hormones that have the opposite effects to those listed in Question 1?
3 What is the difference between phototropism and geotropism? What do you think hydrotropism means?
4 Plants don't have a nervous system. Suggest a reason for this.
5 Gibberellins produce long stems in dwarf plants. Do you think these plants would normally produce gibberellins? Explain your answer.
6 It is said that shoots show negative geotropism and roots show positive geotropism. What do you think is meant by these two terms?

INVESTIGATION

3 Design an experiment

Aim

To design your own experiment to test one of the following:

1 If ethylene is removed from the fruit as it is produced, the fruit won't ripen.
2 Some fruits such as bananas give off more ethylene than others, and cause other fruits to ripen faster.
3 A bag of unripe apples containing one over-ripe apple will ripen faster than a bag full of unripe apples.
4 A black cap on the growing tip of a shoot from a broad bean seed will stop the shoot from growing. Will a transparent cap have the same effect?
5 The colour of light affects the germination and growth of seeds and whether a plant will flower.
6 Bananas cause the eyes of potatoes to grow and start to shoot more quickly than normal.
7 Is it the temperature or the number of hours of daylight that causes a bulb to start growing? (A bulb is a modified stem that is used for reproduction and formed underground. Tulips and daffodils produce bulbs at the end of their growing season and re-grow in the spring from the nutrients contained in the bulb.)

Risk assessment and planning

What are you going to do? What household equipment can you use that is easy to get hold of? Make a list and present your plan to your teacher for approval.

Results, discussion and conclusion

Present your results to the class and assess the effectiveness (success) of your investigation and whether your design could be improved.

PROBLEM SOLVING

How are you going to convince the school community to say 'No' to drugs? Can you make a presentation at a school assembly? Do you have a school newsletter in which you can present information to students and parents? Complete your chapter problem now.

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THINKING SKILLS

1 The following photo shows a structure from a kidney tubule. Which structure is it? Explain.



2 Why do you think there is only a small area in the brain that controls the muscles in the back, but a very large area that controls the muscles in the hands and the mouth?

3 It is possible to be totally occupied with watching TV or reading a book, and to not hear or respond to other stimuli around you. What part of the brain causes this?

4 The cerebral cortex is divided into two hemispheres. They are connected by a bundle of fibres called the *corpus callosum*. Speech, naming objects, logical thinking and reasoning are controlled by the left hemisphere of the brain. Understanding and making sense of the world, artistic ability and musical ability are controlled by the right side of the brain. Movement and feeling on the right side of the body are controlled by the left hemisphere. Movement and feeling on the left side of the body are controlled by the right hemisphere. What would happen if the corpus callosum was cut? Could you:

a name an object?

b talk?

c move your right hand to paint a picture?

d solve a problem?

5 Cats that have a certain part of their brain stimulated eat uncontrollably. Which part of their brain is likely to be stimulated?

6 Hormones and nerves affect a person's behaviour. However a person's behaviour can also affect hormones and nerves. Give an example of how this is possible.

7 Iodine is needed for the thyroid gland to work correctly. Iodine is also found in thyroxin. What would happen to the body if a person did not have iodine in their diet? What would happen to a person with an overactive thyroid?

8 People who have a disease called diabetes cannot regulate the levels of glucose in their blood. They do not produce enough insulin and need to inject themselves with insulin to keep their blood glucose levels constant. Insulin causes body cells to take in glucose. It also causes the conversion of excess glucose to fat.

a What do you predict would happen to blood glucose levels after a person had eaten, if they did not have insulin? Why?

b What would you expect to find in a diabetic's urine if they did produce enough insulin? Why?

9 Write a story called 'I am Gareth's brain' or 'I am Josephine's kidney' or 'I am Ming's pituitary gland' or ...

10 If women drink the same type of alcoholic drink in the same quantity as men, alcohol enters their blood faster. Find out why this occurs. Design an anti-alcohol advertisement that targets women.

11 It is possible to condition somebody to respond automatically to a stimulus. Research the work of a Russian biologist called Pavlov to find out how a *conditioned* response like this works.

12 Use the internet to find out about one of the following:

a diseases of the nervous system such as:

- encephalitis
- meningitis
- multiple sclerosis (MS)
- cerebral palsy
- Bell's palsy

b steroids and how they work

c what is involved in being an organ donor

d what grey matter and white matter are in the brain

e how a plant nursery gets plants to flower out of season.

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 There are four main types of drugs: stimulants, _____, hallucinogens and others. All these drugs are harmful to the body and can cause death.

2 Organs such as the liver and the kidneys keep the concentration and composition of body fluids constant. Another name for this is _____.

3 The main functions of the _____ are to regulate blood sugar, remove amino acids, produce bile and convert poisonous substances into less harmful ones.

4 The term used to describe all the chemical processes that take place in your body cells is _____.The _____ excrete the products of metabolism.

5 The kidneys are made up of a million kidney _____. Each glomerulus acts like a _____, stopping blood cells and proteins from passing into the tubule.

6 The main excretory product of the breakdown of proteins in humans is _____.

7 The nervous system is made up of cells called _____. Sensory neurons carry information towards the _____.

8 _____ are chemicals that travel in the blood.They are secreted from ductless glands called _____ glands.

9 Hormones are produced in the _____ parts of a plant. _____ are a group of hormones that increase stem length.

auxins
brain
depressants
endocrine
filter
growing
homeostasis
hormones
kidneys
liver
metabolism
neurons
tubules
urea

Self-management

Making your own crossword puzzle

A crossword puzzle is made up of words that go down the page, interconnected with words that go across the page. All the clues for the words going down are presented together, with each word numbered. All the clues for the words going across the page are presented in the same way. Follow the steps below to make a crossword puzzle of words from this chapter.

1 Write down 10 words from those listed in bold in this chapter.

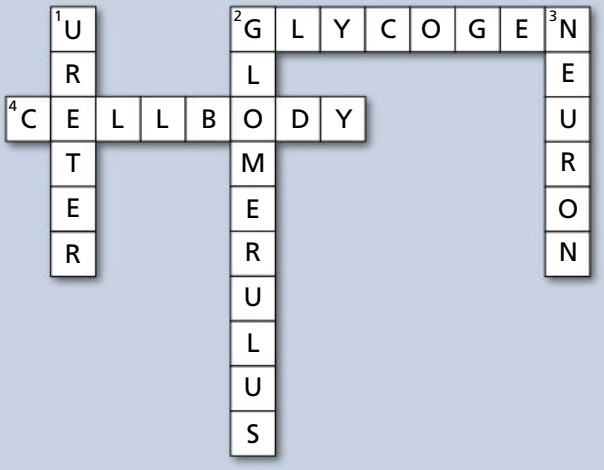
2 Put the largest word down the middle of the page and link another word to it using a common letter, as shown. Link other words to the ones you have, where you can.

3 Draw squares to represent each letter and number the first square of each word. Start at the top left and number the first word.Then work your way down, from left to right, whether they are horizontal or vertical words.

4 Now write a clue for each numbered word in your crossword.

5 List all the clues for the words *across* the page together. Do the same for the words *down* the page.

6 Swap your finished crossword with a partner. Can you complete another group's crossword? Ask your teacher for help if there are any words you don't understand.These words just may appear on your test.



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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 Match the following words with their correct meanings:

homeostasis, hormone, metabolism, auxin, synapse, excrete

a A hormone produced by the growing tip of a shoot

b To remove unwanted substances from the cells of the body

c All the chemical reactions that take place in body cells

d A space that occurs between the end of one neuron and the beginning of the next

e A chemical produced in ductless glands

f Maintaining a constant internal balance in the body

2 The substances most likely to be excreted in urine are:

A amino acids, urea and excess water

B excess water, urea and salts

C blood cells, amino acids and urea

D glucose, amino acids and excess water

3 A reflex action is best described as:

A a link between a motor neuron and the brain

B a bundle of neurons forming a nerve

C a direct link between a receptor, sensory neuron, motor neuron and effector

D a link between the brain, a sensory neuron and a receptor

4 The best way to describe the difference between the endocrine and nervous systems is:

A one acts more quickly than the other

B you can't move your body without nerves

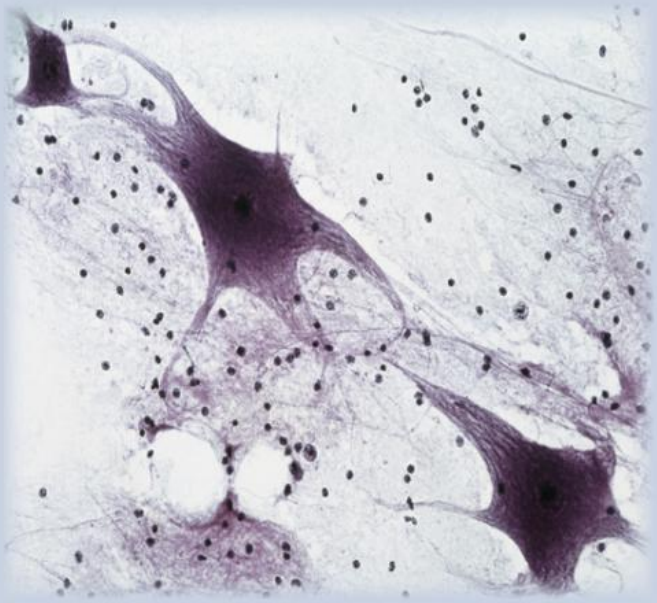
C one relies on hormones, the other on neurons

D both need a stimulus to work

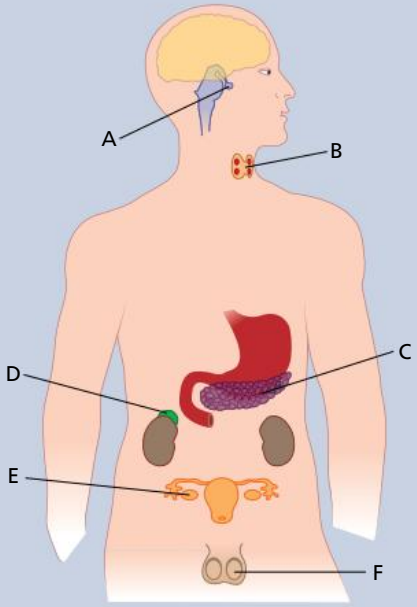
5 Why do animals have a nervous system and an endocrine system to help coordinate their bodies? How do plants coordinate their activities?

6 The area of a horse's brain that controls the skin around the nostrils is almost as large as the area of the brain that controls the rest of the horse's body. Suggest a reason for this.

7 What type of cell is shown in the photo below? Explain your reasoning. List any parts you can identify and explain their function.



8 Label the glands on the diagram below and name one hormone you would find in each.



9 What is the difference between:

a a ureter and a urethra?

b a cloaca and a urethra?

c a sensory neuron and a motor neuron?

d secretion and excretion?

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5


A child born with rubella

Disease

By the end of this chapter you will be able to …

Knowledge and Understanding

- outline some responses of the human body to infectious and non-infectious diseases (LW1c)
- discuss how the values and needs of society can influence the focus of scientific research (LW1e)

Skills–Working Scientifically

- plan and select appropriate methods to collect reliable data (5.2a)
- select and safely use laboratory equipment, either individually or in a group (6a)
- detect bias when interpreting information in tables and graphs (7.2f)
- discuss whether vaccination for children should be compulsory (9a)

LITERACY FOCUS

antibiotic
antiseptic
autoimmune diseases
disinfectant
hepatitis B
immune system
immunisation
immunity
infectious diseases
interferon
lymphocytes
macrophages
malaria
micro-organisms
mutation
pathogens
phagocytes
sepsis
strains of bacteria
vaccination

Focus for learning

Mention the words 'needle' or 'vaccination' and most people shudder at the thought. In days gone by, children suffered from childhood diseases such as measles (M), mumps (M) and rubella (R), which today are uncommon because of the MMR vaccination. As a student in Year 9, you may have already received your final MMR vaccination, which is recommended between the ages of 10 and 16. You may be vaccinated for polio, diphtheria and tetanus before finishing school.

These are not the only diseases you will face in your lifetime. Every year we are bombarded by cold and flu viruses, some of which are quite serious. If you travel overseas, you will need to protect yourself from diseases such as cholera, hepatitis and malaria. Also diseases such as herpes, syphilis, gonorrhoea and AIDS (acquired immunodeficiency syndrome) can be passed on through sexual contact.

Do you have a dog? If so, you will know that your dog should be vaccinated against diseases such as distemper and parvovirus. You should also worm your dog to prevent it from suffering from heartworm, hookworm or roundworm.

Disease-causing organisms (**pathogens**) are everywhere. You can avoid many of these by eating a healthy diet, exercising regularly and maintaining good hygiene. This means showering each day and washing your hands after you go to the toilet and before you eat.

This chapter explains what disease is and what causes different diseases and gives information on some deadly and not-so-deadly diseases. These are presented in information boxes throughout the chapter.



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PROBLEM SOLVING

Herbal remedies

Your task is to design an experiment to see if herbal remedies can slow or prevent the growth of disease-causing organisms. For example, you could test echinacea, camphor, eucalyptus oil or tea-tree oil. You could check whether roses, lavender, dandelions, daisies or marigolds contain substances that can be used to control disease-causing organisms. Honey is often taken to help with colds and flu. Garlic helps fight infections and grape seed oil helps wounds heal faster. Could you test these substances?

You will first need to read this chapter to get a background on disease. The investigations will give you some ideas for your own experiment. Remember, you must not eat or drink anything you make. You must also discuss with your teacher how to dispose safely of agar plates if you use them.



5.1 What is disease?

A disease is any impairment that prevents the body functioning as it should. People are usually sick when they have a disease, and for diseases such as the common cold and flu, this is the case. However, you may not feel sick when you have a disease. For example, hepatitis B is a liver disease that can cause liver cancer. People who have hepatitis B (see box) may have no *signs* (what they can see) or *symptoms* (what they can feel) of the disease. This is also true for AIDS. It may take many years for such a person to show signs of AIDS. This is why it can be so easily passed on or transmitted to others without them being aware of it.

Hepatitis B

Type: hepatitis B virus, but other viral types (e.g. A, C, D and E) cause other types of hepatitis infection

Transmission of the disease: The virus is spread by coming into contact with an infected person's blood, or through sexual contact. It is often spread by drug users who share needles.

Signs and symptoms: Some people show no signs or symptoms, whereas others have fever, nausea, jaundice (yellow colour of the eyes and skin) or abdominal pain. Most people make a full recovery. Others become carriers and may develop liver cancer or cirrhosis (scarring of the liver), which can lead to liver failure and death in later life.

Prevention and/or treatment: Vaccination.

Types of disease

There are a number of different types of disease. *Non-infectious diseases* caused by lifestyle choices include heart disease and cancer. Down syndrome is a non-infectious disease that is inherited. **Infectious diseases** are those that are caused by *micro-organisms*, or microbes. These are bacteria, viruses and organisms such as fungi and protozoa.

Non-infectious diseases

1 *Lifestyle diseases* can be caused from such things as over- or under-eating, drinking alcohol, smoking, lack of exercise or a diet high in fat. Examples include heart disease, stroke, emphysema and cirrhosis.



A person with anorexia nervosa. These people think they are overweight and keep dieting. Many feel they have no control over their lives so they control their weight. Use the internet to find out whether anorexia nervosa and bulimia are diseases.

2 *Genetic diseases* are those you inherit from your family. Haemophilia, thalassaemia and Down syndrome are genetic diseases.

3 *Immunologic diseases* result when the body's defence system malfunctions. For example, the body may react to substances such as dust and pollens in the air, causing hay fever. Or it may react to foods such as gluten and dairy foods, causing eczema. An **autoimmune disease** is also an immunologic disease. In such cases the body reacts against its own body tissues. Rheumatoid arthritis and glomerulonephritis (glo-MER-u-lone-neph-RITE-us) are examples.

Glomerulonephritis

Type: autoimmune

Transmission of the disease: This disease affects the glomeruli of the kidneys so that red blood cells and protein are not filtered from the urine. These waste products then build up in the blood. The disease can be caused by a secondary response to infection in the body, such as tonsillitis, or an autoimmune reaction.

Signs and symptoms: Protein and blood in the urine, swelling in different parts of the body, tiredness and lethargy, headache.

Prevention and/or treatment: In some cases the disease is temporary and treatment produces a full recovery. In other cases permanent kidney failure occurs.

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4 *Diseases caused by incorrect body function* occur when a part of the body does not work properly, causing disease. For example, cancer occurs when cell division is uncontrolled. In this situation a mass of cells forms a tumour, or lump, which affects the body's functioning. Another example is diabetes, where the pancreas is unable to produce enough insulin for body cells to take up glucose.

5 *Diseases caused by parasitic organisms* can be due to infestation with worms, lice, ticks or fleas. The word parasite is used to describe any organism that lives off another (the *host*). Heartworm and tapeworm are examples.

Infectious diseases

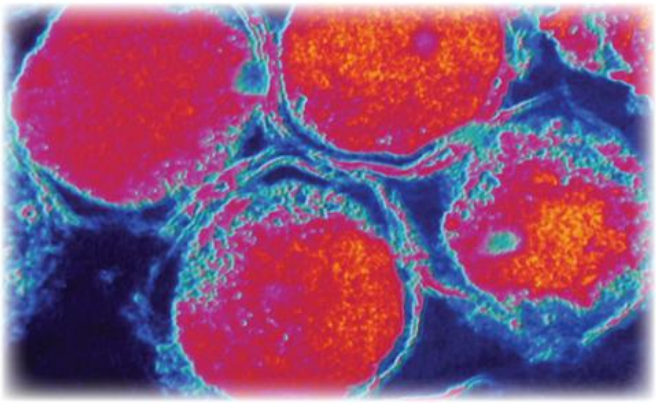
The different types of micro-organisms that cause infectious diseases are presented in this table.

Type of microbe	Characteristics	Example
Protozoa	Unicellular organisms with a nucleus, cell wall and no chlorophyll.	Malaria
Fungi	Some are unicellular but most are multicellular. They have a nucleus and cell wall, but no chlorophyll.	Thrush
Bacteria	Single-celled organisms with no nucleus, only a cell wall.	Chlamydia
Viruses	Not a cell, simply genetic material with a protein coat. Can only be seen with an electron microscope.	Influenza

Micro-organisms cause disease in different ways. Some reproduce in such large numbers that they destroy cells and tissues. Others produce a poison called a *toxin*, which is released from the microbe into the host's tissues.

INQUIRY 1 Pathogens

The table above shows only one example for each type of micro-organism. Copy this table and add a fourth column with the heading 'Effects of disease'. As you work through this chapter, add other examples of diseases to the table from the information boxes provided. Give a brief description of the effects of each disease in the fourth column.



Chlamydia is a sexually transmitted bacterium.

Natural body defences

Pathogens are spread easily from one person to another. They can be present in the nose, mouth and lungs of an infected person. If the person sneezes or coughs, droplets containing the pathogen are spread to others. They may land on food or on objects such as door knobs and eating utensils. Pathogens can be present in faeces, so if a person does not wash their hands properly after going to the toilet, pathogens can be spread to anything they touch. A contaminated water supply can easily spread pathogens. Diseases such as cholera and typhoid are passed on this way.

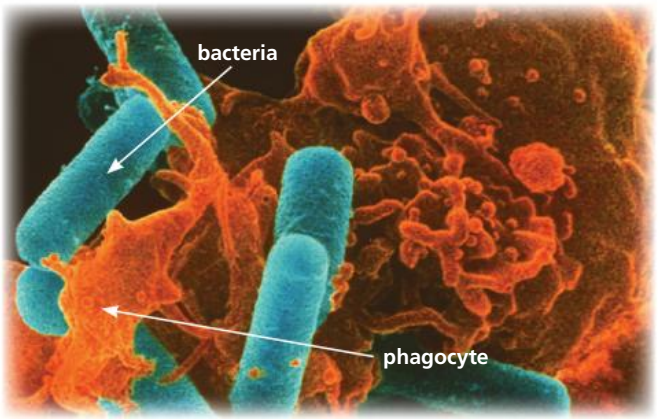
To get into the body, micro-organisms must get through the body's defences called the **immune system**. You are covered with a dead layer of skin, which is the first barrier that prevents pathogens entering your body. This dead skin layer is water-repellent and slightly antiseptic because of the oil that is secreted on it. As dead cells are rubbed off, they are replaced by the living cells underneath. A thin, transparent layer of skin called the *conjunctiva* covers your eyes. Blinking prevents pathogens, dust and dirt from entering your eyes. Your eyes are also washed with tears.

The nose is another place where pathogens can enter the body. They are trapped in the mucus that lines the nasal passages and the trachea. This mucus is moved along by *cilia*, which are fine, hair-like threads of cytoplasm that all beat in one direction. Cilia prevent pathogens reaching the lungs. Most microbes that are swallowed are killed by the hydrochloric acid environment of the stomach.

Once the skin is cut, pathogens have an easy entry to the body. To stop this, blood washes the cut area and platelets cause blood clotting. A mesh of

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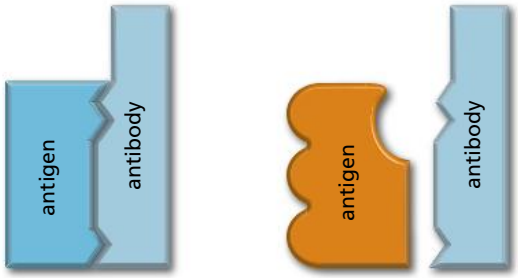
fibrinogen, a blood protein, forms across the break and prevents more blood cells from escaping. White blood cells called **phagocytes** (FAG-o-sites) swallow up any bacteria. Their action causes the wound to become inflamed. Any dead cells produced form pus. If the numbers of pathogens are too large for the phagocytes to control, then the body starts producing antibodies.



Antibodies and antigens

The invading micro-organisms or the toxins they produce are called **antigens**, and their presence in the body stimulates the production of **antibodies**. An antibody is a protein that is produced to destroy an antigen. When the antigen first invades, your body may take a few days or weeks to produce antibodies to fight it. However, once an antibody has been made, your body can remember how to make it again. The next time the same antigen appears the body can quickly produce the correct antibody and prevent you from getting sick again. When this happens you are said to have **immunity** or resistance to the disease caused by the antigen.

Antibodies are specific, which means that only one particular type of antibody can destroy one particular type of antigen. It is believed that antibodies have binding sites that only fit one antigen, like a key only fits into one lock. For example, an antibody that destroys the bacteria that cause whooping cough cannot destroy the bacteria that cause meningitis. For some diseases such as whooping cough and chickenpox, once the antibody has been made the first time, the body remembers how to attack the antigen in the future. In other words, the body develops a lifelong immunity. For diseases such as the common cold and flu, the antigens are constantly changing during reproduction, so the body may not recognise the antigen when it appears again.



Antibodies are specific. An antibody for one antigen does not affect all antigens.

Lymphocytes

White blood cells called **lymphocytes** (LIM-foe-sites) make antibodies. Lymphocytes are found in blood and lymph (a slightly yellow fluid that drains from body tissues), as well as the bone marrow, tonsils, liver and spleen. Once an antigen is detected, lymphocytes in the bone marrow start the process to produce antibodies. Some antibodies stick the antigens together and hold them in clumps. Large cells called **macrophages** then flow around and swallow up (engulf) the clump of antigens. The lymphocytes also produce cells that remember the antigen so it can be attacked the next time it appears.

How to avoid diseases

At certain times in your life you will get a disease. This could be the common cold or a disease that is more serious. However, you can take some simple steps to reduce the number of times you are unwell. Eat healthy food and carry out regular exercise to boost your immune system. Wash your hands after going to the toilet and before eating or preparing food. Avoid touching your nose and mouth or rubbing your eyes. Shower each day and keep your hair clean. Wash your clothes after you have worn them, and change towels and bedding regularly. Dispose of garbage correctly and store food so that other organisms, such as rats, mice, flies and cockroaches, cannot get to it. Do not reheat cooked meat or buy smallgoods (salami and ham) from a place where raw meat is kept in the same cabinet. Do not eat takeaway food that is supposed to be hot if it is served cold.

Safe sex practices, such as using condoms and avoiding multiple sexual partners, can reduce the chance of getting a sexually transmitted disease.

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INVESTIGATION

1 Dead microbes

Aim

To investigate how to control microbes.

Risk assessment and planning

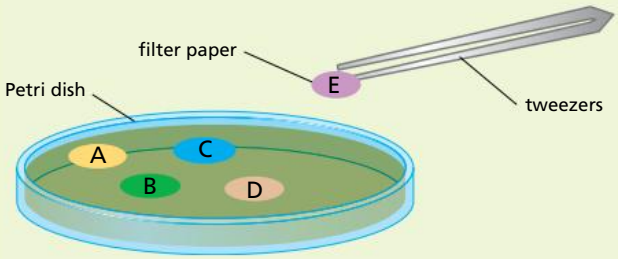
Discuss with your teacher how to safely use and dispose of agar plates. Also discuss why you should not open any agar plates once micro-organisms have grown on them.

Apparatus

- 5 small pieces of filter paper (size of a 5c coin) soaked overnight in distilled water (A), iodine (B), alcohol (C), Pine-O-Cleen (D) and bleach (E)
- dropping bottle of soil mixed with water
- agar plate
- permanent marker
- incubator
- tweezers
- sticky tape

Method

1. Rinse the surface of an agar plate with a mixture of soil and water. Tip off any excess water. Do this without lifting the lid of the agar plate too high and without placing the lid down on the bench.
2. Using tweezers, place the pieces of filter paper soaked in different solutions on the agar plate.
3. Seal the agar plate with sticky tape and place it in a warm incubator set at about 25°C for a few days.



Discussion

1. Which solution prevented the growth of soil microbes? How do you know?
2. Why are disinfectants such as Pine-O-Cleen and bleach used in our homes?
3. Why was distilled water used on one of the pieces of filter paper?

INQUIRY

2 Your health

1. What do you do each day to safeguard yourself against disease? What else could you do?
2. What diseases have you had? What type of diseases were they?
3. Have any family members had a disease? What type were they?
4. Have you been vaccinated? If yes, when were you vaccinated, and for what diseases?
5. Have you travelled overseas? Have you been vaccinated or taken preventive medicine, such as malaria tablets, to travel? Why did you have to take this medicine?
6. Do you have a dog or a cat? What worming tablets do you give them? Have they been vaccinated? If so, for what?

Over to you

1. What is the difference between an infectious and a non-infectious disease? Give examples.
2. What is the difference between a parasite and a pathogen? Give an example of each.
3. What is your immune system? Draw a diagram to show how it works.
4. Write a short story to explain to a child in primary school what antibodies and antigens are and how they work.
5. What types of diseases are anorexia nervosa, hepatitis B and glomerulonephritis? Explain.
6. How has the use of disinfectants contributed to better health?
7. Find out what the difference is between an antiseptic and a disinfectant. When would you use these chemicals?

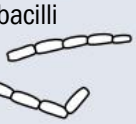
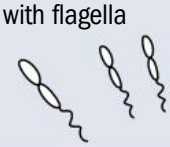
PROBLEM SOLVING

How could you use Investigation 1 to test your own herbal remedy or a range of remedies? What solutions could you test? What precautions do you need to take when using agar plates and growing microbes?

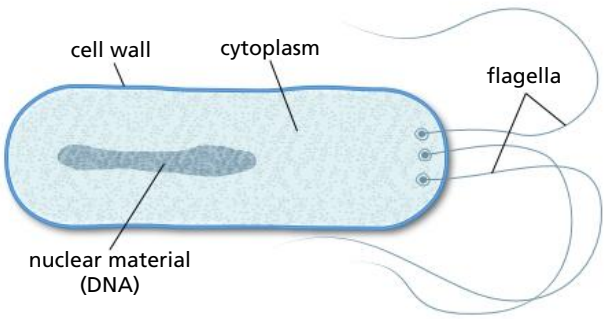
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5.2 Diseases caused by bacteria

Bacteria are single-celled organisms much smaller than your own body cells. Bacteria are only about one thousandth of a millimetre in diameter. There are different-shaped bacteria. Rod-shaped ones are called *bacilli* (singular *bacillus*). Round-shaped ones are called *cocci* (*coccus*) and spiral-shaped ones are called *spirilla* (*spirillum*). When bacteria join to form chains or clusters (see table), each cell is still an independent organism.

Bacteria	Structure	Diseases
Cocci	coccus (single cell)  diplococci (pairs of cells)  streptococci (chains)  staphylococci (clusters) 	gonorrhoea, blood poisoning, boils, dysentery, tonsillitis, scarlet fever, pneumonia, sore throat
Bacilli	bacillus  diplobacilli  chains of bacilli  bacilli with flagella (whip-like structures used to move the bacilli) 	tetanus, anthrax, tuberculosis, bubonic plague, typhoid, leprosy, whooping cough, diphtheria, salmonella
Spirilla	spirillum  spirilla with flagella 	cholera, meningitis

The difference between bacteria and your body cells is that bacteria have a cell wall. This encloses the bacteria and protects each bacterial cell from damage. The cell walls of bacteria are made up of a different material from that in plant cells. Bacteria contain nuclear material such as DNA, but this does not have a membrane around it as your cells do.



Structure of a bacterium

Bacteria are known to cause diseases such as cholera, diphtheria, the plague, gonorrhoea, leprosy, tetanus, scarlet fever, whooping cough, meningitis and typhoid. Some very small types of bacteria, called rickettsias and chlamydias, cause disease too. Many plant diseases are caused by bacteria (for example, fire blight of pears).

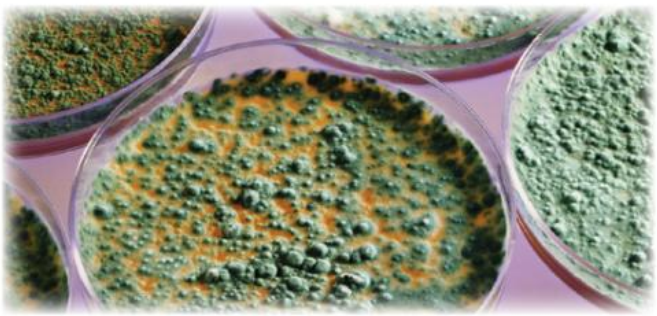
A bacterium divides by copying the material in its nuclear region. This separates and moves into two different parts of the cell. A membrane and wall grow between these parts and divide the cell. In the right conditions a bacterium can divide into two in 20 minutes. This is why food poisoning is so common. *Salmonella* bacteria that cause food poisoning can be present on food. In small numbers, they are easily killed by the body's defences, such as hydrochloric acid in the stomach. Food left out of the refrigerator on a warm day can provide the right conditions for bacteria to grow rapidly. In large numbers, these bacteria invade the body, causing vomiting and diarrhoea, a sign of the disease.

Most bacteria require oxygen to live but some can survive without it. These bacteria carry out fermentation to provide their energy needs and, in the process, new substances such as acetic acid (vinegar) and alcohol are produced. Botulism, an often fatal disease of the nervous system, is caused by eating contaminated food. The bacteria that cause botulism can live without oxygen and survive in sealed containers.

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Control of bacteria

Bacteria can be controlled with chemicals. *Disinfectants* are chemicals that are used to kill bacteria on surfaces. *Antiseptics* are chemicals that kill bacteria on your skin. *Antibiotics* are also effective. The most well-known antibiotic is penicillin, which is produced by a green mould. It is effective because it stops the bacteria from making the substance needed to build their cell walls, so they are unable to reproduce.



Penicillium mould growing on an agar plate

Bacteria themselves can be used to produce antibiotics such as streptomycin and neomycin. Antibiotics can be made artificially in a laboratory by copying the structure of antibiotics made by bacteria.

The problem with antibiotics, however, is that many bacteria are becoming resistant to them, which means that they have been exposed to the antibiotic and survived being killed by it. This means they are genetically different from the bacteria that have been killed by the antibiotic. They have then reproduced and passed their genes and resistance on to their offspring. You will learn more about this in Year 10.

Syphilis

Type: bacteria

Transmission of the disease: It is passed on through sexual contact with a person who has the disease.

Signs and symptoms: Some people do not know they have the disease. In others, painless sores appear at the site of the infection, for example, the mouth and genitals. These disappear in about 4 weeks. Without treatment the disease develops into a body rash, fever, hair loss and tiredness. If left untreated the disease may affect the brain or heart, causing blindness and death.

Prevention and/or treatment: Safe sex practices can prevent this disease. Antibiotics such as penicillin can cure it.

Gonorrhoea (GON-ah-REE-a)

Type: bacteria

Transmission of the disease: The disease is passed on by sexual contact. An infected woman can pass on the disease to her baby at birth.

Signs and symptoms: Some people have no signs or symptoms. In some males, a yellow discharge occurs from the penis and urinating is painful. In women, a discharge may occur from the vagina and urinating is painful. There may also be irregular bleeding and abdominal pain. If left untreated it can spread to the heart, joints and brain. In women, gonorrhoea can result in pelvic inflammatory disease (PID), which causes infertility.

Prevention and/or treatment: Safe sex practices can prevent the disease. Antibiotics can cure it.

Cholera

Type: bacteria

Transmission of the disease: For the first 7–14 days, the infection is passed on through faeces, which can be found in water and food. The bacteria can survive on food for up to 5 days, and resist freezing.

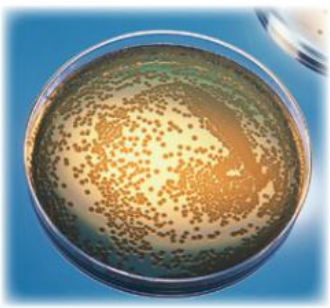
Signs and symptoms: Some people have no signs or symptoms. Others experience vomiting and large amounts of watery diarrhoea, which can lead to severe dehydration if left untreated.

Prevention and/or treatment: A person can be given antibiotics and fluids. There is a vaccine.

INQUIRY 3 Microbes around us

You will need: agar plate, sticky tape, marker

1. Leave the lid off an agar plate for 10 minutes in a place where you think you will find bacteria.
2. After 10 minutes, collect the plate, seal it with sticky tape and label it on the bottom.
3. Leave the agar plate in a warm incubator set at about 25°C for a few days, then examine it. With your teacher's help, identify any microbes that appear.



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INVESTIGATION

2 Passing on microbes

Aim

To see how easily microbes can be transmitted from one organism to the next.

Risk assessment and planning

1 Remember not to eat anything in the laboratory, and dispose of any food you use properly.

2 Read through the experiment and predict which apple will start to decay first. Give a reason for your prediction.

3 Draw up a table to record your results.

Apparatus

- 4 good ripe apples and 2 decaying ones
- incubator
- needle inserted in a cork
- Bunsen burner equipment

Method

1 Apple 1: Hold the needle by the cork and sterilise it in a Bunsen burner. (Leave it in the flame until it is red hot, then let it cool.) Insert the needle into the decaying part of a bad apple, then insert it into a good apple. Sit the inoculated apple in an incubator at 25°C.

2 Apple 2: Place a good apple with a decaying one into the incubator so that both apples sit next to each other without touching.

3 Apple 3: Place a good apple and a decaying one into the incubator so that they touch each other.

4 Apple 4: Sit a good apple in the incubator, making sure that it does not come into contact with any of the others.

5 Record what happens to the apples each day for 2 weeks.

Discussion

1 What happened to each apple? Why?

2 Was your prediction correct? Explain.

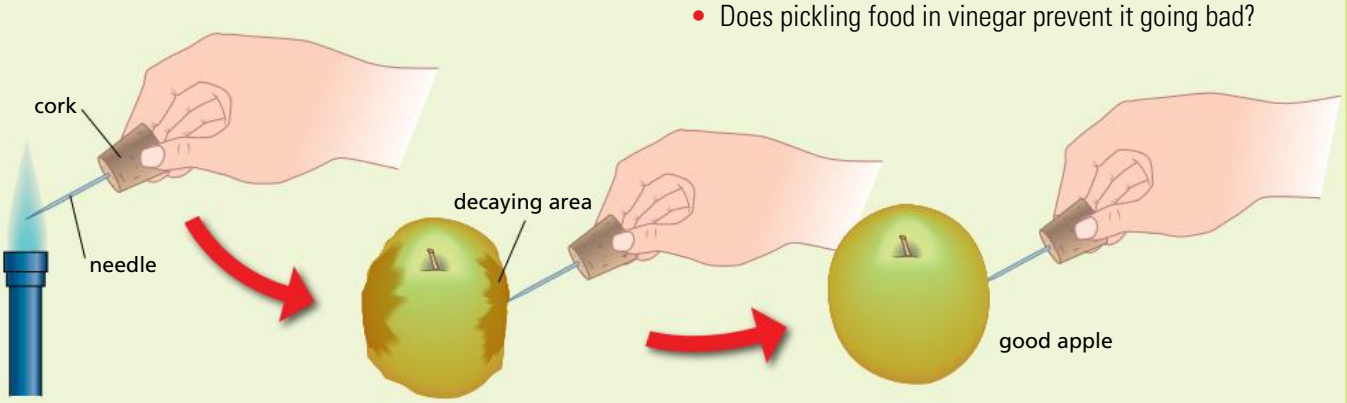
3 Which apple was the control? Why did you need this in your investigation?

4 Each of the apples came into contact with microbes in a different way. Give a real life example of how a disease is transmitted in each way.

Further investigation

Design your own experiment for one of the following:

- How does temperature affect the growth of microbes?
- Do washing powders and detergents affect the growth of microbes?
- Is bottled or filtered water safe?
- Does pickling food in vinegar prevent it going bad?



Over to you

1 Describe three different shapes of bacteria and give an example of a disease caused by each.

2 Why should you avoid food that has been left out in a warm area?

3 How can bacteria survive in sealed food containers?

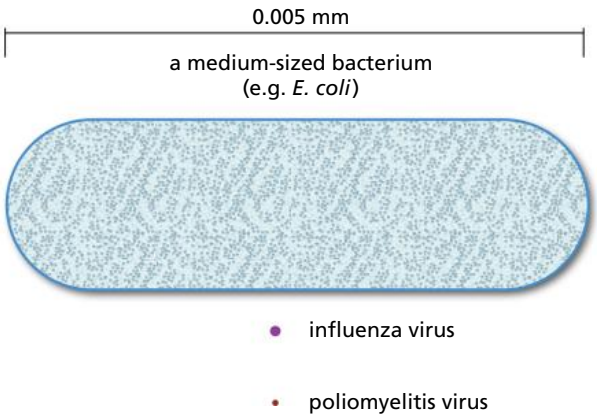
4 How are bacteria becoming resistant to antibiotics? What will this mean for the future?

5 The growth of bacteria in refrigerators is slowed down. But the bacteria are not killed by the cold. Why is it important to know this when eating refrigerated food that has passed its use-by date?

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5.3 Diseases caused by viruses

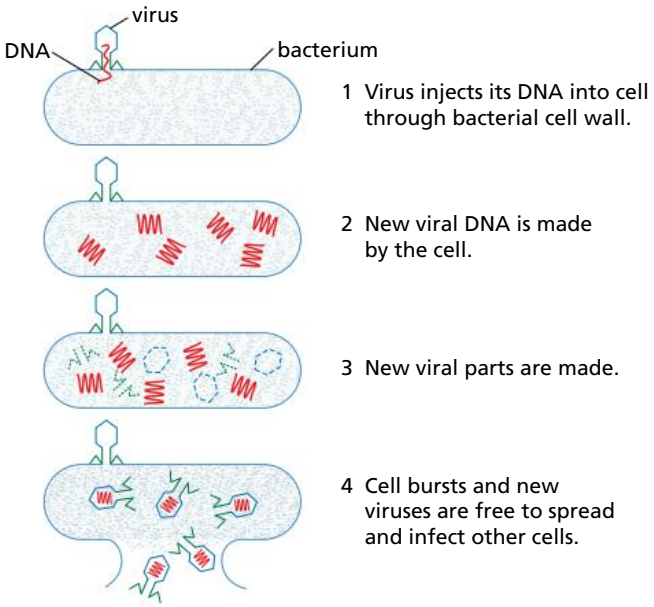
The word virus is a Latin word meaning slimy liquid or poison. While studying diseases of tobacco plants in 1892, Dmitri Iwanowski produced a juice from diseased plants and filtered the juice until it was clear. It was so clear that nothing could be seen in it with a light microscope. When the juice was smeared on healthy tobacco plants, however, they got the disease. Iwanowski believed the liquid was poisonous. It was later found that there were particles that were small enough to pass through filters. These particles were filterable viruses, much smaller than bacteria.



Size of viruses compared to bacteria

It was not until 1935 that it was shown that viruses and bacteria were different, but biologists were not exactly sure what viruses were and whether they were alive. They are not cells and do not seem to carry out all the functions of living cells. For example, they do not produce energy or make proteins. They consist of genetic material (DNA) surrounded by a protein coat.

Without all the functions of a living cell, viruses cannot reproduce by themselves. Instead, they get the cells of the host they invade to make new viruses for them. They do this in two different ways. The entire virus can invade a host cell. In some viruses, like the bacteriophage shown top right, only the genetic material is injected into a host cell. Once the DNA is inside, the host cell is instructed to make DNA, protein and enzymes for the virus. The enzymes are then used to assemble more viruses from the DNA and protein. The host cell then bursts open and spreads about 200 newly made viruses, which are then free to infect more host cells. In other types, the newly made viruses are enclosed in a part of the cell membrane and released.



A bacteriophage is a virus small enough to infect a bacterial cell.

Viruses are known to cause diseases such as smallpox, rabies, chickenpox, mumps, measles, influenza and hepatitis. Some viruses cause cancer. The DNA of these viruses can remain incorporated with the host's DNA in infected cells for life. In this way it is possible for cancer to be passed on to children, which is one explanation of why some cancers run in families.

Some viruses have been deliberately introduced into populations of animals to control them. For example, the virus myxomatosis was brought to Australia to control rabbits.

Many viruses also attack plants. The tobacco mosaic virus is one such example. Viruses also cause diseases in potatoes and cereals. Viruses can be passed on to plants by insects such as greenflies and aphids. When the insects eat the plant tissue or take sap from the stem of plants, the virus they are carrying can enter the plant. Viruses are also spread when one plant comes into contact with another.

Antibiotics do not work against viruses. However, your body does have a defence system against small numbers of viruses. Once a virus has infected your body, a protein called **interferon** is produced by infected cells. Interferon can then alter the membranes of uninfected cells so that they resist the virus when it reaches them. However, vaccination is the only real way to prevent viral infection.

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What is vaccination?

In 1796 Edward Jenner developed a vaccination for smallpox, a deadly disease caused by a virus (see box). Before this there was no cure for the disease. He found that people given an injection of pus from cowpox, a weaker form of the disease, did not get smallpox. The smallpox vaccine was introduced in England in 1798 and in 1853 it was made compulsory for people to have the vaccination. In 1978 the World Health Organization declared that smallpox had been eradicated (wiped out) from the world. This followed an intensive worldwide vaccination program to prevent the disease.

Smallpox

Name: virus called *Variola major* (most severe form of the disease) and *Variola minor* (milder form)

Transmission of the disease: Spread by droplets in the air once a person has flu-like symptoms.

Signs and symptoms: There are no signs and symptoms for the first 12–14 days, then a person has flu-like symptoms, headache, back pain and vomiting. Two days after this, a person has a rash that develops into pus-filled blisters (pustules). It takes up to 14 days for the pustules to form scabs. These leave scars or pockmarks on healing.

Prevention and/or treatment: Vaccination is the only way to safeguard against getting the disease.



Smallpox pustules

Louis Pasteur (1822–95) showed that the anthrax bacterium, which causes disease in cattle, could be weakened by high temperatures. If this bacterium was then injected into healthy cattle, it stopped them developing anthrax when exposed again. The work of Jenner and Pasteur helped people control and overcome disease and increased the health of society.

Today when you have a 'needle' you are injected with micro-organisms that would usually cause the disease, but are either dead or weakened so that they cannot harm you. If the disease is caused by a toxin from bacteria, you are injected with a harmless amount of the toxin, or a toxin that has been deactivated. The tetanus vaccine is a deactivated toxin.

Diseases can also be treated by injecting an antiserum into the body. Antiserums are made by giving an animal (such as a horse) an antigen, then collecting the antibodies the animal produces. Antiserums for diphtheria and tetanus are made this way. People bitten by a poisonous snake or spider can be given an antiserum, if one exists.

Vaccines have not been developed for all diseases. AIDS (acquired immune deficiency syndrome) is one example (see box).

HIV/AIDS

Type: human immunodeficiency virus (HIV)

Transmission of the disease: HIV is found in blood, semen and vaginal fluids. It is passed on during unsafe sex, sharing infected needles and blood transfusions. A blood test is the only way to tell whether you have come in contact with this virus. If you have, you will have HIV antibodies in your blood.

Signs and symptoms: People with HIV infection may show no signs and symptoms and may remain healthy for years. HIV slowly attacks the immune system so that eventually an infected person is not able to fight off other pathogens and they develop an illness that a healthy immune system would normally resist. When this occurs a person is said to have AIDS.

Prevention and/or treatment: Safe sex practices can prevent this disease. There is no vaccination or treatment for HIV/AIDS. However, drugs are available to help people with AIDS live a longer and healthier life.

AIDS has killed 25 million people across the world and 40 million people are infected with HIV. About 21 000 people in Australia are infected with HIV, and 88% of these are male. There are 3600 people living with AIDS in Australia and over 6800 people have died of the disease.

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The vaccination debate

HIV/AIDS shows how many people can be affected when there is no vaccine available to fight the disease. Vaccinations today prevent many children and adults from developing life-threatening diseases that in the past caused millions of deaths. However, there is some debate over whether vaccination is a safe practice, especially for children. At present in Australia children receive the following vaccinations, which are also called **immunisations**. Some of the diseases in the table are explained on this page.

Vaccine	Birth	Months					Years	
		2	4	6	12	18	4	15
DTP (now DTPa): diphtheria, tetanus, pertussis (whooping cough)*		✓	✓	✓		✓	✓	
Hepatitis B		✓	✓	✓				
Hib: *Haemophilus influenzae* type B		✓	✓		✓			
Polio		✓	✓	✓			✓	
MMR: measles, mumps, rubella					✓		✓	✓

* Tetanus/diphtheria vaccines should be given every 10 years.

Rubella (German measles)

Type: virus

Transmission of the disease: It is passed on by contact, coughing and sneezing.

Signs and symptoms: In children, rubella causes a fever and rash that lasts for 2–3 days. In adults, it causes swollen glands, neck pain and joint stiffness. If a woman gets rubella during pregnancy, her baby could be born deaf or blind, or have heart defects and mental retardation.

Treatment: Vaccination.

Diphtheria

Type: bacteria

Transmission of the disease: It is passed on through the air via coughing or sneezing.

Signs and symptoms: The bacteria live in the mouth, nose and throat, so an infected person may have a sore throat, fever and chills. If left untreated it can cause heart failure or paralysis.

Treatment: A vaccine is available and people with the disease can be treated.

Pertussis (per-TUS-is) or whooping cough

Type: bacteria

Transmission of the disease: It is passed on by contact, coughing and sneezing.

Signs and symptoms: The infected person may appear to have a cold and then 2 weeks later coughing begins. They cough until there is no air left in the lungs and inhale so quickly that they make a 'whooping' sound. They then cough again. The coughing can lead to vomiting. This stage of the disease may last up to 6 weeks. The disease can cause convulsions, pneumonia, brain disease and death.

Treatment: Vaccination.

To complete Inquiries 4 and 5 you will need to read the table on the next page and do the Skill on page 107. You should also do some internet research on vaccination.

INQUIRY 4 Corner discussion

1. Your teacher will place one of the following signs in each corner of the classroom: strongly agree, strongly disagree, unsure but I think I agree, unsure but I think I disagree.
2. Do you think it should be compulsory for children to be vaccinated against common childhood diseases? Move to the corner that applies to you.
3. Each corner must now try to convince the people in the two unsure corners to join them. The winner of the discussion is the corner with the most students in it. Every student should be given a chance to speak.



A child with chickenpox

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INQUIRY 5 Swap ideas

In this activity you will discuss the issues involved in the vaccination debate.

1 Draw up a table with the following headings. The first letters of these headings make the word SWAP.

Strengths	Weaknesses	Action	Possibilities

2 Under the heading 'Strengths' write all the points that you can think of in favour of childhood vaccinations.

3 Under the heading 'Weaknesses' write all the points that you can think of against childhood vaccinations.

4 Now explain what needs to happen to turn the arguments against childhood vaccinations (weaknesses) into strengths. Write these in the 'Action' column.

5 Under the heading 'Possibilities', explain what the future holds. You may like to read page 113 before answering this.

Over to you

1 How are viruses different from bacteria?

2 What is vaccination and how does it work?

3 Do you think a virus should be classified as alive? Explain.

4 How could you use the following statements in a debate for and against childhood vaccinations?

- Pharmaceutical companies promote vaccinations because they make money from the sale of vaccines.
- The hepatitis B vaccine contains mercury, a toxic metal, and formaldehyde, which can cause cancer.
- Fully vaccinated children get diseases they are supposed to be immune to.
- In many countries it has been found that when people stop having vaccinations the diseases come back.

5 Should people with a disease such as AIDS, for which there is no present cure, be legally required to inform all people they work or socialise with that they have an incurable disease? Debate this question.

Evidence against vaccination	Evidence in favour of vaccination
• In many countries the numbers of deaths from infectious disease, such as tuberculosis, diphtheria, typhoid, whooping cough and measles, had started to fall long before vaccines for these diseases were introduced. This was due to better hygiene, nutrition, improved working and housing conditions, and clean water. • Deaths from diseases such as typhoid that are passed on through urine and faeces decreased with improved sewage disposal. • Diseases such as colds, flu and chickenpox still occur.	• The introduction of the DTP vaccine in 1949 and the MMR vaccine in 1963 reduced infant death rates from these diseases. Thousands of people had died from measles, and diphtheria was the leading cause of death in young children before these vaccines were introduced. • The numbers of deaths from many diseases did fall with better hygiene but these diseases still killed people each year. Vaccinations made death from these diseases rare.
• Immunisation can have adverse side-effects. For example, MMR has been known to produce swelling of the brain (encephalitis), convulsions and death.	• Reactions to MMR have occurred in about one in a million vaccinations. However, if a million children had measles, at least 1000 would get encephalitis, 7000 would get convulsions and a few hundred would die.
• The DTP vaccine can cause SIDS (Sudden Infant Death Syndrome). For example, in Japan in 1975, when the minimum age for vaccination was changed from 3 months to 2 years, deaths from SIDS virtually ceased. SIDS increased again in the 1980s when the minimum age was again lowered to 3 months.	• Studies have shown that the deaths from SIDS that occurred after a DTP vaccination were a chance occurrence. These children were likely to have died from SIDS even if the vaccine had not been given.
• Vaccines are not necessary because many of the diseases children are immunised for are mild, for example, rubella and chickenpox.	• Children still die from diseases that are considered mild. For example, chickenpox still kills some children who get it. • Childhood diseases such as chickenpox are very serious if unvaccinated people get the disease as adults. Rubella causes birth defects in unborn children if pregnant mothers get the disease.

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SKILL

Detecting bias in graphs

You are often presented with information and asked for your *interpretation*, that is, what the information means to you. Information can be interpreted in a particular way depending on the beliefs, values and biases (prejudices) you hold. This may mean that the same information can be used to support different arguments. For example, look at the table below, which shows the number of measles cases and related encephalitis in Sweden. The MMR vaccination started in Sweden in 1982.

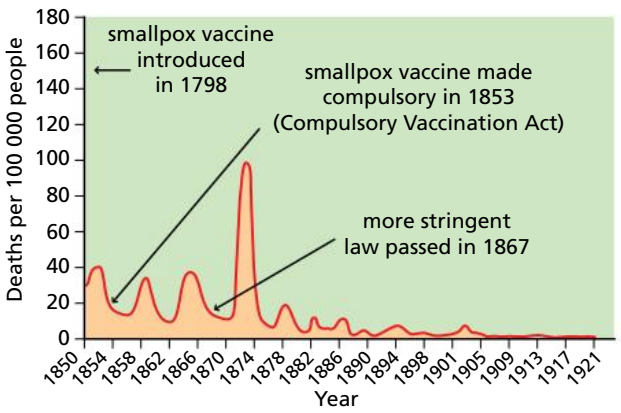
Year	Measles cases	Encephalitis
1981	372	15
1982	388	15
1983	248	8
1984	81	1
1985	9	0
1986	11	0
1987	10	0

People who are pro-vaccination would interpret this table as evidence for the effectiveness of vaccination. The number of cases of measles fell significantly after the MMR vaccination was introduced, and the number of related cases of encephalitis fell to zero. However, people who are anti-vaccination could question the effectiveness of vaccination using this table. They could say that even though the number of measles cases fell after 1982, the MMR vaccination did not eradicate the disease altogether.

You may like to answer the questions below in groups, using the three examples on the right. For each example, answer these questions:

1. What trends and patterns can you see in the information presented? Draw graphs where possible.
2. What inferences can you make to *explain* the information presented?
3. How could the information presented be used as evidence to support vaccination?
4. How could the information presented be used as evidence against vaccination?





Death rates from smallpox in England, 1850–1921

Year	Cases	Deaths
1970	655	5
1971	206	4
1972	269	2
1973	364	4
1974	393	0
1975	1 084	5
1976	2 508	20
1977	5 450	20
1978	9 626	32
1979	13 092	41

Pertussis cases and deaths in Japan, 1970–79. Immunisation was suspended in early 1975.

Year	Cases	Deaths
1960	441 703	380
1961	423 919	434
1962	481 530	408
1963	385 156	364
1964	458 083	421
1965	261 904	276
1966	204 136	261
1967	62 705	81
1968	22 231	24
1969	25 826	41

Measles cases and related deaths in the United States, 1960–69

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SCIENTISTS AT WORK

History of fighting disease

Louis Pasteur was born in France in 1822 and wanted to be an artist but by the age of 17 he had developed an interest in science. After obtaining an arts degree, he decided to study for a science degree in an effort to win a place at a highly prestigious teachers' college in Paris. He failed his science examination the first time but passed it after further study. He then started work teaching mathematics and studying science in his spare time. He obtained his PhD in science in 1847.

As a student Pasteur discovered that the structure of tartaric acid made artificially was different from the structure of tartaric acid made naturally during fermentation. He reasoned that living things were the cause of this difference. He put forward his 'germ theory'—that we are surrounded all the time by tiny organisms that cannot be seen. These organisms are able to make compounds that cause fermentation. These organisms also cause disease and decay.

Pasteur carried out experiments on the 'germs' that cause disease, decay and fermentation. He found that heating milk could kill the germs (bacteria) in it, and the milk lasted longer. This method of treating milk came to be known as pasteurisation and was used to preserve milk products, beer and wine.

After Edward Jenner's discovery of a vaccine against smallpox, Pasteur developed vaccines for anthrax, cholera and rabies. He tried his rabies treatment on a 9-year-old boy who had been bitten by a dog with the disease. His treatment was successful and the boy survived.

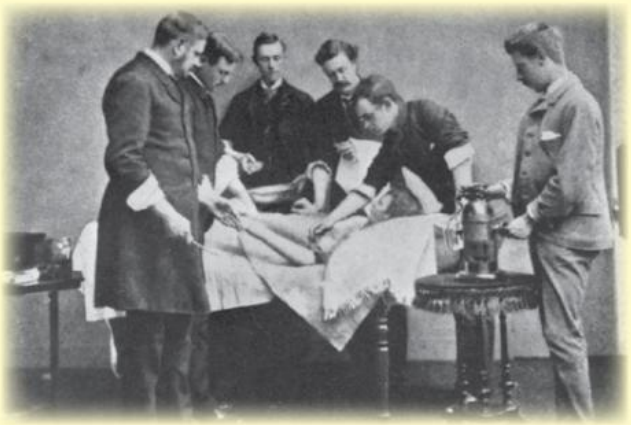
In 1888 Pasteur set up a research institute to investigate infectious diseases. It is called the Pasteur Institute and still exists in Paris today. The Institute discovered a vaccine for tuberculosis and was the first to identify the HIV virus.

Sadly, three of Pasteur's children died from typhoid. Pasteur himself died in 1895 from kidney failure and was buried at the Institute. In 1940, a French soldier who was guarding Pasteur's tomb was ordered to open it by a Nazi officer. The French soldier refused and shot himself. He was the 9-year-old boy Pasteur had saved from rabies.

Pasteur's work also led to other famous discoveries. Joseph Lister was a British surgeon who had been investigating why wounds went 'bad' or became infected. Almost half the patients who had surgery at this time died from a condition called **sepsis**. After Louis Pasteur suggested that germs in the air caused decay, Lister thought that these organisms also caused sepsis.

Carbolic acid had been used to kill a parasite that caused a disease of cattle, so Lister started to use carbolic acid on dressings and to clean wounds. He also sprayed carbolic acid in the air during operations. It became known as *antiseptic* (*anti*—against *sepsis*). In 1867 he was able to state that no sepsis had occurred for 9 months after starting to use carbolic acid.

Lister's work was followed by that of Robert Koch, who used steam to sterilise surgical instruments and dressings to prevent sepsis. These methods are still used today.



Surgery in 1869. What is in the bottle and why are they using it?

1. Imagine that you are taking the photograph of surgery in 1869. Describe what the room is like. What do you think the room feels like, sounds like, smells like? What do you think the doctors would be thinking?
2. Compare and contrast surgery in 1869 with surgery today.
3. Do you think the doctors in the photograph were aware that micro-organisms were present on their bodies, clothes and hair, and could be passed on to others?

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5.4 Other diseases

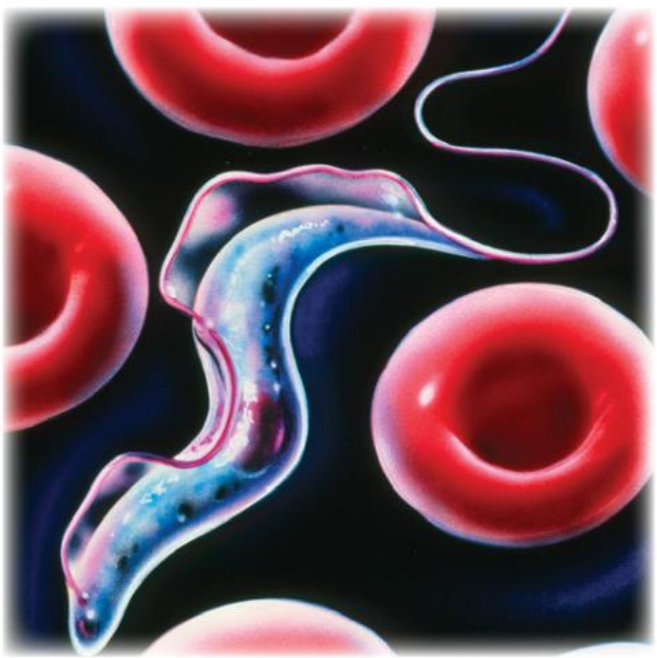
Diseases caused by protozoa

Protozoa are single-celled, microscopic animals. They are classified as protists, along with slime moulds, and algae. *Paramecium* is a member of this group. It can easily be seen in pond water under a microscope.



Paramecium

Most protozoa are very mobile. Some, like *Paramecium*, have *cilia* to move the animal along. Others have *flagella*, which are long, hair-like structures that look like tails. They move with a whip-like action.



Trypanosoma causes African sleeping sickness. Note the flagellum on the protozoan.

Other protozoa, called *pseudopods*, move by forming flowing extensions of their cytoplasm. Each extension looks like a 'false foot', which is what pseudopod means. Amoebic dysentery is caused by a pseudopod.

Most protozoa are harmless but some cause diseases, like those already mentioned. Malaria is caused by a protozoan that is passed from one person to another by mosquitoes (see box).

Malaria

Type: protozoan of the *Plasmodium* species

Transmission of the disease: *Plasmodium* lives in the blood. It is passed on to mosquitoes when they feed on an infected person. The protozoan reproduces sexually in the gut of the mosquito to produce a developmental stage of the parasite (sporozoite) that invades the mosquito's salivary glands. The sporozoites are then injected into the new host from the salivary glands during feeding. In the new host the sporozoites invade the liver and develop to a stage where they invade the blood, causing fever. Depending on which type of *Plasmodium* is causing the disease, it can be fatal.

Signs and symptoms: Fever, anaemia. The brain, liver and kidneys may be affected.

Prevention and/or treatment: Antimalarial drugs can be taken and insect repellents should be used. Treatment is available.

Diseases carried by animals

Another disease carried by mosquitoes is dengue fever (see box). However, the mosquito carries a virus, not protozoa. Other insects such as ticks, mites and fleas can also be carriers of disease. A flea can transmit the plague and typhus, and can carry tapeworm eggs. Flies can carry diseases such as typhoid, cholera and dysentery. Rabies is caused by a virus that is spread to humans by the bite of an infected dog.

Dengue fever

Type: virus

Transmission of the disease: Dengue fever is transmitted by mosquitoes. Once a female mosquito feeds on an infected person, the mosquito becomes infective for its life because the virus remains in its salivary glands.

Signs and symptoms: Some types of dengue fever cause muscle pain, severe headache and fever. Infected people do recover but this may take many months. Other types cause internal bleeding and severe shock, and may be fatal.

Prevention and/or treatment: Avoid being bitten by mosquitoes. There is no treatment or vaccine.

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Disease caused by fungi

Fungi have a cell wall but lack chlorophyll, so they cannot photosynthesise or make their own food. Instead, they absorb nutrients from other organisms. For example, fungi such as mushrooms live on dead decaying matter in the soil. Other fungi that cause thrush and tinea live on living organisms.

Thrush

Type: *Candida*, a yeast

Transmission of the disease: *Candida* live naturally in the bowel and vagina. Excessive growth of this yeast can cause thrush. Why this happens is not always clear. Thrush can occur after treatment with antibiotics, illness, irritation or during pregnancy.

Signs and symptoms: Vaginal itching and discharge, redness and swelling in the vaginal area, stinging when urinating.

Treatment: Antifungal cream.

Tinea (ringworm)

Type: *Tinea corporis*, a fungus on the body, *Tinea pedis*, a fungus on the toes (athlete's foot), *Tinea unguium*, a fungus on the toenails, *Tinea cruris*, a fungus in the groin (jock itch), *Tinea capitis*, a fungus in the hair.

Transmission of the disease: It is passed on by contact with a person who has the fungus, damp floors in public showers, dogs and cats.

Signs and symptoms:

Tinea corporis: small red spots on the body which grow into rings

Tinea pedis: the skin is white and wet on the surface and may be itchy

Tinea unguium: thick and crumbly toenails

Tinea cruris: itchy, sore groin

Tinea capitis: red, itchy, bald parts on the head

Treatment: Antifungal creams and medicine.

Diseases caused by worms

Many worms are parasites that live inside a host. These worms have no digestive system. They take in food through their body from the host's fluids. The pork tapeworm is one example. It lives in human intestines and produces millions of eggs, which are expelled in the host's faeces.

On rare occasions, the eggs may find their way into the environment of a pig. If they are eaten by a pig they start to develop inside the pig's intestines. The developing embryos burrow through the walls of the intestines into the bloodstream. If they find their way to a muscle they develop into bladderworms, which are an inactive tapeworm head in a fluid-filled bag. They then cease development or become dormant. They are harmless to the pig but, if undercooked pig meat is eaten by a human, the tapeworm head becomes active. The worm starts to grow, producing eggs. It can cause nausea, loss of appetite and abdominal pains. Tapeworms can be killed by drugs. Other examples of diseases caused by worms are trichinosis and pinworm.



A tapeworm

Pinworm

Type: roundworm

Transmission of the disease: Spread by touching contaminated objects or food. The pinworms mate in the large intestine. The females move to the anus, lay about 10 000 eggs, then die. The anus becomes itchy, especially at night, so the eggs are spread to the fingers and hands during scratching, passed to the mouth and the cycle starts again.

Signs and symptoms: Anal itching.

Treatment: Hands, body and bed linen must be washed thoroughly. Chemicals can be used to kill the worms.

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INQUIRY 6 Dog hookworm

Study the diagram and answer the questions below.

1 If you had a dog with hookworm, where would you look for eggs?

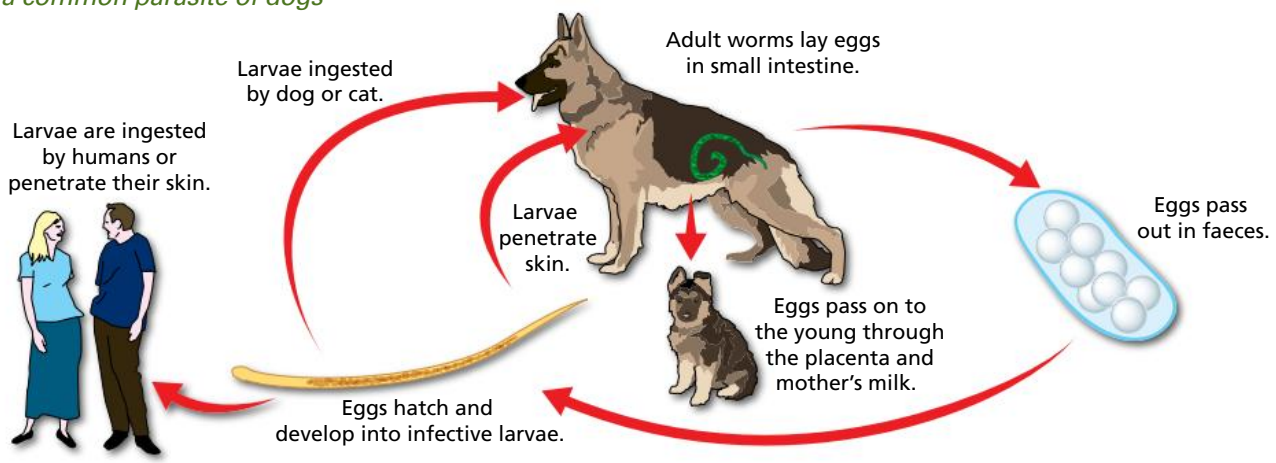
2 Hookworm eggs hatch when there is moisture and a regular temperature of about 23°C. In which parts of Australia would you expect to find hookworms?

3 Hookworms can attach to the human bowel and cause itchy blotches under the skin. How do you think the worm gets into the body?

4 What sort of signs and symptoms do you think the dog may have if hookworms are present?

5 Worming tablets for a dog can be bought at a supermarket or from a veterinarian. What worms do these tablets kill and why should a dog be 'wormed' regularly?

Life cycle of the hookworm, a common parasite of dogs



Over to you

1 List three different ways in which protozoa move.

2 An *amoeba* is a pseudopod. What does this mean?

3 Give an example of an animal that carries a parasite that causes disease in humans.

4 What type of disease can be passed on in wet locker rooms and showers at a gym?

5 Why do you think the pork tapeworm produces 100 million eggs per year compared with humans, who produce only one mature egg per month?

6 Draw a diagram of the tapeworm life cycle (like the one above) using the information on page 110.

7 Draw a diagram showing the life cycle of the protozoan that causes malaria, using the information on page 109.

8 Why do you think it is important to wear shoes when cleaning up a dog's area?

9 If you travel overseas to places where malaria occurs, what do you think you should wear and take with you to prevent getting malaria?

INQUIRY 7 Using a microscope

You will need: prepared specimens of different parasitic worms such as tapeworms, roundworms and hookworms, microscope slides of fungi and protozoa, hand lens, light microscope

1 Examine different prepared specimens of parasitic worms, such as tapeworms. These are large enough to view with the naked eye. Draw and describe what you see. Use a hand lens if you need to.

2 Use a microscope to examine prepared slides of fungi and protozoa. Draw and describe what you see.

3 Explain how the structures of the organisms you have observed help them survive where they live.

10 Heartworm is a disease of dogs in which the worms live inside the heart close to blood vessels. High-risk areas for heartworm in dogs are tropical and subtropical places, where mosquitoes are present. How do you think heartworm is passed on to dogs?

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Aboriginal health problems

Before European settlement of Australia, the Aboriginal people were hunter-gatherers. They collected a variety of plants, for example yams (edible roots), bush tomatoes, desert figs and quandongs (edible fruit), insects, bush honey and eggs. They hunted kangaroos, wallabies, possums, reptiles, fish and birds. Their food was low in fats and sugars, making it low in kilojoules. It was high in carbohydrates, fibre, protein, vitamins and minerals. For example, yams were high in vitamin C, bush tomatoes were high in potassium and desert figs were high in magnesium. This diet was very healthy and it varied, depending on the season and the plants and animals available. And the hunter-gatherer lifestyle meant they had plenty of exercise.



After European settlement the Aboriginal lifestyle changed dramatically. They began to eat European food such as flour, sugar and processed meat. The settlers had destroyed some of their hunting areas and introduced new plants and animals. Many Aboriginal people were removed from their traditional land to government settlements, and others worked on cattle stations. The Aboriginal people's new diet was the opposite of what it was before. It was now *high* in fats and sugars and lacked nutrients such as protein, vitamins and minerals. And they weren't getting the exercise they did as hunter-gatherers. Today the range of foods available in outback communities is limited, especially fresh fruit and vegetables. To make it worse, Aboriginal people living in cities eat more take-away food and ingest more salt than other people do.

European settlers and other visitors to Australia brought new diseases with them. The Aboriginal people had no resistance to these diseases and had no traditional remedies for them. Smallpox epidemics (see page 104) are thought to have caused the death of up to a third of the affected Aboriginal population. And Aboriginal settlements in Victoria and South Australia lost up to 20% of their population in the 1874–5 world pandemic of measles.

As a result of their new lifestyle, Aboriginal people suffer from a range of lifestyle diseases, mainly obesity, cardiovascular disease (heart and blood vessels), diabetes (type 2), high blood pressure, cancer and stroke. The rate of cardiovascular disease is twice that of other Australians, and Aboriginal people are 7–10 times more likely to die from diabetes! Aboriginal people have a life expectancy of 67 years for males and 73 years for females, compared with 79 and 83 for other Australians.

Aboriginal health problems are made worse because of widespread poverty and unemployment, and the fact that many Aboriginal communities are in remote parts of Australia. However there are a number of government programs aimed at closing the gap between the health of Aboriginal people and other Australians.



Over to you

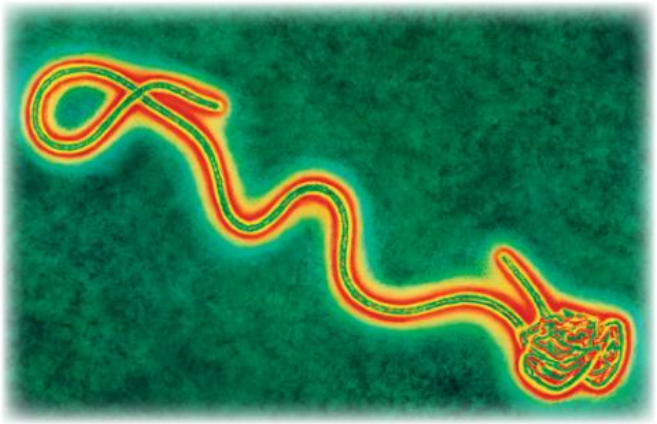
1. How has the diet of Aboriginal people changed over the last 200 years?
2. Use what you have learnt in this chapter to explain why so many Aboriginal people died from introduced diseases such as smallpox and measles.
3. Why is a diet low in fat and sugar, and high in carbohydrates and proteins healthy?
4. Research the following: Type 2 diabetes, the use of alcohol and inhalants by Aboriginal people, and how Fred Hollows helped improve the health of Aboriginal people.

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5.5 The future

Imagine living before the development of vaccines when diseases such as smallpox killed millions of people. It would have been hard to imagine back then that smallpox could be eradicated from the world. However, there are still diseases that exist today for which we have no vaccines. HIV/AIDS is one example but others are also starting to emerge.

In 1976 the Ebola virus emerged in Zaire in Central Africa (near the Ebola River). It has now spread to other parts of Africa. At the start, this virus causes flu-like symptoms, such as fever, aching muscles and headaches. This develops into internal bleeding, vomiting of blood, blindness and death within a week. It is passed on by coming into contact with infected blood. There is also a disease called Marburg haemorrhagic fever that appeared in 1967 in Marburg, Germany. This disease produces similar signs to Ebola. It is possible it came from a shipment of African monkeys. In fact, bats and monkeys are believed to be the source of many of these new diseases.



The worm-like Ebola virus

With an increasing world population, high numbers of people living in cities, and jet travel, new diseases can be spread easily. Some diseases that were controlled, such as tuberculosis, are recurring. This is because new **strains** or types of bacteria are appearing. Many bacteria are also becoming resistant to the antibiotics that killed them in the past.

To combat these micro-organisms and the diseases they cause, new vaccines and drugs are needed. For example, different types of flu appear regularly. This is because the flu virus *mutates* or changes as it reproduces, so new strains appear. Scientists in Australia have found that each strain of the flu virus needs the same protein to move from one cell to the next. By blocking this protein the virus cannot break out of a cell and infect other cells. Deactivating the virus protein, therefore, is a way to stop the flu.

Over to you

1. Explain where new pathogens are coming from.
2. Explain why old pathogens are returning.
3. Use the internet to investigate some of the new diseases that are emerging. Here are some names to search for: Hantaan virus, Lassa virus, Sabia virus, rotavirus, Guanarito virus, Nipah virus. Prepare a 2 minute talk to present the information you have found to the class.

PROBLEM SOLVING

Have you finished your experiment? Can herbal remedies prevent the growth of micro-organisms?

Herbal remedies date back to Ancient Egypt and are being used in conjunction with traditional medicine to cure diseases today. Herbalists believe that if the immune system is weak or out of balance, a person will be more susceptible to disease. Herbal remedies use plants or herbs and the chemicals they contain to improve a person's health. Some herbs may target the body's nervous system, some help digestion, some contain essential vitamins and minerals, and others remove wastes and toxins.

Many people have doubts about the value of herbal medicines. However, many modern-day drugs come from plants. For example, the bark of willow trees is used to make aspirin, morphine is made from opium poppies, and a flower called foxglove is used to make a heart drug. So the power of herbal remedies cannot be easily dismissed.



A crop of pyrethrum daisies. Pyrethrum is used as a natural insecticide. Do any of your flysprays have pyrethrum in them?

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The use of antibiotics

Antibiotics are chemicals made by micro-organisms, such as bacteria and fungi, that can be used to kill other micro-organisms. In 1928 Alexander Fleming found that *Penicillium* mould killed bacteria. This discovery led to the development of the first antibiotic—penicillin.

By the late 1930s the use of antibiotics had caused the death rate from diseases such as meningitis and pneumonia to fall, and life expectancy across the world increased. However, after 4 years it became evident that some bacteria were becoming resistant to penicillin, which means they were not killed by it.

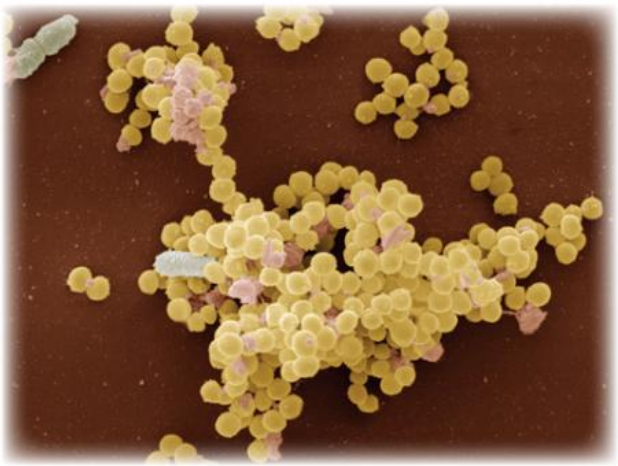
In any population of organisms there is variation between individuals. In other words, the genetic make-up of organisms is different. Some bacteria may carry the genetic blueprint that gives them resistance to penicillin. This resistance may have been passed on during reproduction or it may have occurred through a chance mistake or mutation. The resistant bacteria survive and reproduce, passing this resistance on to their offspring, who survive and reproduce, and so on. In this way, more and more bacteria become resistant to penicillin over time.

In the 1950s an increasing number of bacteria were becoming resistant not only to penicillin but to other antibiotics as well. However, there were many new antibiotics that could be used instead.

Today, though, it is a different story. New antibiotics are not being developed as rapidly as they once were, and all antibiotics have strains of bacteria that are resistant to them. Cases of tuberculosis, a disease that was once easily cured with antibiotics, have appeared which are untreatable. Some strains of 'golden staph' bacteria are resistant to the strongest antibiotics.

Golden staph is so named because of its golden colour when grown on an agar plate. It is normally a harmless bacterium found on our skin. However, it can invade wounds after operations and cause major infections. About 5% of infections with golden staph are caused by a form of this bacteria that is resistant to many different antibiotics.

The misuse of antibiotics for human medicine is one reason that has been put forward to explain why these resistant strains of bacteria are appearing. About 22 doses of antibiotics are prescribed per thousand people in Australia every day, making us one of the highest users of antibiotics in the world. Many minor bacterial infections are treated with antibiotics when they do not need to be. Viruses cannot be killed with antibiotics. Yet people with colds and flu expect to be given antibiotics even though these diseases are caused by viruses. It is estimated that antibiotic use could be halved.



Golden staph

A second reason for the development of resistant bacteria is the number of people who do not finish the course of prescribed antibiotics. This means that instead of wiping out all the bacteria, some bacteria are not killed and survive. These bacteria develop resistance by coming in contact with small amounts of the antibiotic.

A third reason is the use of antibiotics in animal food. Large quantities of antibiotics are fed to pigs, cattle and chickens, which are used for our food. This is done to prevent disease in these animals and to increase their growth rate. However, the antibiotics that are used are very similar to those used in human medicine. Bacteria that develop a resistance to antibiotics used in agriculture will also be resistant to antibiotics used in humans. It is argued that if these animals were not kept in unnatural and crowded conditions, then the use of these antibiotics would not be needed. Better hygiene in agriculture, such as clean cages, has been shown to be equally as effective.

1 Use the internet to research more about the use of antibiotics.

2 Do you think people who go to the doctor expect to be given antibiotics? Explain.

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THINKING SKILLS

1 In the first few days after birth a breastfed baby receives a substance called *colostrum*, which is high in antibodies from its mother. Explain how this is important for newborn babies. How could you use this information to convince a pregnant mother to breastfeed?

2 Biologists have noticed that epidemics occur in groups of organisms when the numbers of individuals are too large. These individuals show less antibody formation. Why do you think this occurs? Do you think the new diseases that are emerging are a result of our increased population?

3 The cell wall of a bacterium is made up of a material called *murein*, which is chemically and structurally different from the cellulose of plant cell walls. Neither animal or plant cells have this material. Without a cell wall the bacterium would swell and burst inside the host's tissue.

- **a** Why do you think this information is important when designing drugs to destroy bacteria in living tissue?
- **b** How do you think these drugs work?
- **c** Some bacterial cells can secrete a material on the surface of their cell wall which forms a capsule around the cell. Why are these bacteria more likely to cause disease?
- **d** Some bacteria become dormant, enclosing themselves in an almost indestructible coat. These bacteria can survive a hot oven for an hour, or being boiled for up to 6 hours. They can also survive being frozen, dried and treated with disinfectant. When conditions are right, the bacteria grow again. Fortunately, only a few disease-causing bacteria can form these special coated cells. Explain what the consequences would be for the way we live if disease-causing bacteria could become dormant like this.

4 If bacteria can divide into two every 20 minutes, how many bacteria will be present after 6 hours?

5 What do you think Hippocrates meant when he said 'A wise man ought to realise that health is his most valuable possession'?

6 In Australia, childhood immunisation is not compulsory. Should immunisation be made compulsory? Explain.

7 Meningitis is a disease that can affect anybody (see box). However, it is most common in children under 5 and young adults aged between 15 and 24. It occurs mostly in winter and early spring. It is also more common in Indigenous people.

- **a** Find out how many people in Australia have had meningitis, died from the disease, recovered completely, or recovered from the disease but have side-effects.
- **b** Do you think children and teenagers should be vaccinated against meningitis?

Meningitis

Type: viral or bacterial

Transmission of the disease: It is passed on through coughing as airborne droplets, and kissing.

Signs and symptoms: Inflammation or swelling of the membranes that surround the brain and spinal cord. This causes headaches, stiff neck and a high fever followed by vomiting, nausea, a dislike of bright lights, sleepiness and confusion. This may lead to seizures and, if left untreated, can cause death within hours. Some people develop brain damage and hearing difficulties.

Treatment: Viral meningitis is a mild disease and no treatment is necessary. Bacterial meningitis can be treated with antibiotics. Vaccination is available.

8 Many Australian scientists have furthered our understanding of disease. Some of these people and their research are listed below. Research one of the following:

- Fiona Stanley (spina bifida in newborn babies caused by lack of folic acid in the mother's diet)
- Suzanne Corey (cell death and cancer)
- Jean MacNamara (myxomatosis in rabbits)
- Howard Florey (penicillin)
- Peter Doherty (recognition of antigens in the body)
- Peter Coleman and Graeme Laver (drug for fighting influenza)
- Gustav Nossal (immunology)

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 A _____ is any impairment that prevents the body functioning as it should. There are infectious diseases, such as smallpox, and _____ diseases, such as heart disease and haemophilia.

2 _____diseases are caused by organisms such as bacteria, viruses, fungi and protozoa. The organisms that cause disease are called _____.

3 Pathogens must get through the body's defences that form the _____. The skin is an example of the first line of defence.

4 Lymphocytes produce _____ and cells that remember the pathogen in case it enters the body again.

5 Any foreign organism or toxin is called an _____. The body produces an antibody for each antigen it encounters.

6 _____ are smaller than bacteria and do not have all the features of a cell. They have DNA but they are unable to reproduce themselves.

7 Viruses cannot be killed by antibiotics like bacteria can. _____ is the only way to guard yourself against viruses.

8 New strains of bacteria are developing that are _____ to antibiotics.

antibodies
antigen
disease
immune system
infectious
non-infectious
pathogens
resistant
vaccination
viruses

Self-management

Using what you know

Read the article on the right and then answer the questions. For each question, state where you would find help in the chapter if you were unsure of the answer.

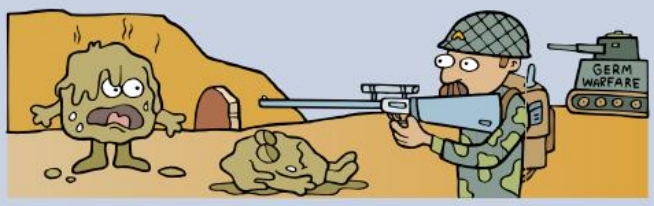
1 What is a virus and how is it different from other pathogens?

2 Briefly describe the diseases encephalitis, malaria and dengue fever.

3 What is meant by a 'mosquito-borne virus'? Outline how malaria is passed on by mosquitoes.

4 What is a vaccine and how does it work?

5 What is meant by 'becoming resistant' and how does this happen?



Germ warfare?

The Australian Army Malaria Institute is based in Brisbane. It is presently trialling a vaccine for a mosquito-borne virus that causes Japanese encephalitis, an often deadly disease. The Institute is also working to develop a vaccine for dengue fever, a disease that infects almost 500 people in Australia each year. Australian soldiers are serving overseas in areas where diseases such as malaria are prevalent, so the work of the Institute is vitally important. Parasites carried by mosquitoes are becoming resistant to the drugs used to kill them. Hence, the Institute is researching new drugs. In 1969, a chance finding that acne medication can combat malaria led to a drug being developed. Variations of this drug are being trialled today.

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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 A disease:
- **A** always makes you feel sick
- **B** is an impairment of the body
- **C** is something you always need a vaccination for
- **D** is only passed on by coughing or breathing

2 An example of an infectious disease is:
- **A** cancer
- **B** heart disease
- **C** hepatitis
- **D** anorexia nervosa

3 A virus is different from a bacterium because it:
- **A** does not have a cell wall
- **B** is made up of protein
- **C** has DNA inside it
- **D** causes disease

4 Name a characteristic that would allow you to distinguish between:
- **a** fungi and bacteria
- **b** a bacterium and a normal body cell
- **c** protozoa and viruses.

5 Why is it important to have the required vaccinations before travelling overseas? Give two reasons.

6 How is a tapeworm adapted to a parasitic way of life?

7 Why are people who inject themselves with drugs more likely to expose themselves to disease than people who do not 'do' drugs?

8 A study of platypuses in the Wollondilly River, 150 km south of Sydney, found that 60% of these animals were carrying antibodies for a disease in cattle. How do you think this disease was passed on to the platypuses in this area?

9 Briefly describe two ways in which new strains of bacteria and viruses are developing.

10 The cartoon top right, by James Gillray, was drawn to show opposition to Jenner's smallpox vaccination. Study the cartoon and then answer the questions.
- **a** What message is being put forward by the cartoonist?
- **b** Explain whether you think the cartoonist has a biased view.
- **c** How is the attitude of the cartoonist similar to the attitudes held today towards childhood vaccination?
- **d** List three arguments in favour of vaccination.

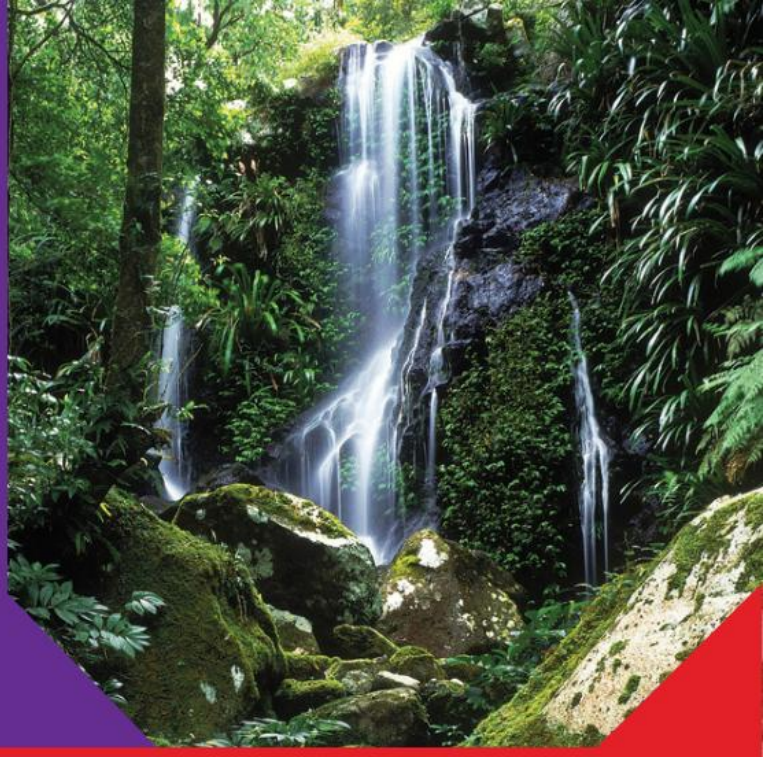


The effects of vaccination

11 In the 17th century, a commonly held belief was that if you put sweaty underwear and wheat husks in a jar and waited a certain length of time, the wheat husks would spring to life as mice. In 1668 a physician called Redi carried out an experiment to show that maggots did not automatically spring to life in decaying meat but came from fly eggs. Redi used a collection of flasks with meat inside them and covered some with gauze, left some open and sealed others.
- **a** How could you explain how the mice came to be in the jar with the wheat husks and sweaty underwear?
- **b** What was Redi trying to show with his experiment?
- **c** What else would you need to know about the experiment performed by Redi to accept his results?
- **d** Did the tests and findings of Louis Pasteur support Redi's findings and show that living things did not automatically spring to life from non-living things?

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6



Ecosystems

By the end of this chapter you will be able to …

Knowledge and Understanding

- recall that ecosystems consist of communities of interdependent organisms and distinguish between biotic and abiotic components of their environment (LW2a)
- analyse how changes in biotic and abiotic components of an ecosystem affect populations of organisms (LW2d)
- discuss how Aboriginal people recognise relationships in local ecosystems and use their knowledge to conserve and manage their environment (LW2e)
- evaluate some examples of strategies used to balance human activities and the needs of ecosystems (LW2f)

Skills–Working scientifically

- plan and select appropriate investigation methods to collect reliable data on water quality in a creek or pond (5.2a)
- select and use equipment to systematically and accurately collect and record data on plant growth (6c)

LITERACY FOCUS

abiotic
adaptations
algae
biotic
carnivore
commensalism
community
ecosystem
environment
food chain
food web
functional
interdependence
larvae
mutualism
nutrients
omnivore
parasite
population
predators

Focus for learning

What do you need to live? Your environment provides you with the things you need. The **environment** is all the conditions or factors that affect an organism where it lives. To survive you need non-living things such as water, minerals, light and warmth. These are called **abiotic** (AY-by-OT-ik) or physical factors. You also need living things such as plants and other organisms. These are **biotic** or biological factors. The feeding relationships and interactions you have with other organisms are essential to your survival.

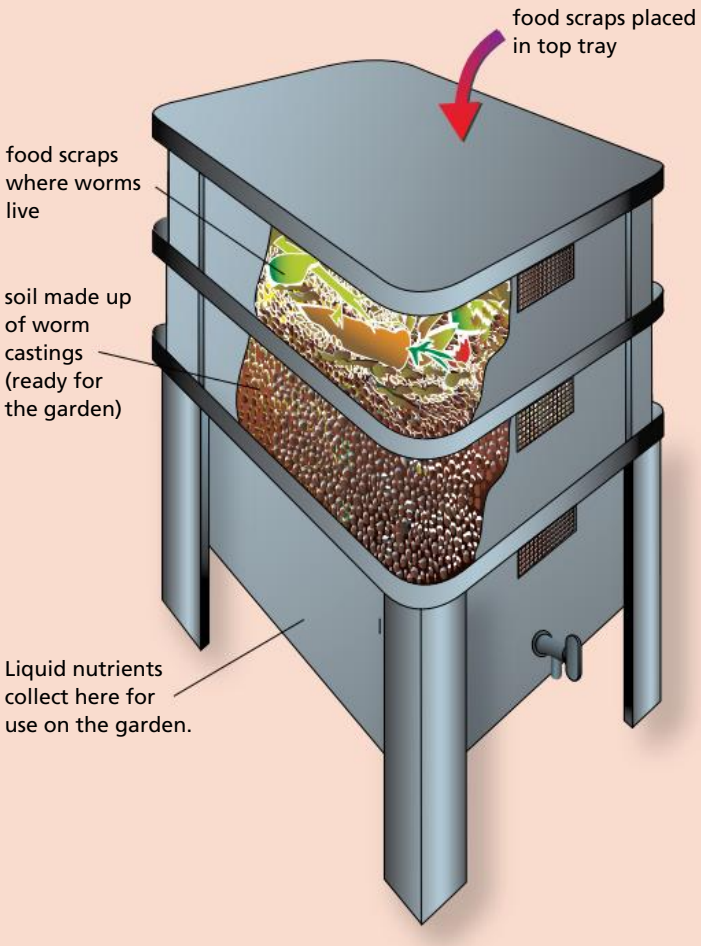
You are part of a group of organisms, all interacting with one another and the environment. Living things and their interactions with each other and the non-living environment form a system called an **ecosystem**.

What you do affects ecosystems. For example, how you dispose of food scraps can affect our environment and the organisms that live there. We throw food down the sink without thinking. This food then finds its way into our waterways. The nutrients in the food cause algae and aquatic plants to grow at a faster rate than normal, clogging waterways and cutting out oxygen and light that other organisms need to survive.

Food scraps can be disposed of in a worm farm, which is a fully functioning ecosystem that uses scraps from fruit and vegetables. The food scraps come from plants that carry out photosynthesis. The worms are consumers. They eat the food scraps, and in this way use some of the energy that the plants absorbed from the sun.

The worm castings or faeces, together with nutrients from the plants, make a rich soil that can be put on the garden, used for pot plants or to grow fruit and vegetables again. Water from the farm collects in the bottom of the tray. It is rich in nutrients and can be used for fertiliser. So there is natural recycling through the worm farm. The worms break down or decompose the food scraps as they eat them. Vinegar flies, red mites and soldier fly larvae make their home in the rich soil made by the worms.

The balance of the worm farm can easily be upset. If the system becomes too wet, the worms die and the food rots. Too much fruit in the food scraps can ferment or produce sugar that kills the worms.



A worm farm

ISBN 978 1 4202 3246 2

PROBLEM SOLVING

Designing an ecosystem

1 Design your own ecosystem. This could be a worm farm or another ecosystem such as a terrarium made up of plants, an aquarium for fish, or an ant farm. Whatever you choose, you must have a system that works naturally.

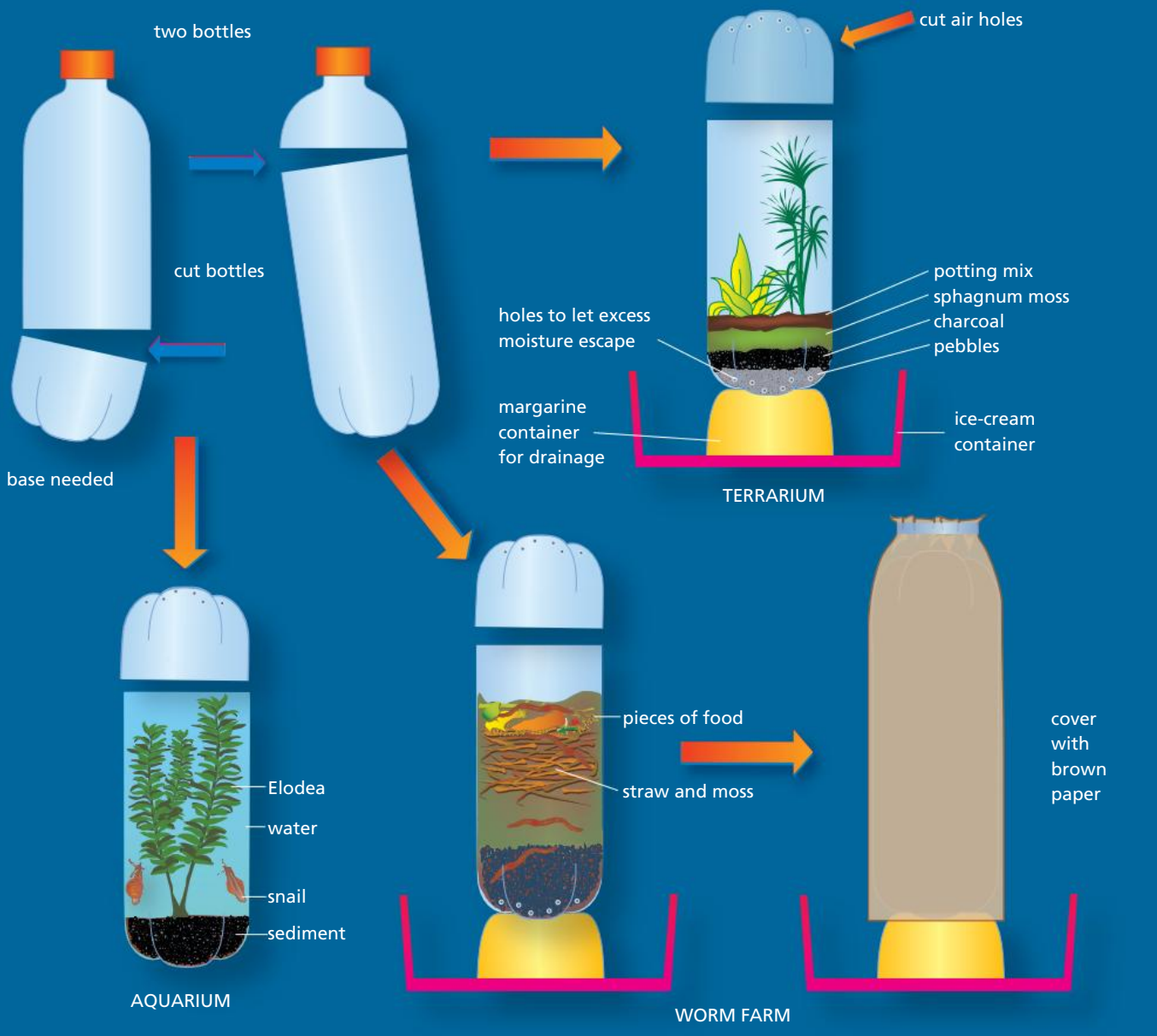
2 Use only recycled materials in your design. For example, you cannot buy a commercial worm farm.

3 Make a drawing of your design, showing how your ecosystem is built.

4 Report on the following:

- **a** How does energy get into your system?
- **b** Identify the producers and consumers.
- **c** Outline the feeding relationships by drawing food chains and food webs.
- **d** Explain how your ecosystem works.
- **e** List the non-living factors that affect your ecosystem.

The diagrams on this page may give you ideas. Reading the chapter will also help. You may need to do some library and internet work. You could also visit places where worm farms and aquariums are sold and find out what is needed to set them up.



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6.1 Why do organisms live where they do?

INQUIRY 1

Northern hairy-nosed wombat

Work in groups of three or four. Read the description on the right of the northern hairy-nosed wombat, and answer the questions below.

Questions

1 The living place of an organism is called its habitat. Describe the habitat of the northern hairy-nosed wombat.

2 Why is this animal only found in this area?

3 How do these animals depend on one another for survival?

4 What other organisms do these animals depend on for survival?

5 In any ecosystem, interactions occur between organisms. How do the northern hairy-nosed wombats:

- **a** work together?
- **b** act as parents?
- **c** reproduce?
- **d** make sure there is enough food and space for all?

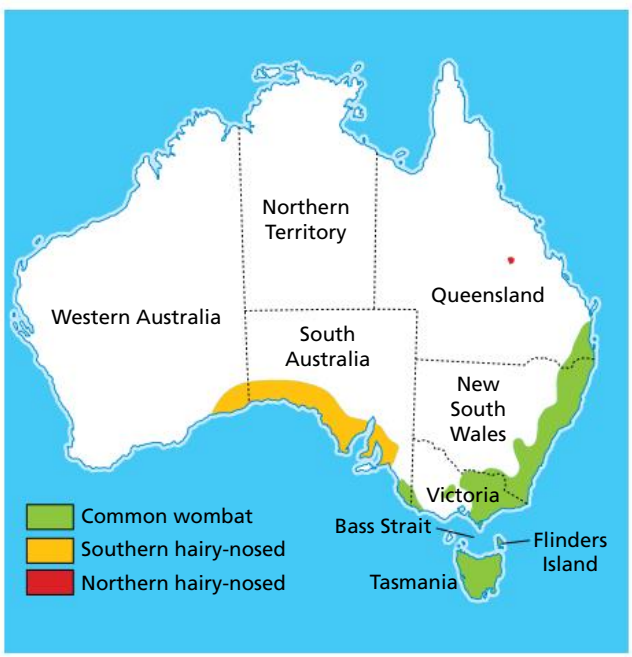
6 Explain how changes in the environment of these animals have affected the interactions in Question 5.

The northern hairy-nosed wombat is estimated to live in an area of 3 square kilometres within Epping Forest National Park in central Queensland. The wombats are critically endangered or very close to becoming wiped out (extinct) as only 176 individuals remain. Northern hairy-nosed wombats live in dry, flat grassland where there is sandy soil or eucalypt and acacia (wattle) woodlands near rivers, and plenty of native grass covering the ground.

Northern hairy-nosed wombats eat native grasses and live in burrows which they dig using their legs and claws. Their burrows can be up to 20 metres long and clustered together. Up to 10 wombats share the tunnels of the burrow cluster, but live alone. They spend most of the day in their burrow and come out at night to feed.

The animal is a marsupial, which means females have a pouch where the young are carried and fed from teats inside. The pouch opens backwards so that it doesn't fill with soil when the animal digs a burrow. When the northern hairy-nosed wombats breed, they produce only one baby at a time. The young wombat stays in the mother's pouch for up to 9 months and then remains with her for about a year. They breed in summer when there is lots of rain and therefore food available. They don't breed if there is not enough rain.

Northern hairy-nosed wombats have declined in numbers in recent times because of drought and destruction of their habitat. They have also had to compete with rabbits, cattle and sheep that feed on the grasses they eat. Dingoes have also killed many of the wombats.





Northern hairy-nosed wombat

ISBN 978 1 4202 3246 2

Adaptations

Here are some of the reasons why organisms such as the northern hairy-nosed wombat live where they do.

A Animals need food and water. For example, the northern hairy-nosed wombat relies on particular grasses for food and it can only be found where these grasses grow. In turn, the grasses need light, water and minerals from the soil.

B There are few **predators** or animals that feed on the particular organism. Predators hunt, capture and kill other animals. For example, the predator of the northern hairy-nosed wombat is the dingo.

C There are few competitors or organisms that need the same type of food, soil, nutrients and living space. For example, northern hairy-nosed wombats compete with rabbits, cattle and sheep for food and territory.

D The climate and weather conditions are suited to the particular organism. This includes a good supply of water and air.

Organisms have characteristics called **adaptations** that enable them to survive in the environment in which they live. These characteristics can be *structural*. For example, the northern hairy-nosed wombat has long, strong claws for digging burrows.

Adaptations can be *functional*, so that how the body works helps the organism survive. For example, the northern hairy-nosed wombat has a constant body temperature so it can remain active all year round, regardless of the temperature. Insects and lizards have a changing body temperature that varies with their surroundings. This is why they are more likely to live in warm climates where the warmth helps their bodies to function.

A *behavioural* adaptation is where the behaviour of an organism helps it to survive. For example, the northern hairy-nosed wombat feeds at night time to avoid predators and the heat of the day.

There are *reproductive* adaptations too. For example, only one baby wombat is born at a time and remains protected in a pouch for part of its development. Breeding only occurs in summer during the wet season when there is plenty of food available.



Dingoes are predators of northern hairy-nosed wombats.

INQUIRY 2

Behaviour for survival

You will need: 2 jam jars or beakers, ice, kettle for hot water, metal baking tray, thermometer, 2 snails

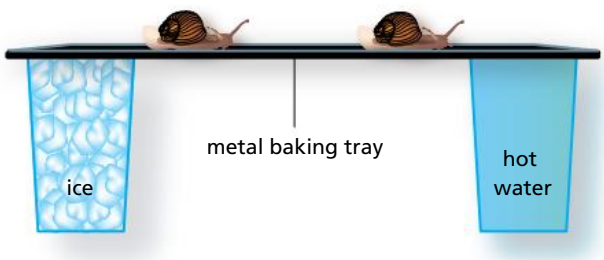
Remember: Never harm a living organism, and return the organism to where it was found when you have finished.

1 Observe the snails in their natural environment. What temperature and environment do they prefer to live in?

2 Fill one jam jar to the top with ice cubes and the other with hot water **(caution)**.

3 Place the jars with the metal tray on top as shown. The ice and hot water must be touching the tray.

4 Place one snail near (not on top of) the jar of ice cubes and the other snail near the jar of hot water. What do you predict will happen?



5 Observe and explain what happens.

6 Design your own experiment to see how different coloured snails behave on different coloured backgrounds, or how they respond to different types of food.

7 Repeat the activity with other organisms such as slaters or ants.

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INQUIRY 3

What can I observe about organisms around me?

In this activity you are going to observe organisms in their natural environment and make inferences about why the organisms live where they do.

You will need: paper, pens, thermometer, other measuring equipment as directed by your teacher

1 First draw up a table with nine rows as shown below.

2 Go into the school yard or a natural environment and observe two different organisms. Fill in the table for each of them. For example, Cathy observed an eel in the creek behind her school. This was her table:

Environment	Creek, very bushy, lots of vegetation such as gum trees, grasses and bulrushes, water clear, many rocks around the edges and in the water.
Food	Bread, meat and vegetable scraps from lunches thrown into the creek. Leaf litter and dead insects.
Predators	None observed. Possibly students.
Competitors	Other fish, turtles.
Climate or conditions	Water temperature taken, 23°C.
Structural adaptations	Fins and body movement help the eel glide through the water and swim effortlessly past rocks.
Functional adaptations	Changing body temperature to survive in a creek. It would waste too much energy trying to maintain a constant body temperature in the creek.
Behavioural adaptations	Eel went behind rocks whenever a student cast a shadow where the eel was swimming. Stayed there until the shadow moved.
Reproductive adaptations	None observed.

3 Infer why the organisms you have observed live where they do.

Over to you

1 In your own words give the meaning of the words:
ecosystem, environment, abiotic and biotic factors.

2 Explain how a worm farm is an ecosystem and how it could reduce our waste and improve our environment.

3 List the abiotic and biotic factors that affect the northern hairy-nosed wombat.

4 Tennille had a pet rabbit that she kept in a run in her garden. One day it got out.
- **a** What factors will determine whether the rabbit survives outside its run?
- **b** Explain why each of the factors you listed is important.

5 Copy and complete the following sentences.
- **a** Spines on the echidna to keep predators away are a _____ adaptation.
- **b** The alarm call of birds to warn of predators is a _____ adaptation.
- **c** Looking after the young birds once they hatch is a _____ adaptation.
- **d** The constant body temperature of the northern hairy-nosed wombat allows it to be active all year round. This is a _____ adaptation.

6 What abiotic and biotic factors would affect the organisms living in the environment below?



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6.2 Food chains and webs

The feeding relationships that exist between organisms can be shown in a **food chain**. Producers start the food chain. They get their food through photosynthesis. They obtain the energy to carry out this process by capturing it from the sun. The food is then used to make their bodies work or it is stored as new leaves, roots, shoots or stems.

Look at the food chain below:

plants → aphids → beetles → large birds

The plants are the producers. They are eaten by the aphids, which are the *first-order consumers* or *herbivores* (plant eaters). The aphids use some of the energy they get from the plants and some is stored in their own bodies.

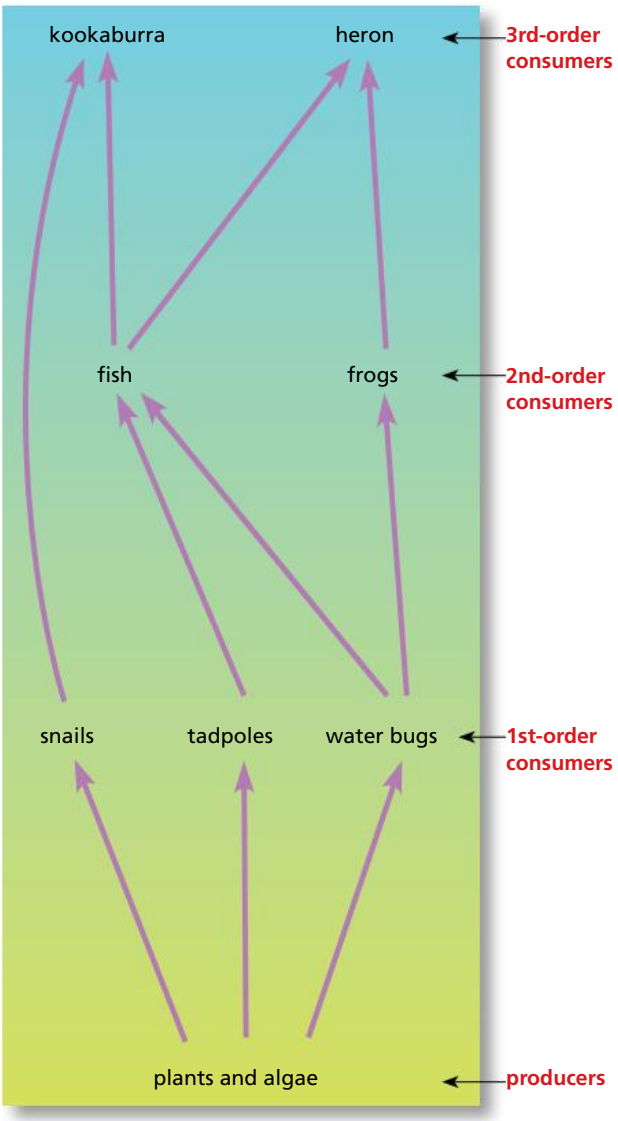
The beetles then eat the aphids. They are *second-order consumers*. They get some of the original energy from the plants that is stored in the aphids' bodies. Finally the large birds eat the beetles. They are *third-order consumers*. They get a smaller amount of the original energy from the plants than is stored in the bodies of the beetles. Second- and third-order consumers are called *carnivores* (meat-eaters). Organisms that eat both plants and animals are called *omnivores*.

The feeding relationships in ecosystems, however, are not quite this simple. Many food chains link to form a **food web** (top right) that shows all the feeding relationships of organisms that live together in a particular place.

Food webs are quite complex since animals usually eat many different foods. For example, in a freshwater ecosystem, algae and water plants can be eaten by snails, tadpoles and water bugs. The tadpoles can be food for fish, but so can water bugs, and both frogs and fish are food for herons. A simple food chain does not show these interactions.

Food webs are usually drawn in a standard way. The producers are placed at the bottom of the food web, followed by the first-order consumers. Finally they are linked to the second- and third-order consumers on top. This can be seen in the food web on this page.

Fungi and bacteria are decomposers and play an important role in a food web. Fungi digest their food externally, so they are not classified as consumers.



A food web is a system, and the organisms in it depend on each other for survival. For example, the snails, tadpoles and water bugs can't exist without the plants and algae. The fish and the frogs can't exist without the tadpoles and water bugs. And the kookaburra and the heron can't exist without the snails, fish and frogs. Because all the organisms in the food web depend on each other, they are said to be *interdependent*.

In general, the idea that the parts of a system depend on each other is called **interdependence**.

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Bacteria are simple organisms that lack chlorophyll in their cells and so get their food from others. As decomposers, fungi and bacteria break down dead organisms into simple materials that pass into the soil, water and air. These nutrients are then used again by plants. For example, carbon dioxide passes back into the air where it can be used again by plants.

In this way, decomposers recycle materials in a food web. Scavengers also help in this recycling process. For example, ants, insects, maggots, crows and hawks eat the flesh and organs of dead organisms. They are consumers. Crabs, lobsters and prawns are scavengers too, feeding on the dead remains of organisms on the bottom of waterways and oceans.

The freshwater food web on the next page shows the important role decomposers play in the natural recycling of materials in ecosystems.

INQUIRY 4 First-, second- or third-order consumers?

You can use food chains to map the organisms you have a feeding relationship with.

1 Copy and complete the table.

Food you have eaten over 24 hour period	Source of food	Original source of food
e.g. milk	cow	grass
e.g. pork chop	pig	vegetables

2 Now draw separate food chains from your table, adding the words producer, first-, second-, third-order consumer, herbivore, carnivore and omnivore:

- e.g. sugar for tea

sugar cane → **human**
(producer) (first-order consumer or herbivore)

- e.g. lamb chops

grass → **lamb** → **human**
(producer) (first-order consumer or herbivore) (second-order consumer or herbivore)

3 Are you a first-, second-, or third- order consumer? Explain.

INQUIRY 5 The helmeted honeyeater

Using the information provided here, draw a food web for the helmeted honeyeater—a critically endangered bird of Victoria.

Energy from the sun goes to the gum trees, paperbarks and tea-trees. The plant leaves are eaten by moths and psyllids (jumping plant lice). Sap and manna from the trunks and branches of the manna gums are eaten by the bellbirds and helmeted honeyeaters, and so are the psyllids. Berries, insects, spiders and prickly currant bushes are also food for these birds.

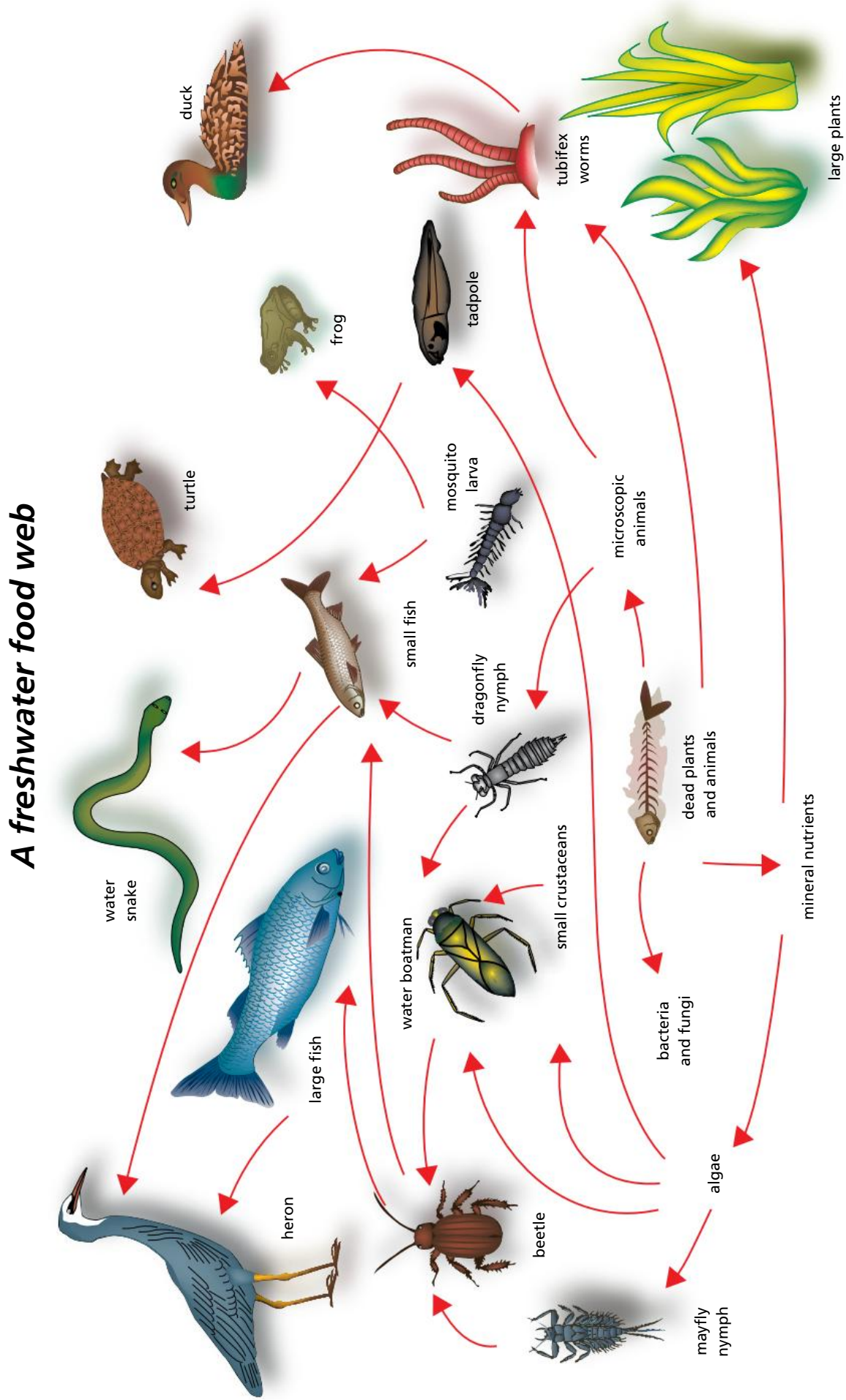
The nectar from the flowers is eaten by the bellbirds, helmeted honeyeaters and brown goshawks. The bellbirds and helmeted honeyeaters are both eaten by brown goshawks, foxes and feral cats. The brown goshawks are also food for the foxes and feral cats.

Finally, when all these organisms die, they are broken down by bacteria and fungi and their nutrients returned to the soil. The nutrients are taken from the soil by the plants.



The helmeted honeyeater

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INQUIRY 6

Seeing a food web

You will need: ball of string, A4 card, marker pen

1 One student is to represent the water plants. Give them the ball of string to start with. The other students will each be given a card with the name of an organism (in bold in the description below). They will sit around the water plants. Another student will read the observations below for a small freshwater pond. As each organism in bold is mentioned, the ball of string is thrown to the student(s) with the card. They hold the string and pass it on to the next organism.

There were **water plants** such as bulrushes and grasses growing around the edges of the pond. **Turtles**, **coots** and **moorhens** ate these plants. (The water plants person throws the string to the turtles, then the string goes back to the plants to be thrown to the coots and so on.) The **moorhens** were eating and walking on waterlilies covering the surface of the pond. The waterlilies were home to numerous insects that had laid their eggs on the underside of the leaves. **Dragonflies** were seen skimming the water, eating the **insects** on and around the waterlilies. There were snails on the waterlilies and **snails** were also seen eating **green algae** on rocks in the pond. The **turtles** ate the **green algae** too. Other algae and plankton (microscopic organisms) floated in the water. **Water fleas** and **mosquito wrigglers** were feeding on **plankton**.

Small fish, **water beetles** and **shrimp** ate the **water fleas**. **Water beetles** ate the **mosquito wrigglers**. **Small fish** also ate pollen sacs from the **ribbon weed** growing submerged in the water. **Frogs** appeared at night eating **water beetles** and **mosquitoes. Green snakes** ate **small fish**, **frogs** and **water beetles**. During the day **herons** flew into the pond to feed on the **water beetles**, **snails** and **large fish**. **Ibis** were seen wading in the shallows of the pond eating any **insects**. There was thick mud at the bottom of the pond that was rich in bacteria. The water plants, waterlilies and ribbon weed had their roots submerged in this mud.

2 Now imagine the pond is sprayed for mosquitoes. The mosquito wrigglers and all types of algae die. All the organisms (students) affected by the spray must drop their string. Any students connected to the dropped string must also drop their string. What happens to the web? Discuss this as a group.

Questions

1 Draw a food web for this pond. The food web on the previous page may help you.

2 Which organisms are producers? Herbivores? Second- and third-order consumers? Predators? Prey?

3 Which organisms compete with other organisms for food and resources?

4 Are there any organisms in this ecosystem that don't get eaten?

5 Draw all the food chains that the herons are a part of.

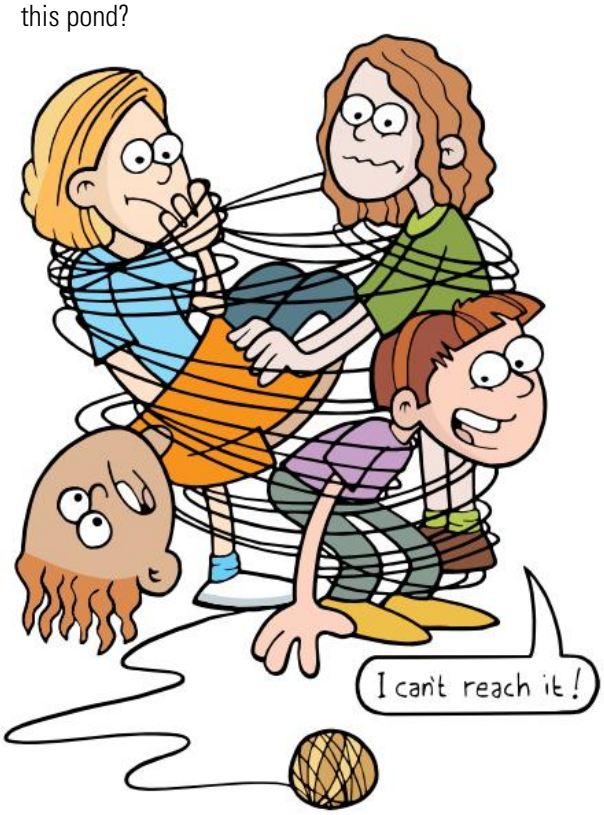
6 Describe what happened to the ecosystem when it was sprayed for mosquitoes. Is this what you would expect to happen in real life? Explain.

7 What would happen to the numbers of other organisms in the creek and pond if the number of fish suddenly increased? Show how you came to this conclusion.

8 Why are waterlilies important to some of the animals in this ecosystem?

9 Do you think this food web would be the same throughout the whole year? Give reasons for your predictions.

10 What are the abiotic and biotic factors that affect life in this pond?



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Over to you

1 State whether the following are true or false.

- **a** Food chains start with producers.
- **b** A herbivore is a first-order consumer.
- **c** All consumers are carnivores.
- **d** Decomposers and bacteria are not important in food webs.
- **e** Food webs in nature are in a delicate balance. They can easily be destroyed.

2 Look back at the food web on page 126.

- **a** Identify two producer organisms.
- **b** Name three first-order consumers and three second-order consumers.
- **c** Draw two food chains including fourth-order consumers.
- **d** Are there any fifth-order consumers? If not, suggest an organism that could be.
- **e** Looking at this food web, can an organism be a first-order and a second-order consumer at the same time? Can it be a third-order and fourth-order consumer at the same time? Explain.

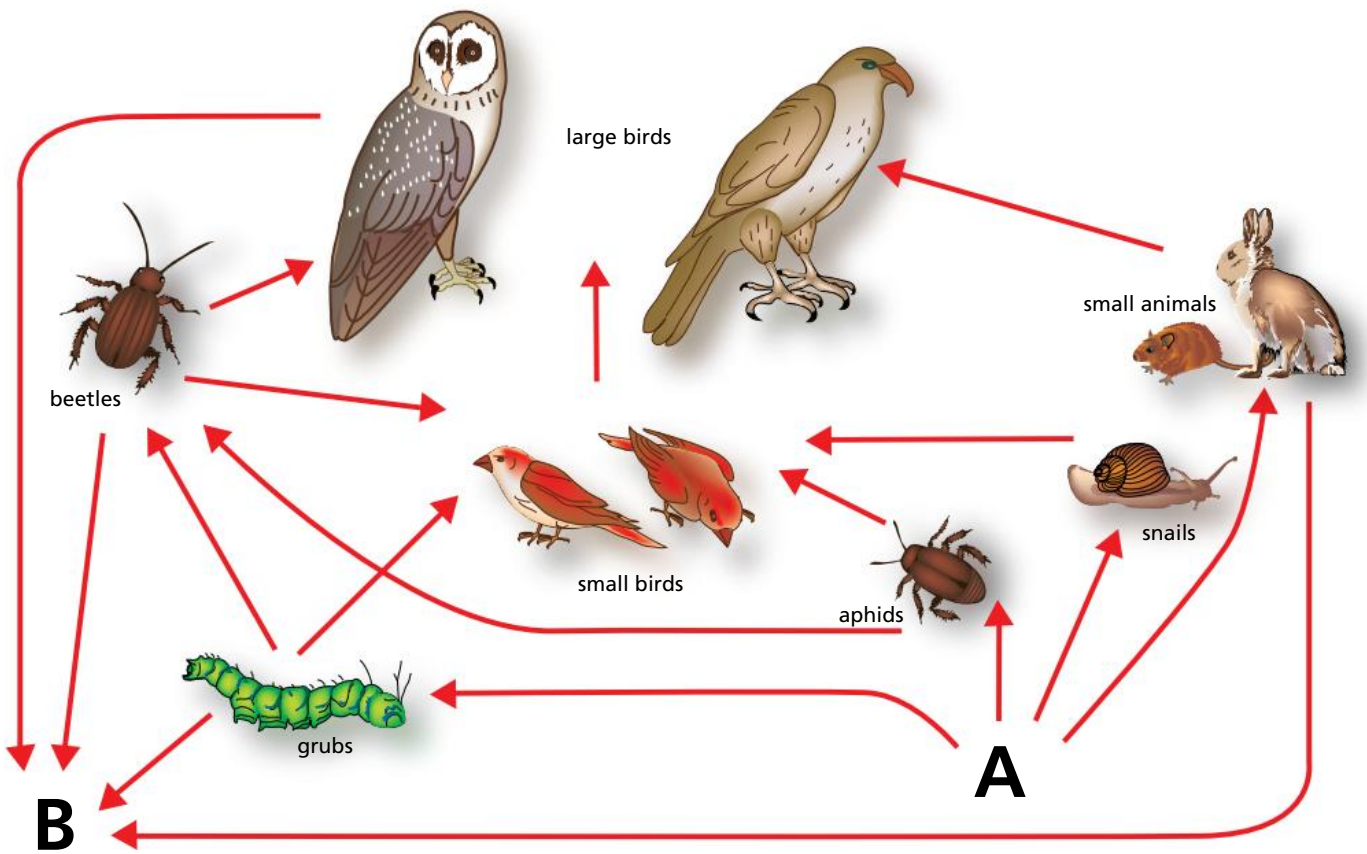
3 Look at the food web at the bottom of this page.

- **a** What would A be in this food web? Give a reason for your answer.
- **b** What would B be in this food web? Give a reason for your answer.
- **c** Explain the role of B in the food web.
- **d** Draw three food chains from this food web.
- **e** From this food web identify the following:
  a herbivore, a carnivore, a predator, two organisms that compete with one another for food, a third-order consumer.

PROBLEM SOLVING

Back to your problem from page 120. You should now be able to:

- List the abiotic and biotic factors that affect the ecosystem you have made.
- Explain where the energy for your ecosystem comes from.
- Draw food chains and webs for your ecosystem.



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6.3 Interactions in ecosystems

Organisms in an ecosystem depend on each other in a variety of ways, and they have many different relationships with each other. You have already looked at some of these relationships.

Producer–consumer relationships

All organisms rely on producers and, ultimately, the sun for their survival. The sun provides producers with energy for photosynthesis. Without producers, no other organisms could exist.

Predator–prey relationships

In any ecosystem there are always animals that are eaten by other animals. The animals hunted and eaten by predators are called *prey*. The numbers of prey affect the numbers of predators, and vice versa. Too many predators and the prey are wiped out. Then the predators die. Too few predators and the prey increase in numbers until the food they rely on cannot support their numbers and they also die. There has to be a balance to have a functioning ecosystem.



Consumer–consumer relationships

There are situations where organisms compete for the same food, resources and living space. This is *competition*. For example, the bellbird competes with the helmeted honeyeater for food, nesting sites and territory.

Collaboration

Organisms can work together or collaborate with one another to increase their chances of survival. For example, helmeted honeyeaters work together to drive intruders from their neighbourhood. This is an example of collaboration since all the birds benefit.

Commensalism

There are relationships where organisms live together and either one or both benefit. In rainforests, plants called epiphytes grow on the trunks of tall trees for support and to be closer to light and rainfall. Epiphytes gain no nutrients from the trees but benefit from living where they do. A relationship like this where one organism benefits from another, and the second organism gains no benefit, but is unharmed, is called **commensalism.**



Mutualism

Mutualism is where both organisms benefit in some way from the relationship. For example, lichens are made up of algae and fungi. The algae carry out photosynthesis and pass nutrients to the fungi. The fungi retain water that the algae use. The picture below shows an oxpecker eating the parasitic insects on an impala. The oxpecker gains food and the impala is cleaned in the process, so both benefit.



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The pollination relationship between plants and animals is another example of mutualism. The bright petals and nectar of the flower attract the insect to the plant to feed. As it does, the insect picks up pollen which it carries to the next flower. At the next flower, the pollen is transferred to the stigma as the insect feeds. So both organisms benefit. Some plants have special ways to ensure that they are pollinated.



Parasite–host relationship

In this relationship one organism (the *parasite*) benefits at the expense of the other (the *host*). In some cases the host dies as a result of the relationship. For example, tapeworms have no digestive system. They live in their host's intestine and steal nutrients meant for the host. Worms like this are a serious problem for animals such as dogs and, of course, humans. They are easily passed on in uncooked meat and in faeces.

Reproduction and parenting relationships

The helmeted honeyeater builds a nest and sits on the eggs for two weeks until they hatch. Young birds remain in the breeding territory until they find their own mate. This is all behaviour that contributes to the survival of the young. The more care the offspring or young are given, the more chance they have to survive. Birds only lay a small number of eggs because they give a high level of care to their young. Fish produce thousand of eggs because they swim off and leave them. The large numbers of eggs released ensure that at least some will survive to reproduce again.



Over to you

1 What relationships do the following show?
   - **a** Hummingbirds see red well, but blue poorly. They have no sense of smell. Flowers that rely on these birds as pollinators are red with no odour.
   - **b** A wasp lays eggs on a caterpillar. When the eggs hatch the larvae feed on the caterpillar.
   - **c** Some species of fish live among sea anemones. They get protection, shelter and scraps of food from the anemones.
   - **d** Seals form mating colonies. They group together to mate and raise their young.

2 Explain how each of the relationships in question 1 increases the survival rate of one or both of the organisms involved.

3 Are there any relationships in question 1 that do *not* improve the survival chances of the organisms involved? Explain.

4 How are predator–prey relationships important in maintaining a balance of organisms in ecosystems?

PROBLEM SOLVING

Look back at the chapter task. Which types of relationships exist in your ecosystem?

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6.4 Populations and communities

Organisms live together and rely on one another for their survival. Generally, the relationships that occur between organisms increase their chances of survival.

Organisms live with members of their own kind and also with different types of organisms. Organisms of the same type living together in a particular place are called a **population**. Herds of buffalo, schools of fish and colonies of bacteria are all words to describe such populations.

On a coral reef you may find colonies of coral living together, but you will also find sea anemones, brittle stars, fish and coral sharks. The different groups of organisms that live together in a particular place form a **community**. The name of the community is often taken from the habitat where the community is found, such as a coral reef community or a rainforest community. A community can also be named after the most abundant or most noticeable organism present, such as a eucalypt community or a mangrove community.

Populations and communities change. They are affected by abiotic and biotic factors and the numbers in them vary because of four factors:

A births

B deaths

C immigration (new individuals entering the population)

D emigration (individuals leaving the population).

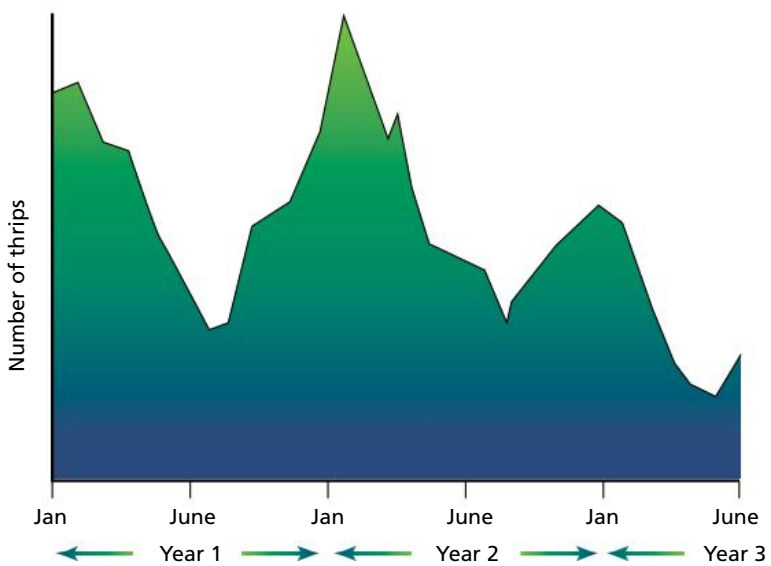
Population numbers are often displayed as a graph. For example, the graph below shows the number of thrips sampled from ten gardenia bushes over a two-and-a-half year period. (Thrips are insects that live and feed off a variety of plants.) Graphs like this can show when the population is at its highest and lowest. The thrips population was at its peak in the February of Year 2. It was at its lowest in the May of Year 3.

A graph like this can also show trends or patterns in population numbers. For example, the number of thrips seems to decrease around June and peak about January every year.

Using a population graph, scientists make inferences to explain their observations. Gardenias flower from spring through to summer, with the greatest number of flowers occurring in the middle of summer. This is also when there are the most thrips. So you can infer that the thrip population peaks in January because there are lots of flowers. The population is at its lowest in June because the gardenia bushes are bare of flowers.

With more flowers in January, there would be more food available, so you would expect the thrips would lay eggs that hatch in January. This would explain the high numbers of thrips at this time of the year. However, you would expect that predators of the thrips would also increase with more thrips available in January. This would result in a lowering of thrip numbers in the months that follow.

In January of the third year, the peak in the thrips population was not as high. This could be because there was a drought that year with far fewer gardenias producing flowers.



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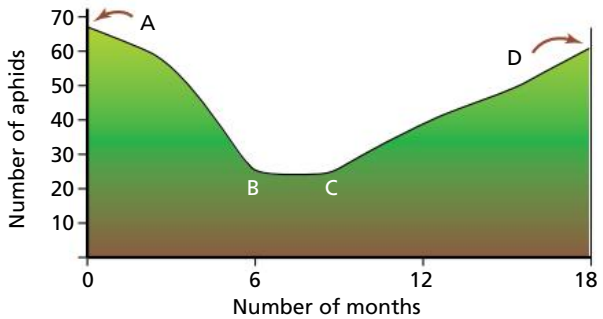
SKILL

Interpreting population graphs

An important skill is to be able to read population graphs. Here's an example.

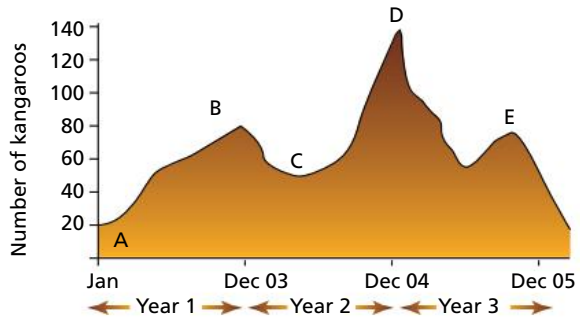
The graph below shows the population of aphids growing on 12 fruit trees in an orchard over an 18 month period. (Aphids are insects that suck sap from young plants.)

- Point A is the start of the population of almost 70 aphids.
- Between A and B there is a steady decrease in the population.
- Between B and C the population stays the same.
- Line CD shows that the population is increasing again.



Kangaroo population

Biologists were asked to monitor the number of kangaroos causing damage to a golf course in Kangaroo Valley, NSW, in an attempt to predict and control population numbers. The kangaroos were counted over 3 years and a population graph drawn.



a How many kangaroos were there at the start of the sampling?

b Describe what happened to the population numbers over the 3 years.

c What abiotic and biotic factors might affect the kangaroos on the golf course?

d The type of grass used on the course needed large amounts of water and had its greatest growing period in summer. In the first and third years, however, there were droughts in summer. Water restrictions prevented the use of sprinklers on the course and new grass growth didn't occur. Explain how this affected the kangaroo population.

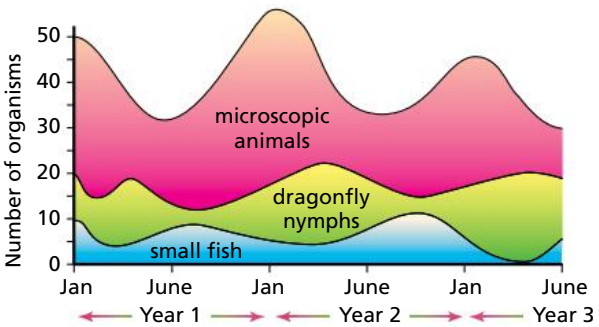
e In December of the second year there was higher than average rainfall. What did this do to the population of kangaroos?

f What seems to be the major factor affecting kangaroo numbers on this course?

g Suggest ways the golf club could control kangaroo numbers.

Freshwater microscopic animals

Microscopic animals live in fresh water. They provide food for dragonfly nymphs. The dragonfly nymphs are food for small fish. Look at the following graph that shows the population numbers of these organisms.



a When was the population of each of the organisms at its highest?

b What were the numbers of each of these populations at these times?

c Suggest inferences to explain why the dragonfly nymphs reached their peak after the microscopic animals, and the small fish reached their peak after the dragonfly nymphs.

d Why were there fewer small fish than dragonfly nymphs?

e Why were there fewer dragonfly nymphs than microscopic animals?

f What type of relationship do the dragonfly nymphs and fish have?

g Explain whether microscopic animals would be the start of this food chain.

h What abiotic factors are likely to affect this community?

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INVESTIGATION

1 Population monitoring

Aim

To carry out population monitoring.

Risk assessment and planning

Do not harm living things.

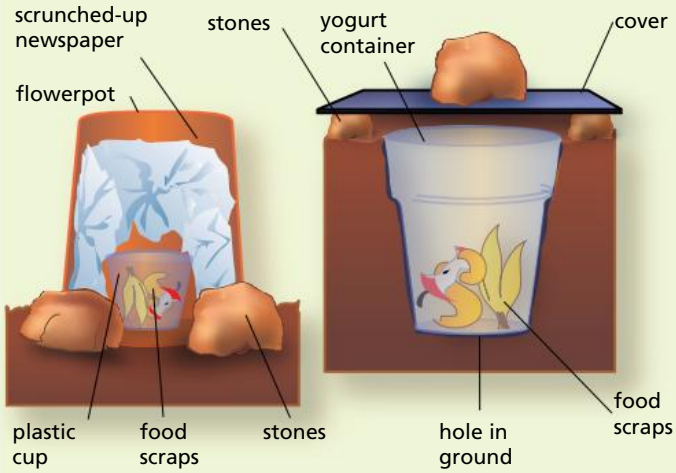
Always use gloves to touch organisms.

Apparatus

Make a list of the apparatus you will need as part of your planning.

Method

1 Choose an area in a garden bed to set up each of the following traps.



2 Each day empty your traps separately onto a tray. Identify and count the organisms, then return them to the area where you found them. Re-set your traps. Record your results in a table. Do this for a week.

3 If you have a thermometer, rain gauge, pH probe or anemometer (wind gauge) you could measure the abiotic factors affecting your site. (Ask your teacher for help.)

Results

Complete these questions as your results.

1 How many different populations did you find? List the numbers of each.

2 Draw a graph for each population of organisms you have found over a week. (Put the days of the week on the x-axis and the numbers of organisms on the y-axis.)

3 What were the abiotic and biotic factors affecting your populations?

Conclusion

Write a summary about the variety of organisms you sampled and how their numbers varied over the week.

Write your report

Write your report in the usual way.



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SCIENTISTS AT WORK

Dr Myriam Bormans

Dr Myriam Bormans is a scientist working to improve our environment. She was born in Belgium and studied maths and science at high school. Myriam completed a degree in physics because she had an inspirational physics teacher, then honours in oceanography. In Canada she completed her PhD in oceanography.

Myriam came to Australia to study the interactions between currents, wind and tides as part of global warming research. In 1991 over 1000 km of the Darling River was covered with toxic blue-green algae (cyanobacteria). CSIRO (Commonwealth Scientific and Industrial Research Organisation) proposed a program to study this. So in 1993 Myriam joined CSIRO to find solutions for restoring the health of rivers affected by excessive land clearing and changed water flow.

Today Myriam looks at how water flow, temperature and turbidity (cloudiness) affect the growth of blue-green algae. These algae need light and nutrients, and grow best in warm and stable conditions. Where water flow is slow, the water is warm on top and blue-green algae float to the surface and grow. In high-flow areas, the water is colder with more turbidity. So there is less light and less blue-green algae.

Myriam has developed flow models to avoid the growth of blue-green algae in our rivers. To improve our waterways we must also preserve native habitats and vegetation so that nutrients and sediments do not run off the land and into rivers when it rains.

Myriam says that her job 'is challenging and always fascinating. You travel and meet people with similar interests from around the world'. There is always the 'extra motivation that you are working on problems where the solutions are needed urgently, and that gives you a sense that you can make a real difference'.

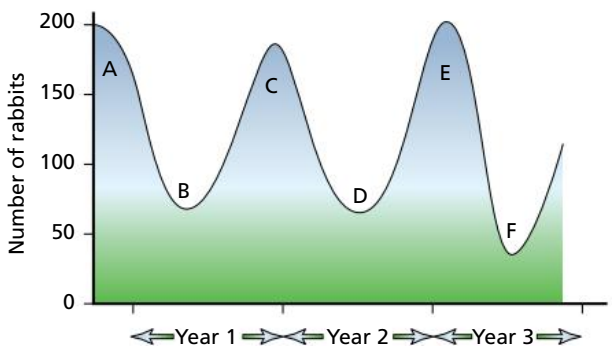


Over to you

1 What is the difference between a population and a community? Give an example of each.

2 What information can population graphs provide? Explain.

3 The graph below shows the number of rabbits living on a beef cattle farm near Warrnambool, Victoria.



a When is the rabbit population at its highest and lowest during the three years?

b Describe any trends or patterns you can see in the graph.

c What abiotic and biotic factors might affect the population of rabbits on the farm?

d Write inferences to explain the patterns you have identified.

e Suggest an inference to explain the lower than average numbers of rabbits in June of Year 3.

f The farmer also has problems on his farm with foxes that are predators of the rabbits. Copy the rabbit population graph, and in a different colour draw what you predict the population graph for foxes would look like.

g Explain your predicted population graph for foxes.

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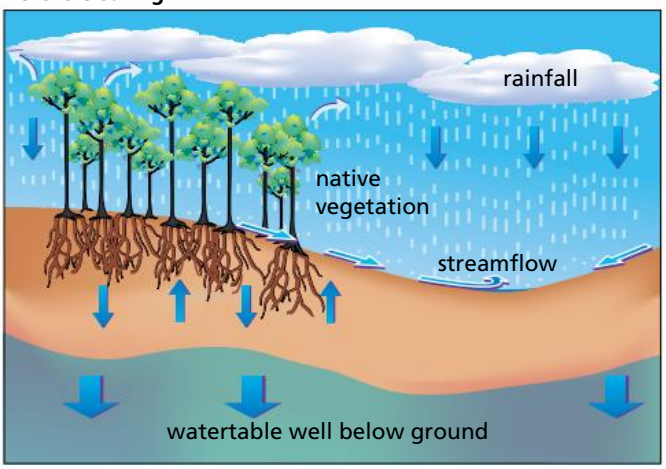
6.5 Changes in the environment

Salinity

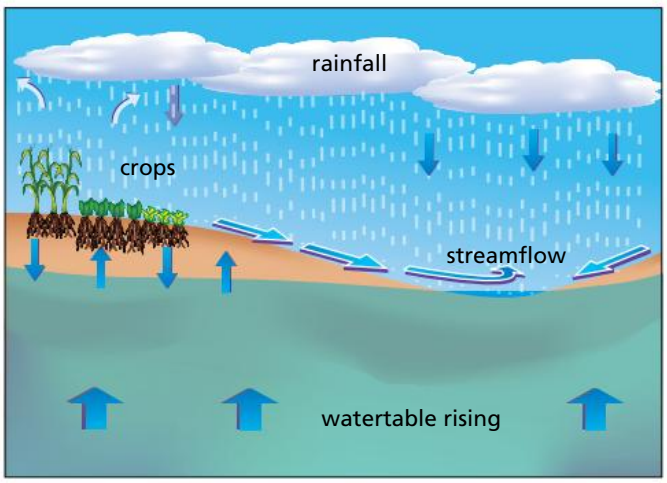
Salinity in Australia is a very serious problem, and shows how small changes in the environment can have drastic effects on ecosystems.

In a natural environment, rainfall soaks through the soil and underlying rocks. It is then called ground water. Eventually it reaches a level underground where the soil and rock is saturated with water. This level is known as the watertable. Native plants have long, deep roots that use large amounts of the incoming rainfall, so the watertable usually stays well below the surface.

Before clearing



After clearing



Early settlers in Australia cleared the land of the natural vegetation and planted crops for food. Crops have short roots that absorb very little incoming rainfall. So without the native vegetation, the watertable started to rise, bringing with it salt that had been contained in the soil for thousands of years.

The salty water at the surface evaporated, concentrating the salt and making the soil useless for crops. The salty water also entered watercourses, affecting the plants and animals that relied on this water.

Salinity is an even bigger problem on irrigated land. The large amounts of extra water dissolve salt from the soil and carry it into the groundwater. To combat salinity, farmers need to preserve natural vegetation and grow long-root crops. Where possible, they need to prevent water soaking into the soil and accumulating. To do this they need to use as much of the surface water as they can and develop irrigation techniques that don't waste water.

INVESTIGATION 2

Design your own experiment

Aim

Design your own experiment to test the hypothesis 'The growth of most plants decreases when the salinity increases'.

You could grow seeds on damp cotton wool or filter paper and give some seeds normal water and others varying levels of salty water. You would of course need to change only one variable (the amount of salt), and keep all other variables the same.

Results

Record what happens to your seeds over 2 weeks.

Write your report

You will need to write an Aim for your experiment, do a Risk assessment, list your Apparatus and describe your Method.

Complete these questions as part of your Method.

1 Why did you give some plants normal water?

2 What were the possible variables in this experiment? How did you control these to make your experiment a fair test?

You will also need to write a suitable conclusion saying whether or not your hypothesis was correct.

ISBN 978 1 4202 3246 2

Environmental pollution

We often think that what we do in our homes doesn't make a difference, but we can harm ecosystems without realising it. Simply mowing the lawn can be a threat to the environment.

Lawn mower pollution

Would you believe that a lawn mower produces 40 times as much pollution as a car, and that two-stroke outboard engines are even worse?

Three-quarters of the pollution from lawn mowers is carbon monoxide, which can cause heart disease, nerve damage and low birth rates. Carbon monoxide is also a major threat to the environment through global warming. Mowers also release:

- benzene, which has been linked to leukaemia and birth defects
- toluene, which can damage your kidneys, vision and hearing
- nitrogen oxides, a major cause of photochemical smog, which is a problem in Sydney, and acid rain.

At present there are no laws to limit air pollution from small engines such as those in lawn mowers, outboard motors, whipper snippers and leaf blowers. It has been suggested that these small engines should be fitted with catalytic converters, as the engines in cars are. Or perhaps homeowners should consider getting rid of their petrol lawn mower in favour of a push-mower or a native garden.



INQUIRY 7 **Chemicals and plants**

Design your own experiment to test the effects of chemicals on plant growth. You could add varying amounts of dilute acid to germinating seeds.

You could mist plants (e.g. beans, grass) with various dilutions of acids (e.g. carbonic, hydrochloric, sulfuric) to investigate the damage to leaves.

You could test the effects of detergents on plant growth. For example, you could compare the growth of plants watered with varying levels of detergent with plants that are given normal water. Report back to the class on your findings.



Water quality

The numbers and types of organisms living in a waterway are good pollution indicators. Some organisms are very sensitive to change and die out quickly. You can monitor the quality of water in a river or creek by looking at the organisms in the water.

The abiotic factors such as the temperature, acidity and *turbidity* of the water can also be used. Organisms have certain temperature requirements, and if the water is too cold or too hot it can affect the activity of organisms. Temperature also affects the amount of oxygen dissolved in the water and available for organisms to use.

The water in a freshwater environment should be like our drinking water. Chemicals that are washed into rivers and streams can affect the water, making it too acidic or too alkaline for the organisms that live there. Dirt, mud and particles suspended in the water can make it cloudy. This blocks the light entering the water and affects the organisms living there.

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INVESTIGATION

3 Checking for water pollution

Aim

To examine the water quality of a body of water.

Risk assessment and planning

Always act sensibly when near water. What risks are there?

What equipment will you need to carry for your own safety?

Apparatus

- hand sampling nets
- sampling nets attached to broom handles
- white ice-cream containers
- hand lens
- plastic pipette
- raincoat
- notebook
- tweezers
- gloves
- gumboots
- abiotic sampling equipment—thermometer, turbidity disk, pH meter

Method

1 Sketch the area that you are sampling. Mark three sites on your sketch to show where you will sample the water.

2 Take the following measurements for each site as instructed: temperature, pH, rate of flow, turbidity at three different depths (surface, middle and bottom).

3 Sweep the nets you have through the water. Empty the contents of each net into an ice-cream container. Examine, count and name the organisms you find. Do this for three different depths at each site.

Results

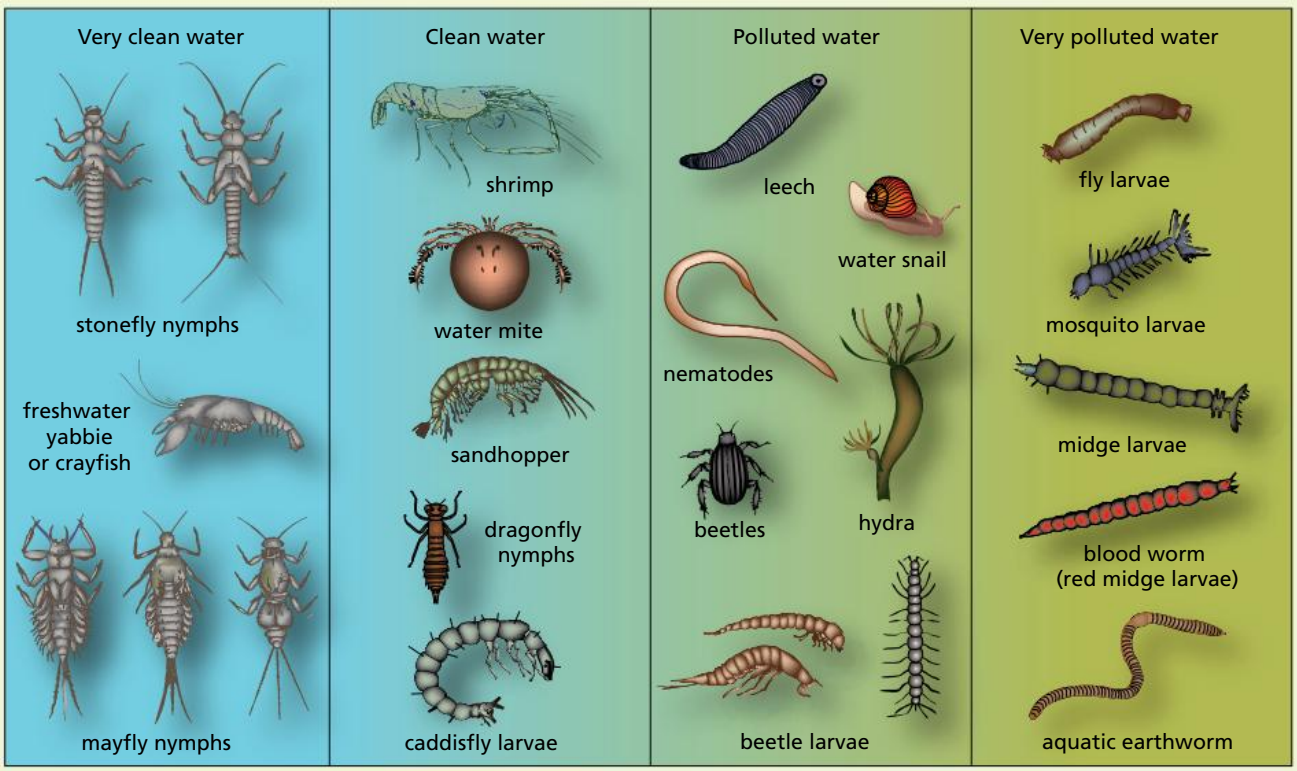
Construct a table with the names and numbers of organisms you find at each site and depth. The different organisms you find indicate how clean or polluted the water is.

Writing up your report

Write a full report of your findings under the following headings: Location and description of area, Abiotic factors that influence each site, Findings at site 1, Findings at site 2, Findings at site 3, Similarities and differences between the sites and inferences to explain these.

Conclusion

Summarise your findings. How healthy is the water you studied?



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Aboriginal ecology

Aboriginal knowledge to be used

The West Australian government has told BHP Billiton they must consult with the Ngalia Aboriginal people before clearing land to develop their new uranium mine at Yeelirrie. The Ngalia people, who use the land to gather food and for tribal ceremonies, wanted to stop the Yeelirrie site from being developed. However BHP Billiton have been allowed to go ahead provided they first consult with the Ngalia people.

A spokesman for the Ngalia people said it was a victory for them because it is the first time that Aboriginal knowledge is to be used in the land clearing process. Until now, only scientific studies of plants and animals have been used.

24 September 2009

✻ Read the article above carefully, then summarise it in your own words.

Ecology is the study of how living things are linked with each other and with their surroundings. To understand *Aboriginal* ecology you need to understand the Australian Aboriginal people's spiritual connection with the land. In the Dreamtime their spirit ancestors roamed the Earth, forming rocks, streams and mountains, and providing the plants and animals for food.

Aboriginal people take what they need from the land, but in return they must give something back to the land. They must respect Mother Earth and conserve the land for their children's children's children. As one Aboriginal elder said, 'We're looking after her 'cause she's looking after us.'

Aboriginal people were traditionally nomadic, which means they moved from place to place, depending on the availability of food and water. They were taught from an early age not to catch more food than they needed. This meant there would be enough food for the future. In other words, their lifestyle was *sustainable*. They were able to continue using the Earth's resources for a very long time without using them up and without damaging the environment. As caretakers of the land, the Aboriginal ancestors gave each tribe a *totem*. This is an animal that the tribe respected and refused to eat. As a result, every Australian animal had a region where it was protected, almost like our modern-day national parks.

Aboriginal people used fire to manage the land and its forests. Instead of allowing the dead leaves and branches to build up on the ground, they lit fires when the weather was not going to let the fire get out of control. This resulted in small fires which cleared undergrowth, flushed out animals for hunting, and encouraged plant growth. When the Sydney area was settled Aboriginal burning stopped. As a result the fuel built up in the forests and there were frequent destructive bushfires.

The Aboriginal people managed the land successfully for over 40 000 years. On the other hand, during 200 years or so of white settlement we have used the land badly and now face environmental problems such as salinity, water shortages and pollution of the atmosphere. Many people think we should view the land more as Aboriginal people do—as something to be respected and conserved.

✻ Aboriginal people see themselves as caretakers, not owners, of the land. Should we have the same view? Explain your answer.

✻ Given the series of tragic bushfires in Australia, should national parks and farming country be burnt on a regular basis to reduce the risk of destructive bushfires? Justify your answer.

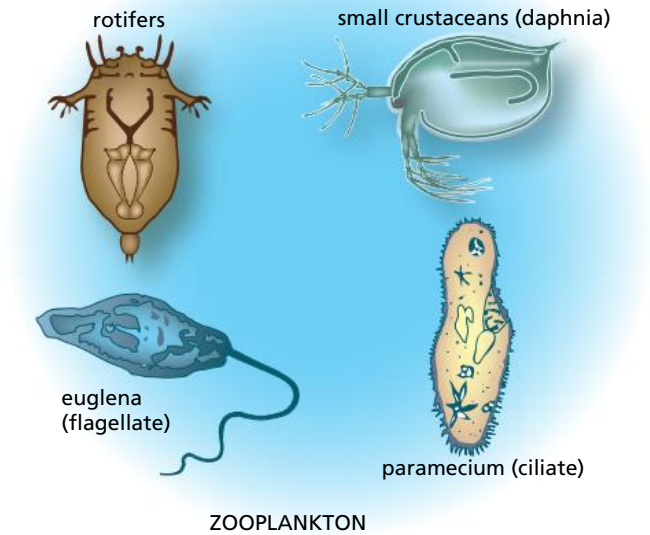


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THINKING SKILLS

On the Central Coast of New South Wales developers are looking at draining inland waterways to build a tourist resort. They say that the resort will bring in millions of dollars for the state and that there is very little life in the water to be drained. You were asked to do an environmental study on the waterways and report to the government about the biological importance of the area. This involved looking at the different types of organisms in an area (the diversity of organisms) as well as their numbers. Your report is shown on the right.

1. Draw a food web for the area.
2. The table on the right shows the diversity of organisms and their numbers sampled from five different sites over a year.
3. Draw population graphs to display this data.
4. What patterns can you identify from these graphs? Make inferences to explain the patterns.
5. From your graphs, are the population numbers large enough and diverse enough for the site to be a valuable environment to keep?
6. Write a recommendation to the government on whether they should let the development go ahead. Make sure you give reasons for your recommendations.

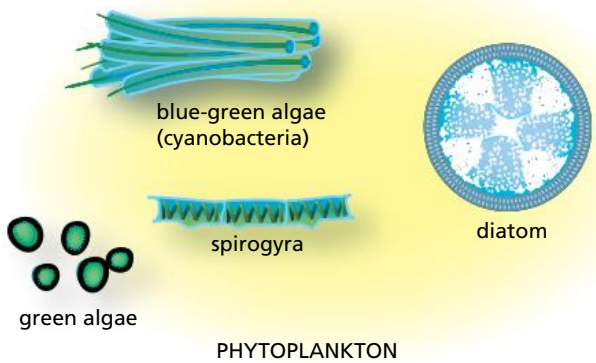


Study on Central Coast waterways

There is an abundance of microscopic organisms such as green algae and diatoms. These microscopic producers are called *phytoplankton*. There is also an abundance of blue-green algae. The first-order consumers feeding on the phytoplankton are called *zooplankton*. They consist of rotifers, small crustaceans, flagellates and ciliates. Some of the larger crustaceans eat the zooplankton too. Small fish eat the phytoplankton and bottom dwellers such as mussels.

The second-order consumers are small fish, such as minnows and perch, that are eaten by eels. The fish also eat the young stages (nymphs) of insects such as dragonflies, mayflies and caddis flies that spend part of their life cycle in the water. These eat the zooplankton. Dragonfly nymphs also eat water boatmen that live off algae. Finally, frogs live off the insects around the water and are consumed by snakes that also eat fish. Herons and kingfishers eat the fish, and kookaburras feed on snakes and lizards. Tubifex worms, bloodworms and fungi feed on the dead remains.

Number of organisms					
	Diatoms	Rotifers	Caddis fly	Fish	Heron
January	2000	1000	500	15	3
April	1500	800	360	10	2
July	1000	400	150	7	2
October	1500	750	278	10	2
January	2000	978	480	15	3



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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 The _____ is all the conditions that affect an organism where it lives. There are _____ and _____ factors that affect organisms.

2 Living things and their interactions with each other and with the non-living environment form a system called an _____.

3 There are many types of relationships in ecosystems. For example, _____ is where both organisms benefit from living together.

4 Organisms have characteristics called adaptations that enable them to survive in the environment in which they live. An adaptation can be structural, functional, _____ or _____.

5 Feeding relationships can be shown in a food _____ made up of producers and _____. Food _____ are more complex diagrams of feeding relationships.

6 Organisms of the same type living together form a _____. The different groups of organisms that live together in a particular place form a _____.

7 Population _____ are useful to biologists because they show the highest and lowest numbers of a population and _____ or trends in the population.

abiotic
behavioural
biotic
chain
community
consumers
ecosystem
environment
graphs
mutualism
patterns
population
reproductive
webs

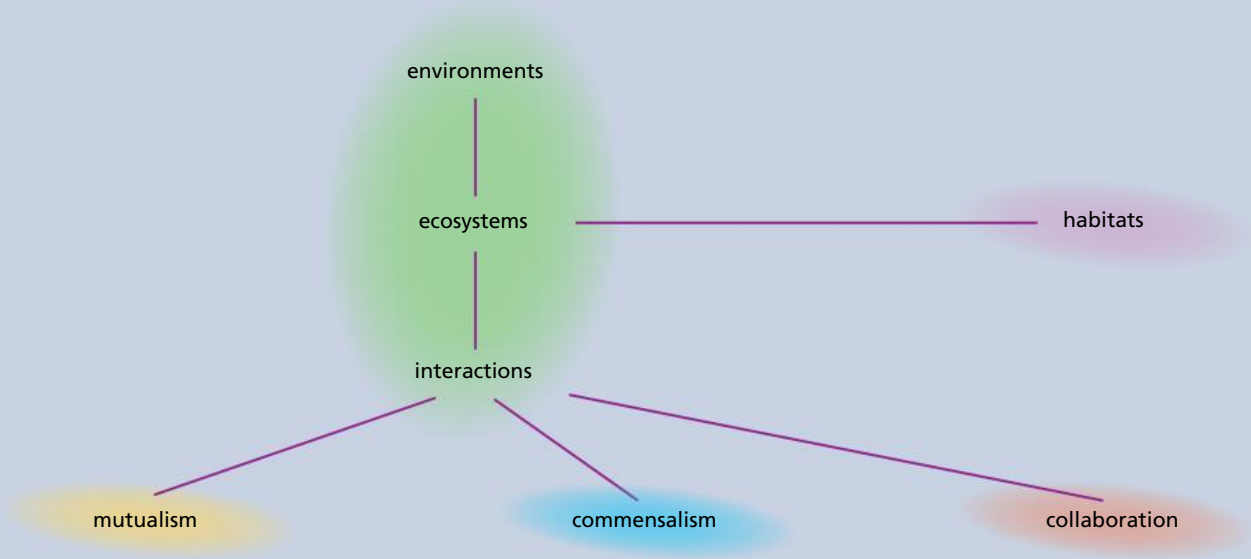
Self-management

A concept map can be used to link all the major words in a chapter together. The line joining the words together can be used to explain the link.

1 Draw a concept map using the words: ecosystems, environments, habitats, predators, prey, producers, interactions, consumers, organisms. An example of the type of concept map you can draw has been started for you here.

2 Once you have linked the given words, add to your map as many words as possible that were highlighted in bold in the chapter.

3 If you are doing this as a class activity, swap your map with someone else. Using a different coloured pen add any links you think they have forgotten, then get your own map back. Did you leave anything out?



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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 Which of the following are true and which are false? Rewrite the false ones.

- **a** An ecosystem is all the conditions that affect where an organism lives.
- **b** Abiotic factors are physical factors.
- **c** The relationship a pollinator has with the flower it pollinates is called a predator–prey relationship.
- **d** A structural adaptation is when an organism hides behind rocks to avoid a predator.
- **e** A food web is a more complex diagram of the feeding relationships in an ecosystem.
- **f** At the start of every food web, there is a producer organism.

2 Match the following words with their meanings:
habitat, decomposers, adaptation, herbivore, ecosystem.

- **a** A system formed from the interactions of living things with the non-living environment.
- **b** The living place of an organism.
- **c** A characteristic that helps an organism to survive in the environment.
- **d** First-order consumers are given this name.
- **e** These organisms break down the dead bodies of others and return their nutrients to the soil.

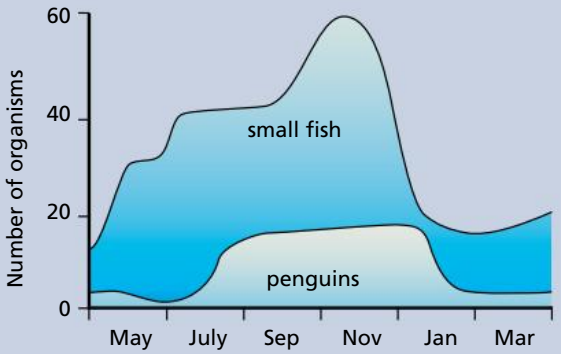
3 Explain the difference between a community and a population.

4 Give an example of:

- **a** a parasite–host relationship
- **b** commensalism
- **c** a structural adaptation

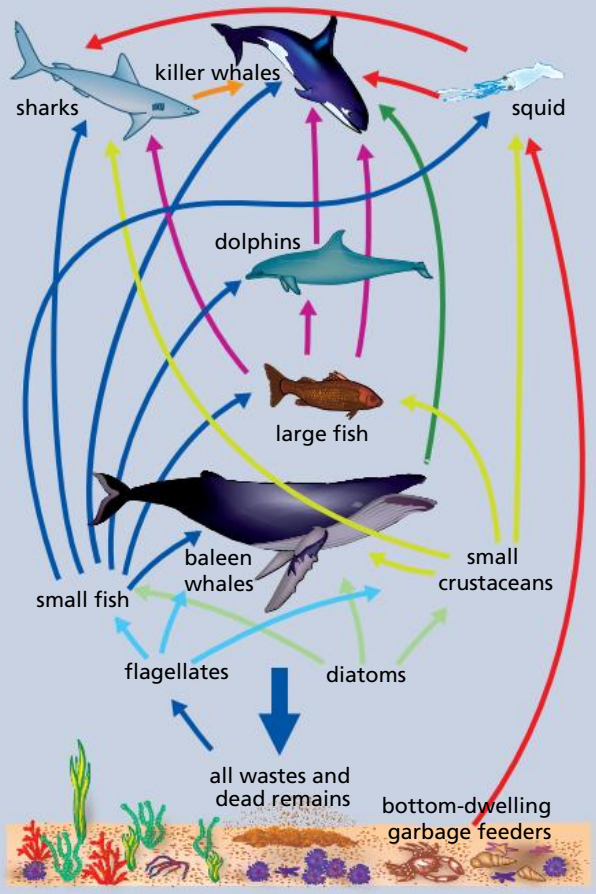
5 The graph top right shows the population of penguins and the small fish they eat.

- **a** When are the highest and lowest populations of fish and penguins?
- **b** How do the numbers of small fish affect the penguin population?
- **c** What factors could cause an increase in the numbers of fish and therefore penguins?
- **d** What factors could cause a decrease in the numbers of fish and therefore penguins?
- **e** Why are there fewer penguins than small fish?



6 The diagram below shows an ocean food web. List the following from this web:

- **a** a producer organism
- **b** two first-order consumers
- **c** a carnivore
- **d** a second-order consumer
- **e** a third-order consumer
- **f** two organisms that compete for food.



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7



Electrical energy

By the end of this chapter you will be able to …

Knowledge and Understanding

- describe electric current, voltage and resistance using analogies (PW3a)
- describe qualitatively the relationship between voltage, resistance and current (PW3b)
- compare the characteristics and uses of series and parallel circuits (PW3c)
- discuss Cathy Foley's career with superconductors (PW3d)

Skills–Working Scientifically

- assess strategies that have been identified as possible solutions to a problem (8b)
- draw circuit diagrams using the correct symbols (9a)

LITERACY FOCUS

alternating current (AC)
ammeter
circuit diagram
direct current (DC)
earth wire
electrical resistance
electric cell
electric circuit
electric current
electric generator
electromagnet
fuse
magnetic field
parallel circuit
series circuit
short-circuit
solenoid
voltage
voltmeter
volts

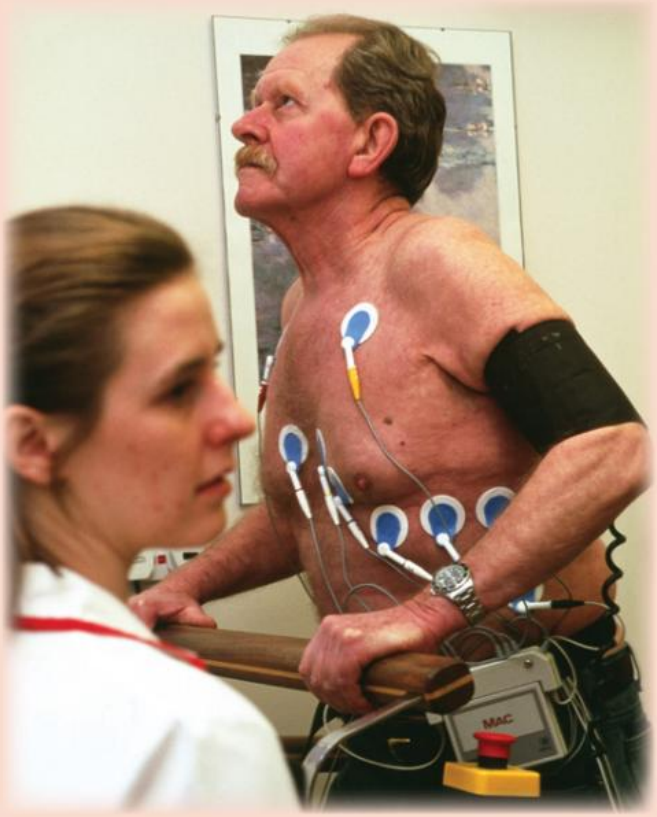
Focus for learning

You use electricity every day. It is supplied to your home, and you just have to flick a switch to turn on a light or an electrical appliance. You can even carry electricity with you in batteries to power watches, torches, CD players, mobile phones and laptops.

Electricity is not just found in our homes and in batteries. It also occurs naturally. Electricity can build up in storm clouds and be released as a flash of lightning.

Electric eels live in South American rivers. They grow up to 2 m long and can produce enough electricity to kill or stun any fish nearby. The dead or stunned fish are then easy to catch.

Your brain and nerves produce electric signals which control your body and keep you alive. For example, your heart needs these signals to keep it beating. If there is a problem with your heart, the doctor does an ECG (electrocardiogram). This shows whether the electrical activity in the heart is normal.

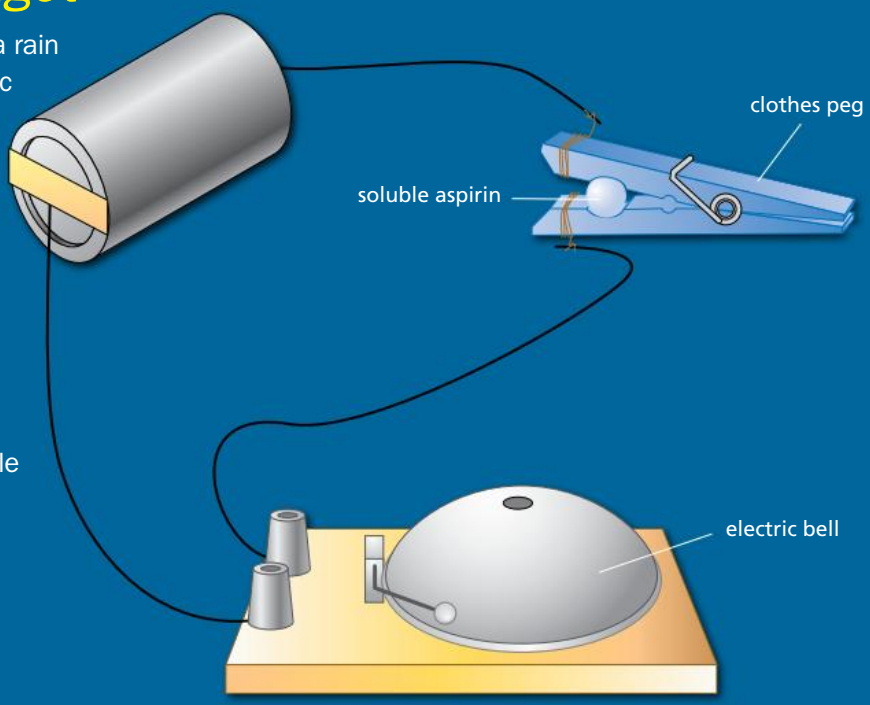


PROBLEM SOLVING

Making an electrical gadget

Caitlin and Trang have made a rain alarm using a battery, an electric bell, a clothes peg, a soluble aspirin and bits of wire. When enough rain falls, the aspirin dissolves, letting the peg close. This connects the wires and lets electricity flow from the battery, causing the bell to ring. Make this rain alarm and see how it works.

Using what you have learnt, design another useful gadget, like the rain alarm, using wires, switches, bulbs and other simple electrical devices. As you work through the chapter you will learn more about electrical gadgets and how to connect them.



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7.1 What is electricity?

INVESTIGATION

1 Battery, bulb and switch

Aim

To investigate different ways of connecting a battery, bulb and switch.

Risk assessment and planning

Don't leave the battery connected, as the wires may become hot. This will flatten the battery and you may burn your fingers.

Apparatus

- 1.5 V torch battery
- torch bulb (2.5 V)
- 4 connecting wires with alligator clips
- 2 switches

Method

Part A: Lighting a bulb

1 Use the battery and one connecting wire to make the bulb glow.
   - ✲ When you have done this, draw a simple diagram of how you connected the battery and bulb.

2 See if you can find other ways of making the bulb glow. For example, does reversing the connections make any difference?
   - ✲ Which parts of the bulb do you need to connect for it to glow?
   - ✲ Which parts of the battery do you need to connect?

3 How can you make the bulb glow using two connecting wires? Does the bulb have to be touching the battery?
   - ✲ Draw diagrams of each circuit you build.

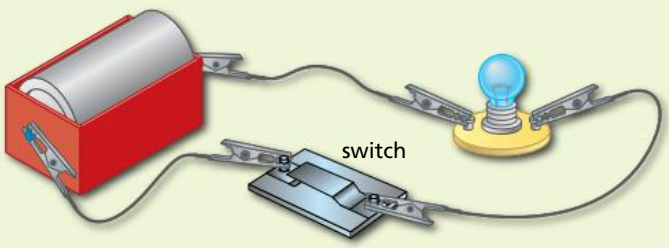
Part B: Using a switch

1 Use three connecting wires to connect the battery and bulb as shown top right.



   - ✲ How can you make the light go on and off?

2 Now connect the switch between the alligator clips. Have a close look at the switch to see how it works. You may need to check the back of it.



3 Use the switch to turn the bulb on and off.
   - ✲ Explain how the switch works.
   - ✲ Does it matter where you connect the switch?
   - ✲ Does it matter which way round the switch is connected?
   - ✲ What happens when you unscrew the bulb from its holder?
   - ✲ Does it make any difference if you reverse the connections to the battery?

Conclusion

Write a sentence or two saying what you have found out about batteries, bulbs and switches.

Electric circuits

In Investigation 1 you should have noticed:

1 You need to connect both ends of the battery to the bulb before it will glow. These metal connection points are called *terminals*. The top of the battery is positive (+) and the bottom is negative (–).

2 The bulb has to be connected the right way. The metal side of the bulb is one terminal, and the metal spot on the bottom is the other. One wire must be connected to each terminal. You can't have two wires connected to one terminal.

3 For the bulb to glow, there must be a closed path joining the battery and the bulb. This is called an **electric circuit**. If there is a gap in the circuit the bulb goes off. A switch is a convenient way to open and close the circuit.

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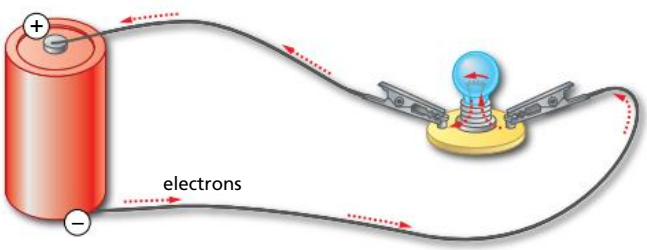
The connecting wires in a circuit are made of metal, which allows the electricity to move through them. The atoms in the metal have positive nuclei, with negative electrons around them. In metals these electrons are free to move from one atom to the next. As one electron leaves an atom, another replaces it. In this way there is a movement of electrons through the metal. This movement of electrons in a wire is called *current* electricity. It is different from *static* electricity, where the electric charges don't move.

Imagine your class is in a narrow corridor. If you pass a ball along from one person to the next this is like an electron moving along a wire. You can also think of the electron as someone surfing the mosh pit.

Electric current

Now you know that electricity is a movement of electrons though a metal, you can explain the electric circuit in Investigation 1. The battery acts like a pump, pushing electrons out of the battery's negative terminal. Because the electrons are negatively charged they are attracted towards the positive terminal of the battery and skip from atom to atom through the metal connecting wires.

If the electrons meet a light bulb they continue to move through the fine metal wire (called a filament) inside the bulb. As they move through this filament they cause it to heat up and glow. The electrons then continue moving from atom to atom on their way to the positive terminal of the battery, and the circuit is complete. This continuous movement of electrons in a wire is called an **electric current**. If there is a break anywhere in the circuit the movement of electrons stops and the bulb does not glow



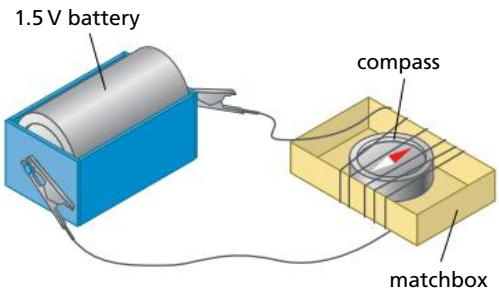
Measuring electric current

Electric current is measured using an **ammeter** (AM-eat-er), which is similar to the current detector you can make in Inquiry 1. It counts the number of electrons passing through it per second. The electric current is measured in **amperes** (abbreviation *amps*, symbol A) or milliamps (1000 mA = 1 A).

INQUIRY 1 Making a current detector

You will need: 1.5 V battery, small magnetic plotting compass, connecting wire about 1 m long with alligator clips, empty matchbox

1. Place the compass in the tray of a matchbox. Wind the connecting wire around the compass in the box, as shown. Connect one end to the battery.
2. Rotate the matchbox so that the needle is parallel with the wire and points north–south.

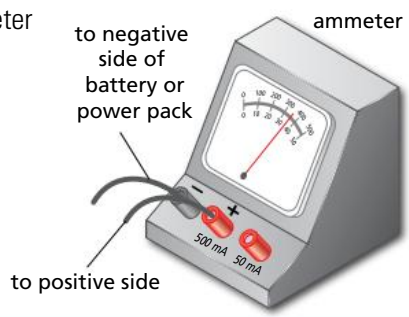


3. Briefly touch the other end of the connecting wire to the other terminal of the battery. What happens?

INQUIRY 2 Using an ammeter

When using an ammeter, the red positive terminal is always connected to the positive side of the battery or power pack. The black negative terminal is connected to the negative side. There may be more than one positive terminal, as in the photo below. If you connect to the 50 mA terminal, the ammeter measures from 0 to 50 mA on the bottom scale. If you connect to the 500 mA terminal, it measures from 0 to 500 mA on the top scale. Always connect to the terminal with the largest scale. This will prevent you from damaging the ammeter with too large a current. You can then change to the more sensitive scale if you need to.

Connect an ammeter into the electric circuit you set up in Investigation 1. Measure the electric current.



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INVESTIGATION

2 Conductor or insulator?

Aim

To test various materials to see whether they are conductors or insulators.

Conductors allow electricity to move through them, that is, they allow electrons to move from atom to atom.
Insulators do not conduct electricity, that is, they make it very difficult for electrons to move through them.

Risk assessment and planning

For each object listed below, you will record the material it is made of, how brightly the bulb glows and the ammeter reading. Design a suitable data table for this.

Apparatus

- metal objects, e.g. paperclips, coins, aluminium foil
- objects made of plastic, wood, rubber, glass, paper, string
- connecting wires of various lengths (Test the insulation on the outside, and the wire inside.)
- the graphite in a lead pencil (Sharpen both ends.)
- ammeter (0–500 mA)
- 2.5 V bulb
- 1.5 V battery

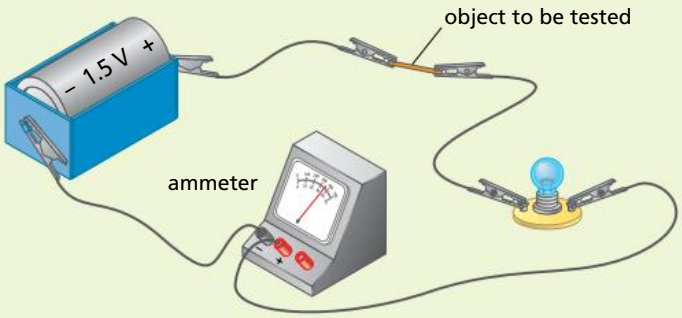
Method

1 Set up a circuit as shown, but with no object between the alligator clips.

2 Touch the alligator clips together to make sure the bulb and circuit work.

✻ Record the electric current on the ammeter.

3 Connect one of the objects between the alligator clips.



✻ Record how brightly the bulb glows, and the ammeter reading.

4 Test each of the other objects and record your results.

5 Is your skin a conductor or an insulator? Does it make any difference how far apart the alligator clips are, or whether your skin is wet or dry?

Results

1 Why is it necessary to have an ammeter in the circuit?

2 How do you know from this experiment whether a material is a conductor or an insulator?

3 List the materials tested, from the best conductor to the worst conductor (best insulator). Explain your order.

4 Some materials didn't make the bulb glow, yet they gave a reading on the ammeter. Explain this.

Conclusion

From the results, write a conclusion about which types of materials are conductors and which are insulators.

Conductors and insulators

Conductors are usually metals, but not all metals conduct electricity equally. The best conductors are silver, copper, gold, aluminium and steel. The reason they are good conductors is that the electrons are only weakly attracted to the nuclei of the atoms, so they are free to skip from atom to atom, forming an electric current. Metals are also good conductors of heat.

The best insulators are plastic, rubber, wood, glass, porcelain and air. This is because in these materials, the electrons are strongly attracted to the nuclei of their atoms and are not free to move.

Connecting wires are made of copper or aluminium, but they are covered in plastic to prevent electric current from escaping into other conductors such as metal appliances or your body. This is also why electrical appliances have plastic cases and plastic handles. The handles of screwdrivers and pliers are often coated with plastic insulation, and electric plugs, sockets and switches are all made of plastic. The wires on power lines are made of aluminium or steel, but they have glass or porcelain insulators to stop any electric current from escaping down the pylons and into the ground.

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Resistors and resistance

Electrical resistance is a measure of how difficult it is for electrons to move through an object. Resistance is measured in *ohms* (symbol Ω). Conductors have a low resistance and insulators have a high resistance. To help you understand this, think about moving along a crowded corridor. The more people there are in the way, the greater the resistance to your movement, and the longer it takes to get through.

As electrons move through a conductor they collide with atoms. This causes the atoms to vibrate more, raising the temperature of the conductor. Some substances—such as platinum, nichrome, tungsten, iron and carbon—offer a lot of resistance, even though they allow the current to pass. These substances can be used to make *resistors*. A resistor with a small resistance lets a large current flow through it, and one with a large resistance lets only a small current through it. This is why resistors are used in electric circuits to control the flow of electric current. In a circuit with a large resistance, only a small current will flow. In a circuit with a small resistance, a large current will flow.

Current flowing through resistors produces heat and this is why appliances such as TV sets become warm when they are operating. Electric stoves, toasters, bar heaters, hair dryers and irons all contain long coils of wire which resist the movement of electrons. They get hotter and hotter as more current flows through them, until they become red-hot. The coiled filament of a light bulb is made of tungsten. Because it has a high resistance it gets so hot it becomes white-hot and glows brightly.

INQUIRY 3 Resistance wires

You will need: 240 V light bulb, hand lens, toaster

1 Look carefully at the light bulb and draw an accurate diagram of it. Use the hand lens for a closer look at the filament—the resistance wire that glows when the bulb is plugged in.
   - Why do you think the filament is coiled?
   - Describe how the light bulb works.

2 Examine an old toaster, bar heater or hair drier with its cord cut off. If possible, remove the casing so that you can see the resistance wires used for heating.
   - Draw a diagram of the appliance showing how it works.

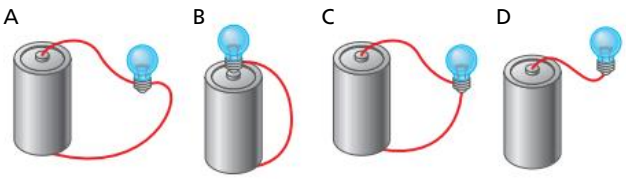
Over to you

1 What is an electric current?

2 **a** What is the difference between a conductor and an insulator?
   b Give two examples of each.

3 Copy and complete these sentences.
   a A path for electricity is called a _____.
   b A _____ lets you open and close a circuit.
   c The movement of electrons in a wire is called an electric _____.
   d Substances which do not allow an electric current to flow through them are called _____.
   e Metals are _____ because they allow an electric current to flow through them.
   f The more current there is flowing around a circuit, the _____ a bulb glows.
   g If the resistance in a circuit increases, the current _____.
   h A conductor has _____ resistance, while an insulator has _____ resistance.

4 In which of these circuits will the bulb glow? For the other set-ups, explain *why* the bulb won't glow.

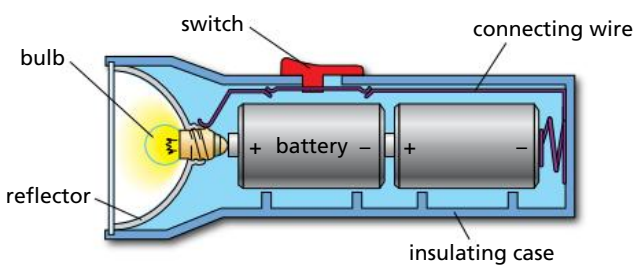


5 How do you measure electric current in a circuit? Name the unit used to measure current.

6 The wires in an appliance are plastic coated, but this coating has to be removed from the wire at the point where it is connected to a part of the circuit. Why is this?

7 Why does a wire become hot when an electric current flows through it?

8 Use the diagram below to explain how a torch works. In your explanation make sure you use the terms *electric current* and *electric circuit*. You might want to make a model torch as your chapter problem.



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SCIENTISTS AT WORK

Cathy Foley and superconductors

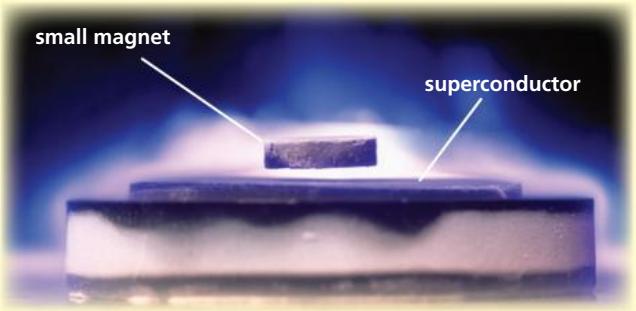
Cathy Foley became interested in science when she was in primary school and she entered several science competitions. However, she thought she had to be as clever as Einstein to become a scientist. After doing her HSC she decided to become a science teacher, but at university she changed her mind and went on to study physics. Then in 1987 she attended a conference in New York that started a revolution in *superconductors*.



If certain materials called superconductors are cooled to very low temperatures, they lose all resistance to the flow of electricity. In electric power lines there is always some loss of energy as heat, due to the resistance of the metal in the wires. If these wires could be made cheaply from superconductors, no energy would be lost and billions of dollars could be saved.

The problem was that to produce a superconductor, a temperature of –270°C was needed. This could only be obtained using liquid helium, which is very expensive and difficult to work with. The big breakthrough in superconductors came in 1986 when two scientists in Switzerland discovered a ceramic compound that became a superconductor at only –200°C. This meant that liquid nitrogen could be used for cooling. Liquid nitrogen is cheaper and easier to use than liquid helium.

As well as having zero resistance, superconductors have a remarkable magnetic property. When liquid nitrogen is poured over a piece of superconducting material and a small magnet held above it, the magnet magically floats in the air!



Because of their unique properties, it is predicted that superconductors could revolutionise our methods of transportation. Powerful electromagnets can be made by winding superconductors into coils and passing electricity through them. These could be used to propel trains which float on air. This technology is called maglev (*mag*netic *lev*itation) and a test train in Japan has reached a speed of 581 km/h. It has even been suggested that maglev could be used to build a space elevator to carry people and materials into space.

It was in this exciting new area of superconductors that Dr Foley chose to work. Dr Foley is now head of a research team at CSIRO in Sydney. She is working with tiny superconductors called SQUIDs, which can detect extremely weak magnetic fields. Dr Foley's team has developed a SQUID system operating at –200°C to explore for minerals in the hot Australian desert. They are also researching other uses for their new superconductor technology. For example, they can use it to detect defects in the heartbeat of a foetus, something that cannot be done any other way. They can also monitor adult hearts without using electrodes, check for unwanted metal fragments in food, and detect nuclear submarines.

Dr Foley loves the challenge of working with materials about which little is known, and developing tests and techniques that have never been tried before. However, she feels that science must provide real world solutions which help people. Having studied nuclear physics, she is aware that scientific research can lead to such things as weapons of mass destruction. This is why she is a member of Scientists for Global Responsibility, a group which encourages discussion about the ethics of scientific research, not just the possible benefits.

★ Use the internet to find out more about superconductors.

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7.2 Batteries and bulbs

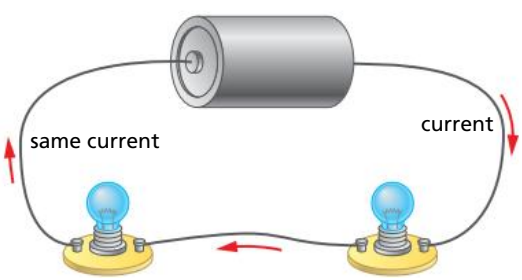
INQUIRY 4 Connecting bulbs

You will need: 1.5 V battery, three 2.5 V bulbs, connecting wires

1 See if you can light two bulbs using one battery and as many wires as you like. This can be done in more than one way, and gives different results. Remember, don't leave the battery connected for any longer than necessary.
   - Draw a diagram of each way you find to connect the bulbs.
   - How many different ways did you find to connect two bulbs and one battery? Look at your drawings and check other people's results.
   - What is different about the way the bulbs are connected? Discuss this with other students.
2 For each way you connect the bulbs, note how brightly they glow. Do they glow as brightly as with one bulb only?
3 Also check what happens when you unscrew one of the bulbs in each set-up.
4 Can you light three bulbs using one battery? Are there different ways of doing this too? Does the brightness of the bulbs change? Explore this and report your findings to the class.

Series circuits

In Inquiry 4 you probably found that there are different ways to connect two bulbs in an electric circuit. One way in which they can be connected is one after the other in a line, without any branches, as shown. This is a **series circuit**, with the bulbs connected in series.



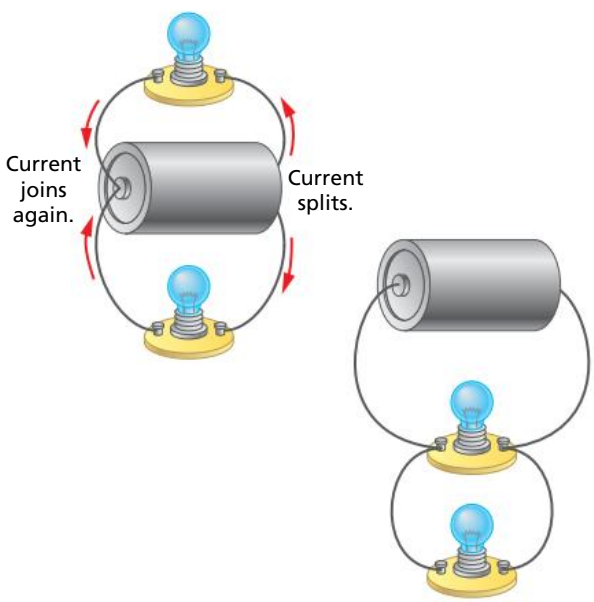
The two bulbs are connected in series.

In this type of circuit there is only one path for the current to flow: from the battery, through the first bulb, through the second bulb, and back to the battery. If you disconnect (unscrew) one of the bulbs the circuit is broken, no current flows and the other bulb goes out. Different parts of the circuit cannot be used separately because there is only one path for the current.

The battery has to push the current through two bulbs, so there is twice as much resistance in the circuit and only half the current. This is why each bulb is dimmer than it would be by itself. If you add a third bulb, each bulb is even dimmer.

Parallel circuits

Two bulbs can also be connected in a circuit with branches, as shown. This is a **parallel circuit**. Notice that there are two different paths for the electric current. Somewhere in the circuit, the current splits. If the bulbs are the same, then half the electrons go into the top circuit and half into the bottom circuit. Each electron passes through only one bulb, so it meets less resistance than in the series circuit where it has to pass through two bulbs. Each bulb glows as brightly as if it was the only bulb in the circuit. If you disconnect one bulb the other still glows, because the current can still flow through the unbroken branch of the circuit. This is a much more useful type of circuit, because each branch can operate independently. Parallel circuits are used in the wiring of a house.

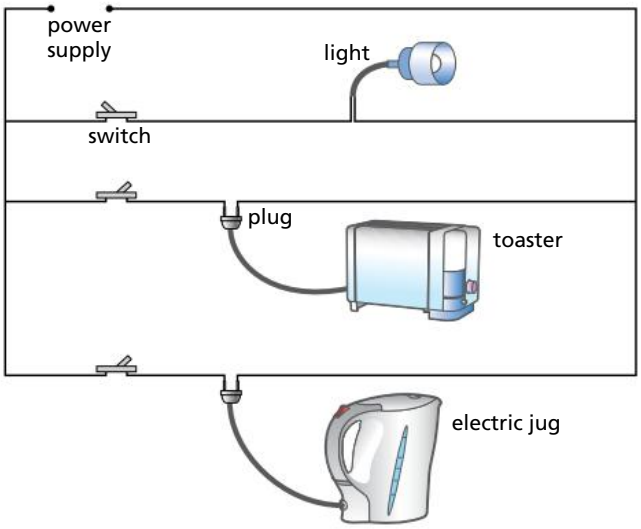


Two different ways of connecting two bulbs in parallel

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House wiring

Look at the simplified diagram of house wiring. The toaster, the light and the electric jug are connected in three different parallel circuits. Each circuit has a switch so you can turn each appliance on and off without affecting the others. If they were connected in series they would have to be all on or all off.



INQUIRY 5 Connecting batteries

You will need: two 1.5 V batteries, two 2.5 V bulbs, connecting wires

1 Connect two batteries and a bulb in series. If the bulb doesn't glow, reverse the connections to the batteries. When the circuit is working, draw it, and mark the positive and negative terminals on the batteries.
   - Why do the batteries have to be connected in a particular way?
   - Does the bulb glow more brightly than with one battery only?

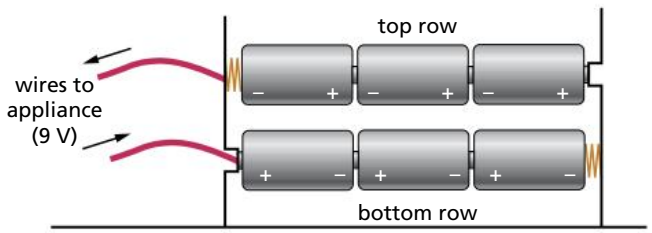
2 Now connect the batteries in parallel. Draw the circuit that works.
   - Check with other students. Did they connect up the circuit the same way as you?
   - Does the bulb glow more brightly than with one battery?
   - Which way would you connect the batteries in a torch—in series or in parallel? Explain your answer.

3 Construct a circuit containing two batteries and two bulbs so that the bulbs glow as brightly as possible. When you have solved this problem, draw the circuit and explain why you connected it the way you did.

Voltage

The **voltage** of a battery is a measure of how much 'push' the battery can give to the electrons in a circuit. It is measured in **volts** (V), using a **voltmeter**. A torch battery has a voltage of 1.5 volts (1.5V). A 9V battery can push a larger current through a circuit than a 1.5V battery can.

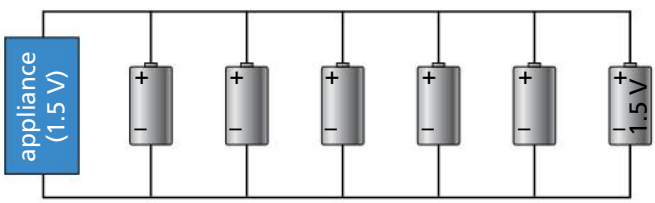
Suppose you have bought a digital radio that needs six 1.5V batteries. The batteries have to be connected in series so that the top positive terminal of one touches the bottom negative terminal of the next. In this example there are two rows of three batteries, one row on top of the other as shown. The batteries are in series, so the electrons in the circuit receive a push from each battery. The total voltage is $1.5\text{V} \times 6 = 9\text{V}$.





When putting batteries into an appliance you must be careful to put them in the right way round.

If six batteries are connected in parallel, the electrons in the circuit receive a push from one battery only, so the total voltage is only 1.5 volts.



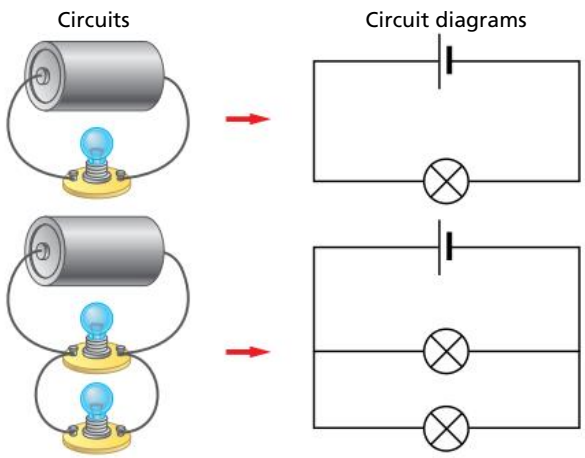
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SKILL

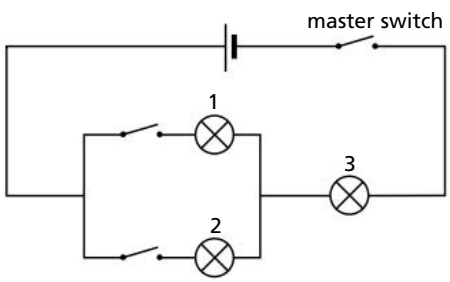
Using circuit diagrams

In the last few activities you probably found that drawing electric circuits with batteries, bulbs and switches takes time. Also, not all batteries, bulbs and switches are the same. For this reason, symbols have been developed for the parts of electric circuits. These symbols are shown below.

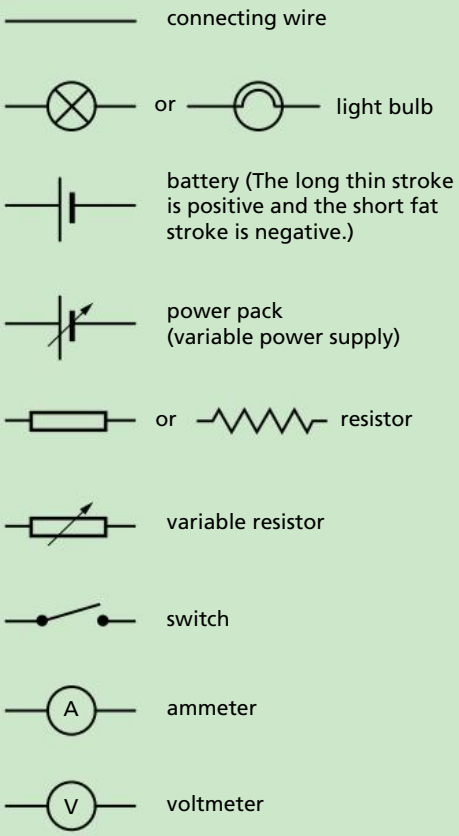
Using these symbols, you can draw plans of electric circuits called **circuit diagrams**. To keep the diagram neat and compact, circuit diagrams are usually drawn in a rectangular shape—with straight lines and right-angle bends. For example, two simple circuits can be drawn as shown. Note that it doesn't matter where the symbols go, so long as they are in the right pattern—series or parallel. For example, in the series circuit you could put the bulb on any side of the rectangle—it doesn't change how the circuit works.



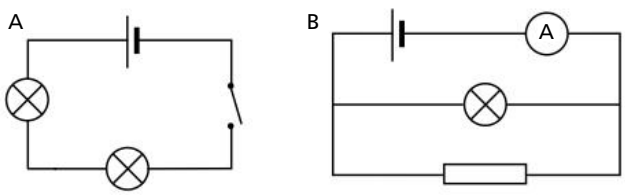
Quite complicated circuits can be drawn using circuit diagrams. For example, in the circuit below, bulbs 1 and 2 are connected in parallel, but they are in series with bulb 3, the battery and the master switch. Bulbs 1 and 2 can be switched on and off independently. And because the master switch is connected in series, it turns all three bulbs on and off.



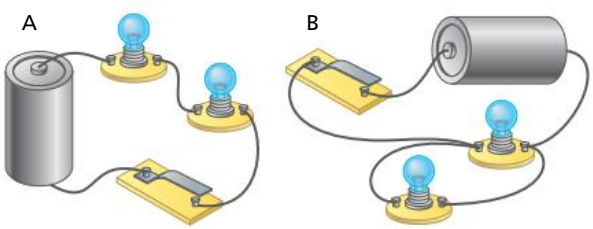
Electric symbols



1 List the equipment needed to set up each of these circuits.



2 Draw a circuit diagram for each of the following circuits.



3 Draw a circuit containing a battery in which two bulbs in series are connected to a third bulb in parallel.

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Over to you

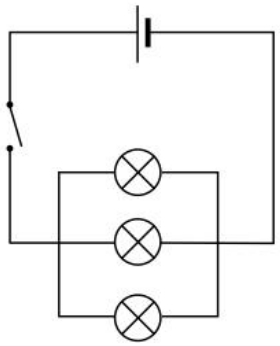
1 Use diagrams to explain the difference between a series circuit and a parallel circuit.

2 A torch bulb is connected to a battery. Will the brightness of this bulb increase, decrease or remain the same when:

a an identical bulb is connected in series with it?

b an identical bulb is connected in parallel with it?

3 Look at the parallel circuit below.



a Does the current flowing through the circuit pass through all three bulbs when the switch is closed?

b With three bulbs working, one is removed from its socket. Three students predict what will happen:

Coen: *The other bulbs will go out.*

Kalani: *The other bulbs will glow brighter than they did before.*

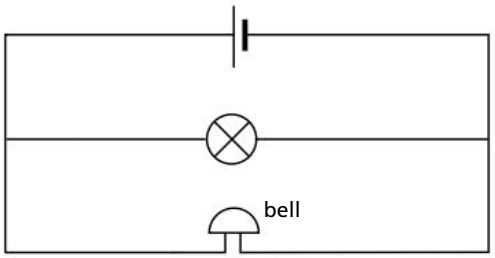
Monique: *The two remaining bulbs will glow just as brightly as they did before.*

Who is correct? Why?

4 Copy the circuit diagram below and add:

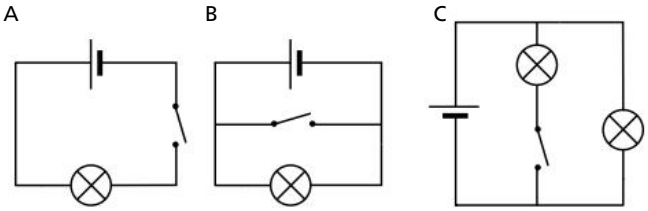
a a switch that will turn the light on and off without affecting the bell

b a second switch that will turn off the light and the bell.



5 In some types of Christmas tree lights, if one bulb blows then all the others go out. In other types, if one bulb blows the rest stay on. Explain this difference.

6 What will happen in each of these circuits when the switch is closed?

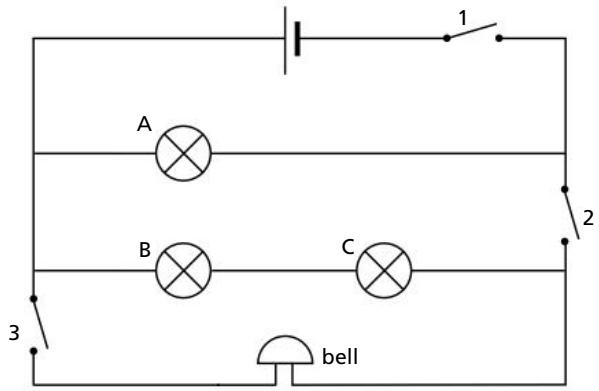


7 Consider the circuit shown below. What will happen when:

a switch 3 is open, but switches 1 and 2 are closed?

b switch 1 is open, but switches 2 and 3 are closed?

c switch 2 is open, but switches 1 and 3 are closed?



8 How would you connect two 1.5 V batteries to produce a total voltage of:

a 3 V?

b 1.5 V?

PROBLEM SOLVING

Have you started on your electrical gadget yet? If not, here are some ideas: model torch (Over to you, page 147), model electric kettle (Thinking skills, page 164), lighthouse, model house, front door bell, burglar alarm, street lights, boom gates, buzzer for quiz show, alarm clock, mousetrap.

You now know how to connect electrical devices in series and in parallel. You also know how to use switches to control electric circuits. Checking through pages 144–151 may also give you some ideas for your gadget.

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7.3 Current and voltage

INVESTIGATION

3 Current and voltage

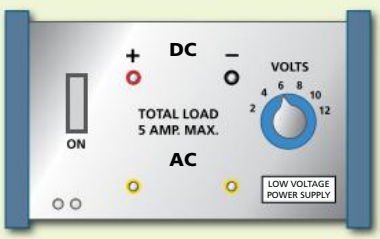
Aim

To use an ammeter and a voltmeter to measure the current and voltage in series and parallel circuits.

Risk assessment and planning

In this investigation you will be using a power pack instead of a battery. Follow these safety rules.

- High voltages will blow the light bulbs. So don't turn up the voltage higher than you are told to, or higher than the voltage marked on the bulbs provided.
- Don't touch the power pack with wet hands or use it on a wet surface. Why?
- Always use the DC (direct current) power outlet on the power pack.
- When you have connected the power pack into a circuit, get the teacher to check it before you start.
- Turn on the switch in the circuit only when you are taking a measurement.



A power pack

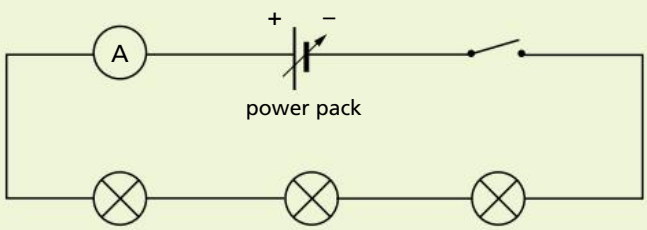
Apparatus

- 50 cm length of nichrome wire
- three 6 V bulbs in holders
- 7 connecting wires
- voltmeter
- power pack
- ammeter
- switch

Method

Part A: Measuring current and voltage

1 Connect the power pack, switch, ammeter and three bulbs in a series circuit, as shown. Set the power pack to 6 V DC.



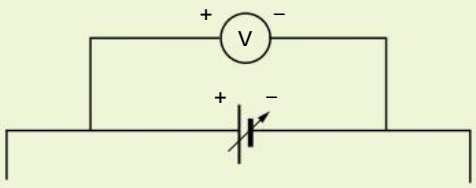
2 Close the switch and measure the current. Draw the circuit and record the current in amps on your diagram.

3 Connect the ammeter at different places in the circuit and record the results on your diagram.

4 Connect the voltmeter in parallel across the power pack terminals as shown. Its positive terminal must be connected to the positive side of the power pack and its negative terminal to the negative side.

If there is more than one positive terminal on the voltmeter, use the one with the highest value first. Use the scale on the voltmeter that matches the connected positive terminal.

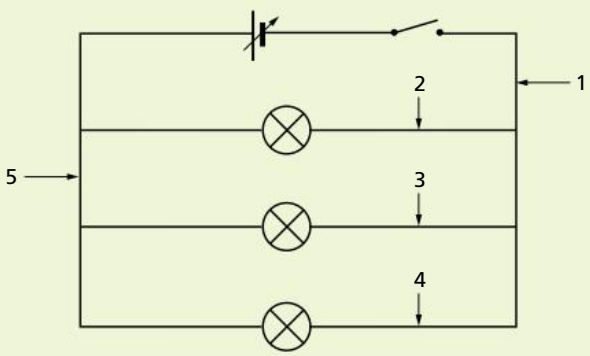
✻ Record the voltage on your diagram.



5 Connect the voltmeter across one of the bulbs and record the voltage. Do this for each bulb.

✻ What pattern can you see in the voltages?

6 Rearrange the circuit so that the three bulbs are in parallel, as shown.



7 Use the ammeter to measure and record the current at points 1, 2, 3, 4 and 5 in the circuit.

8 Use the voltmeter to measure and record the voltage across the three bulbs.

✻ What pattern can you see in the voltages?

Conclusion

Write a short paragraph summarising what you found out about the current and voltage in a series circuit.

Do the same for a parallel circuit.

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INVESTIGATION 3 continued

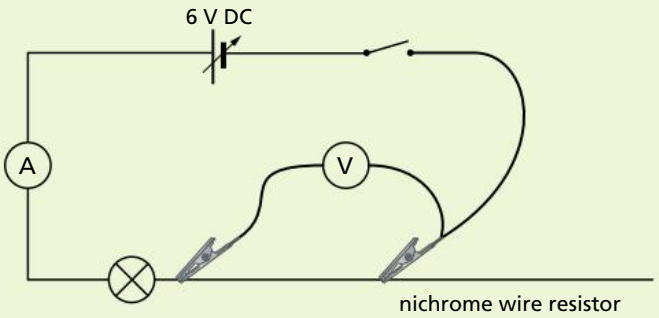
Part B: Nichrome wire resistor

1 Connect up the circuit as shown, with the power pack on 6 V DC. Fasten the alligator clips onto the 50 cm length of nichrome wire as close to each other as possible.

2 Turn on the switch. Observe the brightness of the bulb and the ammeter reading.

3 Investigate what happens as you move the alligator clips apart on the nichrome wire.

4 Write a paragraph summarising what you found out about the current in the circuit and explaining why this happened. In your explanation, the word *resistance* should be used.

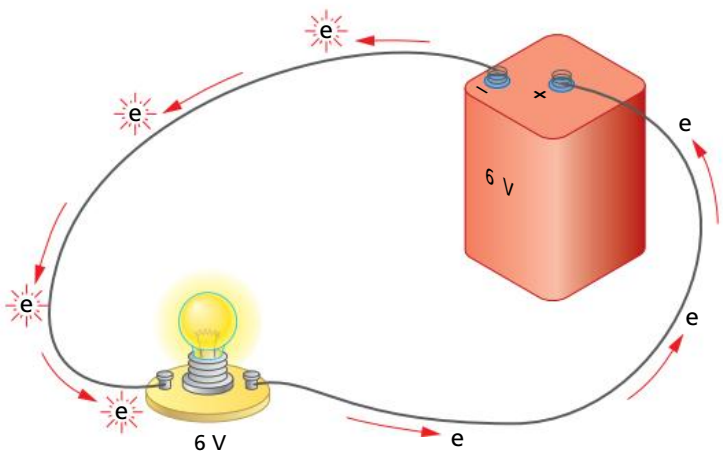


5 Measure the voltage across the bulb and across the alligator clips as you move them apart. What happens? How can you explain this?

Current and voltage

A battery can be thought of as an electron pump. In the battery the electrons gain enough energy to move around a closed circuit. As they move through a resistor such as a light bulb, they collide with the atoms of the resistor, and the energy of the electrons is converted to light and heat. When the electrons return to the battery their energy is renewed for another trip around the circuit. The amount of energy carried around the circuit and converted to light and heat is the same as that given to the electrons by the battery.

The electrons have much more electrical potential energy when they leave the battery than when they return to it. They have the 'potential' to cause changes in the circuit. This difference in the energy of the electrons leaving and returning to the battery is called the *potential difference* or voltage of the battery. It is a measure of the push of the battery.

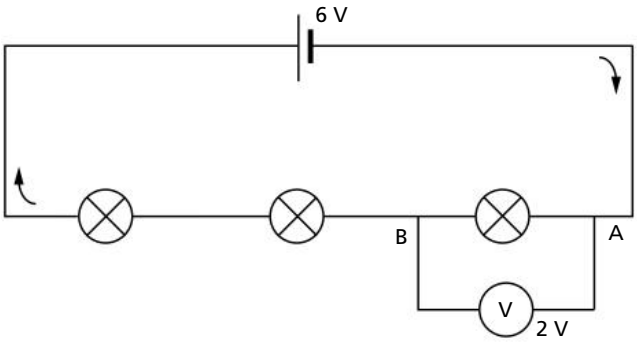


As the electrons move around an electric circuit containing a bulb, their potential energy is converted to light and heat energy. After the electrons have passed through the bulbs they have little energy until they return to the battery. If there is a break anywhere in an electric circuit, no current flows. The potential difference is the difference in energy between the two terminals of the battery, or the energy given to the electrons by the battery.

Series circuits

Consider a circuit with three identical bulbs in series (see next page). The current (moving electrons) has to pass through all three bulbs and is the same throughout the circuit. There is a voltage drop across each bulb, and the total voltage drop is the same as the voltage of the battery. For example, consider the circuit shown at the top of the next page, which contains a 6V battery and three identical bulbs. Each electron gains 6V of energy in the battery. This voltage is divided equally among the three bulbs and drops by 2V as it passes through each bulb. A voltmeter connected as shown would measure 2V. This is the potential difference between A and B.

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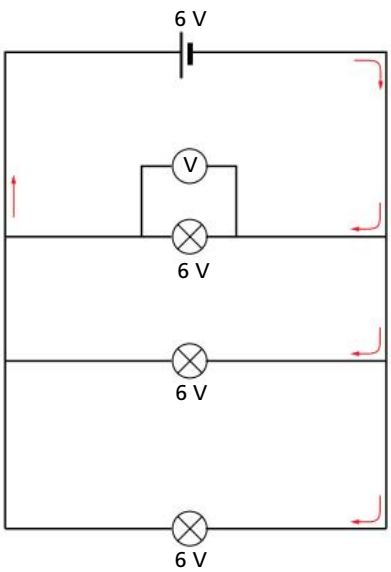


In a series circuit, current passes through each resistor in turn and the voltage is shared between them.

Parallel circuits

In the parallel circuit shown below, the current splits into three. The current that flows through each branch will depend on the resistance. The greater the resistance, the smaller the current that flows. On the other side of the circuit the currents join up again. The voltage drop across each bulb (resistor) is the same and is the same as the voltage of the battery.

For example, if it is a 6V battery, each electron leaves the battery with 6V of energy. As each electron passes through a bulb, it loses all of this 6V of energy. A voltmeter connected as shown would measure a potential difference of 6V.



In a parallel circuit the voltage is the same across each resistor and the current is shared between them.

Variable resistors

In Part B of Investigation 3 you were able to alter the electric current in a circuit by moving the alligator clip along the nichrome wire. The greater the length of wire, the greater the resistance, and the smaller the current. This is an easy way to control the brightness of the bulb.

The piece of nichrome wire is a variable resistor called a *rheostat*. The brightness of a light in a house can be controlled using a rheostat, called a dimmer switch. There are also dimmer switches to control the brightness of the dashboard lights in cars. Model cars have a rheostat in their controllers. Push the control and more current flows to the motor, making it go faster.

Over to you

1 Copy and complete the following sentences.

- **a** Voltage is measured in _____.
- **b** In a series circuit, the same _____ flows through all parts of the circuit.
- **c** If you increase the voltage in a circuit, the current _____.
- **d** If you increase the resistance in a circuit, the current _____.
- **e** A _____ is an electrical device whose resistance can be changed.

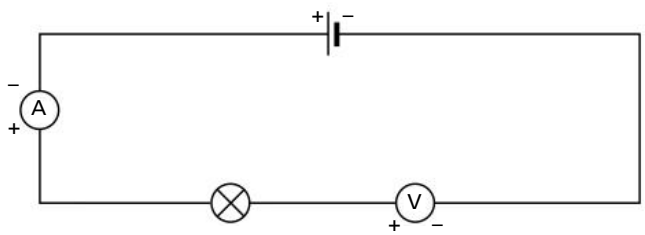
2 What is the difference between electric current and voltage? In your explanation you should talk about electrons.

3 After a battery has gone flat, where is all the energy that was once stored in it?

4 A 6V battery is connected in series with two bulbs. Predict the voltage drop across each bulb.

5 What happens to a light bulb when the resistance of a variable resistor in series with it is increased, as in Part B of Investigation 3 (page 154)? Why?

6 There are two errors in the way this circuit has been connected to measure the current and voltage across the bulb. What are they? Redraw the circuit correctly.



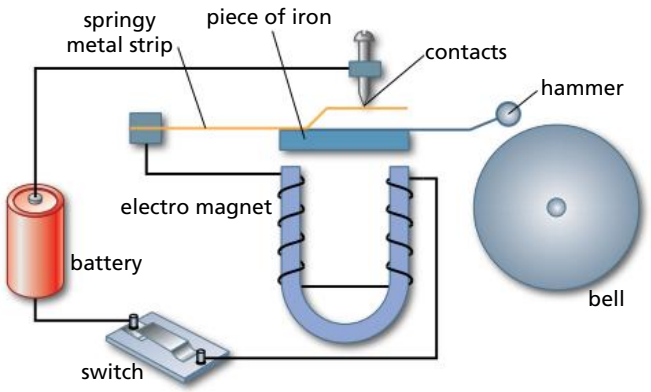
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7.4 Electromagnets

In *Science Essentials 7 for NSW* you learnt how an electromagnet can be made by passing electricity through a coil of wire. In this section you will learn about some more uses of electromagnets.

Electric bell

An electric bell contains an electromagnet that turns on and off very rapidly. As it does this it moves the hammer of a bell as shown.



When you close the switch an electric current flows through the electromagnet. The piece of iron is attracted to the electromagnet and the hammer hits the bell. This movement pulls the contacts apart and the electricity to the electromagnet is cut off. The hammer is then pulled back by the springy metal strip. The contacts close again and the process repeats itself until you open the switch again. Burglar alarms work in much the same way.

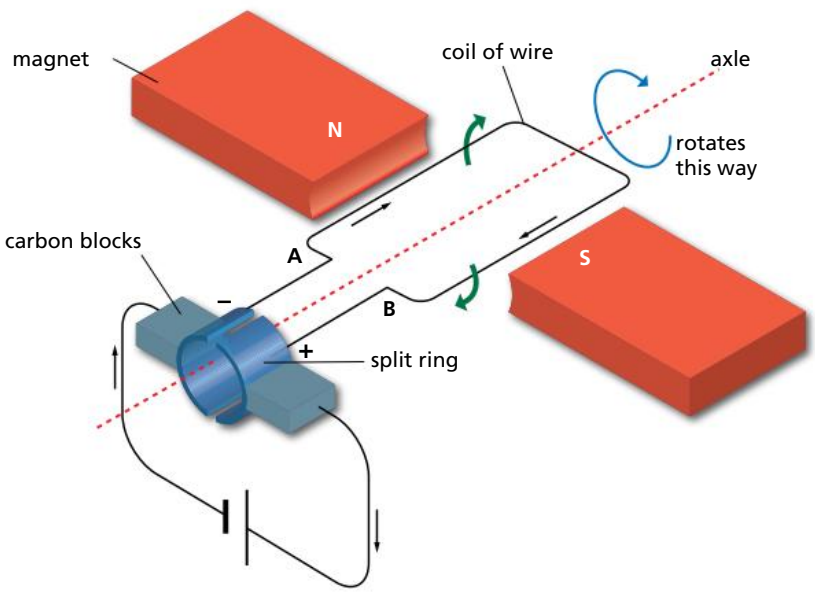
How an electric motor works

When an electric current flows in a wire in a magnetic field, a force is produced which can make the wire move. This is sometimes called the *motor effect*. Scientists and engineers have used this effect to build the electric motors that are so important in our lives. These range from the small motors which spin the CD in a CD player to the powerful motors that move electric trains.

The diagram below shows a simple motor. It consists of a pair of magnets and a coil of wire that rotates on an axle between the poles of these magnets. The ends of the coil are connected to a split ring that rubs against two carbon blocks. This allows an electric current from the battery to flow into the coil without tangling the wires.

In the position shown, an electric current flows into the coil through side A, which is pushed upwards. At the same time, side B is pushed downwards. This causes the coil to spin in a clockwise direction. The coil rotates to the vertical position and continues past this position. Because the coil has now turned over, the current flows into the coil through side B, which is pushed upwards. This keeps the coil moving clockwise. So the motor has converted electrical energy to kinetic energy.

In a real motor there are many turns of wire in the coil. Also, the magnet may be an electromagnet.



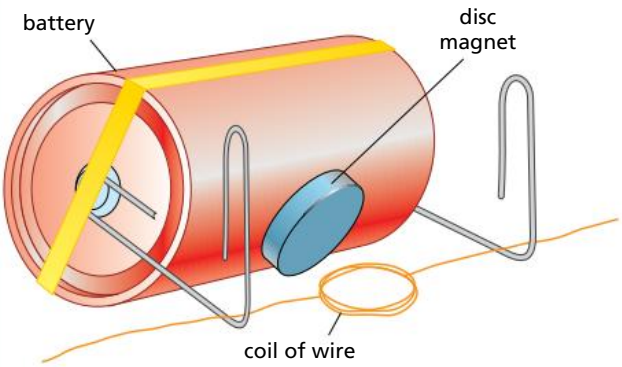
A simple electric motor

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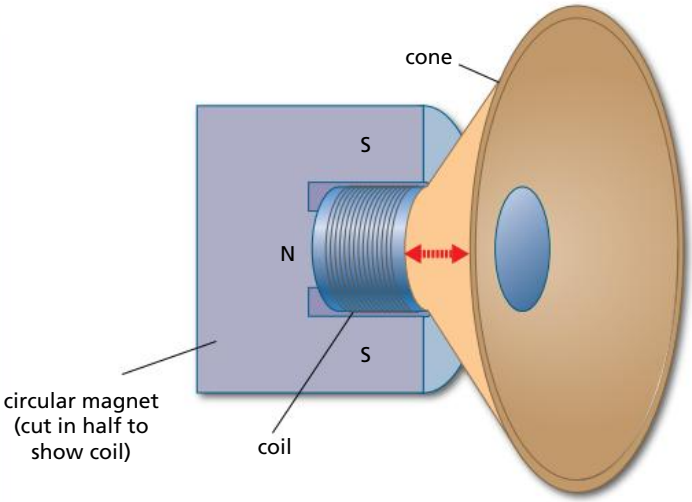
INQUIRY 6 Electric motor

You will need: 1.5 V battery, 2 paperclips, disc magnet, 60 cm enamelled copper wire, marking pen, sandpaper, rubber band

1. Make a coil from the copper wire by winding it around a marking pen. Tie the ends neatly as shown so that about 10 cm sticks out each end.
2. Use the sandpaper to remove the enamel from the same side of each end piece (*one side only*).
3. Bend the paperclips as shown and secure them to the battery using the rubber band.
4. Place the disc magnet on the side of the battery.
5. What happens when you place the coil between the paperclips as shown?



- Try to explain how your motor works.



INQUIRY 7 Loudspeaker

You will need: loudspeaker, signal generator (e.g. radio), styrofoam beads

1. Connect a signal generator to a loudspeaker.
2. Put a handful of styrofoam beads into the cone of the speaker, and switch on the signal generator. What happens?
3. What happens when you slowly increase the volume of the signal?

How a loudspeaker works

A loudspeaker also uses a magnetic field to produce movement. It consists of a cardboard cone, with a coil of wire wound around its base. The coil fits snugly between the poles of a cylindrical magnet. An alternating current from a microphone is fed into the coil. A current in one direction makes the coil move outwards, and a current in the other direction makes it move inwards. As the current varies rapidly, the coil vibrates back and forth, moving the cone with it. The cone pushes the air around it, producing sound waves. So the loudspeaker has converted electrical energy to kinetic energy and then to sound energy.

Over to you

1. What must be brought near a rotating coil of wire to generate an electric current in the coil?
2. Name the energy conversions that occur in:
   - **a** an electric motor
   - **b** an electric generator
   - **c** a loudspeaker
   - **d** an electric guitar.
3. List at least three devices that have an electric motor in them.
4. **a** What are the main parts of an electric motor? What does each part do?
   b Why does the coil of an electric motor have so many turns of copper wire?
5. Suggest three ways in which an electric motor can be made more powerful.
6. **a** A magnet is pushed into a coil. When does the current stop flowing? What happens when the magnet is pulled out of the coil?
   b List the variables that determine the size of the current produced when a magnet is pushed into and out of a coil.

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7.5 Generating electricity

INQUIRY 8 Lemon battery

You will need: 4 lemons, galvanised nails, bare copper wire, galvanometer or microammeter, light-emitting diode (LED), connecting wires (Both the galvanometer and the microammeter measure tiny electric currents. The LED is an electronic light bulb.)

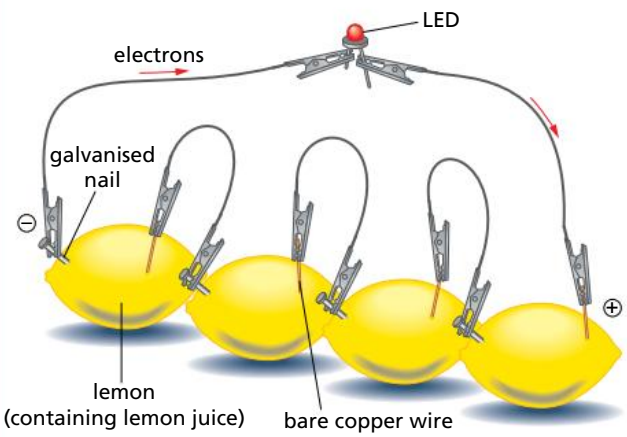
1 Put a galvanised nail and a piece of copper wire into a lemon.

2 Use connecting wires to connect one terminal of the galvanometer (GAL-van-OM-it-er) to the nail and the other end to the copper wire. If you are using a microammeter the positive terminal must be connected to the copper wire.

- Does the lemon produce an electric current?

3 Disconnect the galvanometer and connect the 4 lemons in series as shown. Make sure the longer terminal of the LED is connected to the copper wire.

- Does the LED glow?



4 Investigate one or more of the following. What would happen if you:

- increased the number of lemons?
- squeezed the lemons by rolling them on the bench to start with?
- changed the distance between the nail and the copper wire?
- pushed the nail and the wire further into the lemon?
- used different fruits or vegetables?
- used different metals to stick into the lemon?

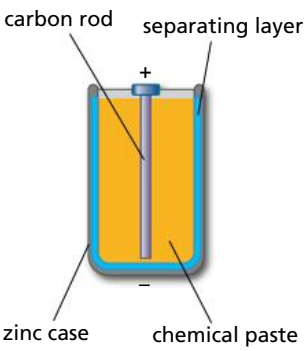
Write a brief report about what you discover.

Cells and batteries

When you put a galvanised nail and a piece of copper into a lemon, you made a simple **electric cell**. The zinc coating on the galvanised nail reacted with the acid in the lemon juice to produce electrons. These moved around the connecting wire to the copper wire. Here they took part in another chemical reaction. The copper wire is the positive *electrode* and the nail is the negative electrode.

A *battery* is made up of two or more cells connected in series. However, in everyday language the word battery is also used for a single cell.

The 1.5 V battery used in a torch is actually a single cell as shown below. It has a central rod made of carbon which forms the positive electrode, and a zinc case which forms the negative electrode. Between the two electrodes is a chemical paste. When you connect the battery in a circuit, a chemical reaction takes place between the paste and the zinc case, producing electrons. A separating layer stops the chemicals reacting when the cell is not being used. Such a cell produces a voltage of 1.5V.





A 1.5V torch cell is usually called a battery. The 9V battery on the right has been cut open to show the six individual 1.5 V cells.

Batteries are made by connecting several cells together. For example, a 9V battery consists of six 1.5 V cells connected in series as shown above. The tiny button cells used in watches and cameras are made in the same way as torch cells, but use different chemicals.

A cell or battery goes 'flat' and has to be thrown out once the chemicals in it are used up. However, with rechargeable cells it is possible to reverse these reactions by passing electricity through them in the opposite direction. Rechargeable cells are widely used in devices such as mobile phones, cordless drills and remote-controlled cars.

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INVESTIGATION

4 Which lasts longer?

Design a controlled experiment to test whether the claims made on TV advertisements for batteries are correct. Choose two different brands of batteries. Does brand A really last longer than brand B?

✻ Which variables will you need to control?

Write a report of your experiment using the usual headings. Other questions that you could investigate are:

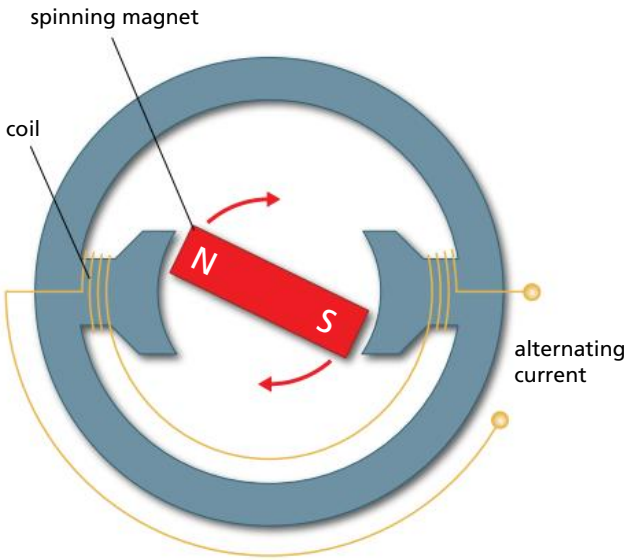
- What effect does the size of the cell have on how long it lasts?
- Alkaline cells last longer than normal cells, but are they better value for money? To compare cells you could divide their cost by the number of hours they last.
- Do two cells connected together last twice as long as one? Does it matter whether they are connected in series or in parallel?

How an electric generator works

An electromagnet uses electricity to produce magnetism. However, in 1831 Michael Faraday discovered that he could produce electricity by using a magnet. Moving a magnet through a coil produces an electric current in the coil. Moving the magnet in the opposite direction reverses the direction of the current that is generated. It doesn't matter whether you move the magnet or the coil, so long as one moves with respect to the other. You can produce a larger current if you increase:

- the strength of the magnet,
- the number of turns of wire in the coil, or
- the speed of relative movement between the coil and the magnet.

A device that converts kinetic energy into electrical energy is called an **electric generator**. It is the opposite of an electric motor. (See the diagram at the bottom of page 156.) In a motor, you pass electricity into the coil to make it spin. In a generator, you spin the coil to produce an electric current. The generators in power stations produce electricity by spinning a magnet inside a huge coil, as shown. Because the magnetic field reverses with every half turn of the magnet, an alternating current (AC) is produced in the coil.



How a generator in a power station works

DC and AC

The current produced by a battery is called **direct current** or **DC**. The electrons move in one direction only—from negative to positive. However, the electricity we use in our homes is generated in power stations by spinning magnets inside huge coils of wire. This produces **alternating current** or **AC**, and the electrons move first in one direction and then in the opposite direction. The electrons change direction 50 times a second.

Both DC and AC can be used to run electrical appliances. When electricity first became available for use in homes in New York, there was much argument about which system was the best. Thomas Edison, the inventor of the light bulb, was promoting the use of DC. His business rival, George Westinghouse, claimed that the AC system was better.

At about this time the electric chair was invented by Harold Brown and it worked on AC. Both rival electricity companies opposed the electric chair because it showed that electricity can kill, and they were afraid that people would not use it. Edison thought that if he showed how dangerous AC was, people would use his DC system. So he allowed Brown to use his laboratories for public demonstrations using AC to electrocute cats. Thousands of people watched these demonstrations but it didn't stop them using AC in their homes. In the end, AC was found to be easier to transmit over large distances.

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INQUIRY 9

Generating electricity

Part A

You will need: solenoid, bar magnet, connecting wires, galvanometer (measures tiny electric currents)

1 Connect the solenoid to the galvanometer.

2 Push the magnet into the coil quickly. What happens?

3 What happens when you:

- **a** leave the magnet inside the solenoid?
- **b** pull the magnet out of the solenoid quickly?
- **c** push the south pole into the solenoid instead of the north pole?
- **d** use two magnets instead of one?
- **e** keep the magnet still and move the coil?

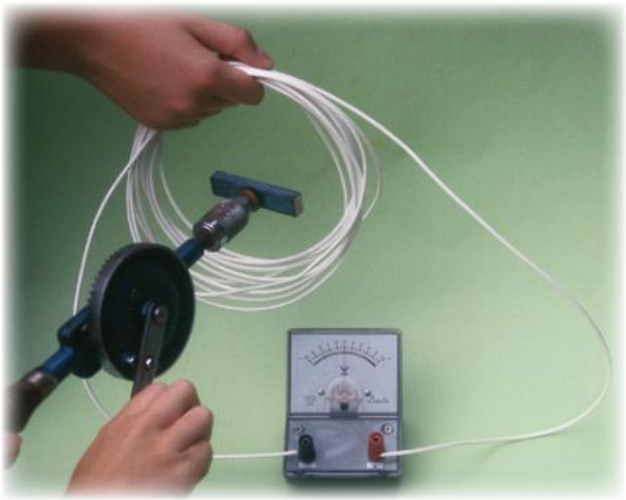
4 Write a generalisation to explain all your observations.

Part B

You will need: hand drill with a bar magnet glued to it

Set up the apparatus as shown on the right.

- Why does the needle of the galvanometer swing backwards and forwards as you use the drill to rotate the magnet?
- What do you call this type of electric current?



Over to you

1 What takes place inside an electric cell to cause a current to flow?

2 What happens to a cell when it goes 'flat'?

3 What is the difference between a cell and a battery?

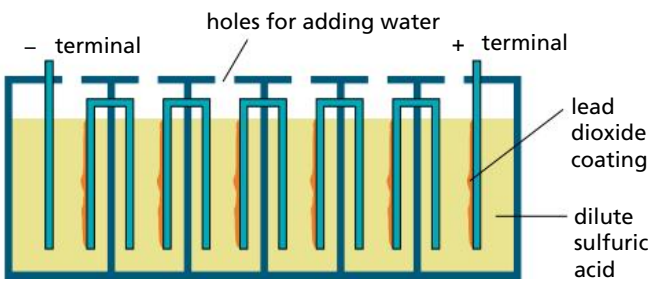
4 How could you make a 6V battery from 1.5V cells?

5 **a** What is the difference between DC and AC?

b Where is DC used? Where is AC used?

6 Below is a cross-section of a car battery.

- **a** How many cells are there in this battery?
- **b** Are the cells connected in series or in parallel?
- **c** If each cell can generate 2 V of electricity, what is the total voltage of the battery?
- **d** What is the electrolyte in this battery?



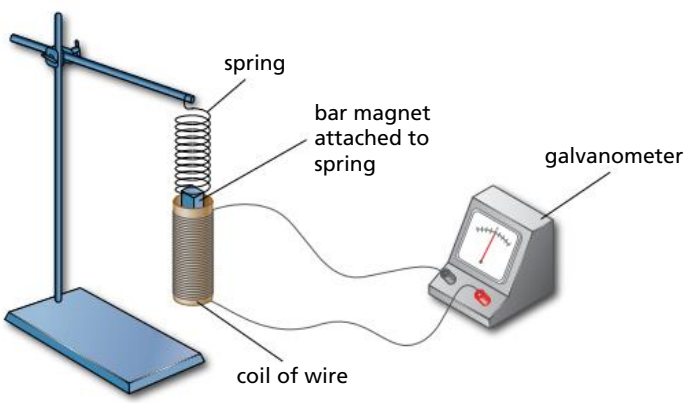
7 What energy conversion occurs in an electric generator?

8 Explain the difference between an electric motor and an electric generator.

9 How could you convert the electric motor on page 156 into an electric generator?

10 Look at the set-up shown below.

- **a** Predict what will happen when the magnet bounces up and down inside the coil of wire. Explain your prediction.
- **b** Suggest ways of making the electric current larger.



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7.6 Safety with electricity

Short-circuits

The electricity we use in our homes is 240 V AC. An electric current as small as 0.05 A passing through your body can cause electrocution.

An electric current always takes the path of least resistance. The heating element in a toaster has a high resistance. This is why it produces so much heat—to cook your toast. If you are foolish enough to stick a knife in a toaster while it is switched on, the electricity will find a pathway of less resistance through the knife then your body to the floor and the ground, where it leaks away. This electric current will burn a path through your body and may cause your heart to stop beating! The size of the current depends on the resistance of your body. If your hands or feet are wet, the resistance is less and the current will be greater. If your hands are dry and you have rubber-soled shoes on, your resistance will be greater and the current will be smaller.



Always stay clear of overhead power lines, especially if they have fallen. You could be electrocuted if you go near them.

An electric current that takes an easier but unintended path is called a **short-circuit**. Short-circuits can occur when the insulation on the cord of an appliance becomes frayed or brittle and bare wires come into contact with each other. This can cause sparking, which can cause a fire (see Inquiry 10).

Fuses

A **fuse** is a thin piece of metal that melts rapidly if the current passing through it reaches a certain limit. The melting of the metal breaks the circuit and thus acts like a switch and stops the current from flowing. If the wiring in a circuit can safely handle a current of up to 8 A, then an 8 A fuse is used. Fuses of 15 A and 30 A are used in circuits able to handle higher currents. Once a fuse has melted or 'blown' it must be replaced with a new one. Never put a 20 A or 30 A fuse in a circuit designed for a current limit of 8 A or 15 A. Doing this can allow too much current in the circuit, causing the wires to overheat and perhaps cause a fire.

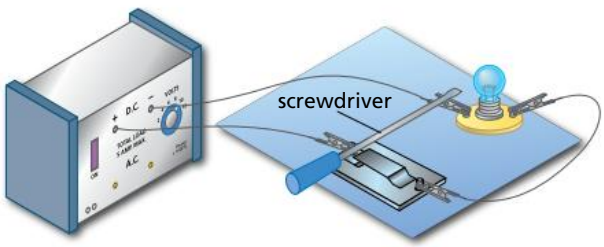
Fuses are used in homes, in cars and in electronic appliances such as computers. There are many different types. Ask an adult to show you the fuse box in a car. Note how the fuses clip into place and how there are different fuses for different circuits.

INQUIRY 10 Short-circuits and fuses

You will need: power pack, 3 connecting wires, 2.5 V bulb, switch, large screwdriver, piece of 8 A fuse wire, rubber stopper, 2 large pins, heatproof mat

Part A: Short-circuit

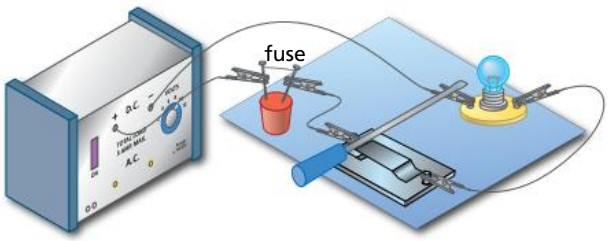
1. Set the power pack on 2 V DC and connect up the circuit shown.
2. Turn on the power and close the switch.
3. Touch a screwdriver across the alligator clips connected to the switch and bulb, as shown. Then *immediately take the screwdriver away.*



- What happened? How can you explain this?

Part B: Fuse

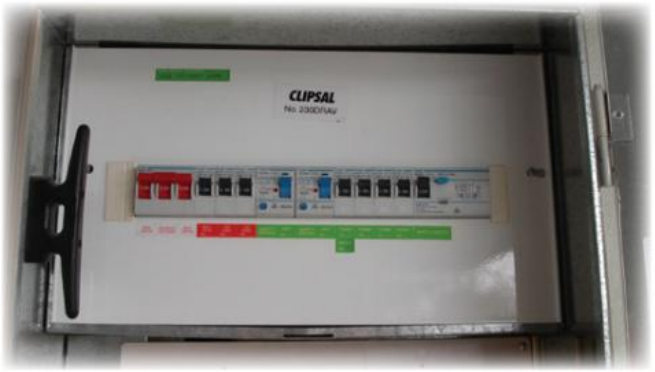
1. Make a fuse from a rubber stopper, two pins and a piece of 8 A fuse wire, as shown.



2. Connect your fuse into the circuit.
3. Touch the screwdriver across the circuit as before.
   - What happens to the fuse? (If nothing happens you may need to increase the voltage of the power pack.)
   - Explain how the fuse works as a safety switch.
4. What difference does it make if you use 15 A fuse wire instead of 8 A wire? Explain what happens.

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Most homes now have *circuit-breakers* instead of fuses. These are automatic switches that turn off when there is too much current in a circuit. They do the same job as a fuse, but are easier to reset once the fault has been fixed.



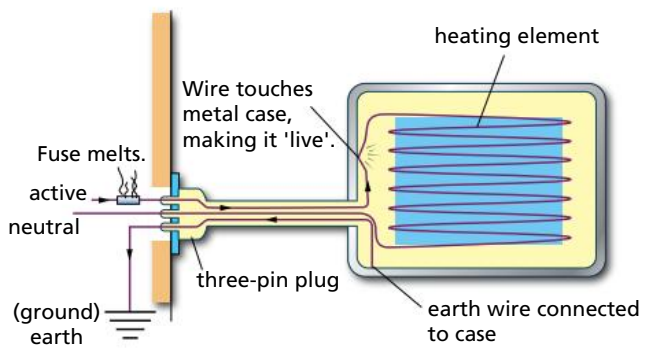
Circuit-breakers in a house meter box

Earthing

Electricity is supplied to your home at 240 V AC via two wires. The *live wire* carries electricity from the power station to your home. It is colour-coded brown for easy recognition. The blue neutral wire returns current to the electricity substation. However, when you plug in an appliance you will notice that there are usually three pins in the plug. The top two are connected to the live and neutral wires, and the longer bottom one is connected to the **earth** wire. This is another safety device. Here's how it works.

One end of the green and yellow earth wire is connected to the metal case of an appliance. The other end is connected to the earth pin of a three-pin plug. This contacts an earth wire in the socket, which is connected to a metal pipe or stake outside or under the house. (See if you can find it.)

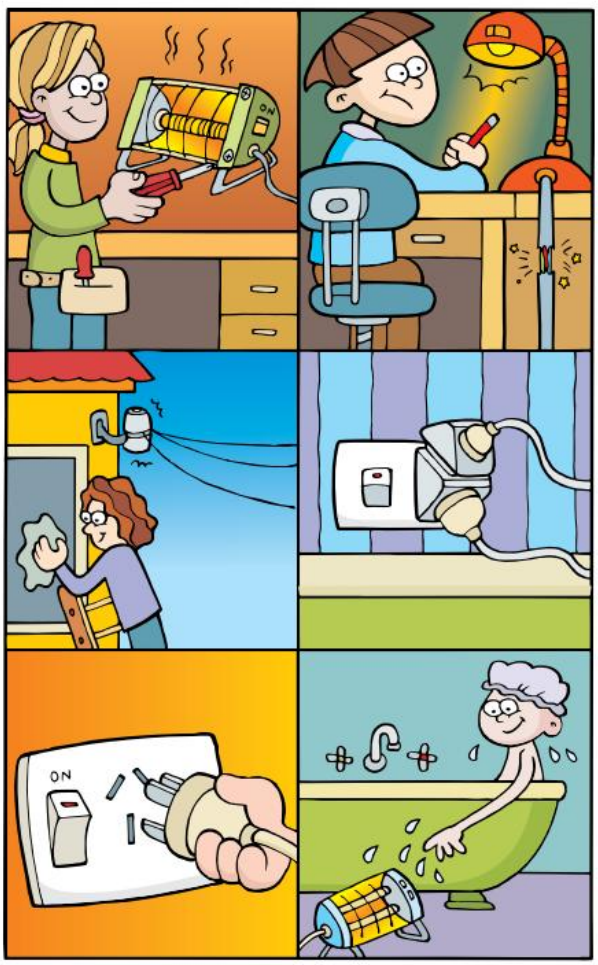
Normally no current flows in the earth wire. This changes if the appliance develops a fault in which the active wire comes in contact with the case of the appliance (see diagram below). Without an earth wire, the case becomes live and could electrocute you if you touched it. With the earth wire in place, current flows through it to the ground. As there is only a small resistance along the earth wire, the current is usually large enough to blow the fuse in the power circuit. This switches off the current and the appliance is no longer live.



Many appliances such as portable radios and hair driers are made with no external metal parts. They are totally surrounded by two layers of plastic. This plastic insulation will protect you if a fault occurs. Such appliances are said to be double-insulated, and have the double insulation symbol ⧈ marked on them. They do not need an earth wire, and have a two-pin plug instead of the normal three-pin plug.

INQUIRY 11 What's unsafe?

Write a sentence about each situation, explaining why it is dangerous.



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Paying for electricity

Different electrical appliances use different amounts of electrical energy. The *rate* at which an appliance uses energy is called its **power**, and this is measured in *watts* (W) or joules per second (J/s). For example, a 40W light bulb uses electricity at the rate of 40J/s, whereas a 100W bulb uses it at a much higher rate—100J/s. The higher the power rating or wattage of an appliance, the more electricity it uses and the more it adds to your electricity bill. The table below shows the power ratings of some common household appliances.

Appliance (using 240 V)	Power rating (W)
calculator	0.0003
clock	5
portable radio	10
light bulb	60
computer	100
television set	200
refrigerator	400–500
toaster	800
microwave oven	1300
air conditioner (medium size)	2000
hotplate (on stove)	2000
dishwasher	2500

Electrical energy is sold in *kilowatt-hours* (kWh). One kilowatt (kW) is 1000W, so 1kWh is 1000W used for one hour. The price for electricity varies, depending on how it is used. To calculate the energy in kilowatt-hours used by an appliance, follow the steps below.

Example

How much does it cost to run a 2500W dishwasher for 45 minutes at 15 cents per kilowatt-hour?

1 Change watts to kilowatts.
Power = 2500W/1000 = 2.5kW

2 Change minutes to hours.
Time = 45 minutes/60 = 0.75 hours

3 Multiply kilowatts × hours × cost.
Cost = 2.5 × 0.75 × 15 cents
= 22.5 cents

Over to you

1 What is the safest way to remove a piece of toast that has jammed in a toaster?

2 **a** What is a short-circuit? Why is it dangerous?

b How do fuses and circuit-breakers help protect you against short-circuits?

3 **a** Which is the earth pin on this three-pin plug?

b What is the purpose of the earth pin?

c Suggest why the earth pin is longer than the other pins.



4 Which of the following two electrical appliances would use the most energy: a 2kW heater turned on for 15 minutes or a 10W clock radio left on for 24 hours? Show your calculations.

5 A 100W light bulb was left on for 5 hours.

a How much electricity did it use?

b If electricity costs 12 cents per kWh, what was the cost of running the bulb?

6 **a** Draw a diagram to show how a person touching a live wire can be electrocuted.

b What difference does it make if the person has wet hands or wet feet?

7 What is the difference between a 10A fuse and a 20A fuse?

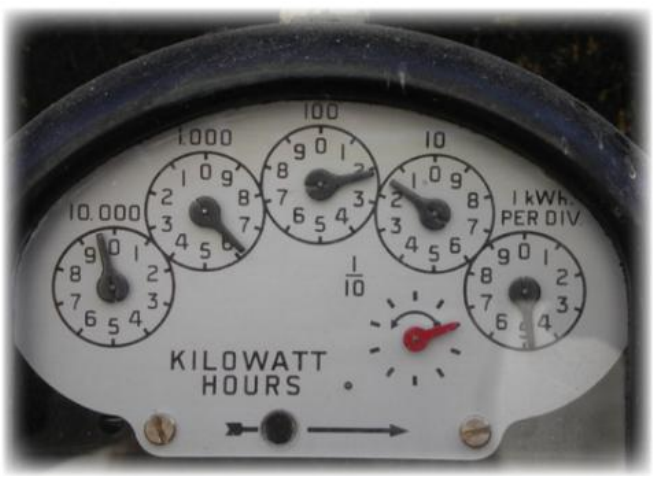
8 If a 10A fuse has blown, it should be replaced by another 10A fuse. What problems could occur if it was replaced by:

a a 5A fuse? **b** a 15A fuse?

9 The power packs used in the laboratory have their own fuse. Why is this?

10 Why can a bird perch safely on a power line and not be electrocuted? Why are bats electrocuted when they hang from *two* wires?

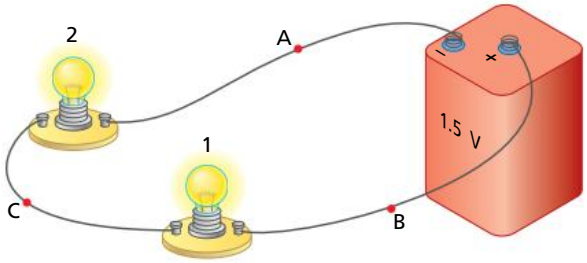
11 What is the reading on this older style electricity meter? Start reading from the left dial and move across to the right, writing down the numbers. If the pointer lies between two numbers, write down the smaller one.



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THINKING SKILLS

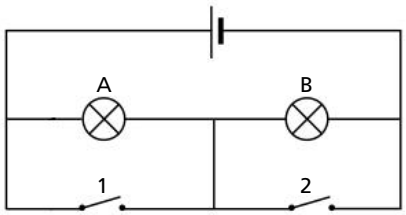
1 Look at the electrical circuit below. Between which two points could you connect a wire so that bulb 1 stays on but bulb 2 goes off?



2 The two bulbs in this circuit glow dimly when both switches are open. Predict what will happen if:

a switch 1 is closed (two things)

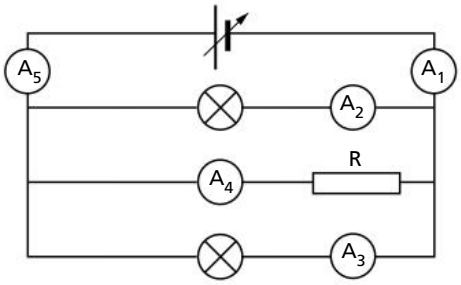
b switch 2 is also closed.



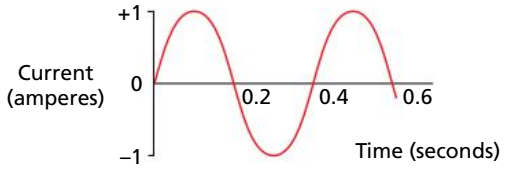
3 The same current flows in an electric bar heater and in the cord connecting it to the power supply. Why don't the wires in the cord become red-hot like those in the heating element?

4 You have a battery, connecting wires and three bulbs, one of which is faulty. Draw a diagram of a circuit you could use to find out which bulb is faulty. It should include all three bulbs at the same time.

5 The two bulbs in the circuit below are identical, and R is a resistor. If the current reading on ammeter A_2 is 0.3 A and that on A_4 is 0.2 A, what current you would expect on ammeters A_1, A_3 and A_5?



6 The graph below shows how the current produced in an electric generator varies with time.



a Is this AC or DC?

b What is the maximum current generated?

c How long does it take for the coil of the generator to rotate once?

d A bulb is connected to the generator. Will the brightness of the bulb vary as the generator is turned? Explain.

7 Suggest three ways of making an electric generator produce a larger current.

8 Draw a circuit diagram for a parallel circuit that has two bulbs and a bell. There should be switches to turn each device on and off, and a switch that turns both bulbs off but doesn't affect the bell.

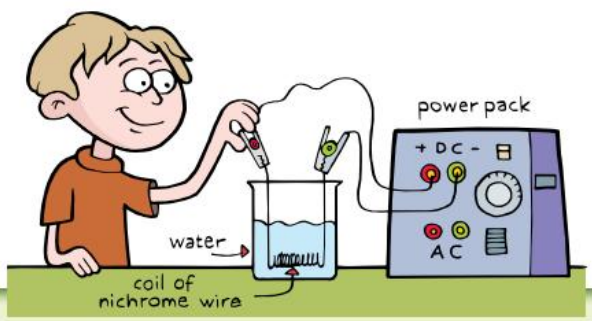
9 Design and sketch a circuit that uses an electromagnet to release a trapdoor when a person steps on a certain section of floor.

10 Make a model electric kettle as shown by coiling a piece of nichrome wire around a pencil. Investigate what would happen if you:

- changed the voltage used
- changed the length of the coil
- changed the diameter of the coil
- used thicker or thinner wire or a different type of wire
- changed the volume of water
- measured the temperature above and below the coil.

This could be your chapter problem.

Remember to change only one variable at a time and to keep all the others the same.



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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1. Electric current is a flow of _____. It is measured in amperes. It flows only if it has a continuous path or _____.
2. Materials with little resistance to the flow of electric current are called _____. Most _____ are good conductors of electricity. Materials with a lot of resistance to the flow of electric current are called _____.
3. In a _____ circuit, the same current flows through all parts of the circuit. In a _____ circuit, the current divides and passes through different branches of the circuit.
4. The electrical push in a circuit is called its _____. It is measured in _____.
5. If you increase the voltage in a circuit, the current _____. If you increase the resistance, the current _____.
6. In an electric cell, chemicals _____ to produce a flow of electrons. Two or more cells joined together make up a _____.
7. _____ current (DC) is a flow of electrons in one direction only. _____ current (AC) is a flow of electrons that continuously reverses direction.
8. An _____ uses electricity to produce magnetism, and an electric generator produces _____ by using a magnet.
9. A 1 kilowatt electrical appliance operating for one hour uses one _____ of electrical energy.

alternating
battery
circuit
conductors
decreases
direct
electricity
electromagnet
electrons
increases
insulators
kilowatt-hour
metals
parallel
react
series
voltage
volts

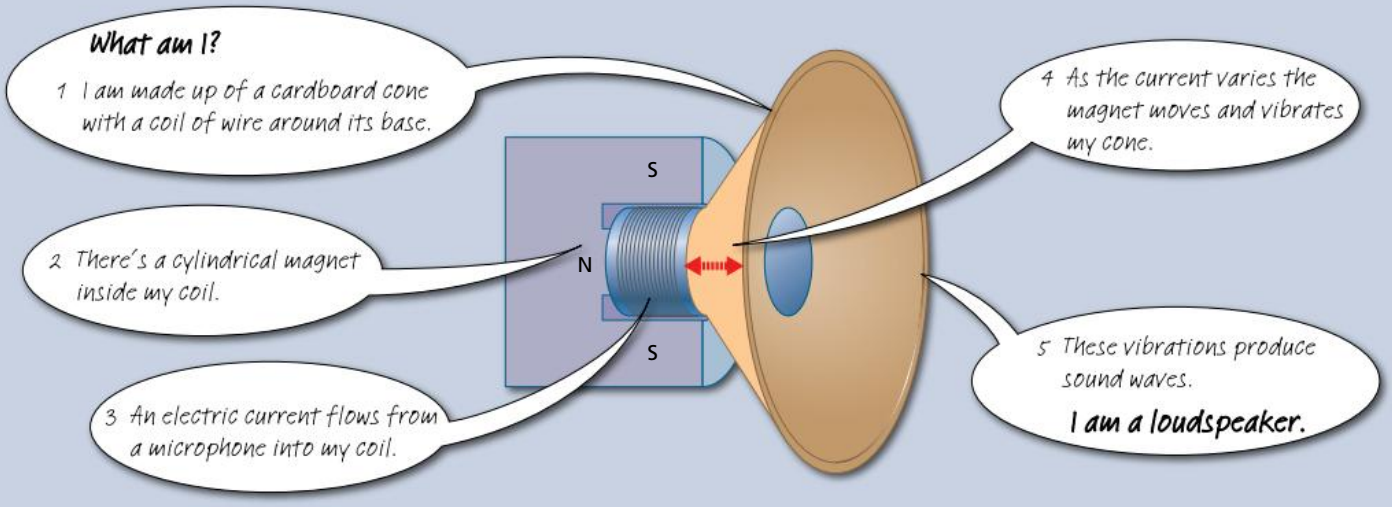
Self-management

What am I?

In groups, select a device from this chapter and write five clues describing it. An example is given below.

Write clues for five different devices, one device from each section of the chapter.

You can now have a competition between groups. Read out your first clue. If the other group correctly identifies the device they get 5 points. If they need two clues before they identify it, they get 4 points, and so on. The group with the most points wins.



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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 A loudspeaker changes:

A electromagnetic waves into sound waves

B sound waves into electric current

C electric current into sound waves

D electric current into electromagnetic waves

2 In which three of the following situations would an electric current be generated?

A A magnet is pushed into a coil of wire.

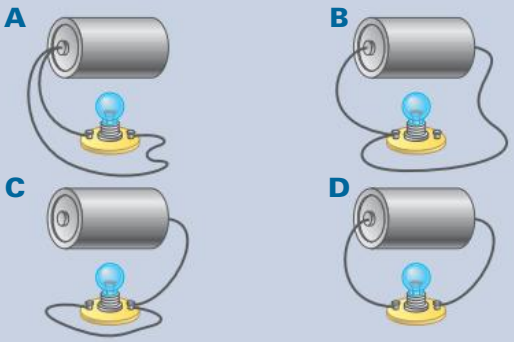
B A magnet is left inside a coil.

C A magnet is taken out of a coil.

D A coil is moved towards a magnet.

E A coil sits beside a magnet.

3 Which one of these set-ups will make the bulb glow? For each one that doesn't glow, give a reason.

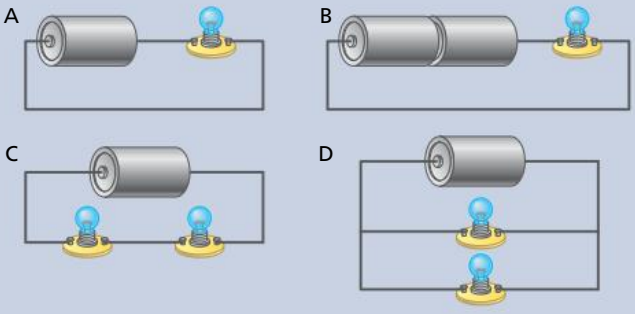


4 Look at the four circuits below.

a Which will have the brightest bulb(s)? Why?

b Which will have the dimmest bulb(s)? Why?

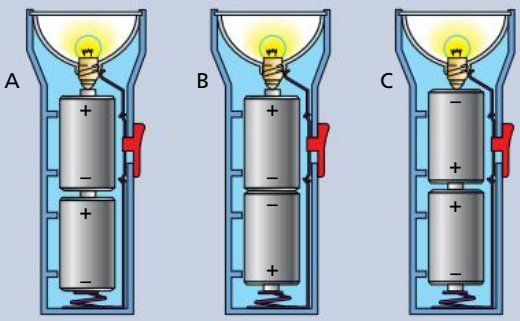
c In which circuit are the bulbs connected in parallel?



5 A circuit contains a 12 V battery and two light bulbs. The voltage drop across one of the bulbs is 8 V. Predict the voltage across the second bulb. Explain your answer.

6 Why are most electrical wires made of copper coated with plastic?

7 Ryan is trying to work out how to put two 1.5V batteries into his torch.



a Which of these arrangements should work?

b Are the batteries connected in series or in parallel?

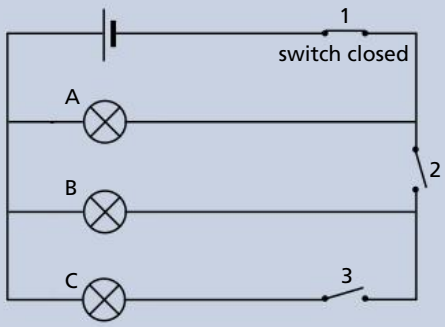
c What is the total voltage used by the torch?

8 In the circuit below, predict what will happen to each of the bulbs A, B and C when you do these three things one after the other:

a close switch 2

b then close switch 3

c then open switch 1.



9 An electric radiator has a small plate on the back that reads: 240V 1500W

a If W is the symbol for watts, what is the power rating in kilowatts?

b If the cost of electrical energy is 15 cents per kilowatt-hour, how much would it cost to run this radiator for 3 hours?

10 Explain why each of the following is unsafe:

a using a knife to clean out the dirt in a power point

b using an electric drill in a room with a wet floor

c putting a 20A fuse in a fuse box socket designed for a 15A fuse.

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8



Light energy

By the end of this chapter you will be able to …

Knowledge and Understanding

- distinguish between the absorption, reflection and refraction of light and identify everyday situations where each occurs (PW1f)

Skills–Working Scientifically

- select appropriate methods to collect and record reliable data on how mirrors and lenses work (5.2a)
- safely construct, assemble and manipulate laboratory equipment (6b)
- apply numerical procedures and mathematical concepts to draw ray diagrams for mirrors and lenses (7.1d)
- use cause-and-effect relationships to explain ideas such as why the sky is blue (8d)
- evaluate approaches used to solve problems (8g)

LITERACY FOCUS

cataracts
concave
convex
cornea
dispersion
focal length
image
iris
laser
law of reflection
long-sighted
optic nerve
pixels
polarised
pupil
refraction
retina
short-sighted
spectrum
total internal reflection

Focus for learning

Light and colour are all around you. There are blue skies, red sunsets, rainbows and the magic colours of fireworks, stage lighting and laser shows.

In your eyes there are lenses to focus the light so you can see things. Cameras work in the same way as your eyes. Lenses control the light in microscopes and telescopes so objects too small or too far away can be seen. You use mirrors to see yourself, and surgeons use optical fibres to see inside your body.

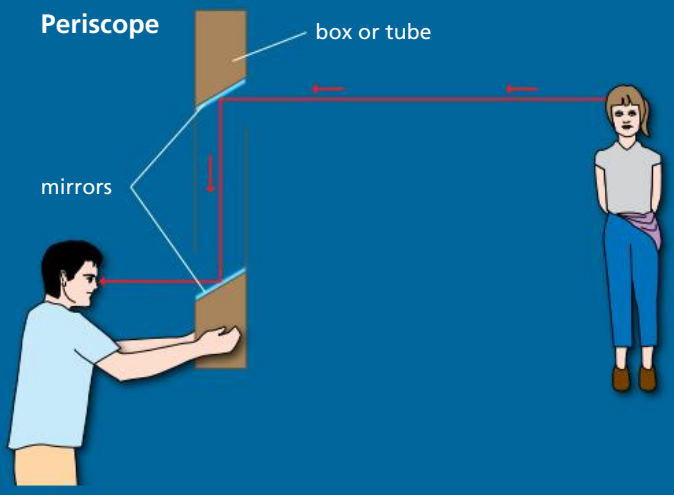
PROBLEM SOLVING

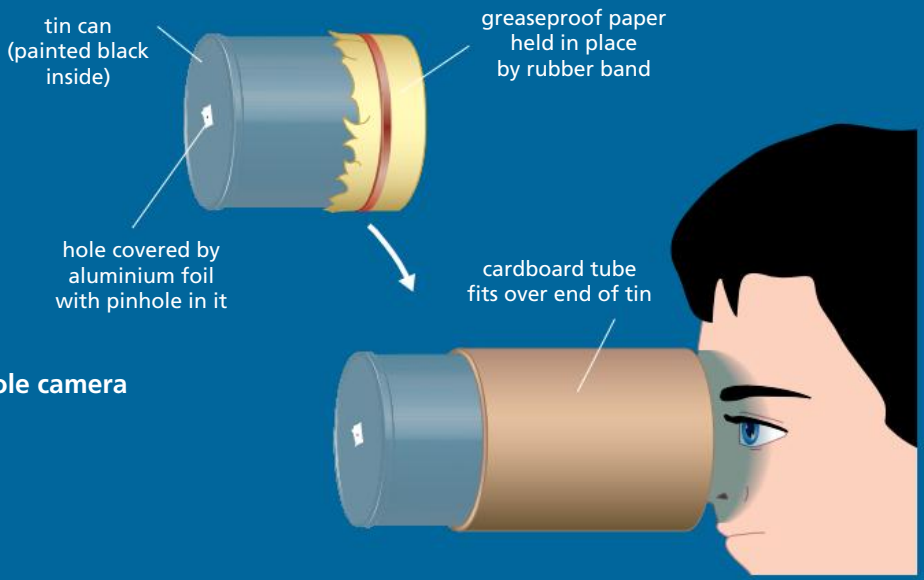
Building an optical device

Design and build an optical device that works. How complex or simple you make your device is up to you. Follow these steps:

1. Decide which device you are going to build. Some suggestions are given here, but you will need to do some research.
2. Draw a plan of your device.
3. Ask your teacher to check your plan and perhaps suggest modifications.
4. Make the device and test it out.
5. Write a report describing how you made the device and where you found information on it. Describe any problems you had and how you overcame them.

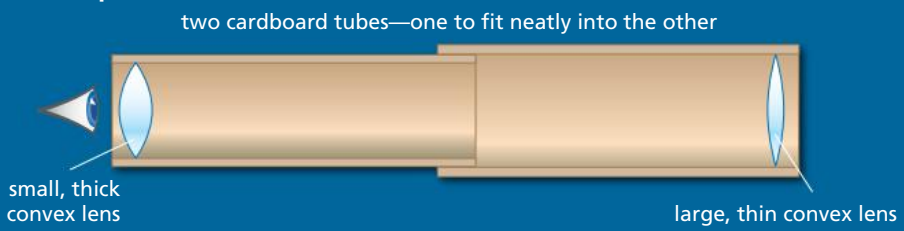
Periscope





Pin hole camera

Telescope



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8.1 Reflection and mirrors

INQUIRY 1 Light and shadow

You will need: candle or electric light, short straight piece of plastic tubing or hose

1 Look at the burning candle through the straight tube.

2 Now bend the tube. Can you still see the candle?

- From this, what can you infer about the way light travels?



3 Draw a diagram to explain why you can't see the candle when the tube is bent.

4 What could you do so that you are able to see the candle through the bent tube?

How light travels

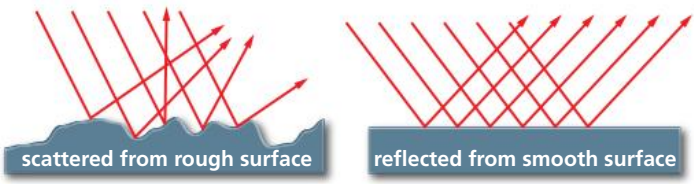
Light is a form of energy produced by *luminous* or glowing objects such as the sun, electric lights and fires. It helps if you imagine that light travels in thin beams or *rays*. A source of light sends out rays in all directions. These rays usually travel in straight lines. Light rays travel from the luminous object to your eyes, and that is why you can see the object. However, most objects are not luminous. We see them only because they reflect light into our eyes. This is why we can see the moon—it reflects light from the sun. It does not produce its own light like the sun does.

Transparent, translucent or opaque

Materials like glass that allow light to pass through them are said to be *transparent*. However some light always reflects (bounces back) from their surfaces. Some materials let just enough light through to allow you to see things on the other side, but scatter so much light that you can't see through them clearly. The frosted glass used in shower screens is like this. Such materials are said to be *translucent*. However, most of the objects around you absorb or reflect all the light striking them. They are said to be *opaque*.

Reflection

How light is reflected from the surface of an object depends on how smooth the surface is. If it is rough, the reflected rays are scattered in all directions, as shown below. Most surfaces are like this. However, if the surface is smooth and shiny, the reflected rays all bounce back evenly in the same direction. When this occurs you can see a reflection or an **image** of yourself and other objects. This happens with mirrors. It also happens with shiny metal surfaces and sometimes with glass.

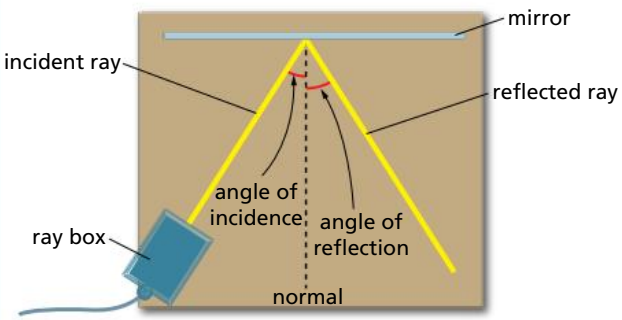


INQUIRY 2 Law of reflection

You will need: ray box kit, flat mirror, sheet of white paper, protractor, ruler

1 Do this activity in a darkened room.

2 Stand the mirror near the edge of a piece of white paper. Shine a single ray of light from the ray box at an angle to the mirror, as shown.



3 Use a pencil to trace along the front of the mirror. Then trace the light ray leaving the ray box. This is called the *incident ray*. Also trace the light ray that bounces back off the mirror. This is the *reflected ray*.

4 Draw a third line at right angles to the mirror at the point where the two rays meet, as shown. This line is called the *normal*.

5 Use a protractor to measure the angle of incidence and the angle of reflection, as shown.

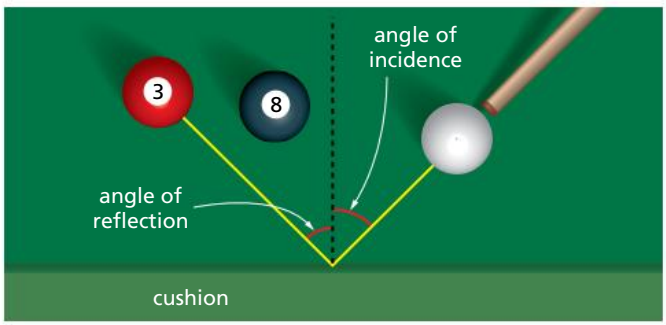
6 Try the ray box in three different positions and measure the angles each time.

- Write a generalisation linking the angle of incidence and the angle of reflection.

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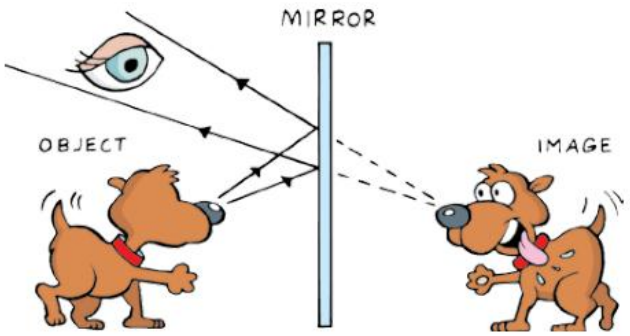
Law of reflection

In Inquiry 2 you should have found that when light reflects from a mirror, the angle of reflection is the same as the angle of incidence. This is called the **law of reflection**. Pool balls also obey the law of reflection. For example in the diagram below, the player has to make the white ball hit the red 3 without touching the black 8. He can do this by bouncing the white ball off the cushion at the same angle it hit the cushion.



Mirror images

The diagram below shows light rays from the tip of the dog's nose being reflected by a mirror. You could draw similar rays from other parts of the dog. The reflected rays travel to your eye. However your brain has been programmed to expect light travelling in straight lines, so it traces the rays back behind the mirror as shown. This is why the image is behind the mirror.



The image you see is not real—there is no dog behind the mirror. Such an image is called a *virtual image*. It is the same distance behind the mirror as the object is in front of the mirror.

The image you see is also back to front. The dog's left ear seems to be on the right side of its head, and its right ear is on the left. This is more obvious with letters. You may have wondered why you can't read the AMBULANCE sign on the front of an ambulance. This has been done so that the word is the right way round when you are looking in a car's rear-vision mirror, which reverses what you see.

Curved mirrors

Sometimes you find mirrors in amusement centres which produce very distorted images. These mirrors are not flat, but curved. **Concave mirrors** have surfaces that curve inwards, like the inside of a spoon. **Convex mirrors** have surfaces that curve outwards like the back of a spoon. In Inquiry 3 you can investigate the images formed in these mirrors.

INQUIRY 3 Curved mirrors

PART A

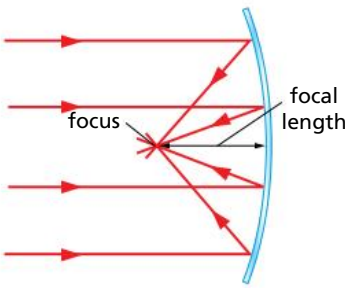
You will need: concave and convex mirrors or a polished soup spoon

1. Begin with the concave mirror nearly touching your eyebrow. Can you see an image of your eye in the mirror? Is it the right way up or upside-down? Is it larger or smaller than your eye?
2. Move the mirror away from your eye. What happens to the image?
3. Repeat steps 1 and 2 with the convex mirror.
   - Which mirror would be better as a shaving or make-up mirror? Why?
   - Which would be better as a rear-vision mirror? Why?
4. Experiment to see if any of the images can be focused onto a screen or a small piece of paper. If they can, they are *real images* rather than virtual images.

PART B

You will need: concave and convex mirrors, ray box, sheet of white paper

1. Use the ray box to produce three or four parallel rays of light.
2. Shine the rays so that they hit the concave mirror.
3. Trace the paths of the incident and reflected rays.
4. The point where the rays meet is called the *focus*. The distance between the mirror and the focus is called the **focal length** of the mirror. Measure the focal length.

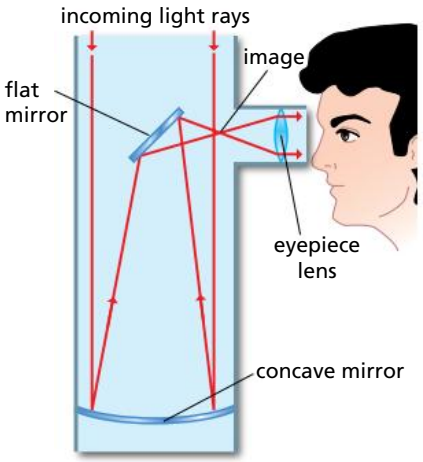


5. Repeat steps 2–4 for the convex mirror. (The focus will be *behind* the mirror.)

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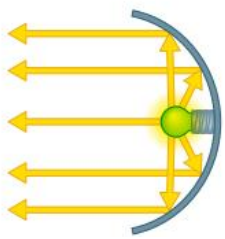
Uses of concave mirrors

Concave mirrors reflect parallel rays of light closer together to form a real image at the focus. In a reflecting telescope, a concave mirror and a flat mirror together form a tiny image of a distant star. This image is then magnified by the eyepiece lens. The larger the mirror, the more light it collects from the star. The mirror in the Anglo-Australian telescope near Coonabarabran in NSW is almost 4 m in diameter. There are plans to build telescopes with mirrors up to 100 m in diameter!



The light path in a reflecting telescope

The concave mirrors in car headlights and torches work in the opposite way to those in telescopes. The bulb is placed at the focus and the light from the bulb is reflected from the mirror to form parallel rays of light which travel out of the headlight.

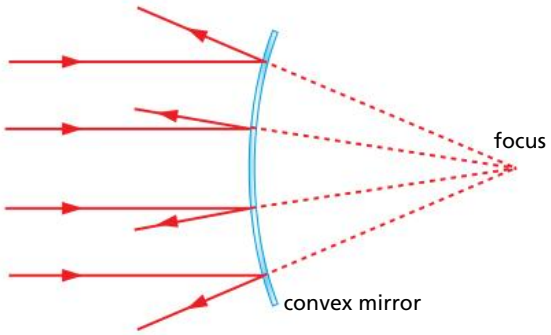


The light path in a car headlight

The Parkes radio telescope in western NSW has a dish 64 m in diameter. Instead of light, it focuses radio waves from space. The control cabin is at the focus of the dish. Satellite dishes work in the same way but they collect TV and other signals beamed to Earth from orbiting satellites.

Uses of convex mirrors

Convex mirrors spread parallel rays of light further apart as shown top right. The reflected rays seem to come from behind the mirror, so the image is virtual, as in a flat mirror. Such mirrors have a wide field of view. This is why they are used as rear-vision mirrors. They are also used for surveillance in shops and to help motorists see around blind corners.

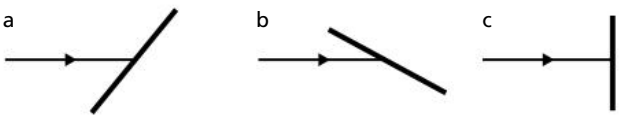


Over to you

1 Classify the following as being transparent, translucent or opaque:

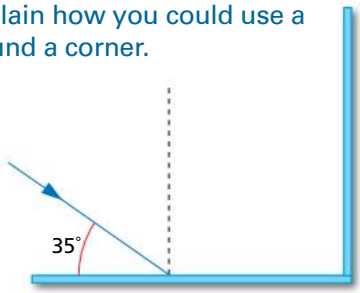
air, aluminium foil, cloud, contact lens, glass beaker, greaseproof paper, leather jacket, lemonade, mirror, nylon stocking, orange juice, plastic wrap

2 Copy the three drawings below and put in the reflected rays.



3 Use a diagram to explain how you could use a flat mirror to see around a corner.

4 Two flat mirrors are arranged so that they meet at 90°. A ray of light strikes the first mirror as shown.



a What is the angle of incidence of the ray of light on the first mirror?

b Copy the diagram into your notebook and draw the path of the ray after it is reflected from the first mirror.

c Find the:

- angle of reflection from the first mirror
- angle of incidence on the second mirror
- angle of reflection from the second mirror.

d What can you say about the original ray and the final reflected ray?

e What name is given to the dashed line?

5 At the hairdresser you look at the back of your head by looking in the mirror in front of you while the hairdresser holds a mirror behind you. Draw a diagram showing how this works, tracing the path of a light ray from the back of your head to your eyes.

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8.2 Refraction and lenses

INQUIRY 4 Light tricks

PART A

You will need: large opaque cup, coin, water container

1. Put the coin in the bottom of the cup.
2. Move your head back a little so that the coin is just out of sight.
3. Have a partner pour water into the cup while you keep your head in exactly the same position. What happens?
4. Move your head and look at the coin in the bottom of the beaker. Can you see an image of the coin in the water? Where is the image in relation to the real coin?

PART B

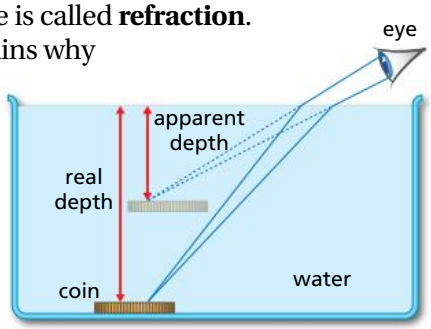
You will need: glass beaker, pencil

1. Three-quarters fill the beaker with water.
2. Put the pencil into the water in a vertical position, with one end out of the water.
3. Now move the top of the pencil so that it is at an angle to the surface of the water. Observe carefully what happens.

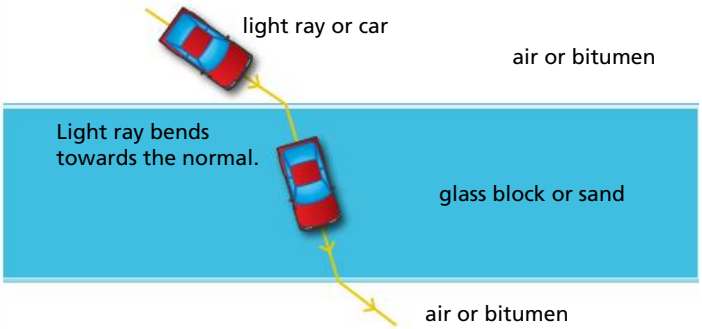
Bending of light

You can explain your observations from Inquiry 4 in terms of the bending of light. Rays of light travel from the coin or the pencil to your eyes. As they pass from the water to the air, they bend as shown below. However, your brain assumes that light travels in straight lines, as shown by the dashed lines. So it seems that the coin is in shallower water than it really is. For this reason, the end of the pencil seems higher than it really is, and this makes it look bent. This bending of light as it passes from one substance to another at an angle is called **refraction**.

Refraction explains why water often looks shallower than it really is. It also explains why someone standing in water seems to have short legs. Objects under water are always deeper than they look, because of refraction.



Refraction occurs because light travels more slowly in glass or water than it does in air. To help you understand what happens when a light ray travels from air to glass, think of a car hitting sand across the road at an angle. The front right-hand wheel hits the sand first and is slowed down, but the other wheels continue at the same speed. This causes the car to swerve to the right. Similarly, when a light ray travels from air to glass or water, it slows down and bends towards the normal. When the light ray leaves the glass and enters the air, it speeds up and bends the other way—away from the normal.

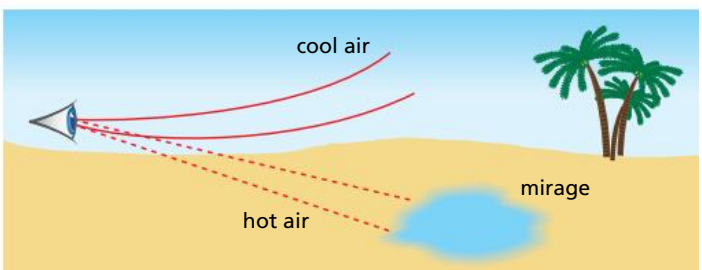


Refractive index

The **refractive index** of a substance is a number that tells you how much the light bends when going from air into the substance. The higher the refractive index, the more the light is slowed down and the more it bends. Glass has a refractive index of about 1.5, whereas diamond has a refractive index of 2.4. So light bends more going from air to diamond than it does from air to glass. Different types of glass can be identified by measuring their refractive index.

Mirages

Have you ever seen a mirage—a 'pool of water' on hot ground that disappears as you get closer? Cool air and hot air have different refractive indexes. A ray of light passing through these layers of air is therefore bent and follows a curved path as shown. Because you are used to light travelling in straight lines, you see an image. The pool of water you think you are seeing is just an upside-down image of the sky.

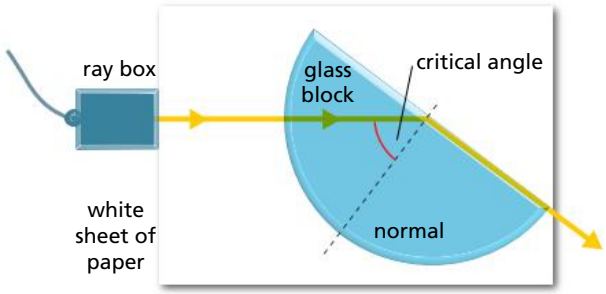


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INQUIRY 5 Critical angle

You will need: semicircular glass or clear plastic block, ray box, protractor, sheet of white paper

1 Set up the apparatus as shown and turn on the ray box. Notice how the light ray is bent as it passes out of the block into the air.
   - Does the light ray bend towards the normal or away from it?



2 Rotate the block until it reaches a position where the light ray does not leave the block but just passes along its straight edge.

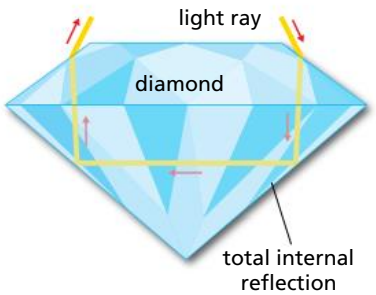
3 Use a pencil to trace around the block on the paper. Mark the path of the light beam and draw in the normal. Then use a protractor to measure the angle of incidence in this position. It is called the *critical angle*.

4 Replace the block in the same position and discover what happens when the angle of incidence is greater than the critical angle. Draw what you observe.

Total internal reflection

When light passes from glass or water into air, some light is reflected and some is refracted. This is why you can sometimes see your reflection in windows. When the angle of incidence increases, it reaches a critical angle at which all of the light is reflected. This is called **total internal reflection**. If you look up towards the surface of a swimming pool at the correct angle, or look up through the side of a fish tank, total internal reflection causes the surface to act like a mirror.

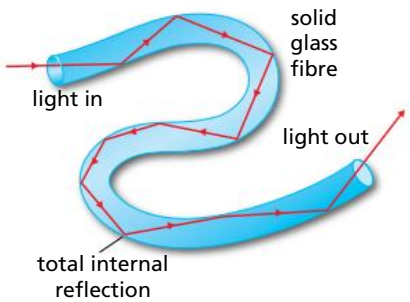
Total internal reflection causes most of the sparkle of a cut diamond. The bottom surface reflects the light rays back up through the top of the diamond as shown.



Reflectors on bikes are designed so that the light from an approaching car is reflected straight back towards the car. 'Cat's eyes' in the middle of the road work in the same way.

Optical fibres

An optical fibre is a very narrow fibre made of high-purity glass with a special coating on it. If a light beam is shone in one end it is totally internally reflected as shown. In this way light can go around corners.

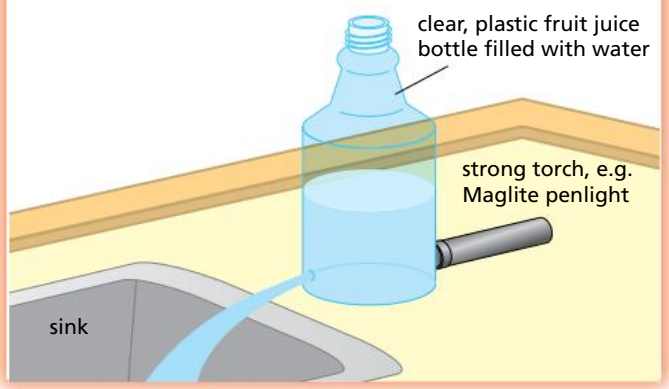


Optical fibres are used in surgery. A light is connected to an optical fibre that is inserted into the body through a small cut. A computer monitor shows what can be seen at the end of the optical fibre. This makes surgery much easier and allows the patient to heal more quickly.

Optical fibres can also carry coded signals as pulses of light from a laser. These can be changed into electrical signals at the receiving end. For example, most telephone calls are now changed to pulses of laser light and transmitted along optical fibres.

INQUIRY 6 Model optical fibre

Set up the equipment shown to make a model optical fibre. You will need a darkened room. You could add a fluorescent dye to the water.



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INVESTIGATION

1 Investigating lenses

Aim

To investigate the images formed in convex lenses (thicker in the middle like a discus) and concave lenses (thicker on the edges).

Risk assessment and planning

Be careful not to drop the lenses.

Before you start Part B you will need to draw up a data table in which to record your results.

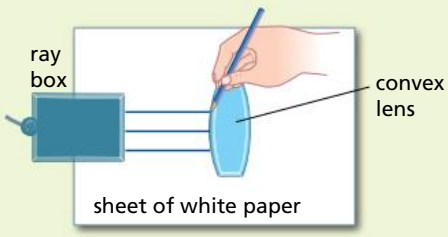
Part A

Apparatus

- ray box kit with lenses
- sheets of white paper

Method

1 Set up the ray box and a convex lens as shown. Trace around the lens and draw in the parallel light rays.



2 Find the focal length of the lens—the distance from the centre of the lens to where the rays meet (the focus).

3 Repeat with a thinner or a fatter convex lens.

4 Repeat with a concave lens. How do you find its focal length?

Conclusion

Summarise what you have found out so far about lenses.

Part B

Apparatus

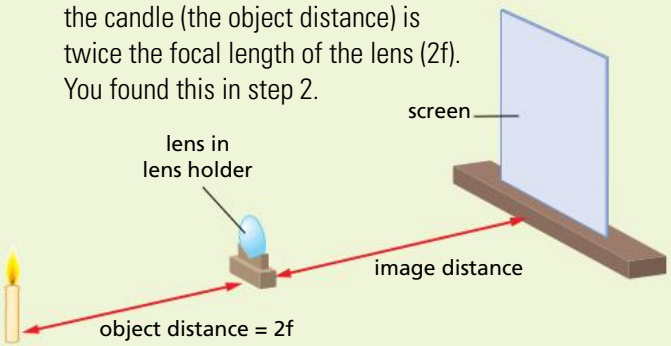
- round convex lens with holder
- candle
- screen
- metre ruler

Method

1 Hold a round convex lens near a window and focus the image of a distant object onto a screen.

2 Measure the distance between the lens and the screen. This is the focal length (f).

3 Light a candle. Then put the lens in its holder and position it so that the distance between the lens and the candle (the object distance) is twice the focal length of the lens (2f). You found this in step 2.



4 Move the screen backwards and forwards until you get a sharp image of the candle. This is the image distance. If you can do this, the image is real.

5 In your data table record:

- the object distance (2f)
- the image distance
- whether the image of the candle is real
- whether the image is upright or inverted
- whether the image is smaller or larger than the object.

6 Repeat steps 3–5 for objects at these distances:

- more than 2f
- between 2f and f
- f
- less than f

Note that to see a virtual image you may need to look through the lens at the candle.

Conclusion

There are several patterns in the data you have collected about lens images. Try to summarise these.

Uses of lenses

A lens bends the light that passes through it. A **convex lens** like that in a magnifying glass focuses the rays of light to a point, producing a real image. A **concave lens** spreads out the rays of light and produces a virtual image, like a flat mirror does.

In cameras, projectors, telescopes and microscopes, several convex lenses work together to control the light passing through them. For example, in a microscope, the condenser and objective lenses form an image inside the microscope. The eyepiece then magnifies this image.

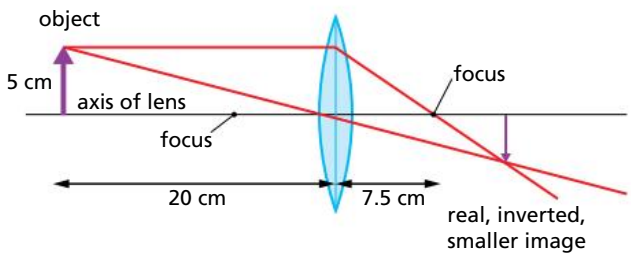
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SKILL

Drawing ray diagrams

You can predict the size and position of the image produced by a lens (or a mirror) by using a scale diagram. For example, suppose you have a convex lens with a focal length of 7.5 cm and an object that is 5 cm high and 20 cm from the lens. To find the image, follow these steps. You need to draw accurately.

1 Draw a horizontal line to represent the axis of the lens. Use a compass to draw a lens in the middle of it as shown. The size of the lens is not important. Draw a vertical line through the centre of the lens.



2 Mark the focus on each side of the lens, measuring from the centre of the lens. If you use a scale of 1:5, then the focal length will be 7.5/5 = 1.5 cm, rather than 7.5 cm.

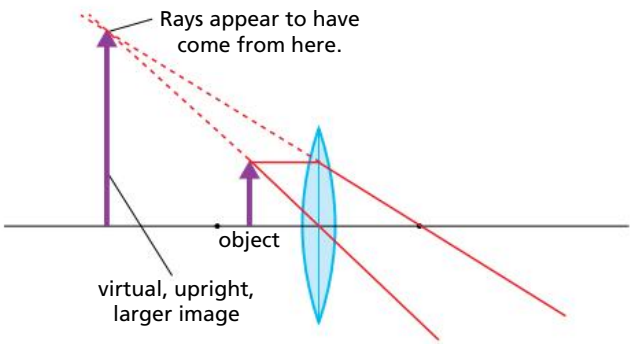
3 Draw the object to scale as well, with an arrow to show which way up it is.

4 Draw a light ray from the tip of the arrow, parallel to the axis, until it reaches the middle of the lens. The ray then bends to go through the focus on the other side of the lens.

5 Draw a second ray through the centre of the lens. It passes straight through.

6 Where the two rays meet is the top of the image, which in this case is real, inverted and smaller than the object.

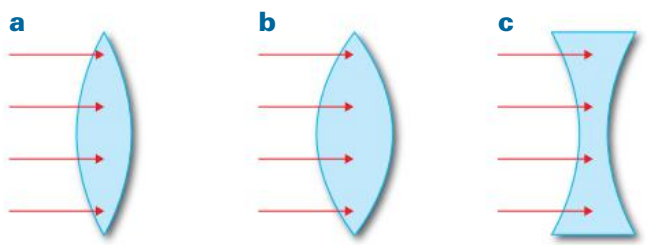
7 In the diagram below, the object is closer to the lens. This time you have to draw dashed lines backwards until they meet. This time the image is virtual, upright and larger than the object (magnified).



★ Suppose you have a lens with a focal length of 10 cm and an object 5 cm high. Use ray diagrams to predict the image for these object distances: 25 cm, 20 cm, 15 cm, 10 cm and 5 cm.

Over to you

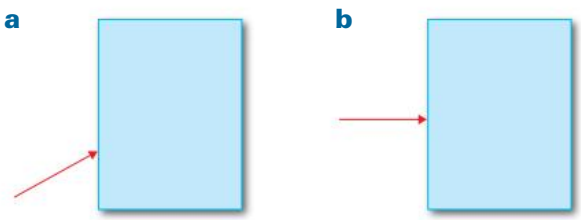
1 Copy the drawings below and show what happens to the light rays when they pass through each lens. Label the focus for each lens.



2 Describe a simple method of finding the focal length of a convex lens.

3 Bottles left in dry grass can start fires. How is this possible?

4 Copy the diagrams below and continue the light rays to show the paths they would take through the glass blocks.



5 Matthew wants to spear a fish swimming in the water near a jetty. Where does he need to aim to hit the fish? Use a diagram to explain.

6 The critical angle of water is 48°. Draw a diagram showing what would happen to a light ray that is shone from under water up to the surface at an angle of incidence of:

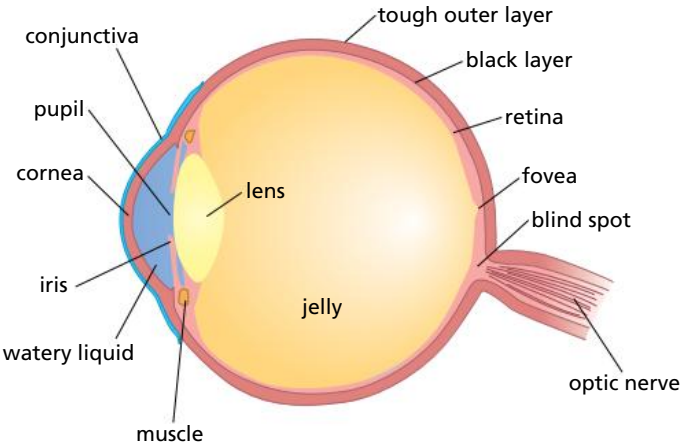
a 30° **b** 50°.

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8.3 Eyes and seeing

How the eye works

Light enters the eye through the transparent **cornea** which is covered by a thin protective layer called the *conjunctiva*. The light then passes through a small opening called the **pupil**. The pupil appears black because it is dark inside the eye. It is surrounded by a coloured ring of muscle called the **iris**, which controls the amount of light entering the eye by contracting and relaxing. In bright light it contracts and lets in less light. When it is dim or dark, the iris relaxes and opens wider.



The cornea and lens together focus the light onto the retina at the back of the eye. The lens is flexible and can be made fatter or thinner by the muscles around it. This changes the focal length and allows you to focus on near or far objects. The inside of the eye is filled with a jelly-like substance which serves mainly to keep the round shape of the eye.

The **retina** contains many tiny receptor cells that are sensitive to light. These detect the light and send electrical impulses to the brain, via the **optic nerve**. Where the optic nerve enters the eye is called the *blind spot*. Light hitting this spot cannot be detected because there are no light-sensitive cells there. The area in the centre of the retina is called the fovea (FOE-vee-a). It has most of the light-sensitive cells and is the area where we see colour and fine detail.

The tough outer layer of connective tissue helps keep the eye rigid. Between this layer and the retina is a layer of blood vessels that provide blood to the retina. This layer is black to prevent reflections inside the eye which would blur the image.

We normally use both eyes to look at an object, and muscles at the back of our eyes cause them to point slightly inwards to look at closer objects.

Because the two eyes look from slightly different angles, they each see a slightly different image. The brain interprets these images to give a three-dimensional picture of the object. The amount our eyes point inwards is interpreted by the brain and used to judge distances. This ability to see in three dimensions and judge distances is called *binocular vision*.

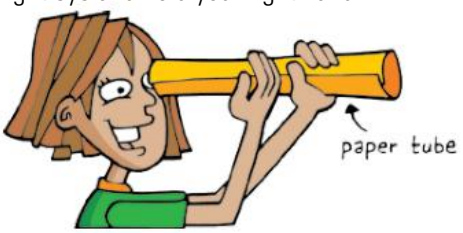
INQUIRY 7 Investigating your sight

Part A: Judging depth

1. Have your partner hold a pencil in front of you.
2. Close or cover one eye and try to touch the tip of the pencil. Do this three times.
3. Do the same with your other eye.
4. Now repeat the activity with both eyes open.
   - What can you conclude from this activity?

Part B: Binocular vision

1. Roll a sheet of paper into a tube and hold it in front of your left eye.
2. Close your right eye and hold your right hand half way along the tube, palm towards you.



3. Now open your right eye. What do you observe?
   - Use what you know about binocular vision to explain your observation.

Part C: Blind spot





1. Close or cover your right eye and, holding this book at arm's length in front of you, look at the girl on the right.
2. Now move the book slowly towards you and note what happens to the boy on the left.
3. Have someone measure your blind spot distance. Is it the same for your other eye? Compare your blind spot distances with those of other students.
4. By drawing simple drawings with light rays, try to work out whether your blind spot is on the nose side or the ear side of your eye.

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INVESTIGATION 2

Dissecting an eye

Aim

To dissect (cut open) a bull's eye and examine the parts.

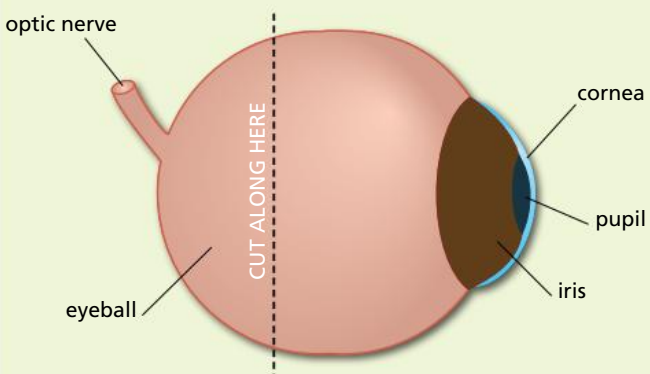
Risk assessment and planning

Read through the investigation and do a risk assessment.

- Discuss with your teacher the reasons for dissecting a real eye, rather than just looking at pictures.
- Your teacher will probably demonstrate the safe use of the dissecting equipment. If you are not confident doing the dissection yourself, your teacher will help you.
- Discuss how you will dispose of wastes.
- Wear protective clothing and disposable gloves.
- If you want to get the most out of the investigation, you need to work very carefully.

Apparatus

- bull's eye
- sheet of newspaper
- sharp and coarse pointed dissecting scissors
- scalpel
- disposable gloves
- piece of newspaper
- cutting board



Method

1. Put the eye on the the cutting board on top of the newspaper. Find the transparent skin at the front of the eye. This is the cornea. Look at the coloured part of the eye behind the cornea. This is the iris. In the centre of the iris is the hole called the pupil.
2. Find the hard white solid tube in the fat at the back of the eye. This is the optic nerve. You may need to cut away some of the fatty tissue.
3. Hold the optic nerve. Using the scalpel and scissors, cut the eye in half along the line as shown. The jelly inside the eye will seep out. Notice how tough the eyeball is.
4. Look at the front part of the eyeball. Carefully squeeze out the hard oval-shaped lens. Can you see the pupil—the hole in the front of the eye? Push your finger through the pupil from the back, so you can see the transparent cornea and conjunctiva which cover the front of the eye.
5. Wash the lens in water. Put it on a piece of newspaper and observe the lettering. Squeeze the sides of the lens and observe the lettering again. What change do you notice?
6. Now turn the back part of the eyeball inside out like a glove. The little white-grey spot in the middle is the blind spot, where the optic nerve is attached to the retina. The retina is the rainbow of colours around this spot.

Results

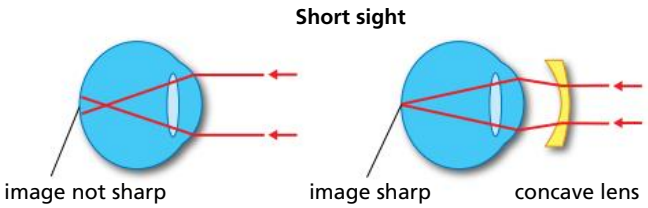
Write a report that includes a labelled diagram or diagrams of the eye, and your observations.

Problems with eyes

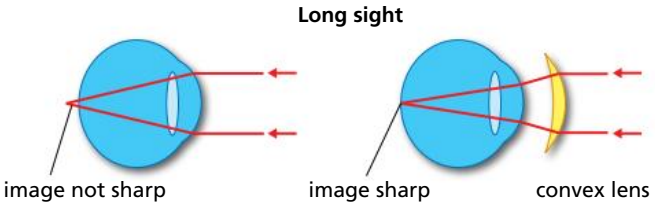
The muscles around the lens in your eye can change the shape of the lens. When you look at distant objects the muscles relax, pulling the lens and making it thinner. When you look at close objects the muscles contract, pushing the lens and making it thicker. However things can go wrong with this system.

A person who is **short-sighted** can see close objects clearly, but distant objects are blurred. For example, reading the blackboard or whiteboard from the back of the room may be difficult. This is because light rays from distant objects are bent so much that the image forms in front of the retina. So what they see is blurred. Short-sightedness usually occurs because the eyeball is too long or the cornea is too curved. This defect can be corrected by glasses with concave lenses, which bend the light rays outwards before they reach the eye.

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A person who is **long-sighted** can see distant objects clearly but can't focus on near objects. Reading road signs in the distance is not a problem, but reading the print on this page could be. This is because light rays from near objects are not bent enough and the image forms behind the retina, again making things blurry. This is because the eyeball is too short or the cornea is too flat. This defect can be corrected by glasses with convex lenses which bend the light rays inwards before they reach the eyes.

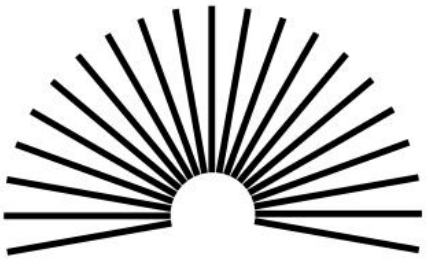


As people get older the lenses in their eyes become stiffer and cannot change shape as much. They may have problems with both close and distant vision. In this case they can wear glasses with lenses in two parts. The top part is used for distant vision and the bottom part for reading. These glasses are called bifocals. Graduated lenses gradually increase in strength from top to bottom.



Bifocals are two pairs of glasses in one. Notice how the bottom half magnifies for reading.

Apart from being short-sighted or long-sighted, the most common problem is astigmatism, or blurred vision for close and distant objects. It is caused by an irregularly shaped cornea. This problem can be corrected by glasses with lenses specially shaped to compensate for the irregular shape of the cornea.



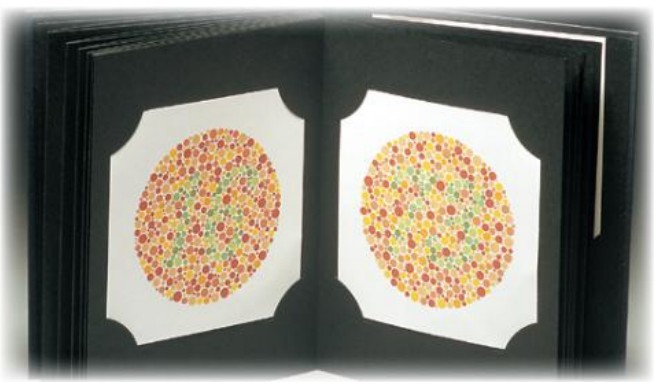
Charts like this are used to test for astigmatism. Hold the chart about 50 cm from your eyes. If some lines appear darker than others, you may have astigmatism and may need to get your eyes tested.

Contact lenses

Many people, especially those who play a lot of sport, prefer contact lenses to glasses. Contact lenses are made of plastic and are less than a centimetre in diameter. They are curved to fit the surface of the cornea and stay in place by clinging to the film of tears covering the cornea.

Colour blindness

Most of us can distinguish colours easily, but some people suffer from colour blindness. This is quite common in males, less so in females, and is usually inherited. A person who is colourblind has difficulty telling particular colours apart. In the most common form red and green objects appear the same colour. These people have to watch traffic lights very carefully.

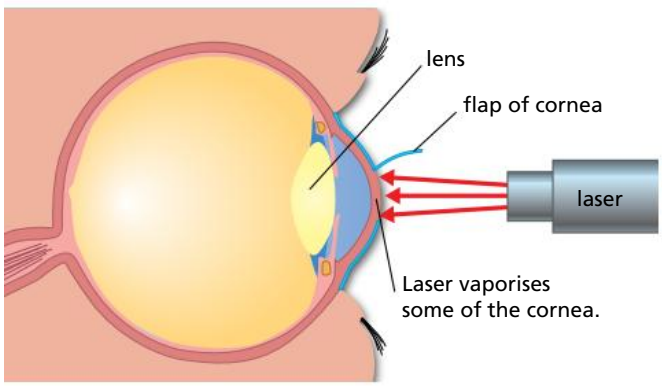


Patterns like this are used to test for colour blindness. If you can see numbers among the dots, you are not colourblind. Note that the colours in this book may not be accurate enough to assess your colour vision. Your teacher may have a colour-blindness chart.

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Laser eye surgery

In recent years laser eye surgery has been used to correct vision problems by reshaping the cornea of the eye. A microscopic knife is used to cut a thin 'skin' less than 0.2 mm thick from the front of the cornea. This is then folded back to make a flap, as shown. A laser (tightly focused beam of light) is then used to vaporise some of the cornea and reshape it. For people who are short-sighted the cornea can be made flatter. For people who are long-sighted it can be made more rounded. The surgeon can control precisely how the cornea is reshaped.



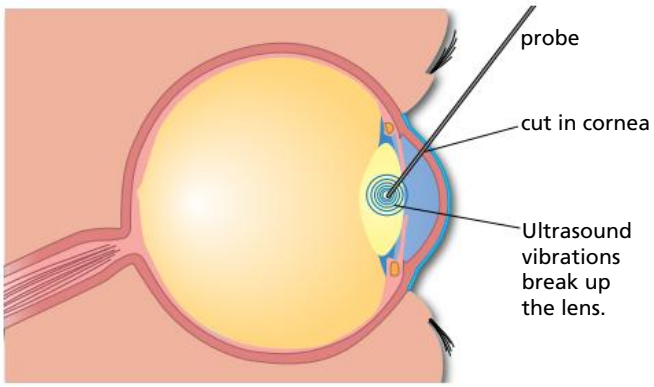
Finally the cornea flap is folded back. No stitches are needed and the cornea heals quickly. In this way the patient's vision is corrected without the need for glasses or contact lenses.

Sometimes the retina becomes detached (separated) from the back of the eye. When this happens a laser beam is passed through the cornea into the eye. When it hits the retina, the heat generated welds the retina back into position.

Cataracts

As the lenses in the eyes become less flexible with age they can become less transparent. Small cloudy spots called **cataracts** can develop on the lenses, causing blurred vision. In severe cases, cataracts can cause blindness as the lens becomes completely opaque. It is thought that cataracts are caused by exposure to the ultraviolet radiation in sunlight. Cataracts usually occur in old age, but are common in people with diabetes.

Once a cataract forms it cannot be reversed. The only treatment is surgical removal of the lens and replacement with a plastic one. In a cataract operation a small cut (3 mm) is made in the side of the cornea as shown top right. A tiny probe with a needle-like tip is inserted through this cut. It vibrates at an extremely high speed, caused by ultrasound. These vibrations break the lens with the cataract into pieces which are sucked out through the eye of the needle. The plastic lens is about 6 mm in diameter and is usually folded in half to fit through the cut in the cornea. Once in place, it flips back to its unfolded shape and the cornea heals itself without stitches.



Over to you

1 Briefly describe the function of each of the following parts of the eye: cornea, pupil, iris, lens, muscle, retina, optic nerve.

2 **a** How can the lenses in your eyes focus on near objects as well as distant objects?

b Explain why it is difficult to focus on objects that are very close to your eyes.

3 The table below shows how the focusing ability of the eye changes with age.

a Draw a line graph to display this data.

b Use your graph to predict the smallest distance at which a clear image can be obtained by an average person of your age.

c Use the graph to predict when most people need to start wearing reading glasses.

Age (years)	Average smallest distance at which clear image can be obtained (cm)
10	7.5
20	9
30	12
40	18
50	50
60	125

4 Nelson can see distant objects clearly but the closest point he can see clearly is 50 cm from his eyes. Would Nelson need a convex or concave lens to read a book held 30 cm from his eyes? Use a diagram to explain your answer.

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SCIENTISTS AT WORK

Fred Hollows

Fred Hollows was born in New Zealand in 1929. His family were religious and Fred thought he'd like to be a missionary. However he changed his mind and decided instead to become an eye doctor or ophthalmologist (OP-tha-MOL-o-gist). He got a job in Australia and was soon head of the eye department at a Sydney hospital.



Fred operating in the street while others watch

Fred believed that everyone deserved the same chance in life. So when he found out about the poor health of Aboriginal people in the Northern Territory and in Sydney, he worked to help set up an Aboriginal medical service. He was shocked to discover that almost all Aboriginal people in outback communities had eye problems. These diseases were caused by dirty conditions and poor health—problems that could easily be avoided.

In the 1970s Fred set up a national program to treat eye disease in Aboriginal Australians. He was very good at inspiring doctors to give their time to the program, and many other people volunteered. Over 3 years his team travelled all over outback Australia. They treated 27 000 people for trachoma, performed 1000 operations and prescribed more than 10 000 pairs of glasses.

Fred became known as the 'wild colonial boy' of Australian surgery, partly because he loved the bush and partly because he had a wild temper. He believed in helping people to help themselves and he had no time for anyone who stood between him and his goals. He said 'When I've seen an opportunity I haven't sat down and called a committee meeting … we've gone and done it.'

Fred looked beyond Australia and found that there were more than 20 million people needlessly suffering from cataract blindness. He visited Eritrea, one of the world's poorest countries, in northern Africa. At the time, the lenses needed for cataract operations cost up to US$400 each and Fred referred to them as 'the most expensive pieces of plastic in the world'. So he raised money for a factory in Eritrea to make affordable, good quality plastic lenses. He also trained local doctors to perform the cataract operation (see page 179).

A factory was also built in Nepal, and lenses can now be produced for about $5 each. This means that cataract operations can be done for an average of $25 per eye, a small price to pay for sight!

In 1990 Fred Hollows was named Australian of the Year, but tragically he died in 1993 of cancer. However, only 6 months before his death he established The Fred Hollows Foundation to continue his work restoring sight to poor people around the world. More than a million people have now been fitted with the plastic lenses Fred helped make affordable and more readily available.



Fred holding one of his plastic lenses

Questions

1. According to Fred, how many people were there in the world needlessly suffering from cataract blindness?
2. Why was it so important to manufacture the plastic lenses needed in cataract surgery cheaply?
3. Fred Hollows believed in teaching people to help themselves. Do you think he managed to achieve this? Explain your answer.

ISBN 978 1 4202 3246 2

8.4 Colour

INQUIRY 8 Rainbow colours

Part A

You will need: ray box, triangular prism, white card

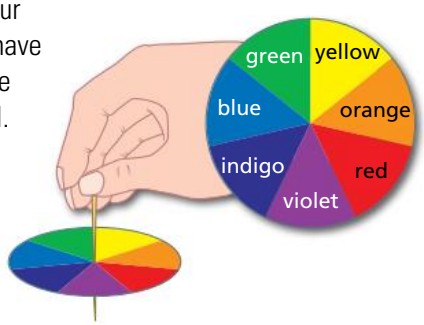
1 Use the ray box to direct a narrow beam of white light onto one side of the prism and onto a piece of white card.
   - What does the prism do to the light? Draw a diagram to show what happens.

Part B

You will need: white card, coloured pencils, toothpick

1 Make your own colour wheel from card by using pencils to colour in the colours of the rainbow as shown.

2 Push a toothpick through the centre of the wheel and spin it quickly on the end of the toothpick. What happens? Your school may have a ready-made colour wheel.

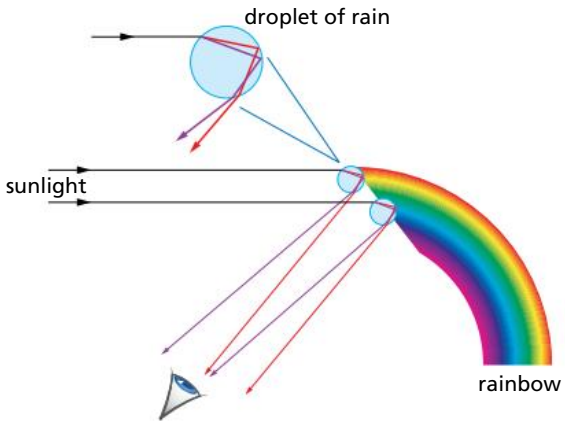


   - How is Part B the opposite of Part A?

How rainbows form

It is said that in 1666 Sir Isaac Newton was the first to use a prism to break sunlight up into the colours of the rainbow. This splitting of white light into the colours of the visible **spectrum** is called **dispersion**. White light is made up of the colours of the rainbow—red, orange, yellow, green, blue, indigo and violet. Violet light is refracted (bent) most by the prism, and red is refracted least.

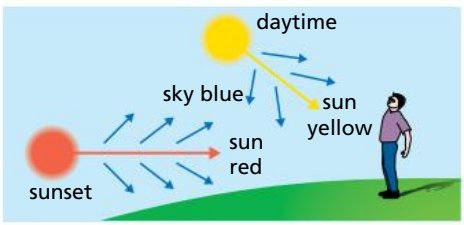
Rainbows are formed because rain droplets in the sky act like tiny prisms, as shown in the diagram top right. The droplets highest in the sky refract red to our eyes. Droplets lower in the sky refract green to our eyes, and the lowest droplets refract violet. The result is that we see a rainbow, with red at the top and violet at the bottom.



The sunlight is internally reflected from inside the droplets, back towards you. Therefore you see a rainbow only if the sun is behind you. Sometimes there is a second fainter rainbow above the first one. This occurs when the light is reflected twice inside the raindrops. This has the effect of reversing the colours in the second rainbow.

Blue skies – red sunsets

Blue skies and red sunsets are not caused by refraction of sunlight, but by the *scattering* of light when light rays collide with molecules in the air. Blue light is scattered more than the other colours, so the sky looks blue because you are seeing scattered light. The sun itself is yellow because most of the blue end of the spectrum has been removed by scattering. When the sun is low in the sky it turns red because the extra thickness of atmosphere scatters even more of the blue light, leaving mainly the red end of the spectrum.



INQUIRY 9 Milky sky

You will need: torch, drinking glass, milk

1 In a darkened room, shine a torch through a glass full of water. Look through the side of the glass and slowly add milk to the water until you can see a blue-white beam shining through the milky water.

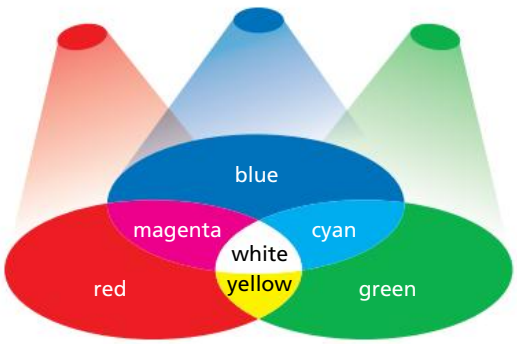
2 Now move around and look directly into the torch beam. What colour is the beam now?

3 Shine the torch up through the bottom of the glass and look down from the top. What colour is it now?

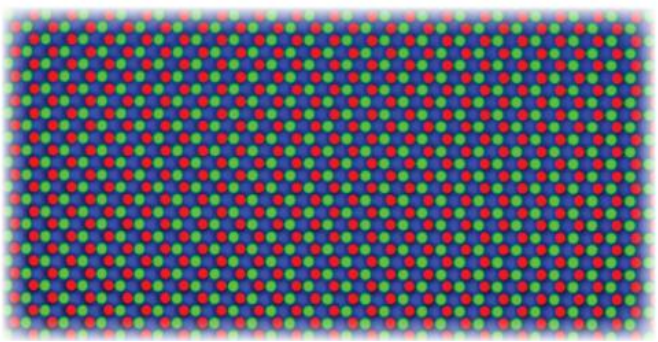
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Coloured lights

Our eyes contain three types of light-sensitive cells. One type responds to light in the red area of the spectrum, another to green light and the third to blue light. Red, green and blue are called the *primary colours*. If your eyes receive red, blue and green light together you 'see' white light. This can be shown by shining three coloured spotlights onto a screen so that they overlap. Where all three colours overlap you see white light. Where only two colours overlap you see *secondary colours*. For example, if red and green lights overlap they make yellow light.



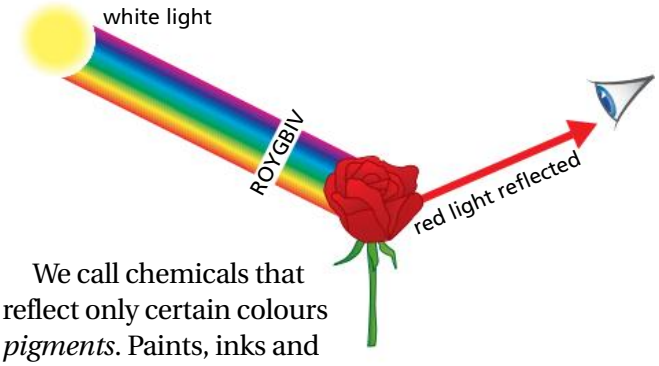
By varying the amount of each primary colour, you can make any colour. This is how a colour TV works. If you look closely at a TV screen you will see many tiny spots called **pixels** coloured either red, blue or green. These pixels glow in response to the electrical signals in the TV. The colour seen on the screen depends on which pixels glow. For example, when the red and green pixels glow, you see yellow.



A magnified view of the red, blue and green pixels on a TV screen

Seeing colours

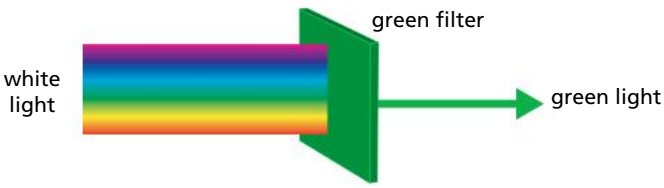
Light from the sun or from a light bulb contains all the colours of the visible spectrum. Why then are objects different colours? The answer is that the materials they are made of absorb some colours and reflect the rest. As a result we see only the colours of the reflected light. A red rose reflects only red light, and probably the colours either side of it in the visible spectrum—in this case orange and perhaps yellow.



We call chemicals that reflect only certain colours *pigments*. Paints, inks and coloured crayons all contain pigments. So do the petals and leaves of plants, and the skins of animals. White paper contains no pigments. It reflects all colours, and so it appears white. Some mixtures of pigments absorb all the colours of the spectrum, so they appear black.

Filters

A filter is a coloured piece of glass or plastic that lets some colours through but filters out the others. For example, a green filter lets green light through but absorbs all the other colours.



Looking through coloured filters or shining coloured light on objects makes the objects appear different colours. For example, a green apple looks green because it reflects green light. If you shine yellow light on it, the apple will appear yellow because it does reflect some yellow, since yellow is next to green in the spectrum. It will also appear blue in blue light. However, if you shine red light on it, it absorbs all the light and doesn't reflect any. This is because green is in the middle of the ROYGBIV spectrum and red is at one end. So the apple appears black. It will also appear black in violet light.

Coloured lights and filters are used to create different colours on the stage. For example a white dress will appear blue under a blue spotlight. Someone dressed in green will seem to disappear under a red spotlight.

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INQUIRY 10 Seeing colours

You will need: hand spectroscope, coloured papers and filters, 100 W light bulb

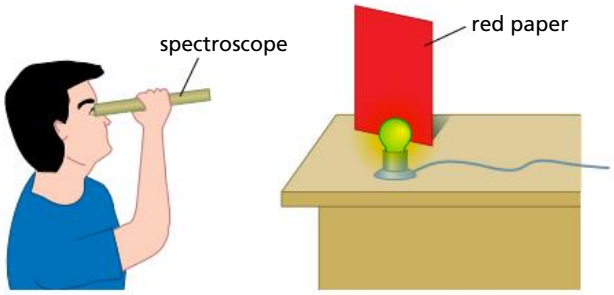
A *spectroscope* is an instrument that breaks up light to produce a spectrum of colours.

1 Look at a light bulb through the spectroscope.

2 Now ask your partner to hold a piece of red paper close to the light source. Look at the paper through the spectroscope.

- Which colours are reflected by the red paper? Which are absorbed?

Repeat for other coloured papers.



3 Hold a red filter in front of the light and observe it through the spectroscope.

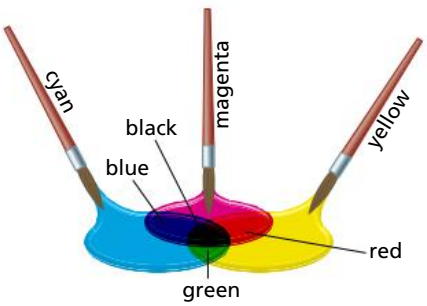
- Which colours come through the filter? Which are filtered out?

4 What happens if you use a red filter and a green filter together? *Explain* your observation.

Mixing colours

Mixing pigments is very different from mixing lights. For example, blue light and yellow (red + green) light mix to make white light, but blue and yellow paint mix to make *green* paint. White light is a mix of colours we call red, orange, yellow, green, blue, indigo and violet. Paints usually reflect and absorb not just one colour, but a small part of this visible spectrum. Blue paint absorbs light from one end of the spectrum (red, orange and yellow), but reflects light from the other end of the spectrum (green, blue, indigo and violet). On the other hand, yellow absorbs blue, indigo and violet and reflects red, orange, yellow and green. A mixture of blue and yellow therefore absorbs all the colours except green, which is reflected. So the mixture appears green.

If you mix a lot of paints together you usually end up with a blackish mess that doesn't reflect any colour.



Mixing paints is different from mixing coloured lights.

Over to you

1 Which of the following statements are true and which are false? Rewrite the false ones to make them correct.
- **a** The splitting up of white light into separate colours is called refraction.
- **b** The colours at opposite ends of the visible spectrum are red and violet.
- **c** You see the yellow colour of a banana because yellow light is absorbed and all the other colours are reflected.
- **d** When white light passes through a green filter, all the colours except those in the green part of the spectrum are absorbed.

2 List the colours of the visible spectrum. Make up a sentence that helps you to remember them in order.

3 Which colours are reflected and which are absorbed when white light is shone onto the following: green trees, white paper, a black shirt?

4 Explain why the light from a torch appears red when the torch is covered with a piece of red cellophane paper.

5 Which colours do you see on a TV screen when the following phosphors glow?
- **a** red and blue
- **b** blue and green
- **c** red, blue and green

6 A fruit shop has a red light above a box of oranges. What colour will the oranges appear to customers? Why?

7 What colour will a blue car look under a yellow street light? (Hint: Where are blue and yellow in the visible spectrum?)

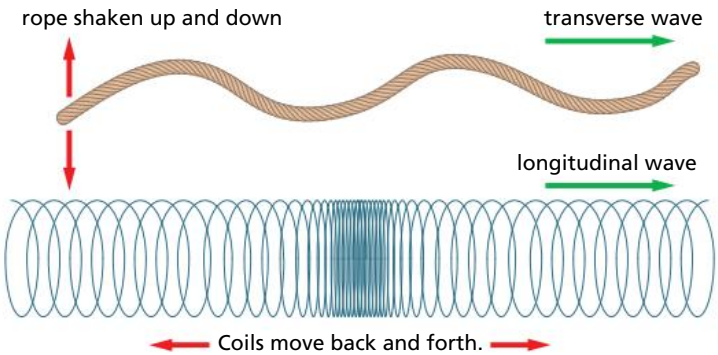
8 Would a rainbow be the same if you looked at it through a piece of red glass? Explain.

PROBLEM SOLVING By now you should have built your optical device. Use what you have learnt in the chapter to explain how it works.

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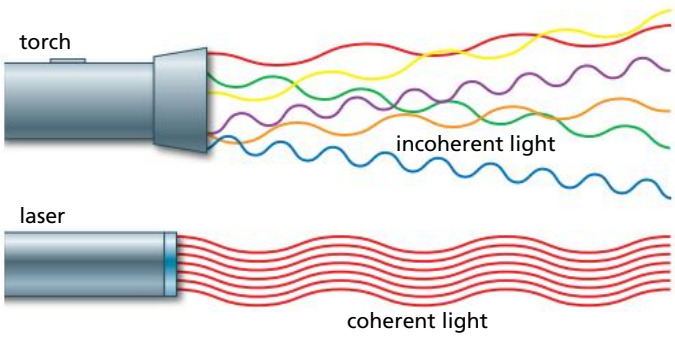
8.5 Light waves

Light is a form of radiation and like all radiation it travels as transverse waves, like waves along a rope flicked up and down. In contrast, sound waves travel as longitudinal waves, like waves along a slinky spring. Light waves travel more easily where there are no particles of matter, so they can travel through space. However, sound waves need particles of matter to vibrate to carry the sound.

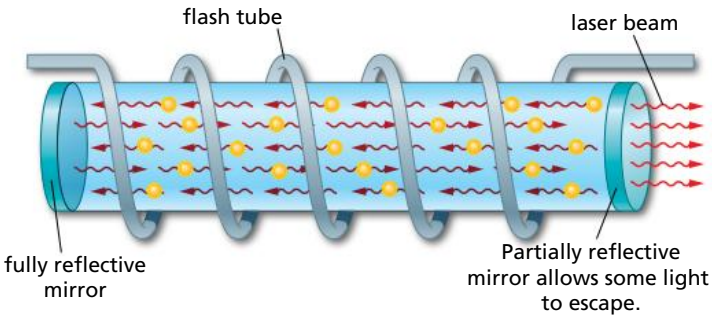


Lasers

The light from a **laser** is different from ordinary light. The white light from a torch is a mixture of different colours, all with different wavelengths. These waves have no pattern and are said to be out of phase. This sort of light is called *incoherent* light. Laser light is light of a single wavelength and the waves are all in phase, as shown. This sort of light is called *coherent* light. The coherent light from a laser forms a narrow, very intense beam that can travel large distances.



Laser light is made in a special tube that contains a solid such as a ruby crystal, or a gas. Ordinary light from a flash tube excites the atoms in the ruby crystal or the gas (see diagram top right). However, the atoms don't stay excited and they release a pulse of light of a particular wavelength that depends on the substance in the tube.



The light pulses are absorbed by nearby atoms, which also become excited and release light energy of the same wavelength. The light gets stronger and stronger as it hits more and more atoms. There are mirrors at both ends of the tube and the light bounces back and forth along the tube. The light gradually builds up in intensity until it is strong enough to pass through the partially reflective mirror. In this way a beam of one colour, one wavelength, coherent light is produced.

INQUIRY 11 Laser pointer

A laser can cause permanent eye damage, so this activity should be done as a teacher demonstration.

You will need: ray box, laser pointer, screen, 2 pieces of card

1. Use a ray box to generate a beam of white light.
2. Make a small hole in a piece of card and use it to project a narrow beam onto the screen.
3. Set up a laser pointer at the same distance from the screen. Make an identical hole in a second piece of card and let the laser shine through it.
4. Compare the spread of each beam on the screen. What happens if you move the screen further away?

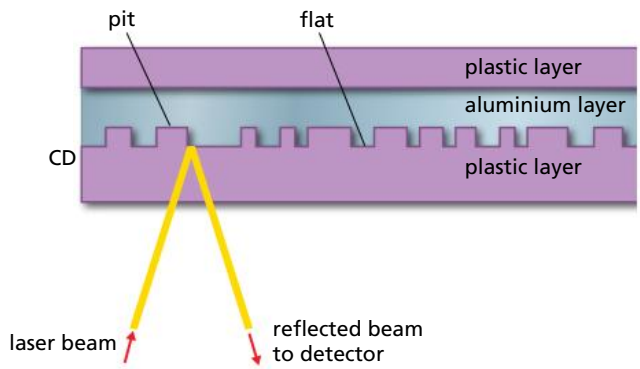
Uses of lasers

Lasers are widely used in surgery. They have the advantage that they make a clean and accurate cut that seals off small blood vessels so that there is less bleeding. They can also be used by dentists to drill teeth without any pain.

A laser beam concentrates a large amount of energy onto a small spot, so it can be used for cutting, welding and drilling of metal and other materials. For example, a computer-controlled laser can cut through 40 or more layers of suit material at the same time, with great speed and accuracy. This way suits can be made more quickly, with less waste.

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Lasers are used to carry telephone calls along optical fibres. They are also used in CD players. The shiny aluminium layer of the disc contains microscopic holes called pits and plain areas called flats. As the player spins the disc, the laser beam scans the uneven surface of this layer. It is then reflected back to a detector. The sequence of pits and flats on the disc modifies the reflected laser beam, producing a sequence of light pulses. The detector converts these light pulses into electrical signals that produce sounds or images.



Lasers are used to scan the barcodes on goods at the supermarket checkout. The white strips of the barcode reflect the red laser light and the black stripes absorb it. The pattern of the stripes forms a code that allows a computer to identify the product and its price.

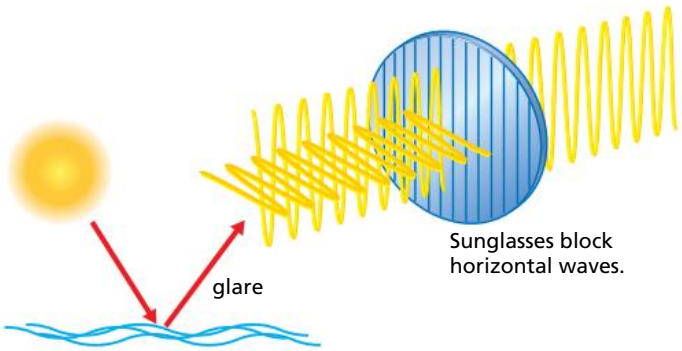
Distances can be measured very precisely using lasers. For example, the distance to the moon was measured by bouncing a powerful laser off a mirror placed on the moon's surface by the Apollo astronauts. By bouncing a laser off an orbiting satellite it has been possible to measure that Australia is moving northwards at a speed of 7 cm per year!

One of the most spectacular uses of lasers is in holograms, where an image of something can be stored electronically, then reproduced in three dimensions. The image looks as real as the original object. In the future it may be possible to interact with the hologram, as they did in the Holodeck in the *Star Trek* movies.

Polarised light

If you flick a rope up and down you can make vertical waves in the rope. If you flick it sideways you can make horizontal waves. A ray of light contains waves that vibrate vertically, horizontally and in all planes in between. When light is reflected from water, sand or snow it becomes partly **polarised**. This means that there are more waves vibrating horizontally than in other directions.

The lenses in polaroid sunglasses contain special filters that allow only the vertical waves through and block the horizontal ones. This is why polaroid sunglasses reduce glare when you are at the beach, skiing or driving.



INQUIRY 12 Sunglasses

You will need: 2 polaroid filters or 2 pairs of polaroid sunglasses, electric light

1. Slowly rotate the polaroid filter as you look through it at the light bulb.
2. Repeat step 1 but this time look at some glary light, like that reflected from a window or a car. If the brightness varies as you rotate the polaroid, the light is partly polarised.
3. Place a second polaroid filter in front of the first and look at the light bulb through both. Slowly rotate one of the filters. What do you notice?
   - Use what you have learnt about polarised light to explain your observations.

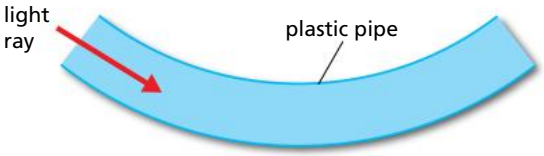
Over to you

1. How is laser light different from other kinds of light?
2. List at least three uses for lasers.
3. Laser light is described as being a pure colour. What does this mean?
4. How can a laser and a mirror be used to measure distances?
5. Explain the difference between polarised light and ordinary light.

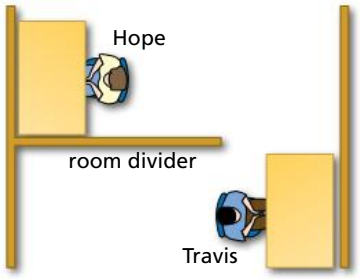
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THINKING SKILLS

1 Copy and complete the diagram below to show how you could use mirrors to make the light ray come out at the other end of the pipe.

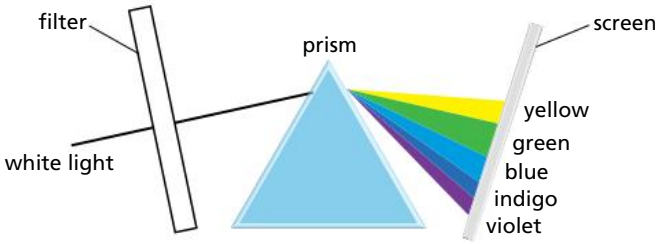


2 Hope works facing a wall of her office. A room divider separates her from her assistant, Travis. How can Hope arrange two mirrors so that she can see Travis' face?



3 A white spotlight was shone onto an actor dressed in blue. When this spotlight was replaced with a different light, the actor still appeared blue. What colour was the second spotlight? Explain your answer.

4 A beam of white light was shone through a filter and then through a glass prism onto a white screen. What colour was the filter?



5 Which colour of light slows down more when it moves from air into glass: red or blue? Explain your answer.

6 Alma and Lily wear their new clothes to the school disco. Alma has a new red top and Lily has a yellow skirt and green shoes. Inside the disco the lighting is nearly all red and blue. What would Alma and Lily's clothes look like in the disco?

(Hint: Write down the colours of the spectrum ROYGBIV to work out which colours will be reflected, as on page 182.)

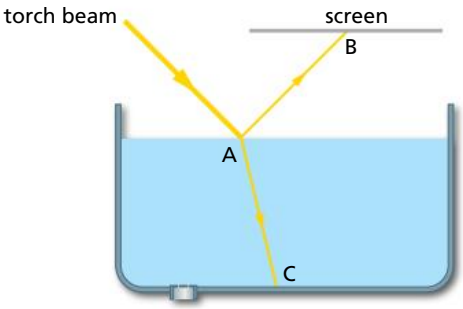
7 White light passes through a prism and forms a spectrum on a white screen. Describe what would happen if:

- **a** a piece of green glass was placed between the light and the prism
- **b** the white screen was replaced by a sheet of red paper.

8 In daylight grass looks green, but by moonlight it looks black. Explain how a stage director could light a piece of scenery to make the grass look green during a daytime scene and black during a moonlight scene.

9 A clock appears to show 10 minutes past 7 when viewed in a mirror. What is the actual time?

10 Light from a torch is shone onto the surface of the water in a sink in a darkened room.



- **a** What is happening to the light at A to cause:
  - the spot on the screen at B?
  - the spot on the bottom of the sink at C?
- **b** If the water is slowly run out of the sink, in which direction will:
  - the spot on the screen move?
  - the spot on the bottom of the sink move?

11 **a** What are the similarities and differences between light and heat radiation?

b What are the similarities and differences between light and sound?

12 There seem to be only six or seven colours in the visible spectrum, yet there are thousands of different colours. How can you explain this?

13 Why are fog lights for cars yellow?

14 Inga thinks that light is something that travels out from your eyes. When it hits an object you see the object, she says. What could you do to convince Inga that her idea is wrong?

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 White light is a mixture of different _____ with different wavelengths. Laser light is light of a single _____.

2 Images form in _____ because light is reflected from their smooth surfaces. They may be flat, concave or _____.

3 Light rays travel in straight lines. When they reflect from mirrors the angle of _____ is equal to the angle of reflection. This is called the _____.

4 _____ is the bending of light caused by a change in the _____ of light as it passes from one transparent substance to another at an angle. Light can be bent using _____.

5 The _____ and lens in your eye focus light onto the _____ which contains the light-sensitive cells.

6 Eye problems such as short-sight and _____ can be corrected with _____ or contact lenses.

7 White light can be split by a prism into the colours of the visible _____. This is called _____.

8 A coloured object reflects some colours and _____ the rest. The colour you see depends upon the colours that are _____.

absorbs
colours
convex
cornea
dispersion
glasses
incidence
law of reflection
lenses
long-sight
mirrors
reflected
refraction
retina
spectrum
speed
wavelength

Self-management

Radio interview

Work in pairs for this activity. You will need a tape recorder to record the interview.

Pretend one of you is an expert on light and sight. Think of a name for yourself. Your partner is a radio announcer who doesn't know much about light.

Go through the chapter and write down one or two questions from each section, plus the answers. Use these questions and answers to plan and record an interview about light and sight that starts and ends something like this:

Announcer: Morning listeners. This is your favourite station _____ and I'm _____.
This morning I'm delighted to have with me _____ who is an expert on light and sight. Welcome _____.

Expert: Thank you _____.

Announcer: I don't know much about light, except it's dark when you turn the light off. Can you shed some light on the subject for me?

Expert: Well to start with, you see light because
. . . . . .

Announcer: Thanks so much for that, _____.
I now know all about mirrors, lenses, glasses, rainbows and lasers. And I'm sure the listeners out there have learnt a lot. Be sure to be listening next week when I will be interviewing another expert. This is _____ signing off for now.



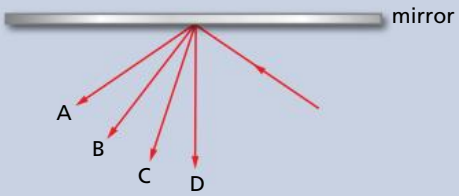
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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 Look at the diagram below. Which of A, B, C or D shows the correct reflection in the mirror?



2 Utpala is using a fine spray from a hose to water her garden on a sunny day. When she sprays the water into the air she sees the colours of the rainbow. The rainbow is caused by the:

A absorption of light
B dispersion of light
C reflection of light
D scattering of light

3 The part of the eye most likely to change when a distant object is brought close to the eye with the same lighting conditions is the:

A cornea
B lens
C pupil
D retina

4 Arda is colourblind. Which part of his eye is likely to be causing the problem?

A lens
B lens muscles
C shape of eyeball
D retina

5 Morgan puts his hand into a round goldfish bowl to clean it. He notices that his hand seems enlarged and out of shape.



a This is an example of light being:

A polarised
B reflected
C refracted
D filtered

b The goldfish bowl and the water are acting like a:

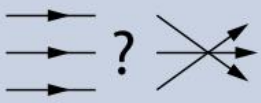
A flat mirror
B convex mirror
C concave lens
D convex lens

6 Blue, red and yellow beams of light are shone onto a white screen. A coloured filter is placed in the path of the beams and only blue light is seen on the screen.

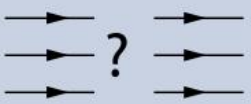
a Which colours are being allowed through by the filter?
b Which colours are being absorbed?
c What is the colour of the filter?

7 Keri is using a ray box to investigate what happens to light rays when they pass through these six different devices: concave mirror, concave lens, convex lens, flat mirror, glass prism, rectangular slab of glass. Match each of the diagrams to one of these devices.

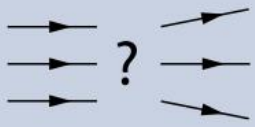
a



b



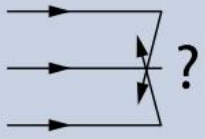
c



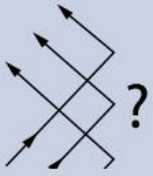
d



e



f



8 In a murder investigation, it may be important to know whether the victim was long-sighted or short-sighted. How could a crime scene investigator decide by examining a pair of glasses found at the scene of the crime?

9 A laser beam is shone through a prism. Would you expect to see a spectrum of colours? Why or why not?

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9 Using radiation

By the end of this chapter you will be able to …

Knowledge and Understanding

- identify situations where waves transfer energy (PW1b)
- describe the features of waves—wavelength, frequency and speed (PW1c)
- name and describe the properties of the different types of radiation that make up the electromagnetic spectrum (PW1e)
- relate the properties of different types of radiation to their uses in everyday life, including communications technology (PW1e)

Skills–Working Scientifically

- use mathematical equations to describe relationships between the variables of wavelength, frequency and speed (7.2b/9c)
- discuss the reliability of scientific studies, using a mobile phone study as an example (7.2g)

LITERACY FOCUS

amplitude modulation
analog signal
binary number
capacitor
digital signal
diode
electromagnetic radiation
electronics
fluorescent
frequency modulation
gamma rays
hertz
infrared
liquid crystal display (LCD)
microchip
modem
phosphors
semiconductor
transistor
ultraviolet

Focus for learning

Every day we use devices such as mobile phones, television sets, radios and microwave ovens. These devices all use the latest advances in electronics. They also use electromagnetic radiation and in this chapter you will find out what this is.

By the end of this chapter you should have enough science knowledge to be able to explain how these devices work. It makes life more interesting if you understand how the gadgets used in everyday life operate. And it is fun to say to your parents and friends 'It works like this …'







PROBLEM SOLVING

Making an electrical device

Working in a group, choose an electrical device you would like to make. The chapter will give you some ideas, but you will need to do considerable library research. Some devices you could make are:

- a radio
- an electronic circuit such as a flashing light or siren
- an electric motor
- an electric bell or buzzer
- a maglev train that floats on a magnetic field.

When you have built the device and got it to work you can demonstrate it to the class. Don't forget to say where your ideas came from.

You can use what you learn in the chapter and from your research to explain to others how the device works.

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9.1 Electromagnetic radiation

Light is a form of electromagnetic radiation. The human eye can detect light—from red to violet. However, there are other types of electromagnetic radiation that our eyes cannot detect, for example ultraviolet light, radio waves, and X-rays. These were discovered separately but scientists now realise they are all electromagnetic waves. These waves consist of electric and magnetic fields that vibrate at right angles to the direction of travel. They are transverse waves, not longitudinal waves like sound waves. Unlike sound, they can travel through empty spaces (a vacuum). They travel in straight lines, at the speed of light (300 000 km/s).

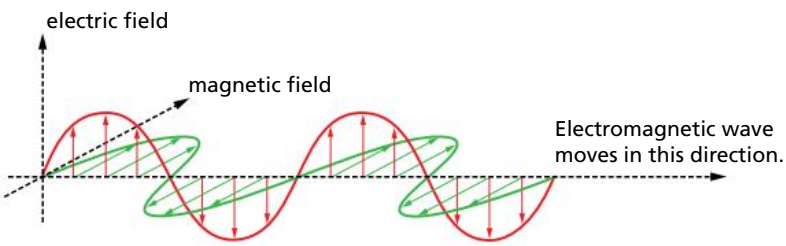
All electromagnetic waves transfer energy. A source loses energy when it emits (sends out) waves, and a material gains energy when it absorbs waves. The only difference between the different types of electromagnetic radiation is their frequency and their wavelength. Frequency is measured in hertz (cycles per second), kilohertz (thousands of waves per second) or megahertz (millions of waves per second). Frequency and wavelength are related by the equation:

frequency × wavelength = speed of light

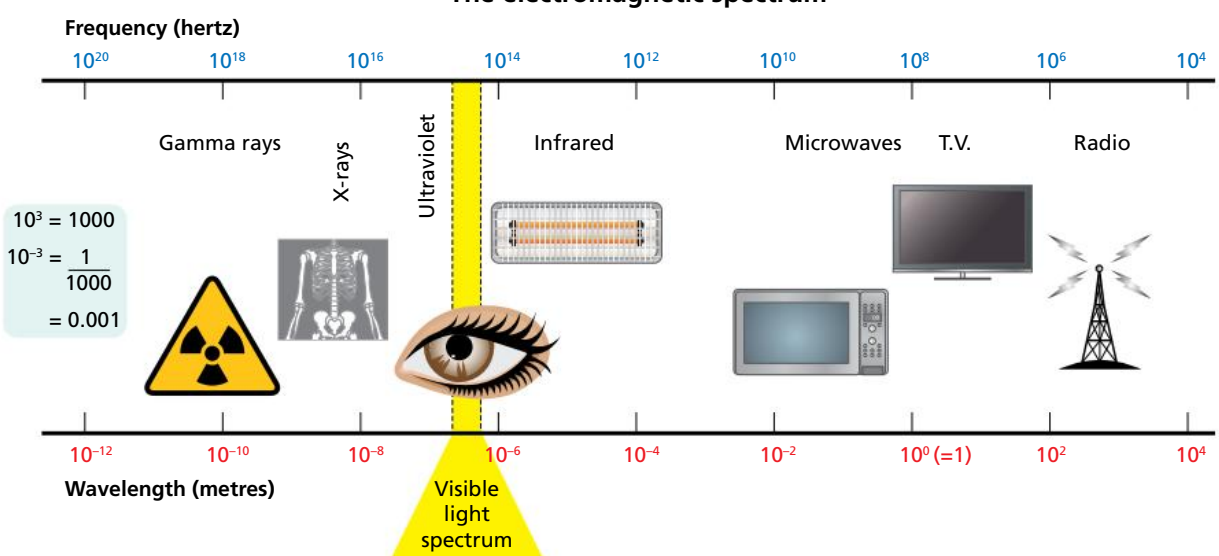
So if a wave has a high frequency it has a small wavelength. And if it has a low frequency it has a large wavelength. The full range of electromagnetic radiation is called the **electromagnetic spectrum**, as shown below. Just like the colours of the rainbow (the visible spectrum), the different types of radiation gradually merge into each other. The waves with the highest frequency and the smallest wavelength have the most energy, and the greatest penetrating power.

Gamma rays

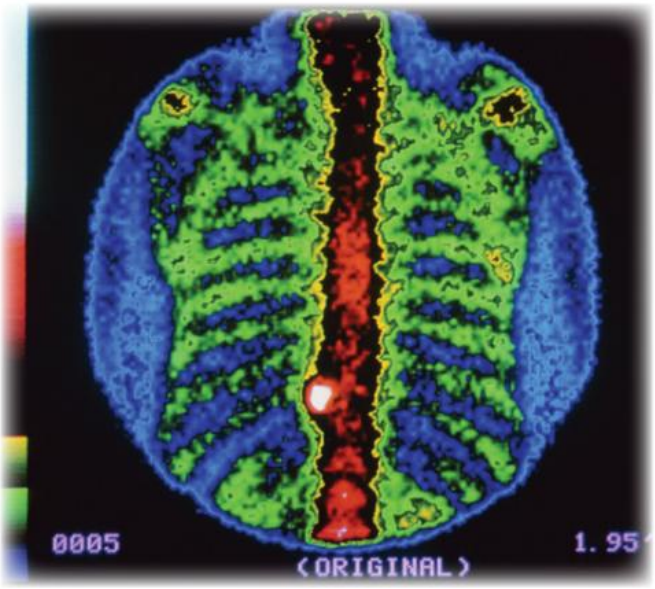
Gamma rays have the shortest wavelength and the most energy of all electromagnetic radiation. They come from radioactive materials such as uranium and radon, found in the Earth's crust (see Chapter 2). Gamma rays are also produced in nuclear reactors



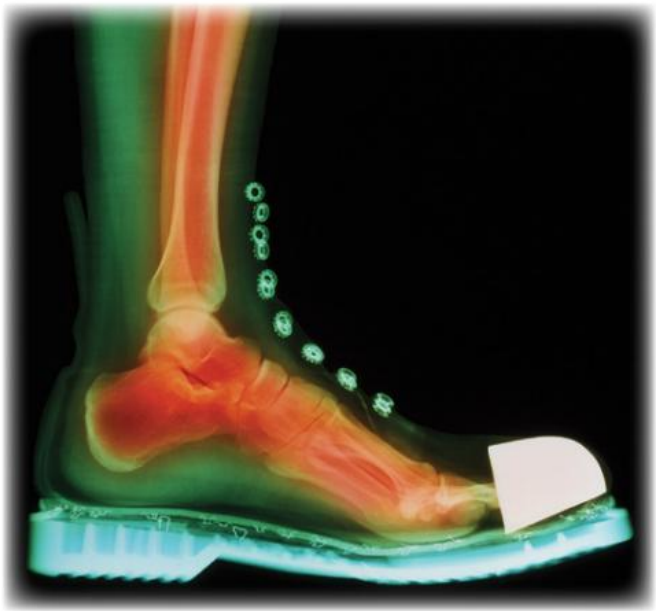
The electromagnetic spectrum



ISBN 978 1 4202 3246 2



A gamma ray scan of a person with a bone cancer on their spine



A coloured X-ray of a man's foot in a Doc Martens boot

and nuclear explosions. They can be detected using photographic film or a Geiger counter. They are harmful to living things, and can cause mutations and the development of cancers.

Strangely, gamma rays can also be used to detect cancer in the body. The photo above shows a bone tumour on a person's spine. When a radioisotope is injected into the body it becomes concentrated in the tumour and shows up as a white spot. Gamma rays can also be used to destroy cancer cells, which are more sensitive to radiation than normal cells.

Because gamma rays can kill cells, they are used to kill harmful bacteria, for example to sterilise food and medical equipment. Because they have the greatest penetrating power of all electromagnetic radiation, they are used in industry, for example to find leaks in water pipes embedded deep in concrete.

X-rays

X-rays have longer wavelengths and therefore less energy than gamma rays. They are produced when fast-moving electrons hit a metal target. They are very penetrating and can even pass through dense metals like lead. In a medical X-ray the photographic film blackens where the X-rays hit it, so the areas of skin and muscle show up black. Fewer X-rays pass through the bones, so these show up as white on the X-ray. The photo top right is a coloured X-ray of a man's foot in a Doc Martens boot.

X-rays are dangerous because they have a lot of energy and can damage cells deep in the body, causing cancer. For this reason, when you have to have an X-ray, exposure times are kept short. CAT scans are continuous scans that are processed by computer to give cross-sectional views of the body.

Ultraviolet radiation

Very hot objects such as the sun emit some of their radiation beyond the violet end of the visible spectrum. (*Ultra* means 'beyond'.) Fortunately, most of the sun's **ultraviolet radiation** does not reach the Earth's surface. The higher-energy UV-A and UV-B are absorbed by the ozone layer. Only the 'near' ultraviolet (UV-A and some UV-B) gets through. This ultraviolet radiation is still harmful to living cells, and can cause skin cancer. Skin develops a tan to try to protect itself against ultraviolet radiation. Ultraviolet can also damage your eyes. Some exposure to sunlight is necessary for the body to produce vitamin D. However, prolonged exposure is potentially dangerous, and you should use sunscreen to protect your skin, and sunglasses to protect your eyes.

Some materials *fluoresce* when they absorb ultraviolet light and then re-emit it as visible light. The photo on the next page shows a young woman under UV light with glowing hair, lips and fingernails. Fluorescent materials are added to washing powders. They absorb UV light in sunlight, then release it as visible light. This makes your clothes 'whiter than white'. Fluorescent tubes are coated on the inside with a white powder which fluoresces when UV light hits it.

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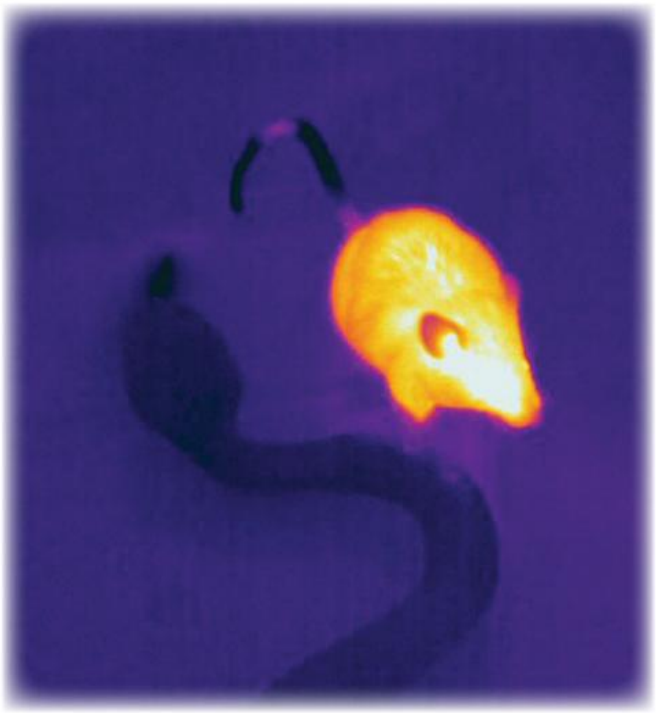
A portrait of a woman under UV light with fluorescent hair, lips and fingernails

Visible light

Visible light is just a small part of the electromagnetic spectrum. But it is very important to us because our eyes happen to be sensitive to this particular range of wavelengths. The shortest wavelength we can detect with our eyes is violet light, and the longest is that of red light.

Infrared radiation

Infrared radiation has a lower frequency than red light. (*Infra* means 'below'.) When you are in the sun or near a heater you can detect the infrared radiation coming from it. You notice the heating effect on your skin when it absorbs the radiation. All objects emit some infrared because of the vibration of their atoms and molecules. The hotter the object the more the vibration, and the more infrared radiation that is released. Some snakes have specially designed sense organs which can 'see' a warm object, such as a mouse, in the dark. In the infrared photo top right the different colours represent different temperatures. The warm-blooded mouse is a light colour, while the cold-blooded snake is dark.



A thermogram of a mouse and a snake, showing that the mouse is much warmer than the snake

Infrared sensors are used by emergency services to search for people. Infrared satellites monitor weather patterns and ocean temperatures such as the passage of El Niño across the Pacific Ocean. And remote controls use infrared to operate televisions, stereos and automatic garage doors.

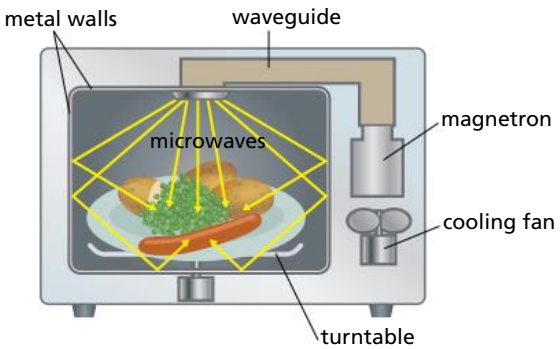


This is the remains of a supernova—a massive star that exploded. The blue area is a source of intense X-rays, and the red and green rings are infrared sources.

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Microwaves

Microwaves are sometimes called short-wave radio waves. They are generated by vibrating electrons and typically have a wavelength of a few centimetres. Water molecules in food vibrate at the same frequency as microwaves. In a microwave oven, food strongly absorbs microwaves, converting their energy into heat energy. Glass, paper and many plastics don't absorb microwaves, and metal reflects them. The microwaves are reflected by the metal grid in the glass door because their wavelength is much larger than the holes in the grid.



Microwaves are used for satellite and radar communication, and are ideal for mobile phone communications. Like all electromagnetic radiation, microwaves travel only in straight lines, so the dish-like aerials are placed up high on towers or hills.

Radio waves

Radio waves are similar to microwaves, but have longer wavelengths and lower frequencies. FM radio waves have wavelengths of just a few metres, whereas AM waves have wavelengths of several hundred metres. Most television is broadcast in the FM region.

Over to you

1 Complete these sentences in your notebook.
- **a** Red light has waves of a different _____ from waves of blue light.
- **b** The visible spectrum is a small part of the _____ spectrum.
- **c** All warm objects emit _____ radiation, which is invisible to humans.
- **d** The longest electromagnetic waves are _____ waves, and the shortest are _____ rays.
- **e** The higher the frequency of a wave, the more _____ it carries.
- **f** _____ radiation in sunlight causes sunburn.
- **g** _____ rays are emitted by radioactive substances.

2 Name a type of electromagnetic radiation which is:
- **a** visible to the eye
- **b** absorbed by the ozone layer
- **c** used for radar
- **d** the most dangerous to humans.

3 List three differences between sound waves and electromagnetic waves.

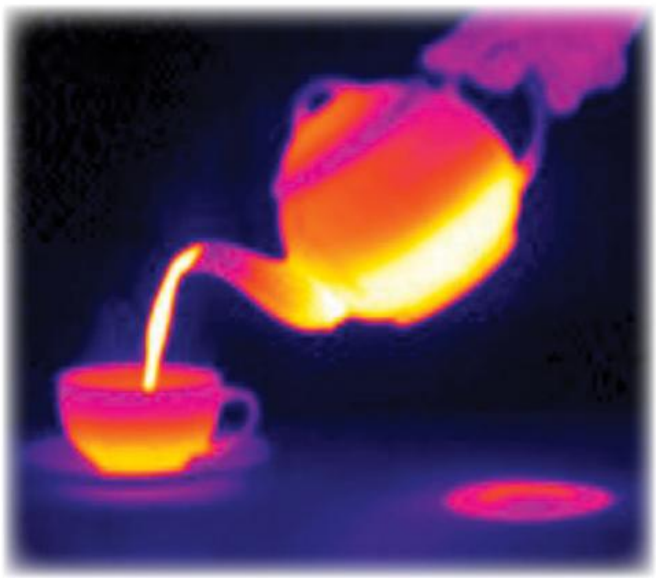
4 Explain the following:
- **a** You should always wear sunscreen when you are in the sun.
- **b** People with pale skin are more likely to get skin cancer than people with dark skin.
- **c** X-ray pictures show bones as light areas.
- **d** Snakes can catch mice in the dark.

5 Which region of the electromagnetic spectrum would contain waves with these wavelengths? Use the diagram on page 191.
- **a** 1 m
- **b** 1×10^{-5} m
- **c** 1×10^{-11} m
- **d** 1 km
- **e** 1 mm

6 Infrared cameras can help find a lost bushwalker. How is this possible?

7 The sun is 150 000 000 km from Earth. Calculate how long it takes for the sun's light to reach us.

8 Look at the infrared photo below.
- **a** What do the different colours mean?
- **b** How can you explain the pink circle bottom right?



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9.2 World of electronics

SKILL

Connecting up electric circuits

Aim

To practise connecting electric circuits and to review how to draw and interpret circuit diagrams.

Risk assessment and planning

Do a risk assessment.

Draw up a suitable data table to record your results in Part A.

Apparatus

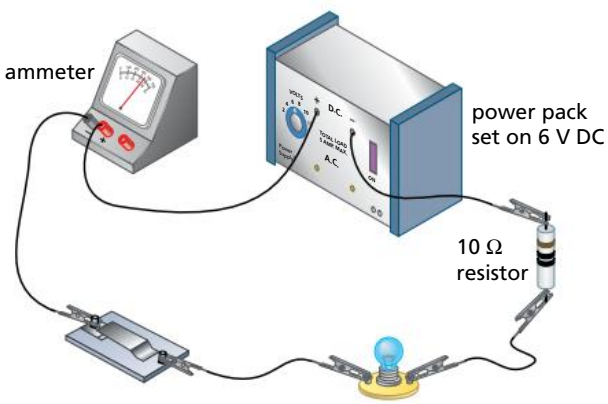
- selection of resistors from 10 Ω to 100 Ω
- light-dependent resistor (LDR)
- switch
- connecting wires
- power pack
- 6 V light bulb
- ammeter

Part A: Resistors

Method

1 Connect the circuit as shown, using the resistor with the smallest resistance.

Make sure the positive terminal of the ammeter is connected to the positive side of the power pack. Set the power pack on 6 V DC.



2 Turn on the switch and record the ammeter reading and the brightness of the bulb for the smallest resistance.

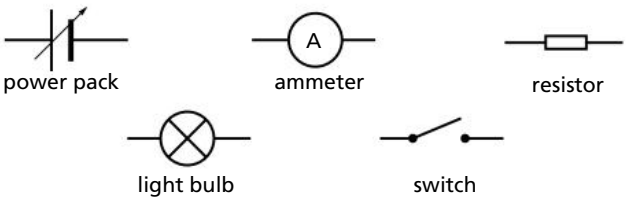
3 Repeat for the other resistors, in order of increasing resistance.

Results

1 What pattern can you see in the results? You could draw a graph to display them.

2 How can you explain this pattern?

3 Use these symbols to draw a circuit diagram for Part A.



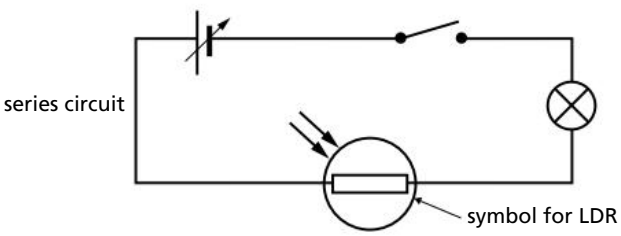
Remember, circuit diagrams are usually drawn in a rectangular shape—with straight lines and right-angle bends. Look at the circuit diagrams below.

Part B: Light-dependent resistor

Method

A light-dependent resistor (LDR) is an electronic device whose resistance depends on the amount of light that falls on it. When light shines on it, the LDR has a low resistance and allows current to flow through it. When light does not shine on it, the LDR has a very high resistance and current does not flow through it.

1 First connect the LDR into the series circuit shown. Use 6 V DC.

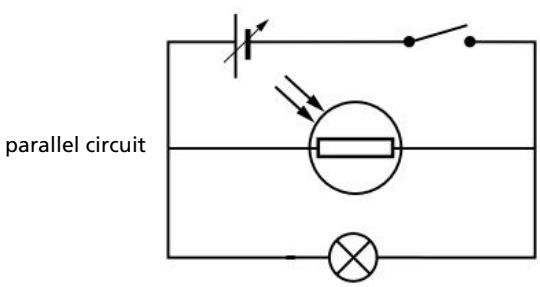


✻ Does the bulb light up?

✻ What happens when you cover the LDR so no light shines on it? How can you explain this?

2 Now connect the LDR into the parallel circuit. What happens now when you cover the LDR?

✻ Explain your observations.



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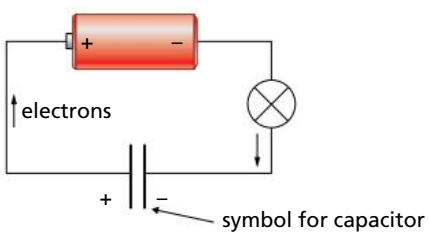
Electronics is the term used to describe the use of devices that control the flow of electrons in electric circuits. One particular circuit may tune a radio to your favourite station. Another may make a weak signal from an electric guitar stronger, that is, amplify it. Yet another circuit may count numbers. These circuits contain electronic devices such as resistors, which can control current and voltage in a circuit, as you saw in the Skill on the previous page. Other electronic components are capacitors, diodes and transistors.

Capacitors

A **capacitor** can store electricity. Like a toilet cistern, it fills up to a certain level, then stops. Once the stored electricity has been used, the capacitor can be charged again. This is like when you flush the toilet and the cistern empties, then begins to fill again.

A capacitor has a positive and a negative terminal. Inside the capacitor these terminals are connected to two metal plates separated by air, paper, plastic or anything that doesn't conduct electricity and keeps the plates from touching each other.

Suppose you connect a capacitor to a battery and bulb as shown below. The plate of the capacitor connected to the negative terminal of the battery accepts the electrons the battery is producing. So it becomes negatively charged. The other plate loses electrons to the battery and so becomes positively charged. Once both plates are charged, the capacitor has the same voltage as the battery. If you now remove the battery, the bulb again lights up as electrons flow from the capacitor around the circuit. The bulb gets dimmer and dimmer and finally goes out, because the capacitor has lost its charge.

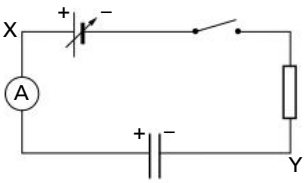


Capacitors are used to charge the electronic flash in a camera. The battery charges up the capacitor over several seconds and the capacitor then dumps the full charge into the flash tube almost instantly. Capacitors are widely used in electronic circuits, for example TV sets. Because they can store charge, you can get an electric shock even when the power is switched off.

INQUIRY 1 Charging a capacitor

You will need: power pack, resistor (1000 Ω), capacitor (1000 µF electrolytic), centre-reading milliammeter, switch, connecting wires

1 Set up the circuit as shown. Make sure the positive terminal of the capacitor is connected to the positive side of the power pack. Set the power pack on 12 V DC.



2 Turn on the switch and note what happens to the milliammeter.

- How do you explain the changes in the electric current?

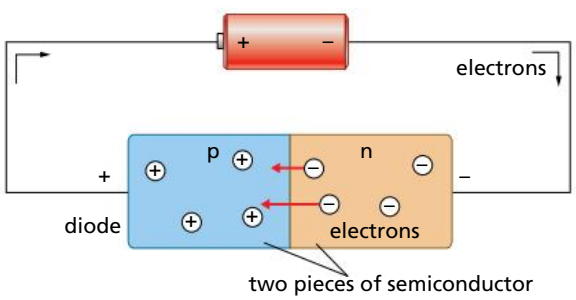
3 Turn off the switch and connect a wire between points X and Y. Watch the milliammeter closely.

- Explain your observations.

Diodes

A **diode** is an electronic device that allows current to flow in one direction but not the other. It is like a turnstile at a sports stadium that lets people go in but not out. It is made from two small pieces of silicon, which is a **semiconductor** (a material which conducts electricity but not as well as metals do). One piece has been treated so that it has an excess of electrons. It is called n-type (negative). The other piece has been treated so that it has a shortage of electrons. It is called p-type (positive). The two pieces are joined together as shown below. When the diode is connected to a battery, the electrons flow from the n side to the p side of the diode. However, if you connect the battery the other way round, no current flows.

A special kind of diode is the light-emitting diode (LED) that lights up when a current flows through it. LEDs are used widely in digital displays, traffic lights and tail-lights on cars.



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INVESTIGATION

1 Investigating diodes

Aim

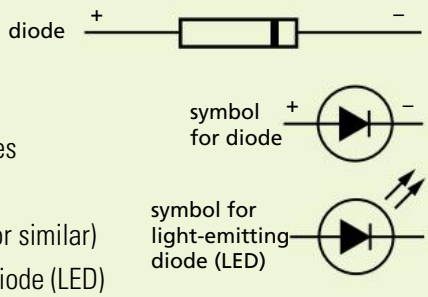
To investigate how a diode works in an electric circuit.

Risk assessment and planning

One end of a diode is marked with a band. This is the negative end.

Apparatus

- switch
- power pack
- 6 V torch bulb
- connecting wires
- 100 Ω resistor
- diode (IN4002 or similar)
- light-emitting diode (LED)
- cathode ray oscilloscope (CRO)

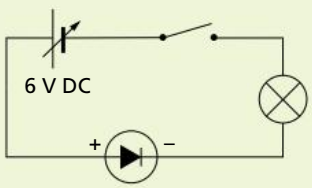


Method

Part A: Testing a diode

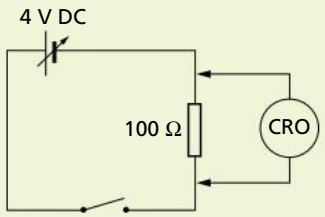
1 Connect up the circuit shown, with the power pack set on 6 V DC. Does the bulb glow when you close the switch? (It is a good idea to test the bulb before you add the diode to the circuit.)

2 Reverse the connections to the diode. What happens now?



Part B: Effect of diode on AC

This is a teacher demonstration.



1 Set up the circuit shown, with the power pack set on 4 V AC.

2 Connect the cathode ray oscilloscope (CRO) across the resistor as shown.

✻ Sketch the pattern on the CRO.

3 Connect a diode into the circuit and sketch the pattern on the CRO now.

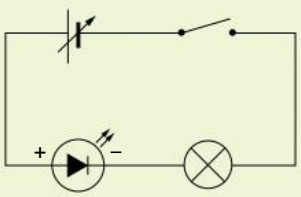
4 What happens if you reverse the connections to the diode?

✻ Try to explain all your observations in Part B.

Part C: Light-emitting diode

1 Set up the circuit shown, containing a light-emitting diode (LED). Set the power pack on DC.

2 Experiment to find out:



a whether the LED lets current flow in one direction only

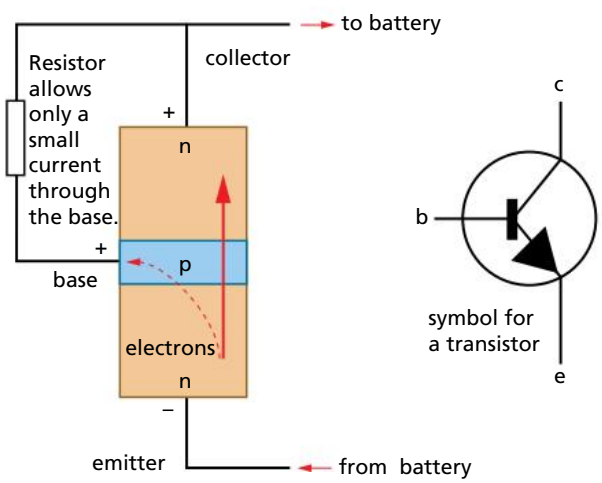
b which leg of the LED is positive and which leg is negative

c which lights up first (the bulb or the LED) as you increase the voltage.

Transistors

Transistors are tiny switches that control the operation of electronic devices. They are similar to diodes except they are made from *three* pieces of semiconductor as shown.

A transistor has three terminals—the emitter (e), the base (b) and the collector (c). When the base is positive it pulls electrons from the emitter. This movement of electrons allows a much larger flow of electrons from the emitter to the collector. If the base is negative then no electrons can flow. So a small current through the base of the transistor can control a much larger current through the other two terminals. This is a bit like one person controlling a gate that lets thousands of people through.



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INVESTIGATION

2 Investigating transistors

Aim

To investigate how a transistor can act as a switch or amplify (enlarge) an electric current.

Risk assessment and planning

Read the three parts carefully before you start.

You must be careful that you connect the three terminals of the transistor correctly as shown below.



Apparatus

- transistor (BC547 or similar)
- 1000 Ω resistor
- 15 000 Ω resistor
- power pack
- bulb (50–100 mA)
- connecting wires
- 2 wires with bare ends (to act as probes)
- light-dependent resistor (LDR)

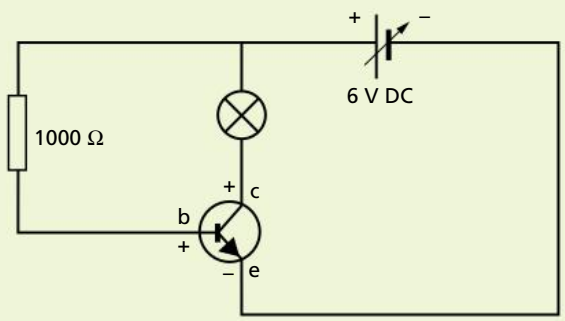
Method

Part A: A transistor as a switch

1 Connect the circuit shown below. Note that the base and collector are connected to the positive side of the power pack, and the emitter to the negative side.

2 Disconnect one of the wires to the resistor.

✻ Use what you know about how a transistor works to explain what happened.

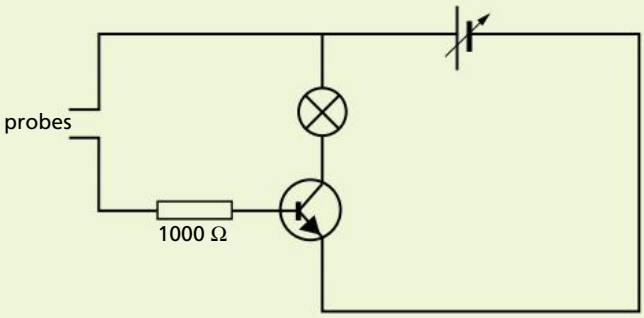


Part B: A moisture detector

1 Set up the circuit shown below. Remember that a small current through the base of the transistor causes a large current through the collector. What happens when you touch the two probes together?

2 Dip the two probes into a container of water. What happens now?

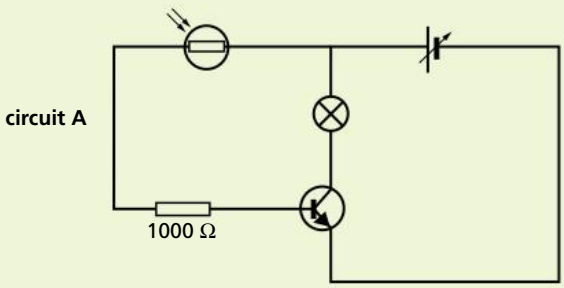
✻ Try to explain how the moisture detector works.



PART C: A light-operated switch

1 Set up circuit A. What happens when light shines on the LDR? What happens when no light shines on it?

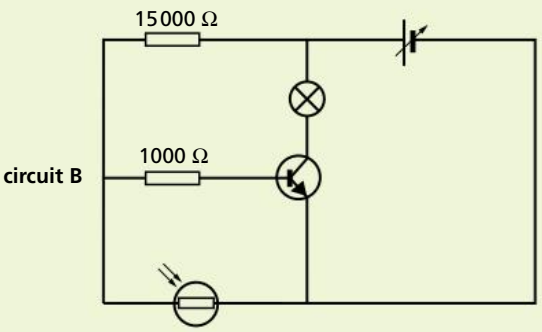
✻ Explain how circuit A works.



2 Set up circuit B. What happens when there is light on the LDR and when there is no light?

✻ Explain how circuit B works. (Hint: The two resistors control the current in the left-hand side of the circuit.)

✻ Which circuit (A or B) could be used to turn on a light when it gets dark?



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Integrated circuits

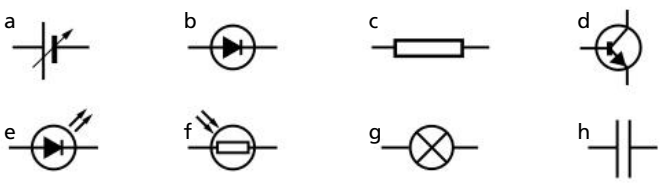
A great breakthrough in electronics took place with the development of the *integrated circuit* or **microchip**. Such a 'chip' contains thousands of electronic components with their connections etched onto a tiny piece of silicon by photographic and chemical processes. Electronics engineers are continually finding ways to pack more components onto a single chip. This allows you to make electronic devices smaller.



Over to you

1 What is the main element in the semiconductors used in diodes and transistors?

2 What do the following symbols represent? For each device, say what its function is.



3 How does a diode convert alternating current (AC) to direct current (DC)? (Hint: Remember Investigation 1 Part B.)

4 Explain in your own words how a transistor can amplify an electric current.

PROBLEM SOLVING

You could use what you have learnt in this section to build some electronic circuits. If your parents agree you could use an electronics kit, e.g. Dick Smith's *Funway* to build an interesting device. You simply follow the instructions to put the electronic components together.

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SCIENTISTS AT WORK

Solar cars

The photo shows the Japanese solar car *Tokai Challenger*. It won the World Solar Challenge in 2011. It has a cockroach design and is covered in solar cells that convert the energy of sunlight into electricity, which runs the car's motor.



A **solar cell** is similar to a diode and consists of a p-type semiconductor joined to an n-type semiconductor. It is covered with glass and has a special coating to stop light being reflected away from the cell. When light enters the cell it knocks electrons out of the atoms in the semiconductor. These electrons are free to move around an electric circuit. If many solar cells are connected together, enough electricity can be produced to run an electric motor.

The cars in the first World Solar Challenge in 1987 travelled the 3000 km from Darwin to Adelaide at an average speed of 67 km/h. However, the winning car in 2011 averaged 100 km/h. This increase in speed is due mainly to improvements in the efficiency of the solar cells used to cover the cars.

For many years solar cells could not be made more than 15% efficient. In other words, for every 100 J (joules) of solar energy hitting the cells, only 15 J were converted to electricity. However, two Australian scientists, Martin Green and Stuart Wenham, made special high-efficiency solar cells especially for the World Solar Challenge. For 15 years they held the world record of 24.5% for the most efficient solar cells. The cells used by the winner of the 2011 World Solar Challenge were developed for use in satellites and are 30% efficient.

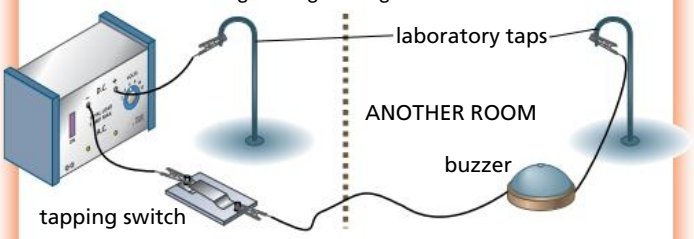
9.3 Communications

After the discovery of electric current, inventors tried to find ways to use it to send and receive messages. In 1836 the telegraph was invented, and in 1844 Samuel Morse worked out a code that allowed messages to be sent simply by opening and closing a switch. The invention of the telephone by Alexander Graham Bell in 1876 made it possible for the sound of a voice to be transmitted through telegraph wires.

INQUIRY 2 Making a telegraph

You will need: power pack, buzzer or bulb, tapping switch, connecting wires (3 short and one long)

1. To make a telegraph, connect a switch and buzzer in series with a power pack set on 6 V DC. Test it to see if it works.
2. Remove one of the connecting wires from the power pack and connect it to 'earth' by clipping it to a laboratory tap, as shown. Do the same with the wire from the buzzer. Does it still work?
3. Move the buzzer to another room and connect it to the switch using a single long wire.



4. Write down a short message without your partner seeing it. Start with only one or two words. Now translate it into Morse code.

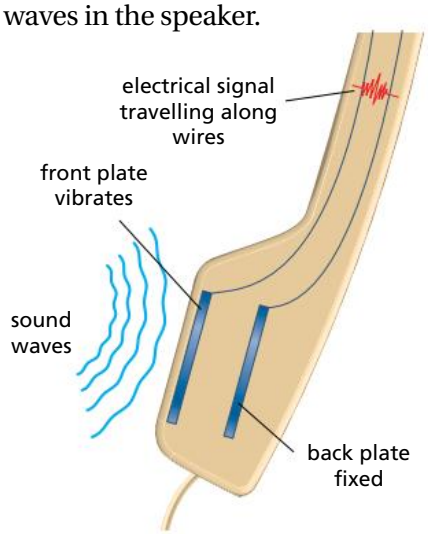
A ·—	F ··—·	K —·—	P ·——·	U ··—
B —···	G ——·	L ·—··	Q ——·—	V ···—
C —·—·	H ····	M ——	R ·—·	W ·——
D —··	I ··	N —·	S ···	X —··—
E ·	J ·———	O ———	T —	Y —·——
				Z ——··

- A dash is as long as three dots.
- Leave a space as long as one dot between each tap.
- Leave a space as long as one dash between each letter of a word.
- Leave a space as long as five dots between each word of a sentence.

5. Use the tapping switch to send a message to your partner in the next room. He or she will write down the message in code and then translate it into words. You will need to practise.
6. Switch roles and repeat the procedure.

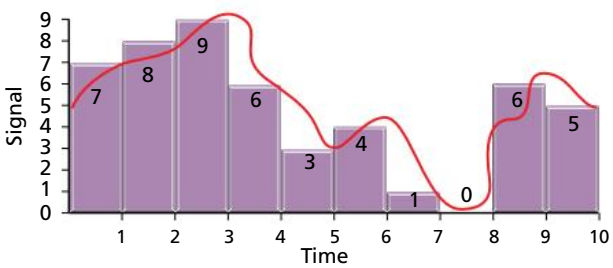
How a telephone works

The mouthpiece of a telephone contains a *microphone*. It usually contains two plates that act as a capacitor. Sound waves cause the front plate to vibrate. This changes the charge that is stored and hence produces a changing electrical signal. This signal then travels via the telephone lines to another telephone. Here the electrical signal is changed back to sound waves in the speaker.



Analog and digital

Suppose the red line on the graph below is part of the electrical signal from a telephone. It is a continuously changing wave that can have any value. This is called an **analog signal**. In this example each unit on the x-axis represents one thousandth of a second.



By sampling this analog signal every thousandth of a second, you can convert it to a **digital signal**, which is a series of numbers instead of a wave. For example, after 0.001 seconds the signal has a value of about 7. After 0.002 seconds it is about 8, and so on. The purple bars together represent the original signal.

The numbers representing the signal then need to be converted to **binary numbers**, that is 1 or 0. These numbers can be understood by computers and are easy to send over long distances because 1 means a pulse of electricity and 0 means no pulse. Binary

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numbers have columns like ordinary numbers, but the columns have different values.

ordinary numbers:	thousands	hundreds	tens	units
binary numbers:	eights	fours	twos	units

For example, 6 becomes 110 (one four, one two, no units). The signal in the graph on the previous page (7, 8, 9, 6 ...) can then be represented by a series of ones (on) and zeroes (off)—0111 1000 1001 0110...

The telephone network

From a telephone, the electrical signals are carried by copper wires to the nearest automatic telephone exchange. Here they are converted to digital signals and transmitted to other exchanges. They are then converted back to analog signals before reaching the receiver's telephone.

Telephone exchanges are linked by bundles of copper wires called *coaxial cables* which can carry almost 3000 two-way conversations. However, the major cities in Australia are now linked by optical fibres (see page 173). In an optical fibre the electrical signals are converted to pulses of light by lasers. The lasers can be switched on (1) and off (0) many millions of times per second, making them ideal for transmitting digital data. An optical fibre just one centimetre in diameter can carry nearly 30 000 conversations.



A fibre optic cable used for telephones

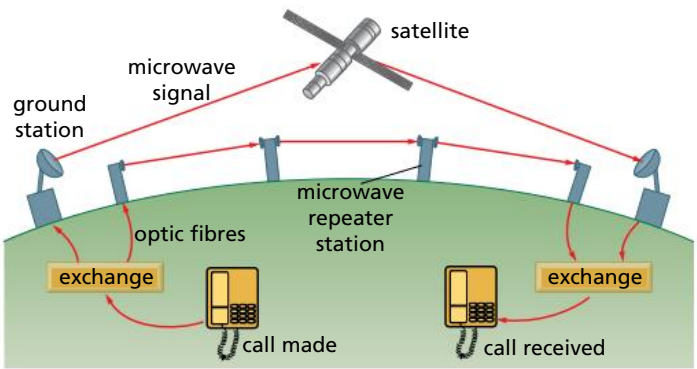
Using microwaves

Telephone signals can also be transmitted through the air by microwaves—another form of electromagnetic radiation, like light. As the electrical signal switches on and off in a transmitting antenna, the electrons vibrate, producing electromagnetic waves.

Microwaves have a wavelength of about 3 cm. They can carry many signals at the same time. However, repeater towers are needed to pass the signal on so that it doesn't fade away before it reaches its destination. The dish-shaped antennas receive the microwave signals and send them on to the next tower. Each repeater tower needs to be within sight of the next one because microwaves, like light, travel in straight lines. This is why repeater towers are usually built on top of hills.

Using satellites

In 1945 the famous science fiction writer Arthur C. Clarke wrote about a way of providing worldwide communications. He suggested that a satellite could be made to 'hover' above a point on the Earth's equator. Clarke's dream became a reality 20 years later when the first geostationary satellite was put into orbit around the Earth. Signals are transmitted to the satellite via radio waves or microwaves. The signals are then sent back to another part of the world or to another satellite. In this way your telephone call can travel across the world at the speed of light (300 000 km/s).



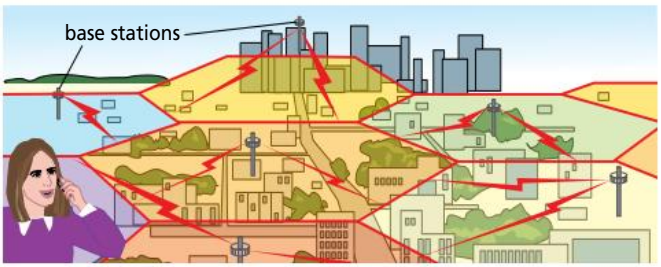
Mobile phones

Mobile phones don't need to be connected by wires. Instead they have a built-in radio transmitter and receiver. When you make a call, the mobile phone sends out a radio signal with a wavelength of about 35 cm. This signal is picked up by a base station that consists of several antennas at the top of a large tower or tall building. The base station is connected to a switching centre, which switches the call to other base stations or to the fixed telephone system.

In America mobile phones are called *cell phones*. This is because the base stations are set up in a network of hexagonal cells, as shown on the next page. The cells range in size from 100 m across to

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more than 30 km across. The base stations receive and transmit mobile phone signals from the cells next to them. A mobile phone signal is passed from cell to cell until it reaches its destination.



Faxes and modems

The telephone network also carries data from fax machines, computer modems, and credit card and EFTPOS terminals in shops. To send a fax you feed the document into the machine and a detector scans the page as it passes through. The scanner detects areas of light and dark. This information is then converted to electrical signals and sent through the telephone system to another fax machine. The receiving fax machine decodes the electrical signals and prints a copy of the original message on paper.

Email messages are also sent via the telephone network. A computer produces digital signals and these must be converted to analog signals before they can be transmitted. This process is called *modulation*, and is done by a **modem**. A modem can also convert analog signals received into digital ones by the process of demodulation. This is where the modem gets its name: **mo**dulation–**dem**odulation.

Electromagnetic pollution

All electrical appliances such as computers and mobile phones use millions of pulses of electricity (moving electrons) every second. They all emit some electromagnetic radiation, which is produced whenever electrons change their speed or direction rapidly. Microwave ovens and power lines also produce electromagnetic radiation.

Stray electromagnetic radiation has caused many problems in recent years. For example, laptop computers have caused aircraft to go off course. Mobile phones have interfered with heart monitors and other hospital equipment. Military helicopters have been affected by interference from nearby television stations. This is why the use of laptop computers, mobile phones and computer games is restricted on aircraft and in hospitals.

Some people think that electromagnetic radiation can cause cancer, birth defects and other medical problems. Because mobile phones are held so close to your head, they are considered especially hazardous. As yet there is no proof that mobile phones can affect your health, but no one knows for sure.

INQUIRY 3 A communication system

Do a project on a communication system—past, present or future. There is some information in this section, but you will need to do library research, including use of the internet.

You should prepare a report and present it to the class. In this report you will need to explain in detail how the communication system operates. Also include energy chains showing how energy is transformed from one form to another by the system, and how energy is transferred from one point of the system to another.

You may be able to build a communication device and test it. This could be your chapter problem.

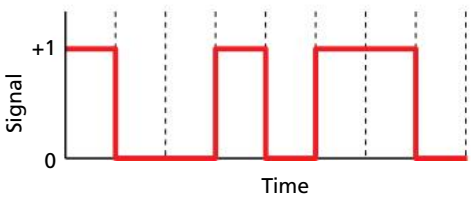
Over to you

1 How are mobile phones different from fixed telephones in the way they transmit and receive voice messages?

2 Why are mobile phones in America called cell phones?

3 Draw diagrams to show the difference between an analog signal and a digital one.

4 What binary number is represented by this digital signal?



5 **a** What is electromagnetic radiation?
b How is it produced?

6 Eshref heard static (crackling) on his radio when his mother turned on the microwave oven. Why do you think this happened?

7 The microwave path from Australia to Britain via satellite is about 70 000 km long. Calculate the time taken for a phone call to travel this distance. (Remember microwaves are electromagnetic and travel at 300 000 km/s.)

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Are mobile phones safe?



Mobile phones use microwave radiation. They receive this radiation from a nearby base station and send radiation back. When you use a mobile phone some of this microwave radiation warms your brain ever so slightly and this can damage cells, possibly leading to brain tumours. Distance from the radiation source is important as the intensity of the radiation decreases rapidly with distance. This is why some people use a hands-free kit to keep the mobile phone away from their head.

Mobile phone studies

Most people in Australia use mobile phones, and there have been many studies to see if prolonged use of these phones can cause cancer. The largest study to date was the Interphone study, conducted over 12 years in 13 countries (including Australia), with 5000 participants. It found no link between mobile phone use and brain cancer. The study did find that people who used their phones for at least 30 minutes a day for 10 years faced an increased risk of developing brain cancer, but the results were inconclusive. Critics of the study say that it doesn't tell you what happens beyond 12 years. Also, none of the participants in the study were children or teenagers. And much of the study was sponsored by the mobile phone industry.

Studies like the mobile phone study compare people in two different groups. The researchers try to find if one particular variable, such as mobile phone use or eating a particular type of food, makes a difference to these people's health. To check whether the results of a study are *reliable* (can be accepted as correct), there are two important things to check.

1 *Are the groups selected so that the comparison is fair?* Suppose the study is to see whether mobile phone use increases the risk of brain cancer. The study would need to compare the health of two groups: a sample of mobile phone users and a sample of non-users. The people in both samples should be matched on as many variables as possible. For example, each sample should have similar numbers of people of different ages.

2 *Are the numbers in each group (sample) large enough?* With small samples the results can be strongly affected by chance. For example, some people are more likely to develop brain cancer than others. With larger samples this is less likely to affect the results. So you get a more accurate picture of the whole group.

What should you do?

Scientific evidence at this stage suggests that mobile phones are 'unlikely' to be harmful, but this is not yet certain. Until we know for sure, experts say:

- Some people, particularly children, may be at greater risk of harm.
- Children under eight should not use mobile phones.
- People can choose to take care by making fewer and shorter calls.
- When buying a mobile phone, choose one with a lower SAR value (radiation exposure).

Questions

1 Drinking a glass of water is an everyday activity. Explain why even this is not completely safe.

2 Explain why the risk of using a mobile phone is reduced by texting rather than making a voice call.

3 The Interphone study did not include users in rural areas. How might this affect the results?

4 One study found that frequent use of a mobile phone reduced men's sperm counts. It was based on a sample of 15 men. Why is this study not reliable?

5 Suppose your risk of developing a brain tumour is about 1 in 20000. Would you continue to use your mobile phone if you read a study that said that this risk was doubled by using a mobile phone?

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9.4 Radio and television

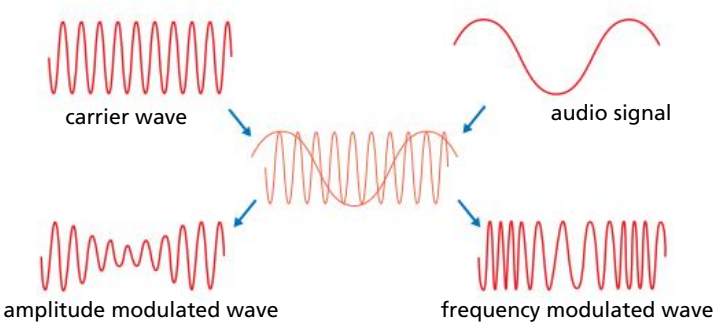
In 1895 Guglielmo Marconi, an Italian scientist working in England, sent a message without wires over a distance of 10 m. By the end of the year he had increased the range to 2 km. Thus the radio, or 'wireless' as it was known, was born.

Radio works by changing sounds into electrical signals, like those on an oscilloscope. These electrical signals are then amplified and passed to an antenna where they produce radio waves. These radio waves have wavelengths that range from less than a metre to several kilometres long. They travel through the air until they reach a receiving antenna where the process is reversed. The radio waves cause the electrons in the antenna to vibrate, producing an electrical signal that is converted to sound. Each radio station has its own frequency and the tuner in a radio receiver enables you to select the frequency you want. For example, 2GB in Sydney has a frequency of 873 kHz and 3AW in Melbourne has a frequency of 693 kHz. Triple J has a much higher frequency of 105.7 MHz.

AM and FM

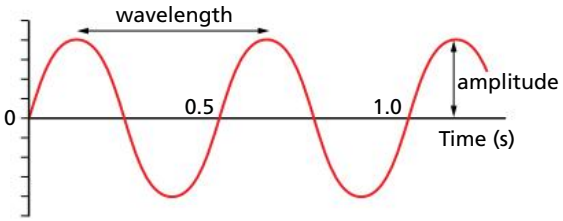
A microphone converts sound waves into an electronic audio signal. These are low frequency waves and if broadcast would travel only a few metres through air. To overcome this problem, radio stations mix the audio signal with a much higher frequency wave that can travel hundreds of kilometres. This is called a *carrier wave*, and the combined wave is said to be *modulated*.

There are two ways in which the audio signal can be combined with the carrier wave. In the first way, the audio signal changes the amplitude of the wave, but the frequency stays the same. This is called **amplitude modulation**, or **AM**. The other way is for the audio signal to change the frequency of the carrier wave without changing the amplitude. This is called **frequency modulation** or **FM**.



INQUIRY 4 **Wave patterns**

You will need: audio generator, cathode ray oscilloscope (CRO)



1 Look at the wave pattern produced by the audio generator.

The frequency of the wave is measured in hertz (Hz), where one hertz is one wave per second. The wave above has a frequency of 2 Hz as two waves pass every second. A kilohertz (kHz) is 1000 Hz and a megahertz is 1 000 000 Hz.

2 Observe the wave on the CRO when you increase the frequency (pitch).

- What happens to the wavelength?
- Write a generalisation saying how the wavelength changes as you change the frequency.

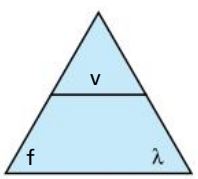
3 What happens when you turn up the volume of the generator?

4 The frequency and wavelength of an electromagnetic wave are linked by the *wave equation*:

speed of light (m/s) = frequency (Hz) × wavelength (m)

or $v = f \times \lambda$

You can rearrange the equation by using the triangle rule. Your teacher may need to explain this.



$v = f\lambda$

$f = \frac{v}{\lambda}$

$\lambda = \frac{v}{f}$

- Calculate the speed of a water wave with a frequency of 3 Hz and a wavelength of 15 m.
- The speed of a wave is 25 m/s and its frequency is 5 Hz. What is its wavelength?
- A radio wave has a frequency of 1000 kHz. What is its wavelength? (Radio waves, like all electromagnetic radiation, travel at 300 000 km/s.)
- A radio wave has a wavelength of 3 m. What is its frequency in megahertz?

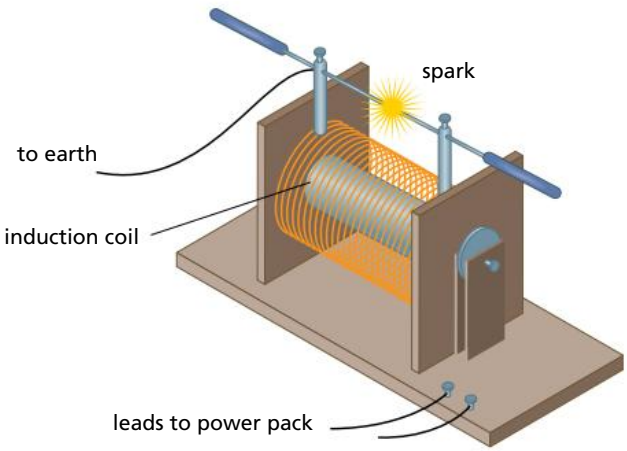
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AM radio waves can travel distances of up to 1000 km, but there may be considerable electrical interference (static). FM radio waves are less affected by electrical interference and therefore give you better quality sound. However, FM waves can only travel about 100 km.

INQUIRY 5 Radio waves

You will need: induction coil, power pack, radio

1 Connect the induction coil to a 6 V DC power pack. Move the points on the coil until there is consistent sparking. **The coil produces a high voltage, so don't touch it.**



2 Place the radio nearby and turn it on. Tune it so that it is between stations. Turn the volume on full. Listen to the radio with the coil on and off. What do you notice?

- Try to explain your observations.

3 What happens when you move the radio around?

Digital radio

From 2009 radio stations in Australia have been broadcasting digital radio, which is quite different from AM or FM. The audio signal is first digitised as shown on page 200 (bottom right), and it is the resulting digital data that modulates the radio signal.

The big advantage of digital over AM or FM is that the quality is better. All radio signals weaken as they travel, and there is interference. However, with digital signals these effects can be corrected. Even if the incoming signals have added noise, it is still possible to tell the 1s from the 0s, as these are the only values the signal can have. A regenerator can then be used to restore the pulses to their original quality.

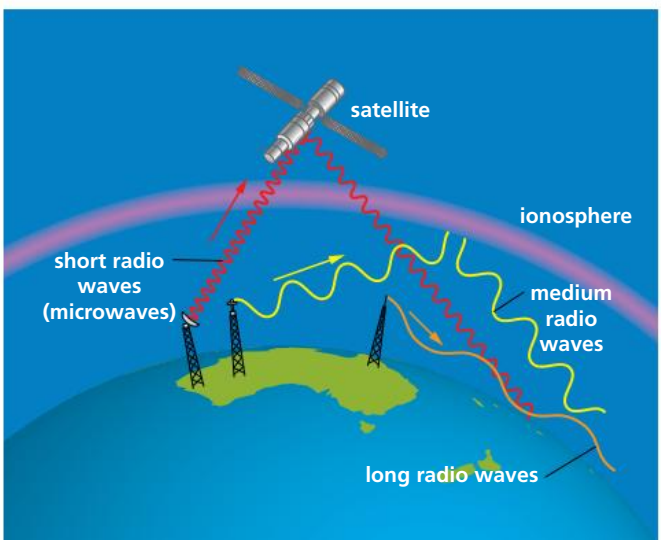
To listen to digital radio you need a digital radio, which usually has a small screen. You tune by station name, rather than by frequency, making it easier to find your favourite stations. The screen can display information such as program details, the name of the track currently being played, web addresses, competition details, news, sports and weather. With some digital radios you can even pause and replay, as you can with digital TV.

Using radio waves

Radio waves have different wavelengths. Long radio waves travel close to the ground and are suitable for local radio only. Medium-length radio waves are reflected by the ionosphere and also by the ground. This means they can travel around the world. Very short radio waves (or microwaves) can pass straight through the ionosphere and link up with communication satellites in space.

Radar stands for **ra**dio **d**etection **a**nd **r**anging. It uses radio waves to track planes and guide them in for smooth landings. The radio waves leave the transmitter at a speed of 300 000 km/s and are reflected from the aircraft back to the receiver. The time taken for the waves to make this return journey allows the distance to the aircraft to be measured.

Radar can be used to track thunderstorms. Radio waves with a wavelength of about 1 cm pass through normal clouds but are reflected by storm clouds, because they are more dense. Radar can also be used to map the details of a planet's surface.



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INQUIRY 6 Tinkering with a radio

You will need: old battery-powered radio that no longer works

Carefully pull the radio apart to see the parts inside. For example, you may be able to find resistors, coils, diodes, transistors and capacitors. Can you see the tuning capacitor move when you turn the dial? You may even be able to get the radio to work.

Over to you

1. How can radio messages travel from one place to another without wires?
2. **a** List at least two different types of electromagnetic radiation.
   b How are the different types similar? How are they different?
3. If you know the frequency of a radio wave, how can you find its wavelength?
4. List the radio stations in your area, with their transmitting frequencies. How do the frequencies of AM and FM stations differ?
5. Explain the difference between the way in which AM and FM radio waves carry audio signals.
6. List one advantage and one disadvantage of FM radio compared to AM radio.
7. Why does a car radio sometimes crackle when you are near high voltage power lines?
8. Do you think it is worth buying a digital radio? Why or why not?
9. Astronauts on the moon communicated with Earth via radio waves. The moon is almost 400 000 km from Earth. How long does it take a radio signal to cover this distance?
10. A rock band is using microphones in a large hall. A person listening to a live radio broadcast of the band will hear the music before people sitting at the back of the hall hear it. Explain.

Television

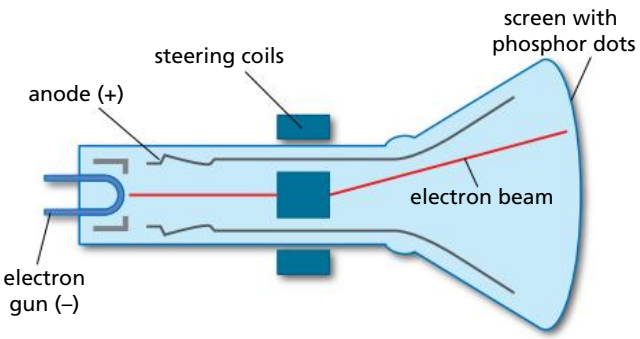
We tend to take television for granted, but you should now know enough to understand how it works. It works like radio, but is a bit more complicated.

When a TV program is filmed, light enters the TV cameras and hits a light-sensitive screen and produces an electrical pattern. A beam of electrons scans this screen 50 times per second and passes the electrical signals down the wires. Sound is picked up at the same time. The three primary colours—red, green and blue—are separated in the camera.

The TV signals are then transmitted from the TV station on two different carrier waves. The visual signal is added to one carrier wave using amplitude modulation. The audio signal is carried on a separate carrier wave using frequency modulation. The two waves are then added together, amplified and transmitted.

The TV antenna at your house picks up the TV waves and converts them back to electrical signals, which go to the TV set. Here the sound signal is separated and sent to audio amplifiers.

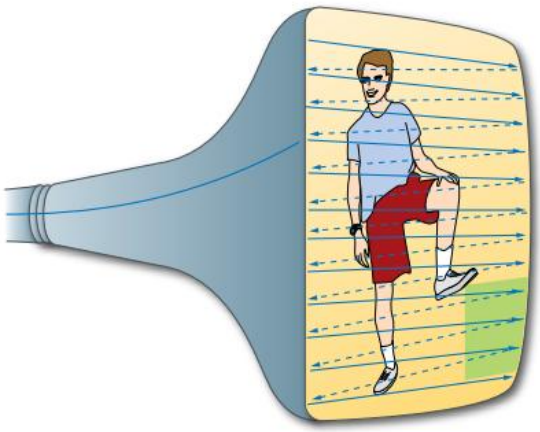
Until fairly recently all TV sets had a picture tube. This is a type of cathode ray tube (CRT), which is also found in a cathode ray oscilloscope (see Inquiry 7). It contains an electron gun in a vacuum inside a glass tube, as shown below. This electron gun is a heated filament not unlike the one in a light bulb. It produces a stream of electrons that are attracted to a positive anode and accelerated down the tube. There are three different electron guns—one for each colour.



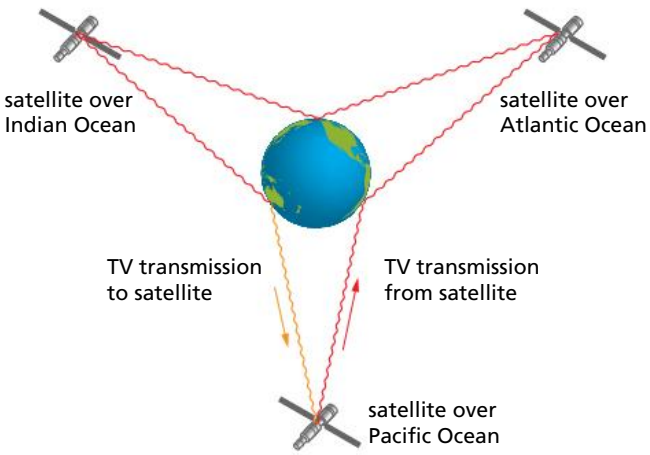
The electrons hit the inside of the screen which is coated with tiny spots of special substances called *phosphors* (FOS-fours). One type glows red when hit by an electron beam, another glows green and the third glows blue. A red, a green and a blue phosphor together form a pixel. See the photo on page 182. There might be 800 × 600 pixels on a screen.

The steering coils produce magnetic fields that move the electron beam. They sweep the electron beam over the screen from left to right. The beam then quickly flies back to the left, moves down slightly and paints another horizontal line, and so on down the screen as shown. Each complete picture on the screen is made up of 625 horizontal lines, and each set of 625 lines is scanned 25 times every second. These changes are too fast for your eyes to detect, so you see a continuous picture on the screen.

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The signal transmitted by the TV station needs to be strengthened about every 100 km, so the signal is sent via a network of repeater towers. TV signals can also be transmitted around the world via microwaves and communications satellites. In this way we can see live events from anywhere in the world.



INQUIRY 7 Steering an electron beam

A cathode ray oscilloscope (CRO) works in much the same way as a TV picture tube. Your teacher will adjust the CRO to produce a spot in the centre of the screen. This is where the electron beam is hitting the phosphor coating. What happens when you bring a magnet near the spot?

- Explain your observations.
- How is this similar to what happens in a TV picture tube?

Warning: Don't try this with a TV set as it may permanently affect the picture quality.

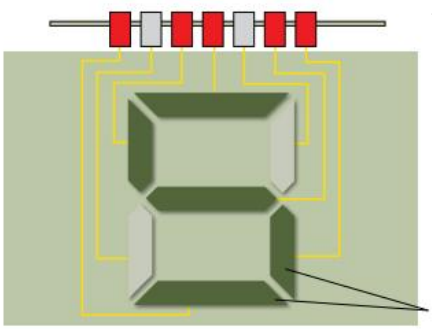
Over the last few years Australia has changed from analog to digital TV. The difference between analog and digital is explained on page 200. The big advantage of digital is that you can see pictures with the same crispness and detail as on a computer screen. At the same time the old bulky CRT screens are being replaced by flat screens.

Flat screen TVs

The picture tubes used in older screens and computer monitors were quite bulky. The flat screens used in recent computers, especially laptop computers, use flat **liquid crystal displays** (**LCDs**). A liquid crystal has the properties of both a liquid and a solid. The long molecules in a liquid crystal stay in position like the molecules in a solid, but they also move around like the molecules in a liquid.

To make an LCD, two polarising filters (like those in polaroid sunglasses) are used. When these are arranged at 90° to each other, no light passes through them (see Inquiry 12 on page 185). The liquid crystals are placed between the filters and arranged in a twisted pattern that allows light to pass through. However, when an electric field is passed through the liquid crystals, the twist is removed. This means that light cannot pass through and the area appears dark.

The LCDs are sandwiched between two glass plates which have elements coated on them with a substance that conducts electricity. For example, the calculator element shown has seven parts. By charging different terminals you can make different numbers.



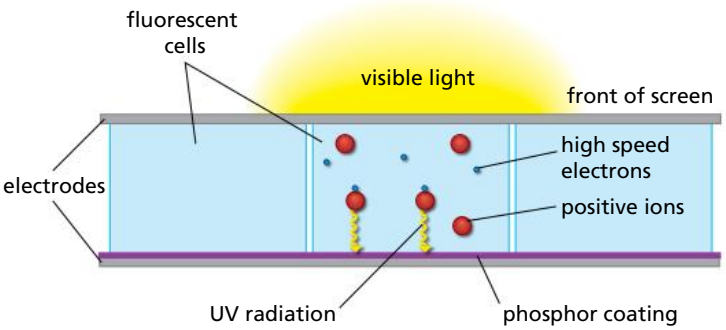
LCDs do not emit light. Those in digital watches and calculators have a mirror behind them to reflect light, so they don't work in the dark. In flat TV screens, each pixel is an LCD instead of a phosphor. They have red, green and blue filters above them to produce colours. And the LCDs are lit from the back by tiny fluorescent tubes or LEDs.

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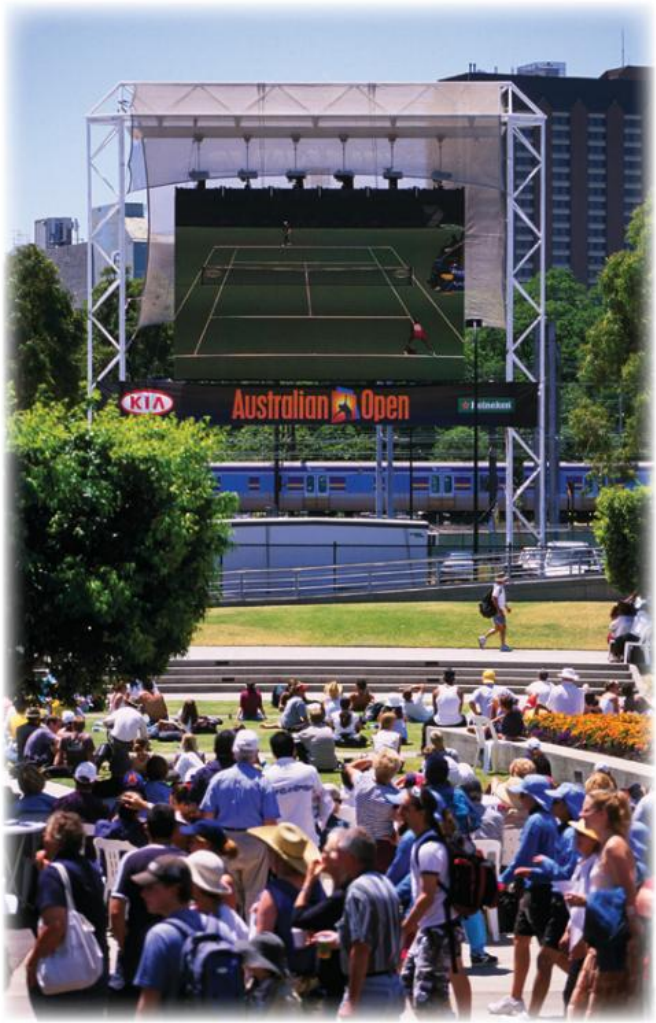
Plasma screens

You can also buy plasma TV screens. These are much larger than normal screens and are only about 15 cm thick. As a result they can be mounted on the wall. However, they are very expensive.

In a plasma screen each pixel consists of three tiny fluorescent cells, like a normal fluorescent tube. Inside each fluorescent cell is a mixture of xenon and neon gases. When a voltage is passed through the gas, high-speed electrons are produced. These electrons collide with the atoms in the gas, knocking loose other electrons and creating positive ions. This mixture of positive ions and free electrons is a plasma. Particles rush madly in all directions and are constantly bumping into each other. These collisions excite the atoms in the plasma, causing them to release invisible ultraviolet radiation. When this UV radiation hits the phosphor on the bottom of the cell, it produces visible light.







The huge jumbo screens in sporting stadiums use millions of light-emitting diodes as pixels.

Over to you

1. How does the TV signal get from the TV station to your house?
2. How is it possible to receive live TV broadcasts of events taking place on the other side of the world?
3. Why does a colour TV screen have pixels in groups of threes?
4. Use the diagram on this page to explain in your own words how a picture is formed on a plasma TV screen.
5. If someone next door is using a power tool it may cause interference on your TV set. How?
6. What are the similarities and differences between the face of a digital watch and the screen of a laptop computer with an LCD screen?
7. Could you make a large colour TV screen using electric light bulbs? How?

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THINKING SKILLS

1 Make a copy of the table below. Rearrange the electromagnetic wave types in the first column so they are listed in order of increasing wavelength. Then complete the table by filling in the other three columns.

2 Name a type of electromagnetic radiation that:

a causes sunburn

b passes through thin metal sheets

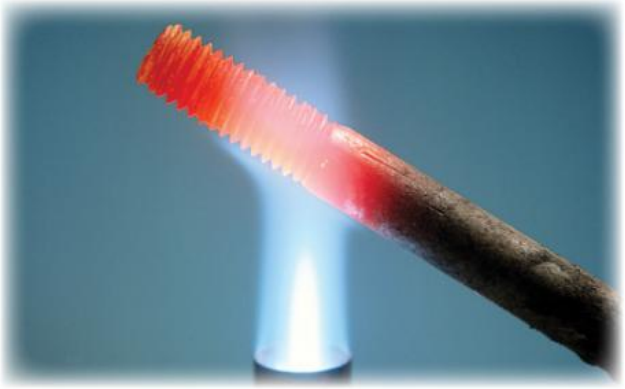
c is used in remote controls

d is used for satellite communication.

3 A radio station is broadcasting on a frequency of 100 MHz. How many radio waves does it send out every second?

4 Is UV radiation good, bad or both? Explain your answer.

5 Why does a metal bar start to glow red when it is heated?



6 Objects that emit heat can be detected by infrared sensors. Give examples of where this technology can be useful.

7 How can photographs of the insides of our body be taken?

8 The moon is about 400 000 km from Earth. When astronauts walked on the moon they sent messages home by radio. How long did it take the radio waves to reach Earth?



9 A radiographer (person who takes X-rays) always leaves the room when the X-ray photographs are being taken. Why?

10 It is almost impossible to become sunburned behind glass. Suggest a reason for this.

11 A TV remote control emits an infrared beam that carries coded information to the TV set. Explain how you might use this to find out which everyday materials absorb infrared and which transmit it (allow it to pass through).

12 Someone claims to have invented a machine that produces X-rays so penetrating that they can pass through any known material. Why would these X-rays be of no use for medical photos or security checks at airports?

Electromagnetic wave type	Approximate range of wavelength (m)	Properties	Uses
infrared radiation			
gamma rays			
ultraviolet radiation			
light			
X-rays			
radio			

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1. _____ waves consist of vibrating electric and _____ fields and travel at the speed of light.
2. The electromagnetic _____ is the full range of radiation from short waves such as _____ rays to _____ waves such as radio waves.
3. The wavelength and frequency of electromagnetic radiation are linked by the equation _____ = frequency × wavelength.
4. _____ is the use of resistors, capacitors, diodes and transistors to control electric currents in electric _____.
5. In a _____, sound waves are converted to electrical signals, then back to sound waves. The electrical signals travel through wires, or can be converted to pulses of _____.
6. Electrons vibrating in an antenna produce electromagnetic _____ that can travel through the air and then be converted back to electrical signals in a receiving _____. Radio and television works like this.
7. A telecommunication signal may be _____ where its value varies smoothly, or it may be _____ where it is either on (1) or off (0).

analog
antenna
circuits
digital
electromagnetic
electronics
gamma
light
long
magnetic
radiation
spectrum
speed of light
telephone

Self-management

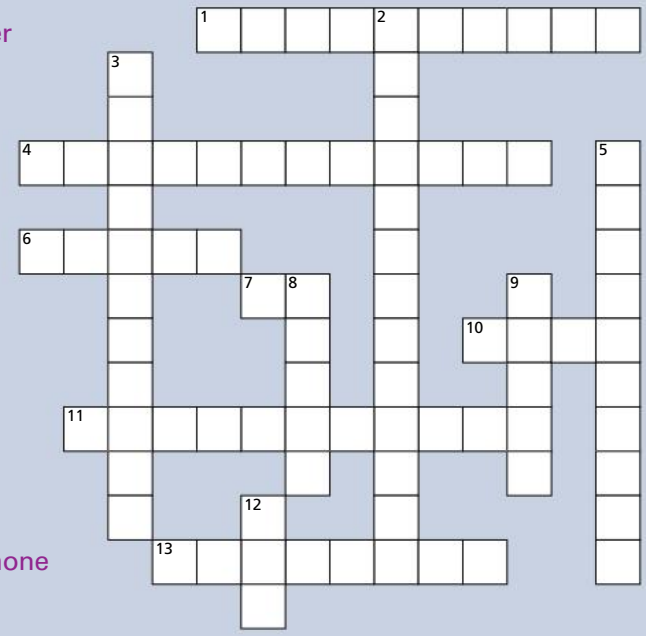
Your teacher will give you a copy of this crossword. Don't write your answers in your textbook.

Across

1. An electronic device that can act as a switch or amplifier
4. Thin glass fibre used to carry pulses of light (2 words)
6. Used to detect broken bones
7. Frequency modulation
10. The inventor of the telephone
11. Glowing under ultraviolet light

Down

2. Material used to make diodes and transistors
3. The ozone layer stops most of this reaching the Earth
5. The distance between one peak or trough of a wave and the next
8. A device that transmits and receives data via the telephone system
9. Unit used to measure frequency



Make up your own crossword of 10 words only. Use words from the chapter that were not used here.

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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 Which of the following is *not* electromagnetic radiation?

A microwaves
B radio waves
C visible light
D sound waves

2 Match each of the words in Column 1 with words from Column 2.

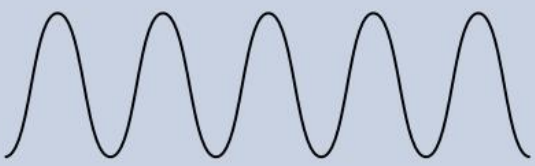
Column 1	*Column 2*
colour	gamma rays
communications	infrared
heat	radio
medicine	visible light
radioactivity	ultraviolet
sunburn	X-rays

3 The main regions of the electromagnetic spectrum are given below.

gamma rays
infrared
microwaves
radio waves
visible light
ultraviolet
X-rays

a Put these in order, from the smallest to the largest wavelength.
b State three things that all these waves have in common.
c Compare the wavelengths and frequencies of radio waves and X-rays.
d What colours make up the visible spectrum?
e Give two uses for microwaves.
f Give two uses for gamma rays.

4 The wave below went past a given point in 10 seconds.



a What is the frequency of the wave?
b What is its wavelength? (Measure it.)
c What is its amplitude? (Measure it.)

5 Name the electronics component that:

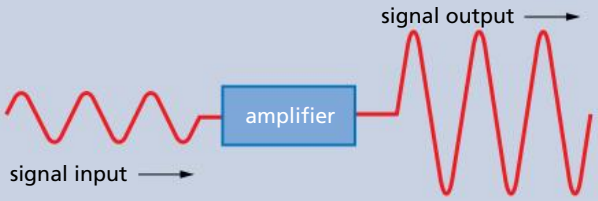
a stores charge for a short time
b changes its resistance as the amount of light on it changes
c controls current and voltage
d acts as a switch or an amplifier
e changes AC to DC.

6 Name the TV set component that:

a changes electrical signals into sound
b gives off light when hit by electrons or UV radiation
c uses electricity to control light passing through it
d changes electromagnetic radiation into electrical signals

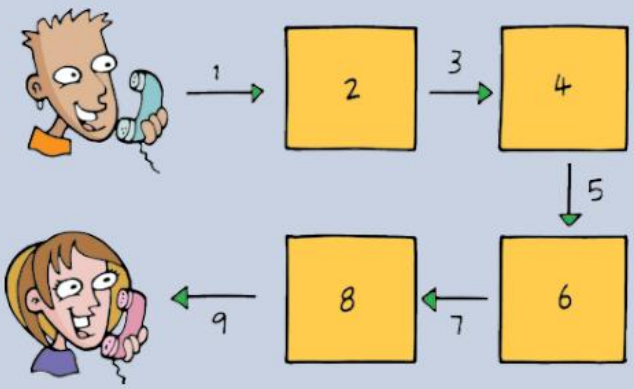
7 The diagram shows how an amplifier works.

a What happens to the wavelength, frequency and amplitude of the signal as it passes through the amplifier?
b How does an amplifier change sound?



8 The diagram below shows how a telephone works. Select words from the following list to match the numbers in the diagram. (You will need to use some words twice.)

analog electrical signals
digital light signals
microphone
sound waves
speaker
telephone exchange



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10



Forensic skills

By the end of this chapter you will be able to …

Skills—Working Scientifically

- explain why various types of forensic evidence need to be collected to solve a crime (5.1b)
- describe the logical procedures for collecting different types of forensic evidence (5.2b)
- use a table to record and analyse evidence from a crime scene (7.1a)
- identify data that supports or discounts a question or hypothesis being investigated (7.1e)
- use knowledge or scientific concepts to draw conclusions that are consistent with evidence (7.2d)
- evaluate conclusions and evidence, identifying sources of uncertainty and possible alternative explanations (7.2f)

LITERACY FOCUS

antibodies
antigens
autopsy
ballistics
chromatography
coroner
cuticle
deoxyribonucleic acid (DNA)
electrophoresis
entomology
forensic medicine
forensic pathology
forensic science
forgery
haematology
humus
hypothesis
immunology
toxicology
whorl

Focus for learning

The word 'forensic' comes from the Latin word *forum* meaning 'public meeting place'. In Roman times the forum was where disputes were settled. Today forensic means 'connected to or used in courts of law'. Forensic testing provides evidence for presentation in court. Here's an example of this.



On 4 August 1962, one of the world's most famous movie stars, Marilyn Monroe, died. Her death was recorded as suicide from a drug overdose, as she was found lying on her bedroom floor with a bottle of sleeping tablets nearby. Marilyn was addicted to drugs and alcohol, and an **autopsy** (examination of the body after death) showed that there were drugs present in her body. Marilyn had overdosed on drugs on four other occasions. So a decision of probable suicide was reached.

A death like that of Marilyn Monroe shows how forensics works. Careful observations are made at a crime scene, witnesses are interviewed, evidence (data) is gathered, tests are made and conclusions reached from the findings. You can see how this process works in this chapter.

PROBLEM SOLVING

Who's guilty?

Read this story about a crime that has taken place. Work through the chapter and gather evidence as you read, then present the following:

a the tests needed to solve the crime

b who you think is guilty and the evidence that led you to that conclusion.

A theft has occurred at an office building in Pitt Street, Sydney. It appears that a person or persons unknown smashed the window of the office tearoom to enter the building. Sneaker footprints were found in the soil underneath the tearoom window. The footprints led towards and away from the window. There was glass on the floor of the tearoom. A piece of wool and some hair were caught in the glass in the window. What appeared to be blood was smeared on a jagged edge of the glass. There were scratch marks on the window frame. Soil and sneaker footprints led from the tearoom into the pay room. Here a safe had been opened using an electronic code, and papers were scattered across the floor. Money and cheques had been taken.

The police have five suspects: Robert Lawson, Trisha Court and Wendy Gray, who work in the pay room, and Gary Silver, the cleaner, who was working in an office nearby when the crime took place. Silver called the police when he heard the alarm at 5 am. The fifth suspect is Peter Hanson, the gardener, who said he started work early because it was going to be a hot day. He was at the scene when the police arrived.

You could start to solve the crime by:

1 drawing a diagram of the crime scene based on the evidence presented here, showing where evidence is positioned

2 listing all the observations made at the crime scene you are investigating.

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INQUIRY 1

Marilyn Monroe

Forensic testing raised many questions about Marilyn's death and led people to suspect that she did not commit suicide. Some people suggested she had been murdered because of her relationship with President of the United States, John F. Kennedy, and his brother Robert. It was also suggested that she mixed two drugs by accident, not realising the effect this would have.

1 In groups discuss each piece of evidence presented here and then make a statement that explains whether you think Marilyn Monroe died by murder, accident or suicide.

A When police sergeant Clemmons was called to the scene to investigate, he noted that Marilyn's body was face down, her arms at her side and her legs straight. He thought she had been placed in this position because drug overdose victims he had seen died in a contorted (twisted and bent) way, suffering from vomiting convulsions and a horrible death.

B There was no drinking glass or anything to indicate how she had taken the drugs.

C Eunice Murray, who shared the house with Marilyn, said that she died around 3.30 am on 5 August. She had seen a light on under Marilyn's bedroom door at this time, and had forced open the locked door to see if Marilyn was all right. This was untrue because the thickness of the carpet prevented any light from showing under Marilyn's bedroom door, and the door had no sign of forced entry.

D Eunice and her son-in-law had different stories about the events of the evening. The son-in-law stated that Robert Kennedy and two other men came to the house between 9.30 pm and 10 pm on 4 August. A neighbour confirmed this. Eunice doesn't mention it in her statement.

E When Marilyn's body was taken to the morgue, rigor mortis (where the muscles in the body stiffen) was quite advanced. It occurs after death and lasts from 36–48 hours, when muscle decomposition (breakdown) starts. Rigor mortis indicated Marilyn had died between 9.30 pm and 11.30 pm on 4 August.

F Marilyn had taken drugs on 4 August. The high level of drugs (barbiturates) found in her liver confirmed this. The liver breaks down substances from the digestive system over time. For barbiturates to be in Marilyn's liver, they must have been in her body for a long time, not taken just before she died.

G There were also high levels of two drugs in her blood—barbiturates prescribed for her two days earlier by one doctor and chloral hydrate or sleeping tablets (sedatives), which had been prescribed by a different doctor to help her stop using barbiturates.

H If Marilyn had taken sleeping tablets that night then the remains of the capsules should have been in her stomach. None were found. There were also no needle marks on her body to indicate she had been injected with any drugs.

I Marilyn was believed to have had affairs with Robert Kennedy and President John F. Kennedy and what she knew about these men could have destroyed their reputation.



2 The following questions remain unanswered about Marilyn's death. Are there any other unanswered questions you can think of? Discuss this as a class.

a How did such high levels of drugs get into Marilyn's body?

b Did the mixing of the two drugs kill her?

c Why was nothing made of the visit by Robert Kennedy and two other men the night Marilyn died?

d Is it possible that somebody close to the President caused Marilyn's death because she knew enough to destroy him?

3 Can you answer any of these questions or put forward possible *inferences* or explanations for the observations presented here? Discuss this as a class.

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10.1 Forensics

Forensics relies on the fact that every contact leaves a trace, which means that whenever two surfaces meet something is left behind. For example, if you touch a glass, your fingerprints will be left on the surface. Forensics is not just about solving murders. It can be used to provide evidence for forgeries, fraud, paternity disputes (where the identity of a parent is in doubt), rape cases and robberies. Forensics can even be used to determine whether factory emissions meet environmental standards.

Forensics is a term that covers three areas:

- **Forensic science** is made up of several different scientific fields. For example, *palynology* PAL-in-OL-oh-gee (the study of pollen, spores and microscopic organisms), *toxicology* (the study of poisons and their effects) and *entomology* (the study of insects).
- **Forensic medicine** is practised by medical practitioners (doctors). It also involves other specialist areas such as pharmacology (the study of drugs), psychiatry (the study of mental disease) and dentistry (*odontology*).
- **Forensic pathology** is made up of several different fields such as *haematology* HEME-a-TOL-oh-gee (the study of blood), and *immunology* (the study of the immune system). *Forensic pathologists* are doctors who investigate the cause of injury and death.

These three fields each contribute to solving cases. For example an odontologist might identify an unknown deceased (dead) person by using dental records. An entomologist might estimate the time of death of the deceased by examining maggots in the body. The developmental stages of the maggots indicate how old they are and this can be used to say how long the body has been dead.

If a body is found and the cause of death is unknown or unnatural, the **coroner** becomes involved in the investigation. This is usually a magistrate who determines who the deceased was, and where, when and how they died. They do this by holding an inquiry (*inquest*) into the person's death. Here the evidence collected is presented in a formal court hearing.

Securing the crime scene

When the police first arrive at the scene of a crime they take control of the area. They make sure that nobody touches, alters, destroys or contaminates the evidence available. They secure the crime scene so that no additional factors can affect their investigation. For example, if somebody did move Marilyn Monroe, then they altered the evidence that would explain how she died.

Investigators at a crime scene must make careful records about what they find. They record their time of arrival, who was present and what the crime scene looks like. Photographers take pictures of the scene, while forensic investigators place all evidence in labelled plastic bags. Fibres, hair, blood, soil, plant material, diaries, documents, tapes, computer files, weapons or statements from witnesses are all evidence. Accurate records must be taken so they can be used in court.

INQUIRY 2 First on the scene

Your teacher will set up a room that shows where people have been carrying out an activity and been disturbed. The photograph is an example of such a scene. You will be taken and shown the room.



Complete the following:

1. What time did you arrive and who was with you?
2. Who was already at the scene?
3. What did you observe as you entered the room?
4. If this was a crime scene, what would you do first and why? Would the type of crime alter what you would do?
5. What evidence can you collect?
6. Can you explain any of your observations at this point? For example, what were the people doing in the room? Was the room hot or cold? What age and sex were the people in the room? Were they supposed to be there?

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Making observations

In Inquiry 1 you were presented with observations about Marilyn Monroe's death. Careful *observation* is the basis of any scientific investigation. The police sergeant observed the position of Marilyn Monroe's body. She was face down with her arms by her side. He then put forward a possible explanation for his observations. This is called making an *inference*. The sergeant inferred that Marilyn had been moved and placed where she was, because her position was not consistent with his own observations of other drug-overdose victims. He based this on a *generalisation* or a statement that is true most of the time, that is: *drug overdose victims die in a contorted way*.

In Inquiry 1 you were asked to make *a statement based on all the evidence, observations and information available to you* about whether you thought Marilyn's death was murder, accident or suicide. A statement like this is called a *hypothesis*. For example, *Marilyn Monroe was murdered by somebody tampering with her drug prescriptions*. A hypothesis can be tested by collecting more evidence, making more observations and performing more tests.

In this way, forensics follows the scientific method you have learnt in previous study. Let's compare these two methods.

INQUIRY 3 Role-play observations

When a crime occurs, the stories from witnesses about the events are often very different. (Remember Eunice and her son-in-law on page 214.) Also people tend to offer inferences to explain their observations and this often affects what they *think* they saw.

1. In groups of five, devise a 2-minute role-play enacting a crime or some event, so that all five students participate.
2. Write down five questions about your role-play that you can ask the class afterwards.
3. Each group must present their role-play to the class and ask their questions. They must then provide the answers and check who observed most accurately.



Scientific method

observations
lead to
↓
questions
↓
inferences
generalisations
hypotheses
↓
testing and collecting data
(designing and carrying out experiments)
↓
discussion
(analysing the results and the method used)
↓
making conclusions
↓
accept hypothesis or modify hypothesis

Forensics

observing and securing the crime scene
leads to
↓
questions
↓
inferences
generalisations
hypotheses
↓
testing and collecting data
(collecting samples, talking to witnesses, carrying out tests)
↓
analysing data
(identify possible suspects)
↓
making conclusions
↓
solve the case and present findings at an inquest or in court, or modify hypothesis

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Shoe prints, treads and scratches

Once evidence has been collected at a crime scene, it is then taken back to the laboratory to be *analysed* (examined). Many different scientific techniques are used.

In the crime you have to solve from page 213, the first piece of evidence is sneaker footprints under the window. There are also sneaker footprints leading away from the tearoom window and into the pay room.

Many things can leave prints. For example, shoes, car tyres, bicycle wheels and strollers. In most cases photographs are taken of the prints found. It is possible to make casts of prints as in Investigation 1. Scratches or dents in metal or wood can be treated in the same way.

INVESTIGATION

1 Making casts

Aim

To make a cast of a shoe print.

Risk assessment and planning

Read through the investigation and discuss any possible safety issues with your teacher.

Apparatus

- greaseproof paper such as Glad® Bake
- baking tray
- damp sand
- plaster of Paris
- kitchen spatula
- scoop or small plastic spade
- ice-cream container
- small brush
- chisel and hammer
- small block of pine
- plasticine
- gap filler or PVA glue
- G-clamp

Method

Part A

1. Working in groups of three, place a piece of Glad® Bake in a baking tray so that it completely covers the sides of the tray and overhangs it.
2. Fill the baking tray with damp sand, using the scoop. Make the surface of the sand smooth.
3. Put the baking tray on the floor and carefully make an impression in the sand with someone's shoe.
4. In an ice-cream container, make a plaster mix that can be poured into your shoe print. (Follow the directions on the plaster of Paris.) Avoid getting the plaster too close to the edges of the baking tray because it makes it hard to remove the plaster once it sets.
5. Let the plaster set overnight and then gently remove it from the sand. Use the brush to clean any sand off the plaster.
6. As a class, collect the casts and the shoes used to make them. See if you can match up the shoes with the prints.



Part B

1. Clamp the piece of pine to the bench.
2. Use the chisel and hammer to make some marks in the piece of pine. **Move the chisel away from you to make the marks**.
3. Build a plasticine mould around the marks.
4. Fill the mould with PVA glue or gap filler. Do not make it too thick.
5. When the glue or filler has set, remove the cast from the mould. How successful were you in making a cast of the marks?

Discussion

1. How could you make a cast of a tyre print on a dirt road? Try it.
2. Why do you think photographs are usually taken of any prints, treads or scratches in wood found at a crime scene? When do you think casts would be used?
3. Explain whether you think shoe prints are reliable evidence.
4. How can making casts help you solve the crime from page 213?

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Soil

Shoe prints on their own may not be enough to identify a criminal. For example, sneaker brands such as Reebok and Nike leave characteristic tread marks, but many people own these brands of sneakers. Also, in the crime you are solving, sneaker prints in the office may have been made at any time during the day, not necessarily during the break-in. However, if the soil on all the sneaker prints is the same, and matches the soil outside the window, it is more than likely the prints were made during the crime.

Soil is made from the breakdown of rocks, so it has minerals in it. Soil can contain different minerals depending on the rock it came from. For example, gravel and sand in soil comes from sedimentary rocks. Soil also contains water, decomposed plant and animal material (**humus**) and pollen. Each of these substances affects the texture (how rough or fine the soil is), its colour, the amount of nutrients in it, the water content and the pH.

pH is a measure of whether a substance is acidic or basic (see Chapter 1). Acids have a pH of 1–6 and bases have a pH of 8–14. Neutral substances have a pH of about 7. Most soils are slightly acidic, with a pH of about 5.5. Substances in the soil can affect its pH. For example, lime is added to acidic soils to make them neutral or more alkaline.

Over to you

1 What does the word 'forensics' mean?

2 Name three different branches of science that are involved in forensics.

3 What does a coroner do?

4 How do forensic investigators and the police control the scene of a crime?

5 What kind of evidence is collected at a crime scene?

6 What properties of soil can be tested to help identify a soil sample?

7 **a** If shoes from a suspect of a crime have the same prints as shoe prints found at a crime scene, could this evidence alone be used to convict the suspect?

b If the shoes also have soil on them that matches the soil found at a crime scene, is this evidence more convincing? Explain.

INQUIRY 4

Comparing soil samples

You will need: hand lens, tweezers, dropping bottle of universal indicator solution, dropping bottle of distilled water, 10 mL measuring cylinder, test tubes, test-tube rack, spatula, different soil samples, microscope, minigrid

1 Examine each soil sample with a hand lens. Describe the particles in the soil. If you know how to use a microscope and a minigrid you could measure the size of the soil particles. For example:

Gravel: particles greater than 2 mm in diameter
Sand: 0.1–0.3 mm in diameter
Clay: 0.001–0.003 mm in diameter

2 Squeeze each soil sample to see how well the particles stick together. Soils made of gravel and sand do not hold water, so they fall apart easily. Clay is a sticky soil because water gets trapped between the particles and cannot drain away.

3 Place a spatula of each soil sample in a separate test tube and add 10 mL of distilled water to each. Shake each test tube well. Add 5 drops of universal indicator solution to each. Record the pH by comparing the colour of each sample with the colour chart provided (see page 11). You could also test soil using the method in Inquiry 5 on page 17.

4 What other tests could you perform on each soil sample? Discuss these as a group.

PROBLEM SOLVING

1 What inferences can you make to explain the observations you made earlier?

2 Can you make any *hypotheses* about who committed the crime?

Here are some clues to help you with solving your crime after the shoe print analysis.

Clues:

- The sneaker prints in the garden under the tearoom window all belong to Peter Hanson and Wendy Gray.
- The sneaker prints on the floor of the tearoom, and between the tearoom and the pay room belong to Wendy Gray and Gary Silver.

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10.2 Hair, fibres and glass

Hair

Hair is often transferred from one person to another and can easily be left at a crime scene. A single hair is made of *keratin* (a protein) with a scaly covering called the *cuticle*. Each hair is attached to the scalp by a root. The hair of every animal group or species is different. For example, the root, shape, length, colour and microscopic features of a dog hair are different from those of a human hair.

Hair from different body parts is not the same. For example, human head hair is different from human facial hair. A skilled examiner can also tell the difference between hair from different races, for example Asian hair compared to African hair.

Hair can be used to tell whether a person is a drug taker and in some cases how a person died. For example, hair that is burnt is very different from unburnt hair. Any hair that is forcibly removed can show signs of stretching and damage to the root and may even have scalp tissue attached to it.



A burnt hair (left) and a razor-cut hair (right)

A light microscope is used to examine any hair found. It is then compared to any known hairs available, for example a suspect's hair. This is done with a *comparison microscope*, which is made up of two light microscopes connected together as shown in the photograph top right. This allows both samples to be viewed together. A comparison microscope can also be used in *ballistics* (the examination of projectiles) to compare bullets.

Fibres

Like hair, fibres from materials are quite different. Natural fibres are rough and have a less uniform appearance than synthetic fibres. For example, it is quite easy to see the difference between wool and nylon. If enough material is present, it is possible to see the weave or knit pattern. You can also tell if fibres, like hair, have been cut, burnt or stretched. They may even contain other things. For example dog hair and glass fragments are easily caught in fibres.



Forensic officer using a comparison microscope



A microscope view of a piece of cotton

Glass

The properties of light make it possible to distinguish between different transparent materials. Light travels in a straight line, but when it passes through different transparent materials at an angle, it bends. This is because the speed of light changes when it passes from one material to another, for example from air into water, glass or perspex. This bending of light is called *refraction* (see page 172).

The *refractive index* is a measure of how much light bends when it passes through different materials. The higher the refractive index, the more the light is slowed down, and the more it bends. Gems such as diamonds have a high refractive index because the light is bent much more, which is why they appear to sparkle. Forensic scientists use computer systems to measure the refractive index of glass fragments in a forensic investigation.

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INQUIRY 5 Hair and fibres

You will need: microscope (review with your teacher how to use one), microscope slides, coverslips, hair and fibre samples as listed below, crucible and lid (to burn hair and fibres in), scissors, tweezers

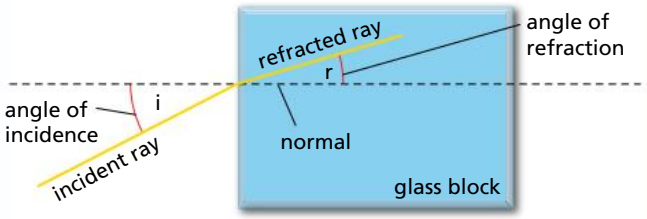
1 Using the equipment available, describe the differences between:
   - **a** human hair and dog or cat hair
   - **b** human hair and hair from a synthetic wig
   - **c** human hair and burnt or stretched human hair
   - **d** snapped human hair and cut human hair
   - **e** cotton, woollen, nylon and polyester fibres
   - **f** torn fabric and cut fabric
   - **g** normal fabric and burnt or stretched fabric.
2 Collect some fibres of lint from the filter of a clothes dryer. Bring the fibres to the laboratory to view. Place these fibres under a microscope. Are there any other materials mixed with the fibres?

INQUIRY 6 Glass analysis

In this activity you will measure how much light bends when it enters different materials.

You will need: different glass samples, perspex, light box, protractor

1 Set up the light box so that a single beam shines from the box through the sample as shown.



2 Use the protractor to measure the angle of refraction.
3 Repeat for the other samples, keeping the angle of incidence the same for each.
4 If you have a SINE function on your calculator you can work out the refractive index of light passing from air into each sample provided. To do this, measure the angle of incidence and the angle of refraction for each sample. Then divide the sine of the angle of incidence by the sine of the angle of refraction.

Over to you

1 List three properties of hair that make it useful as evidence at a crime scene.
2 The samples on the right show hair from a Maori and from a Caucasian. Describe the differences between the samples. What part of the hair are you describing?



Hair from a Maori (left) and a Caucasian (right)

3 Why do you think synthetic fibres are more uniform in appearance than natural fibres?
4 Why are comparison microscopes used in forensics?
5 What property of light makes it useful for examining samples of glass?
6 What is meant by the refractive index of glass?

PROBLEM SOLVING

Draw up a table like the one below to record the clues that are presented as you go through the chapter. Add more columns as necessary. You can fill in the first three columns so far.

Name	Sneaker prints	Hair and fibres	Glass	DNA and blood
Robert Lawson				
Trisha Court				
Wendy Gray				
Gary Silver				
Peter Hanson				

Here are some clues to help you with solving your crime after the glass and hair testing.

Clues:

- The wool caught on the glass in the tearoom matched the fibres in a jumper taken from Peter Hanson.
- When questioned about this Peter said that he looked in the window when he got to work to see what had happened, and he must have caught his jumper on the glass.
- Glass fragments were also found in the jumper, and they matched the glass from the tearoom window. The hair in the window glass matched known hairs of Wendy Gray.

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SKILL

Interpreting evidence

A valuable skill is to be able to interpret evidence. Read the following story, then use what you know about forensics to answer the questions on the next page.

'A dingo's got my baby'

On the night of 17 August 1980, at a campground at Uluru (Ayers Rock), Lindy Chamberlain cried out the now famous words 'A dingo's got my baby'. This started one of the strangest criminal cases in history. Lindy had put her young sons Reagan and Aidan and her 10-week-old daughter Azaria to bed in the family tent. Later, Lindy thought she saw a dingo coming out of the tent carrying something. She entered the tent and found Azaria missing. In panic she inferred that the dingo had taken Azaria.



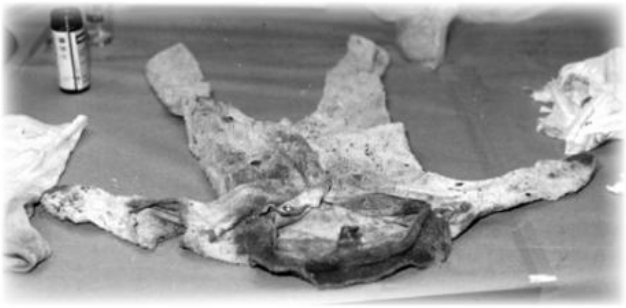
The Chamberlains' tent in the Uluru campground

A search of the area around the campsite that night found no sign of Azaria. The head ranger and campers found blood on clothing and sleeping bags in the tent. Dingo tracks were found leading from the tent, and Aboriginal trackers were brought in to follow them. The Chamberlains were moved to a local motel. No statements were taken from witnesses or the Chamberlains, the area was not cordoned off, and nothing was photographed.

The Chamberlains arrived home in Mount Isa on 21 August. During the next couple of weeks, Lindy found paw-prints and blood on Azaria's blanket and bloodstains on her own sleeping bag. She gave them to the police to help them with the investigation.

On 24 August a baby's jumpsuit was found that matched a description of Azaria's jumpsuit. The position of the jumpsuit was in question, as it looked as if it had been placed neatly where it was found. The police handled the clothing to see if there were any bloodstains on it.

On 29 September the police arrived at the Chamberlain home to take statements from them. They suspected Lindy of killing Azaria because an expert had said that the holes in Azaria's jumpsuit were not made by a dingo. Also the hairs on the blanket were cat hairs. Bloodstains that matched Lindy's blood group had been found in the Fertility Cave—close to where Azaria's jumpsuit was found.



Azaria's jumpsuit

The inquests

On 15 December 1980 an inquest was held into Azaria's death. The findings stated that a dingo had taken and killed Azaria, and humans had somehow disposed of her body.

In September 1981 the Chamberlains learnt that new evidence had been found. James Cameron, a professor of forensic medicine in London, and Bernard Sims, a forensic odontologist, had examined the jumpsuit and believed the baby had been decapitated. Cameron also found a blood-stained, female handprint on the jumpsuit which he said confirmed his findings.

On 14 December 1981 a second inquest began. By this stage the Chamberlains' car had been examined. Forensic biologist Joy Kuhl had found what she inferred to be baby's blood in the interior of the car. Fabric tuffs from a jumpsuit had been found on the floor of the car and in a camera bag. They had been cut with scissors. Blood and baby hairs were also found in the camera bag.

Cameron said he had used a special ultraviolet technique to show where the bloodstains were on the jumpsuit and to highlight the handprint found. He inferred that the baby had been buried while still wearing the jumpsuit. Sims explained that the marks on the jumpsuit were not consistent with bite marks made by dingoes, and there was no evidence of tooth marks or saliva.

On 2 February 1982, the second inquest ended. The findings were that Azaria had been murdered in the family car by Lindy Chamberlain and carried to the tent. Michael, Lindy's husband, had taken the body and buried it. Lindy had made up the story of a dingo and Michael had dug up the jumpsuit and placed it where it was found to support her story. Lindy was charged with Azaria's murder and Michael was charged with assisting her.

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SKILL

continued

The Chamberlain trial began on 13 September 1982, even though there was evidence suggesting their innocence, such as:

- Witnesses claimed that Lindy had not had time to kill Azaria in the car and return to the tent.
- The jumpsuit had been moved, so no reliable evidence could be taken from it.
- Some of the jumpsuit fibres had been torn.

Despite this evidence, Lindy and Michael were both found guilty. Michael received a suspended sentence with a 3 year probationary period. Lindy was imprisoned. During the next 6 years Lindy and Michael appealed against their convictions without success.

A Royal Commission

Public support for the Chamberlains was so strong that on 8 May 1986 a Royal Commission of Inquiry into their convictions began. This meant that the government appointed a group of people to investigate whether they had been wrongly convicted.

New tests performed by Tony Raymond, a forensic biologist, showed that there was no blood in the car. Les Smith, a scientist, claimed that the evidence presented against the Chamberlains was false. For example the blood spray pattern found in the car was a chemical spray pattern produced during manufacture. Other cars of the same make had a similar pattern. He showed that the cuts in the jumpsuit could have been made by a dog, such as a dingo. The hairs on the blanket were identified as dingo hair. The blood tests carried out by Kuhl were positive for milk as well as blood, so they were not conclusive. Finally, evidence from an Aboriginal tracker, Nipper Winmarti, confirmed the presence of dingo footprints leading from the tent to the place where the clothing had been found.



Lindy and Michael outside the court

In May 1987, Lindy and Michael Chamberlain were cleared of all charges against them, and in June 2012 a coroner ruled that Azaria had been killed by a dingo.

1. What observations were made on the night of 17 August 1980?
2. What inferences were made to explain these observations?
3. What hypotheses were made during the case?
4. Did the police follow the correct procedures when they investigated the crime scene and the jumpsuit? Explain.
5. What is an inquest and why were two inquests held into Azaria's death?
6. What is a Royal Commission and why was it held?
7. What forensic tests were carried out?
8. How would scientists know that the fibres on the jumpsuit were cut and that the hair was dingo hair?
9. What fields of forensics were involved in this investigation?
10. At the time, the case caused huge public debate over whether Lindy Chamberlain was guilty. Draw up a table with the following headings and place each piece of evidence in the correct column.

Evidence indicating Lindy Chamberlain was guilty	Evidence indicating Lindy Chamberlain was innocent

11. Use your completed table to say how you think Azaria died. Give reasons for your answer.

Corner discussion

1. Your teacher will place one of the following signs in each corner of the classroom: strongly agree, strongly disagree, unsure but I think I agree, unsure but I think I disagree.
2. Do you think Lindy Chamberlain killed her daughter Azaria? Move to the corner that applies to you.
3. Each corner must now try to convince the people in the other corners to join them. The winner of the discussion is the corner with the most students in it. Every student should contribute.

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10.3 Blood and DNA

Blood

Blood left at the scene of a crime is useful evidence. The size, shape, location and direction of bloodstains all provide information about how they were made. Bloodstain pattern analysis can show where the victim and their attacker(s) were, what happened and the possible weapon used.



Bloodstain patterns can tell a story about a crime.

Identifying a person's blood group and comparing it to blood found at the crime scene can make the person a suspect or rule out their involvement. For example, Lindy Chamberlain's blood group made her a possible suspect after blood analysis was carried out in the Chamberlain case.

There are two major systems for determining blood groups. The first is the ABO system based on *antigens* and *antibodies*. Antibodies fight substances in the body that are normally seen as foreign to the body. These substances are called antigens. The ABO system is based on the type of antigens you have on the surface of your red blood cells. For example if you have A antigen present in your blood, then your blood group is A. Similarly, B antigen means blood group B. If both antigens are present, the blood group is AB. If neither is present, then it is blood group O.

This blood grouping is also based on the antibodies present in the blood. For example blood group A has anti-B antibodies present. B blood has anti-A antibodies, AB has no antibodies and O has both antibodies. This is very important when blood transfusions are being given. Antigens and antibodies react together to produce clotting of the blood. So, a person with type A blood cannot be given type B blood because if the anti-B antibodies in the type A blood come in contact with B antigens in the type B blood, clotting will occur, destroying the red blood cells.

The Rhesus (Rh) system is the second type of blood grouping. If you are Rh positive there are D antigens present in your blood. If you are Rh negative there are no D antigens. The two blood grouping systems together classify people into eight blood types as shown in the table.

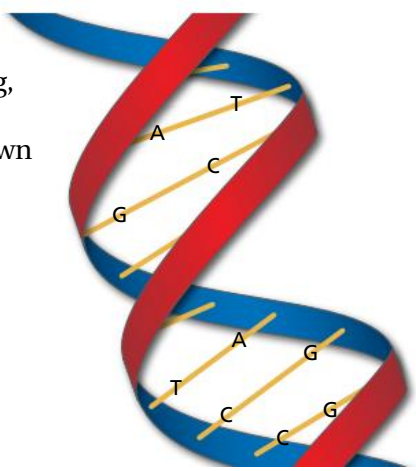
Blood groups	Percentage in Australian population
O positive	40
O negative	9
A positive	31
A negative	7
B positive	8
B negative	2
AB positive	2
AB negative	1

If blood at the scene of a crime was found to be AB negative and the suspect had AB negative blood, then this would be a strong piece of evidence to link the suspect to the crime, given the low percentage of people with this blood group. However, if the blood at the scene and the suspect's blood were both O positive, then this would not be as convincing. If the suspect had a different blood type altogether, then they could not be placed at the crime scene based on blood group alone.

DNA profiling

DNA profiling was introduced in 1985 by Alec Jeffreys. It was called DNA fingerprinting because, just as each person has a characteristic set of fingerprints that sets them apart from others, so too every person has a characteristic DNA fingerprint.

DNA stands for **d**eoxyribo**n**ucleic **a**cid. It is the genetic information contained in each cell nucleus in your body that makes you the person you are, and different from everybody else. The DNA throughout your body is the same. So the DNA found in your blood, skin and bone will be the same as the DNA found in your hair roots and saliva. Each DNA molecule looks like a long, twisted ladder made up of units called bases, shown here as A, T, C and G.



The diagram shows part of a DNA molecule with the bases labelled. Adenine (A) pairs with thymine (T); cytosine (C) pairs with guanine (G).

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There are about 3 billion DNA bases in each cell. These bases vary between individuals and are clustered together. One type of cluster is called a single tandem repeat, and is where base sequences are repeated. You inherit some of these repeated base sequences from your mother and some from your father. To make a DNA profile or to carry out DNA profiling, repeated base sequences are examined at 10 sites or places on the DNA.

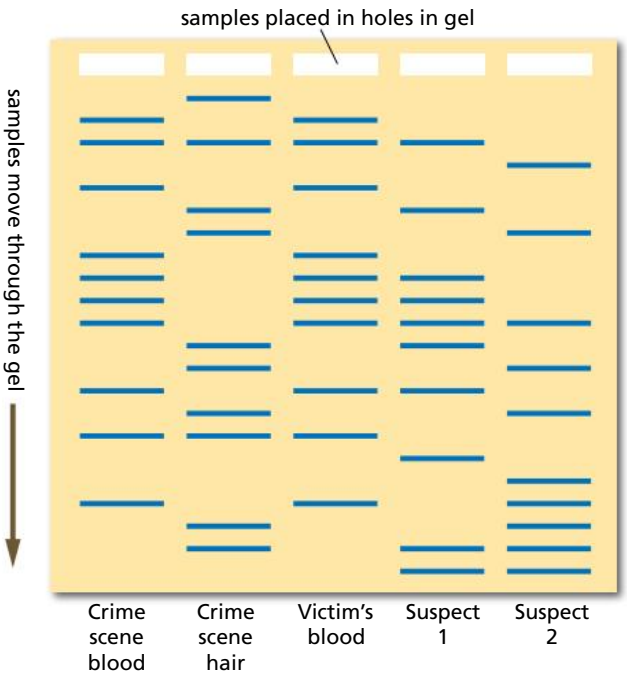
In Australia the chance of two people having the same profile at all 10 sites on the DNA is one in hundreds of millions. (This is not true for identical twins, who will have the same profile.) So if the DNA profile made from DNA found at a crime scene matches the DNA profile of a suspect, then the DNA almost certainly came from that person.

To make a DNA profile a special process is carried out. Enzymes are used to cut the repeated base sequences into fragments at specific sites. These fragments are usually made up of 3–7 bases. Slight variations between the size and shape of these fragments from one person to another can be detected using a process called *electrophoresis* (electro-for-EE-sis). The DNA fragments are placed in wells or holes at one end of a plate of thick gel. The gel near the DNA is negatively charged and so are the DNA fragments. The gel at the opposite end of the plate is positively charged. So when an electric field is created, the DNA fragments are attracted to the positive end of the plate and start to move through the gel.



Placing samples of DNA into a gel to make a DNA profile

The smaller, lighter fragments of DNA move through the gel much faster than the larger fragments. When the process is finished, the gel is stained with dye and each DNA fragment shows up in the gel as a band, a bit like a barcode. The patterns of the bands can then be compared with patterns from other individuals. The diagram below shows how five samples can be tested and compared. In this case, the only blood found at the crime scene is the victim's blood, and neither suspect can be placed at the scene of the crime on the basis of their DNA profile. This is because the 10 bands produced in the gel by the movement of the 10 DNA fragments are not all in exactly the same place. A complete match with all 10 bands is needed to place a suspect at the scene of a crime.



DNA profiling can also be used to establish whether a person is the parent of a particular child. In cases like these, some of the bands on the child's profile match the profile of the mother and some of the bands match that of the father. To establish parentage, at least four bands must match.

It is possible to make copies of DNA to produce a larger sample. So only a trace of blood, skin, semen or even a single hair is needed. Scientists can replicate the DNA found to make a sample large enough to produce a DNA profile. So a single hair could link a suspect to a crime scene or eliminate them from further investigation.

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INQUIRY 7

O. J. Simpson

One of the largest criminal cases in history was the trial of Orenthal James Simpson, a famous United States football player and sports commentator. He was accused of killing his ex-wife, Nicole Brown, and Ronald Goldman on 12 June 1994. Goldman had been returning a pair of glasses to Brown, which she had left at the restaurant where he worked



O.J. Simpson and Nicole Brown

The bodies of Brown and Goldman were found in the garden outside Brown's house in Los Angeles. A set of keys, a blue knit cap, a bloodstained leather glove and an envelope with glasses inside it lay next to her body. Brown's head was almost severed from her body. Her feet were clean, which meant she had not walked in any blood, so it was inferred that she died where she was attacked. The wounds to Brown indicated that the attacker was right-handed and had cut her throat from behind.

Goldman also had his throat slashed, and had stab wounds to his body and left thigh. His shirt was crumpled up around him, indicating his body had been dragged. Bloody footprints leading away from the scene indicated just one killer.

O.J. Simpson was immediately considered to be a suspect. He had physically abused Brown during their marriage and never accepted their divorce, or her dating other men. When the police arrived at Simpson's house they found blood spots on and in his car, and blood spots leading from the car to the house. A bloodstained leather glove was found in his garden, a match to the one found near Brown's body.

Simpson had left very late the night before to go to Chicago. After evading the police, he was taken and interviewed. His fingerprints and a blood sample were taken. He had a cut on the middle finger of his left hand. Later his house was searched and evidence was collected, including socks found in his bedroom. DNA profiling showed that blood on the socks matched Brown's blood, with odds of 1 in 10 billion that it was someone else's blood.

Blood found on the glove in Simpson's garden matched his blood and that of the two victims. Hair found on the cap matched Simpson's hair. Blood drops at the crime scene matched his blood group, and blood in his car belonged to him, Brown and Goldman. The footprints at the crime scene matched the shoes that Simpson had been photographed wearing. He was known to have purchased a knife that was similar to the murder weapon.

The trial began on 23 January 1995. Simpson's defence was that he was innocent because the evidence found with Brown and Goodman had been planted. The defence disputed the DNA evidence because they claimed it had been contaminated during collection. They also showed that Simpson's hands were too large to fit into the gloves found. He could not get his hand into one of the gloves in court.



O.J. Simpson trying on the glove. 'They're too tight' he said.

After a trial that lasted nine months, O.J. Simpson was found not guilty. It was a result that amazed all involved.

1. What observations were made about the bodies of Brown and Goldman when they were found?
2. What inferences were made to explain these observations?
3. In many murder investigations the police look for a *motive* or reason why a person would commit a crime. What motive was given to explain why Simpson killed his wife?
4. List all the pieces of evidence that were found and the possible forensic tests that could be performed on each.
5. Explain in your own words how DNA profiling works.
6. From the evidence presented here, do you think O.J. Simpson is guilty? Explain your reasoning and present your findings to the class.

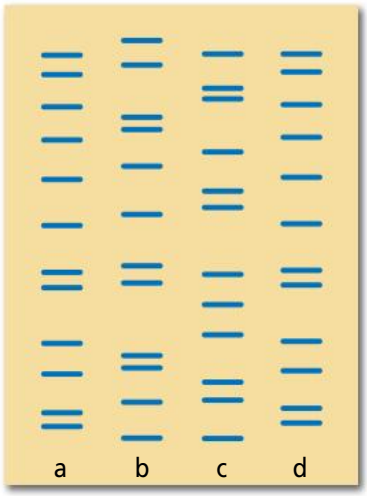
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INQUIRY 8 DNA profiles

You will be presented with three different cases to solve using DNA profiles. Examine the profiles carefully and present your findings to the class.

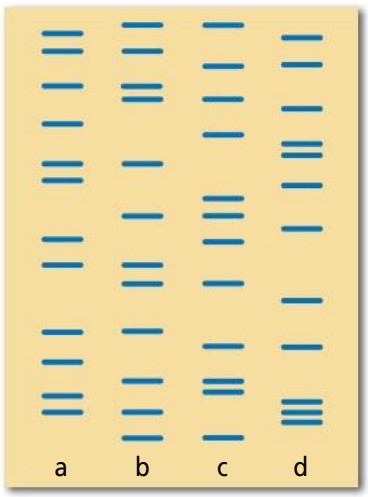
1 Do the profiles of any of the three suspects match the crime scene DNA? Can any suspects be eliminated?

- **a** Crime scene
- **b** Suspect 1
- **c** Suspect 2
- **d** Suspect 3



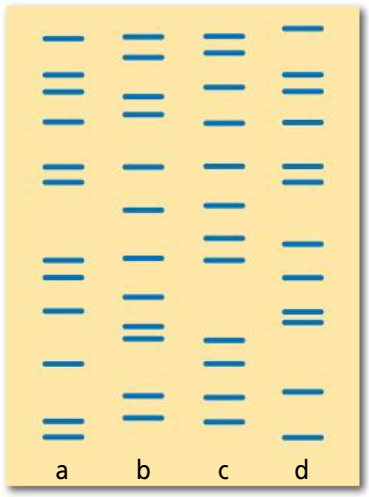
2 There is doubt over which male is the father of a child. Is there a match between the child and the mother? Which male is the father?

- **a** Mother
- **b** Child
- **c** Male 1
- **d** Male 2



3 Are either of the bodies recovered from a housefire the missing son of the mother and father tested? Explain your reasoning.

- **a** Body 1
- **b** Body 2
- **c** Mother
- **d** Father



INQUIRY 9 UV light and stains

In the Azaria Chamberlain case, James Cameron found a bloodstained handprint on the jumpsuit by using UV light.

You will need: UV light, white cotton squares 10 cm × 10 cm stained with different materials and left to dry, e.g. blood from meat, glue, moisturising lotion, detergent, lemonade, tonic water, hairspray, water, methylated spirits, kerosene, milk, perfume

Examine each of the stains provided under UV light.

- What difference does the UV light make to each stain?
- Explain whether it is easy to tell the difference between stains, for example between milk and blood?

Over to you

1 What can bloodstain pattern analysis reveal at a crime scene?
2 How is the ABO blood group system different from the Rhesus blood group system?
3 If you have type B blood, which antigen do you have in your blood? Where is this antigen found?
4 Draw a column graph showing the percentages of various blood groups in Australia.
5 If a suspect had AB positive blood and this matched the blood found at the crime scene, why would this be more convincing evidence, than if the suspect had A positive blood?
6 What is DNA? How can DNA be used in a criminal investigation?
7 If crime scene DNA matches a suspect's DNA, can the suspect be convicted on this evidence alone?

PROBLEM SOLVING

Have you started to see a pattern in your crime scene evidence? Do you think you know who committed the crime? Here are some more clues after DNA profiling was performed.

Clues:

- The DNA profile of the hair caught in the glass matched the DNA profile of hair from Wendy Gray.
- The DNA profile of blood smeared on the jagged edge of the glass matched the DNA profile of blood from Gary Silver.

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10.4 Fingerprints and ink

Identical twins have the same DNA profile, but they don't have the same fingerprints.

When you sweat, salts, excess water and urea are secreted onto the skin. Glands in the skin also produce oil that finds its way to the skin surface. Substances such as dirt and grease can stick to the skin too. These substances dry and remain on the skin. They can then be transferred onto surfaces, producing a print of the patterns on the skin surface.

There are three basic fingerprint patterns, shown below. Fingerprints can also be a combination of these patterns. These are called *composite* prints.



Loop



Arch



Whorl



Composite

INQUIRY 10 Your own fingerprints

You will need: ink pad, chalk, carbon powder (charcoal), talcum powder, plain and glossy white paper, plain and glossy black paper, microscope and slide

1. Use the ink pad to make a copy of each of your fingerprints. Describe the different patterns in your fingerprints. Are they all the same? Are they different? How many different patterns do you have?
2. Use the materials provided to make different types of fingerprints. Which materials give the best prints? Which prints would last the longest?

INQUIRY 11 Identical twins

The following prints were taken from identical twins.

	Left hand				Right hand				
	little	ring	middle	index	thumb	thumb	index	middle	ring	little
Twin 1										
Twin 2										

1. What patterns can you see in the fingerprints of each twin?
2. Describe the similarities and differences between the sets of prints from the twins.
3. Explain whether you expected the fingerprints of the twins to be the same or different. Is this the case for their DNA profile?

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INVESTIGATION

2 Fingerprints

Aim

To obtain fingerprints from different surfaces.

Risk assessment and planning

1 What chemicals will you be using in this practical?

2 Do any procedures need a fume cupboard? Discuss any safety requirements with your teacher.

Apparatus

- carbon powder
- clean drinking glass
- paint brush
- ninhydrin solution
- *iodine crystals*
- superglue
- plain white paper
- tweezers
- 250 mL beaker
- snaplock sandwich bags
- gas jar and glass cover
- small test tube
- empty takeaway sauce container
- scissors



Method

Part A

1 Hold the drinking glass with your fingers.

2 Dip the paint brush in the carbon powder and lightly dust the glass with the powder where your fingers were.

3 Describe how successful you were in obtaining your prints in this way.

Part B

1 Cut a piece of plain white paper so that it is small enough to fit into a beaker.

2 Press your fingerprints onto the paper.

3 Using tweezers, dip the paper with your prints on it into a beaker of ninhydrin solution.

Do this in a fume cupboard.

Remove the paper from the solution, allow it to drain and place it in a snaplock sandwich bag.

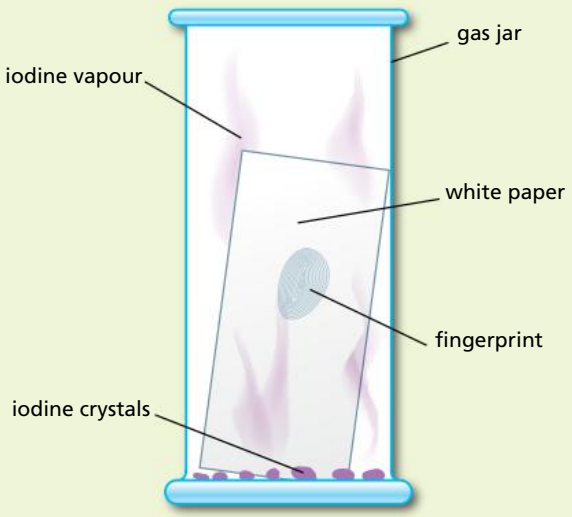
4 Seal the bag and leave it in a warm place for about 24 hours (an incubator may be needed). Observe your fingerprints after this time.

Part C: Teacher demonstration

1 Cut a piece of plain white paper small enough to fit into a gas jar.

2 Press your fingerprints onto the paper, then place it into the jar.

3 Using tweezers, place some iodine crystals into the bottom of the gas jar. Cover the jar. The vapour from the iodine should produce brown prints on the paper.



Part D

1 Hold a small test tube with your fingers.

2 Carefully place the test tube into a snaplock sandwich bag.

3 Squeeze a generous amount of superglue into a takeaway sauce container. Place this into the bag next to the test tube. Be careful not to spill the glue.

4 Seal the bag and leave it in a warm place for 24 hours (an incubator may be needed). The vapours from the glue should crystallise and form white fingerprints.

Results

1 Describe the fingerprints you produced. Which procedure was the easiest to perform and which produced the clearest prints?

2 What does it mean when the police 'dust for prints'?

3 Why do you think the police seal off a crime scene and stop people from touching or moving any evidence?

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Altering documents

Documents that are used as evidence in court can be examined to see if they have been illegally altered. Something that is altered or copied in this way is called a **forgery**. Signatures can be verified, handwriting comparisons can be made, notes and diary entries can be dated, and latent (hidden) writing impressions can be developed. For example, if a person writes in a notebook an impression of their writing may be left on the pages underneath.

Documents can be tested to see if all the details they contain were written at the same time or on different occasions. As no two people write in exactly the same way, samples of handwriting can be compared and the writer identified or suspects eliminated. Signature forgeries using tracings or photocopies can also be detected. Instruments that use UV and infrared light can detect different papers and inks used, and any alterations to documents.

These techniques are very important because medical records, minutes of meetings, diary entries, agreements, contracts, wills, receipts, cheques, anonymous letters, personal notes and application forms can be altered to support a person's claim.

Chromatography

Chromatography is used to separate mixtures into their parts by allowing the mixture to be adsorbed by a solid. In paper chromatography, paper is used to separate ink mixtures. Drugs such as barbiturates, cocaine, heroin and alcohol can be separated from blood by gas chromatography. The blood is turned into a gas or vaporised at high temperatures. It is then passed through a column that separates the different chemicals in the blood. Gas chromatography can also be used to detect if any accelerants have been used in a fire. Accelerants are highly flammable substances that can be used to start a fire, for example petrol, kerosene, diesel and mineral turpentine.

PROBLEM SOLVING

Here are the final clues to help you solve your crime after the fingerprint analysis.

Clues:

- The fingerprints on the papers scattered across the floor belonged to Robert Lawson, Tricia Court and Wendy Gray.
- The cheques presented at a local bank the next morning were recovered. A forged signature had been used on each of the cheques. Handwriting analysis showed the signatures were forged by Wendy Gray.

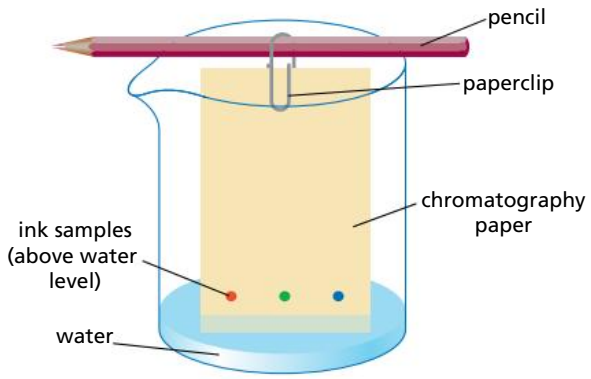
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INQUIRY 12 **Forgery**

You will need: ink from different non-permanent pens, different paper samples, chromatography paper, paperclip, pencil, UV light, crayon or charcoal

1 Test the different inks and paper samples under UV light. What differences can you detect?

2 Set up the inks and chromatography paper as shown below. What differences can you find between the inks used?



3 Place a piece of paper over blank pages in your notebook. Write your name on the paper, pressing firmly with a pencil so that you leave an impression of your name underneath. Remove the top piece of paper, and rub charcoal or crayon gently over the impression.

Over to you

1 Explain whether fingerprints or DNA left at a crime scene would provide better evidence.

2 How are fingerprints collected at a crime scene?

3 How many different fingerprint patterns are there? Describe each one.

4 If the fingerprints found at a crime scene belonged to a suspect with an identical twin, could you be certain the fingerprints were the suspect's? Explain.

5 Explain why you think people would want to illegally alter:

- **a** a will
- **b** medical records
- **c** a diary
- **d** a receipt
- **e** artwork
- **f** an insurance certificate.

SCIENTISTS AT WORK

Dr David Ranson

Dr David Ranson is a medical practitioner who specialises in forensic pathology. This means he investigates the cause of any unnatural death, and carries out wound and injury interpretation. The results of the investigations he performs are given to the coroner so a finding can be made about how the person died. They can also be given to the police or to lawyers for court cases, or used in coronial inquests.

Dr Ronson studied medicine at the University of Nottingham in England. He then worked as a pathologist and later as lecturer in pathology at Bristol University, teaching forensic medicine to medical and dental students, and carrying out research. He went on to complete a law degree and work as a police surgeon. In this position he assessed the injuries of people for the police. For example, if a person said they had been raped or abused, Dr Ranson would examine their injuries.

In 1988, Dr Ranson came to Melbourne to work at the Victorian Institute of Forensic Pathology as Senior Pathologist. He has written articles, journals and books on forensic medicine, pathology and autopsies.

Dr Ranson's day

There are usually 10–15 autopsies that need to be performed each day. Dr Ranson starts his day by meeting with other pathologists to review and allocate cases. Autopsies are performed when people die suddenly and unexpectedly. For example, a person might be found dead in their home, a patient might die on the operating table, somebody may have died in a light plane crash, or the driver of a car may have hit a tree.

Fewer than 5% or 65–75 cases per year in Victoria are homicides, and about the same number again are regarded as suspicious. For example, a person may have been found dead in a hotel car park with a head injury. The injury may have occurred from falling or from being hit on the head.

Before an autopsy is performed, forensic technicians weigh and measure the body, take blood samples for analysis, and take the body for X-rays. So when Dr Ranson starts the autopsy, X-rays are available for him to view. X-rays can tell a lot about how a person died. For example if a pilot died in a plane accident, an X-ray may reveal whether the pilot was holding the controls of the plane when it crashed.

On average Dr Ranson performs about three autopsies per day. Some take about an hour to complete, while others can take 6 hours or more. For example, if a person is stabbed 80 times, the size, shape and location of each wound must be described. This could take 24 hours.

After the autopsy, Dr Ranson writes a report for each case. This involves reviewing the biopsies (tissue samples taken from the body), blood analysis, and reports from specialised areas (for example, toxicology, if a drug analysis was done).

Dr Ranson's day could also involve going to court to present his findings, visiting the scene of a crime to look for evidence that could assist him in confirming the cause of death of one of his cases, or talking to relatives of a deceased person who want to know how their loved one died. He works up to 11–12 hours each day.

Dr Ranson's job is not pretty. He has seen some horrible sights, such as dismembered bodies and bodies that have been involved in an explosion. There is also the smell (which doesn't bother him), as well as bodies arriving with flies buzzing around them and full of maggots. His job is a bit different from the way it is shown in books and TV shows. While these shows may sometimes be technically correct, he doesn't chase or talk to suspects, or use a gun. However, his work does help solve the mystery of how many people die.



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THINKING SKILLS

1 *Asphyxiation* is death from lack of oxygen in the blood. This can occur as a result of gas poisoning in which another gas takes the place of the oxygen. What gas present in the blood of a deceased person would indicate death from car exhaust fumes?

2 In the O.J. Simpson trial, the murderer must have hidden in the bushes in the garden waiting to attack. It has been suggested that forensic palynology or using 'pollen fingerprints' could have helped solve this case.
- **a** What is palynology and how could it have helped with the Simpson case?
- **b** Where would pollen samples need to be taken?
- **c** What sort of results would implicate Simpson?
- **d** What sort of results would eliminate Simpson as a suspect?

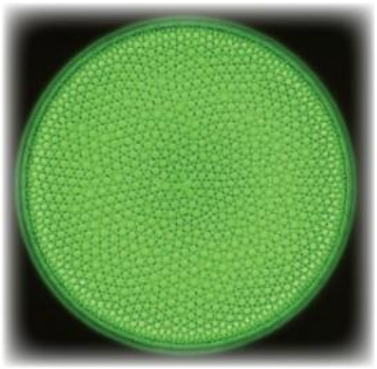
3 How could palynology be used to show whether a person is growing marijuana?

4 It has been said that 'A jury consists of 12 persons chosen to decide who has the better lawyer'.
- **a** What do you think is meant by this statement?
- **b** Does the O.J. Simpson case support this statement? Give reasons for your answer.

5 Hair can show whether a person has taken drugs and if so, for how long. Hair grows about 1 cm per month. So 1 cm of hair would provide a detection time for drugs of about one month.
- **a** How could hair be used for random drug testing in sport?
- **b** Why would hair be more useful than a urine test for detecting drugs?

6 It is possible to identify a suspect from bite marks left in food or other materials at a crime scene.
- **a** What field of forensics would be involved in this type of investigation?
- **b** What sort of procedure do you think would be needed to identify the bite marks?
- **c** Design your own procedure to show how bite marks can be used as evidence.

7 When a body is found in a river, stream or lake, and the cause of death is drowning, it is necessary to determine whether the person died in the water or somewhere else, for example a bathtub. The presence or absence of *diatoms* in the water in the lungs will indicate where the person drowned.
- **a** Find out what diatoms are and where they are found.
- **b** Explain whether you are likely to find diatoms in household water.
- **c** How can diatoms be used in a drowning to determine where the person died?
- **d** Examine drops of fresh water or sea water under a microscope. Can you see any diatoms?



One type of diatom

8 The inside of the barrel of a gun is grooved. When the gun is fired, these grooves leave rifling marks on a bullet. If a bullet is found at a crime scene, it can be compared with bullets fired from any guns discovered, to see if there is a match. This type of investigation is carried out by a ballistics expert. Find out more about ballistics and the procedures used to identify bullets and guns.

9 A school staffroom was robbed of money. The science staff placed a $5 note painted with methyl violet in an open drawer, hoping the thief would return. One morning, the staff entered their staffroom to find they had been robbed again. There were fingerprints everywhere and the thief was easily found.
- **a** Experiment with methyl violet.
- **b** Why couldn't the methyl violet be detected on the note?
- **c** What colour were the fingerprints?

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 Forensics provides evidence for presentation in _____. It relies on the belief that every contact leaves a _____.
2 There are three main areas of forensics. Forensic _____, forensic medicine and forensic _____. Each field contributes to the collection of evidence.
3 A _____ is a magistrate who determines how, when and why a person died. They do this by holding an _____, at which all evidence is presented.
4 Soil can be identified by the substances in it such as gravel, water, humus and _____.Tests such as pH can distinguish between different soil samples.
5 The properties of a _____ such as the root, shape, length, and colour can be used to identify it. _____ can be identified in a similar way.
6 A measure of how much light bends when it passes through different transparent materials is called the _____.
7 Blood, hair and skin can be used to make a _____. No two people other than identical twins have the same DNA.
8 No two individuals have the same _____.
9 Documents can be easily _____. Forensic techniques can detect any alterations to documents such as wills, receipts, medical records and diaries.

coroner
court
DNA profile
fibres
fingerprints
forged
hair
inquest
pathology
pollen
refractive index
science
trace

Self-management

Writing multiple-choice questions

Multiple-choice questions are often used in tests. Each question has four possible answers, the correct one and three incorrect ones. Usually two of the incorrect responses are obviously wrong, and a third one is close to being right, to trick people who are trying to guess. Here's an example:

The word 'forensic' means:

A every contact leaves a trace
B all scientific testing
C connected to or used in courts of law
D solving cases.

In this example:

A is an underlying principle behind forensics, but isn't what 'forensic' means
B is wrong because not all scientific testing relates to forensics
C is the correct response
D is wrong because it doesn't explain what 'forensic' means.

Words like *all*, *every*, *always*, *many*, *some*, *sometimes* are often used in multiple-choice questions to make generalisations and mislead the reader. Answers with these words in them need to be thought about carefully.

1 In groups of three, write three multiple-choice questions using information from this chapter. Make sure each question has only one correct answer. Record the correct responses too.
2 Swap your group's questions with those of another group and answer their questions.
3 Check the answers. How good were you at writing and completing multiple-choice questions?

PROBLEM SOLVING

Did you solve the crime? Discuss your decision with the class. Here's the verdict:

Peter Hanson, Gary Silver and Wendy Gray together committed the crime. Peter Hanson broke the tearoom window. Peter and Gary Silver (inside the room) helped Wendy Gray climb in through the window. Wendy Gray opened and emptied the safe. Gary Silver helped Wendy Gray out of the window back to Peter Hanson.

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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources

OneStopDigital

1 A comparison microscope would be used to:

A examine the marks on a single bullet

B examine a single hair

C carry out a blood test

D compare a hair found at the crime scene with a hair from a suspect.

2 Fingerprint evidence is very useful at a crime scene because:

A no two individuals have the same fingerprints

B you can see what the criminal touched

C they are sweaty, so DNA is left behind

D they show what the criminal had on his hands.

3 A forensic pathologist would examine:

A the teeth of a victim to identify the body

B maggots in a body to determine the time of death

C pollen samples from the crime scene

D changes in the body due to wounds and injury

4 A very small amount of DNA is found at a crime scene. What procedure would need to be carried out *first* to analyse the DNA?

A a blood test, so the blood group is known

B cutting up the DNA with enzymes

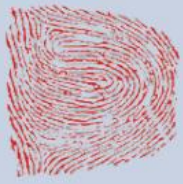
C making copies of the DNA to make a larger sample

D electrophoresis to separate the DNA

5 **a** Classify each of these fingerprints.



b The fingerprints you have just identified were found at a crime scene. The main suspect had the following fingerprint. Could this fingerprint be used to place the suspect at the crime scene? Explain.



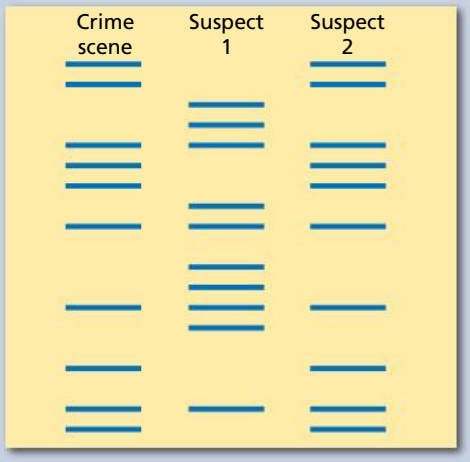
c Would this evidence be enough to convict the suspect? Explain.

6 What is the difference between forensic science, forensic medicine and forensic pathology?

7 **a** What forensic procedure would be used to determine whether a fire was deliberately lit?

b What type of material would this procedure identify if the fire was deliberately lit?

8 The following DNA profiles were compared.



a What do the bands on the DNA profiles represent?

b How are these bands created?

c To make a DNA profile, repeated base sequences are examined at how many sites?

d Would the same number of sites be needed for a match in a paternity suit?

e Explain whether either of the suspects could be placed at the crime scene.

f Could any other people have the same DNA profile as the guilty person? Explain.

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11



Plate tectonics

By the end of this chapter you will be able to …

Knowledge and Understanding

- outline how the theory of plate tectonics has changed ideas about the structure of the Earth and continental movement over geological time (ES2a)
- describe how heat energy and convection currents in the Earth's mantle cause the movement of Earth's plates (ES2b)
- outline how the theory of plate tectonics explains global patterns of geological activity, including earthquakes and volcanoes (ES2c)
- describe how technological developments have increased scientific understanding of global patterns of geological activity (ES2d)
- describe some impacts of volcanic eruptions and earthquakes (ES3b)

Skills—Working Scientifically

- use models to explain geological phenomena and make predictions (8e)

LITERACY FOCUS

anticline
asthenosphere
continental drift
convection current
fault
folding
geothermal
Gondwana
lithosphere
mantle
nickel
Pangaea
plate tectonics
porous
strata
subduction
syncline
tsunami
Uluru
weathering

Focus for learning

Would it amaze you to know that an earthquake occurs in the world almost every day? You may think that they are far away from you, but earthquakes have occurred in Indonesia, New Guinea, Fiji, New Zealand and even in Australia.

Earthquakes show that the Earth is not a ball of solid rock floating in space, but a planet that is constantly changing. Earthquakes are not the only forces changing the face of the Earth. There are also active volcanoes scattered throughout the world. On average, a volcano erupts somewhere in the world once a week! Over millions of years mountain ranges are being formed and rocks are being lifted to the surface of the Earth. These rocks are then slowly worn down again by weathering and erosion. Rivers, lakes and seas carve away the landscape, sometimes leaving strange rock formations.

The Earth is forever changing. Some of these changes go unnoticed. Others are reported in newspapers and TV news channels because they cause so much damage and loss of life. This chapter looks at some of these changes and examines why they occur.

The earthquake in Christchurch, New Zealand on 22 February 2011 killed 181 people.

PROBLEM SOLVING

Building a model

Your task is to make a model to explain one feature of the Earth that causes change. For example, you could choose to model:

a seafloor spreading

b plate boundaries

c continental drift

d folding and faulting

e mountain formation

f convection currents in the mantle.

Some of these terms of course won't mean much to you at the moment, but they will become clearer as you read through the chapter.

Display your model in a 2 minute class presentation, explaining what it shows. The rest of the chapter will help you with this task.



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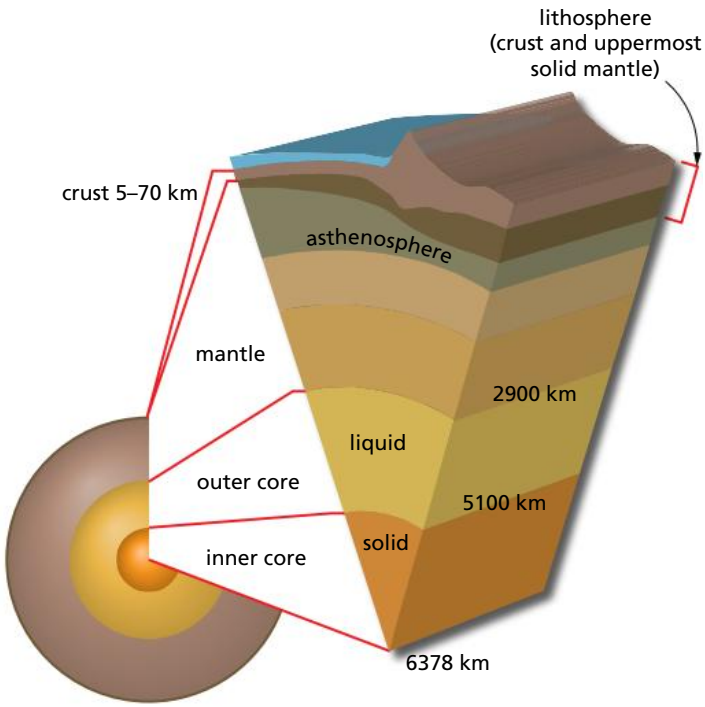
11.1 Inside the Earth

To understand the changes that take place on the surface of the Earth and explain why they occur, you need to know what the inside of the Earth is like. Let's review what you should know from previous study.

The layers of the Earth

Layer of the Earth	Thickness and temperature	Made up of	Special features
crust	35–70 km thick under continents, 5–10 km thick under oceans, 20°C up to 870°C	continental crust: granite oceanic crust: basalt	The Earth's crust is not as thick as the other layers, and can break. It can be as thin as 5 km, especially under the oceans and volcanic regions, and as thick as 70 km under mountain ranges.
mantle	2900 km thick, 870°C to 2200°C	iron, magnesium, silicon, aluminium and calcium	The mantle consists of two layers—the upper and lower mantle. Most of the heat of the Earth is contained in the mantle.
core	3500 km thick, 5000°C	nickel–iron alloy in outer core (2200 km thick) and an iron inner core (1278 km in radius)	Made up of two layers—a solid central core and a liquid outer region. The rotation of the Earth causes the liquid outer core to spin, creating a magnetic field around the Earth.

The crust and upper part of the mantle form the solid topmost layer of the Earth. It is called the *lithosphere*, from the Greek word *lithos* meaning stone. This solid layer is broken up into large pieces called plates. The continents and oceans are on top of these plates, which slide under, over or next to one another. Geologists infer that this movement occurs because the lithosphere floats on a very hot, semi-solid part of the mantle. This layer is called the *asthenosphere*, from the Greek word for weak—*asthenes*. The asthenosphere is soft and flows under high heat and pressure. To picture this you need to imagine a broken Caramello Easter egg that hasn't fallen apart. The chocolate shell itself (lithosphere) is very thin and brittle compared to the layers underneath. Each broken fragment sits on a thick, gooey layer of caramel (asthenosphere) which flows more when the egg is warm. If this Easter egg had a solid chocolate centre, this could represent the Earth's inner core.

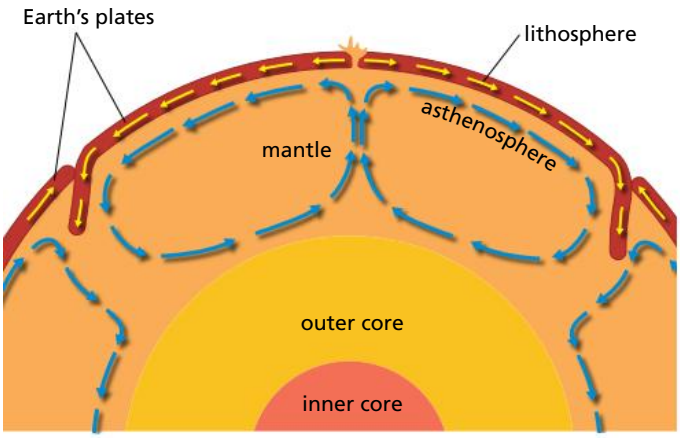


What causes the Earth's crust to move?

There is still huge debate as to what causes the Earth's plates to move. Scientists infer that the hot, semi-solid mantle that lies underneath the plates causes them to move. The semi-solid material in the mantle flows because it has experienced millions of years of tremendous heat and pressure inside the Earth.

The hot semi-solid material is heated and rises to the surface of the Earth. It then starts to cool and sinks again, and the cycle is repeated. This circular movement is called *convection*. The plates move because of the convective flow underneath them, like a person riding an escalator. (See the diagram on the next page.)

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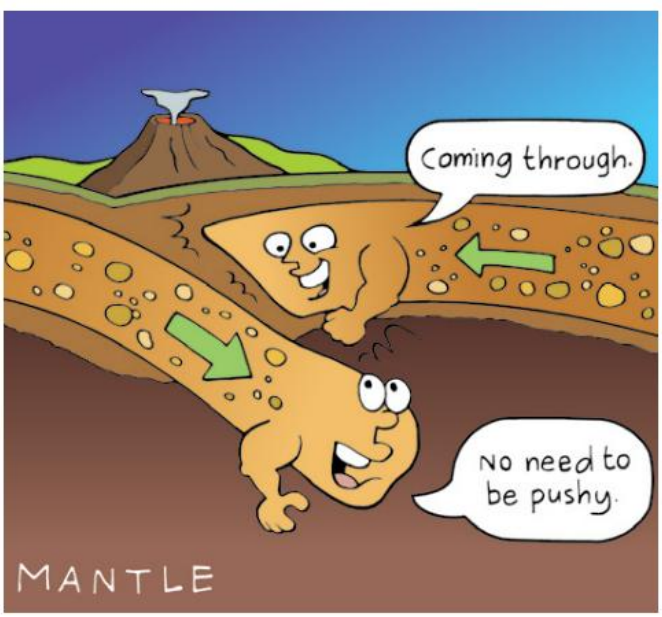


Convection currents in the mantle

In Chapter 2 of this book you learnt about radioactive decay and how this produces energy in the form of heat. As radioactive elements like uranium and potassium inside the Earth decay, massive amounts of heat are produced. Scientists believe this produces the heat needed for convection in the mantle to occur.

The Earth formed 4.6 billion years ago when gravitational forces pulled and squeezed together gas, dust and solid particles in space. The heat left over from this process also contributes to the heating of the Earth's interior.

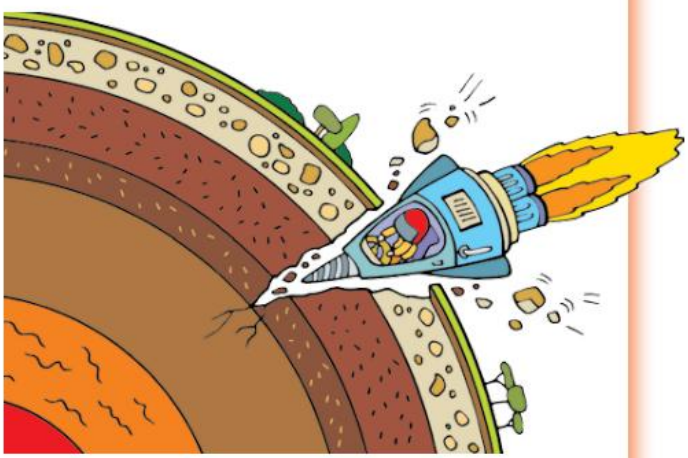
In certain places on the Earth's surface, one plate rides on top of another plate, forcing the bottom plate to sink into the mantle. The slow sinking of the bottom plate pulls the rest of the plate behind it. Some scientists infer that this action, as well as convection, causes plate movement.



INQUIRY 1

Journey to the centre of the Earth

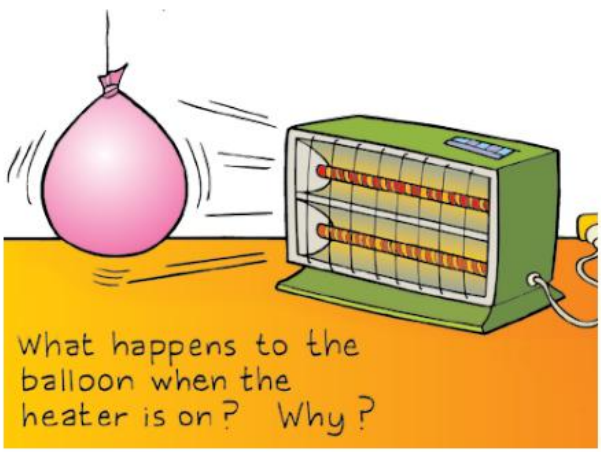
Jules Verne wrote a well known novel called *Journey to the Centre of the Earth*. In it he described how a group of explorers moved through the Earth to its core and found their way back out again. It was of course all fantasy. Imagine you have an Earthship that can blast through the Earth's interior, withstanding the massive heat and pressures there. Describe your journey to the centre of the Earth.



INQUIRY 2

Convection currents

Design your own activity to demonstrate how convection currents work. There are many ways to do this, but one way is shown below. Use your demonstration to explain how convection could move the plates on the surface of the Earth.

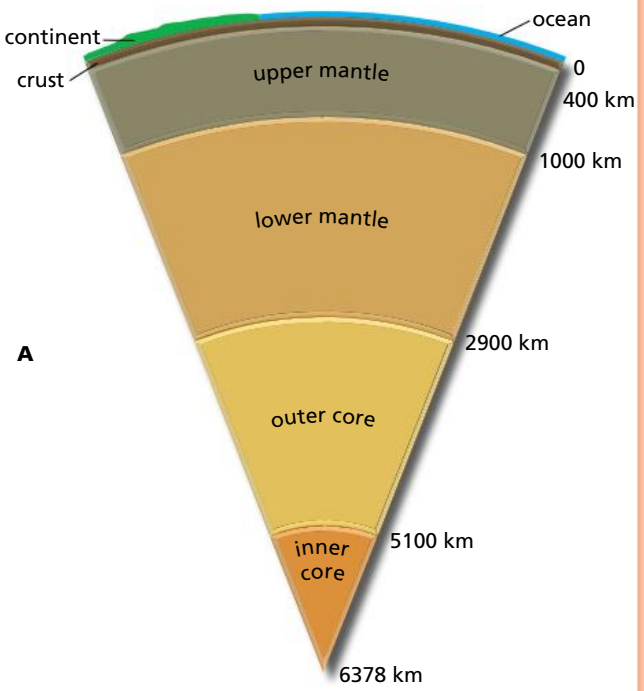


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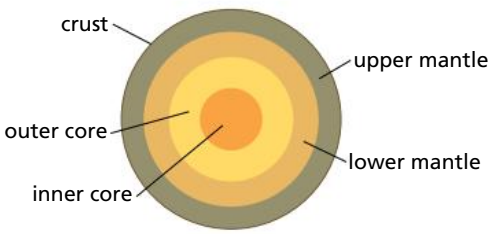
INQUIRY 3 Earth diagrams

There are many diagrams that show the different layers of the Earth. Three of these are presented here. Explain which diagram you think is best. What are the good points and the limitations of each of the diagrams? Draw your own diagram of the Earth that shows the different layers inside. Use colour to show the temperature of each layer.

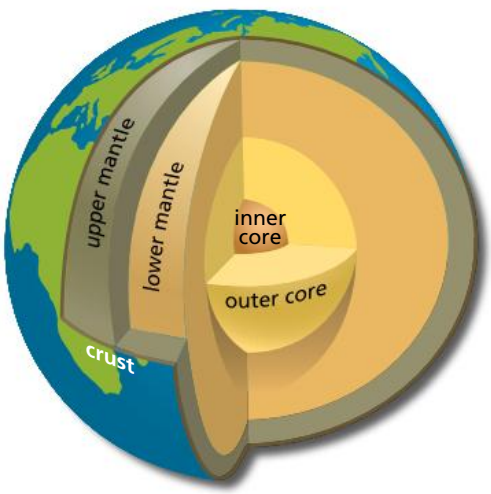
A



B



C



INQUIRY 4 Modelling the crust and the mantle

Using any resources that are available to you, make a model to show how the Earth's crust is thicker under the continents than under the oceans. Show also how the crust is broken into numerous plates and how these sit on the semi-solid mantle. You could make this your chapter problem.



Over to you

1. The mantle makes up 84% of the Earth's volume, the core is 15% and the crust is only 1%. Draw a pie chart to display these figures.
2. What is the difference between the lithosphere and the asthenosphere? Using your own model (other than a Caramello Easter egg), describe the layers of the Earth.
3. What explanations have been put forward to explain the movement of the Earth's crust?
4. How is enough heat generated within the interior of the Earth to cause convection currents in the mantle?
5. If the Earth's plates float on top of the mantle, what can you infer about the density of these plates compared to the semi-liquid material that makes up the mantle?
6. The Russians have drilled a hole 12 km into the Earth. What difficulties are they likely to encounter as the depth increases?
7. If the mantle was solid, not semi-liquid, what effect do you think this would have on the Earth? Explain.

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11.2 Continental drift

The picture we have of the Earth today is very different from what scientists inferred it was like years ago. Early ideas were that the Earth was solid and the features on its surface permanent.

In 1596 a Dutch map maker called Abraham Ortelius noticed that the coasts of North and South America, Europe and Africa had shapes that could be fitted together. In 1620 Sir Francis Bacon also examined the coastlines of South America and Africa and suggested they might once have been joined together.

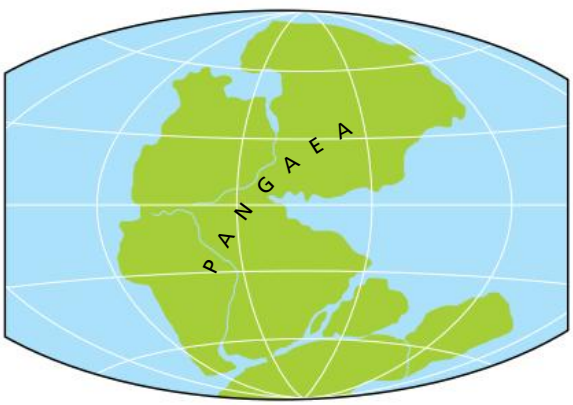
In 1912 a meteorologist named Alfred Lothar Wegener (VEG-en-er) put forward the theory of **continental drift**. He suggested that all the continents of the world were once joined together to form a large 'supercontinent' called Pangaea (pan-GEE-a). About 200 million years ago Pangaea broke apart and the continents have been moving ever since. Wegener's theory was not taken very seriously because Wegener could not suggest how such large pieces of land were able to move around the Earth.

In the 1930s an English geologist called Arthur Holmes put forward the idea that circular movements of the mantle acted like conveyor belts moving the continents around. When the ocean floors were mapped, and their rocks and fossils studied, a clearer picture of the history of the Earth emerged. The evidence gathered seemed to confirm Wegener's idea that about 225 million years ago Pangaea did exist.

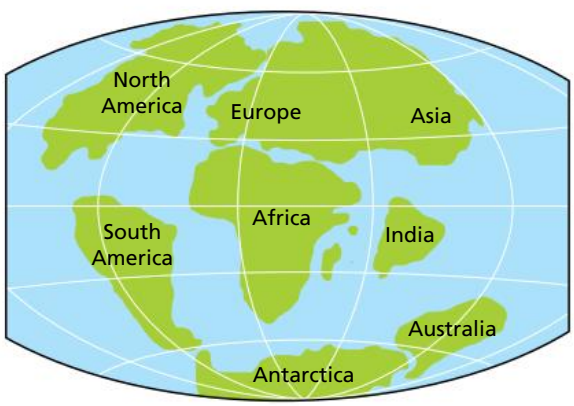
The evidence suggests that about 135 million years ago Pangaea split into two land masses called *Gondwana* (gon-DWAN-a) in the south and *Laurasia* in the north. Australia, Africa, South America, India and Antarctica together formed Gondwana. About 65 million years ago Gondwana also split apart. Australia has been drifting away from the other continents ever since. Look at the series of diagrams on this page.



135 million years ago



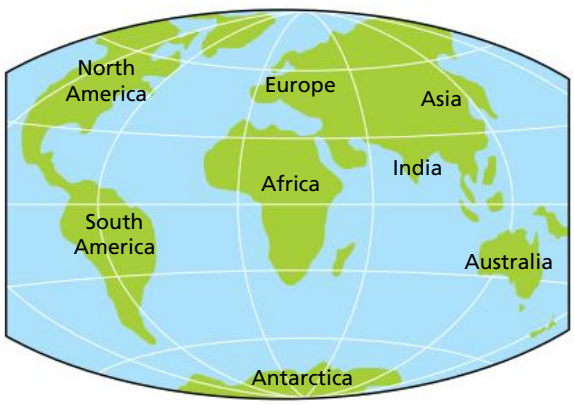
225 million years ago



65 million years ago



200 million years ago



Present day

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SCIENTISTS AT WORK

Alfred Lothar Wegener

Wegener was born in Berlin, Germany, on 1 November 1880. He completed his PhD in astronomy in 1905, but his interests lay in meteorology. He was the first to use air balloons to monitor air circulation. In 1906 and 1912 he visited Greenland to study air circulation there. During this time he was a tutor at the University of Marburg, in Germany. In 1914 when war broke out, Wegener joined the army, but after being wounded he entered the army weather forecasting service. After the war he received a professorship in meteorology in Austria at the University of Graz. He died in 1930 on an expedition to Greenland. He had taken supplies to a research station, but died trying to make it back to base camp.

Wegener had noticed that the shapes of the continents could be fitted together. He reasoned that the continents must have once been joined together, because similar plants and animals had been found on different continents. Wegener was able to show that rock layers and mountain features on different continents matched one another. From this he inferred that at one time they were probably joined in those places.

He found evidence of plant fossils from warm climates in polar regions. He also discovered past evidence of glaciers in Africa, which further supported his ideas.

Perhaps the continents moved by ploughing through the ocean floor, he reasoned. In 1915 he published *The Origin of Continents and Oceans*, which explained his theory of continental drift. Although his theory was not accepted at the time, it was the forerunner to the theory of plate tectonics, which is explained in the next section.

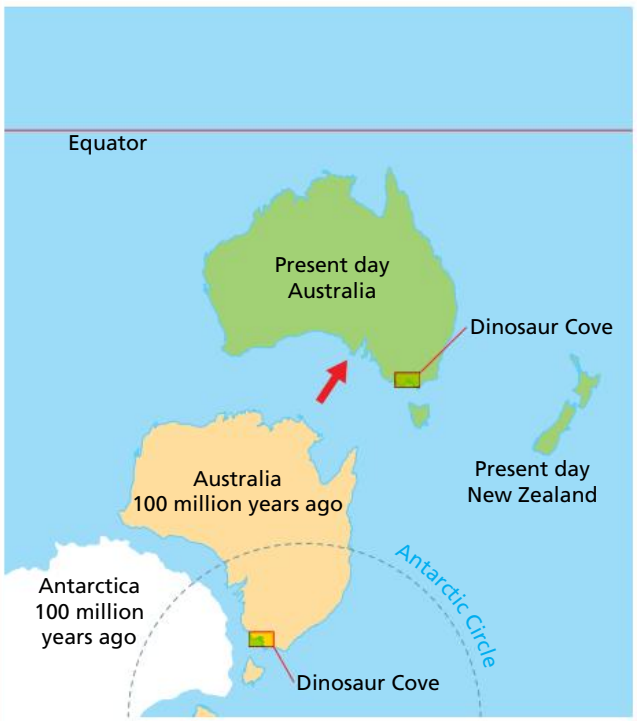


Wegener smoking his pipe

INQUIRY 5

Polar dinosaurs

Dinosaur fossils found in Dinosaur Cove at Cape Otway, Victoria, appear to have lived and survived in the cold. They were warm-blooded and had very good night vision. Scientists infer that this was an adaptation to living and capturing food through long winters. These dinosaurs lived 100 million years ago. The following map shows the position of Australia at that time compared to today.



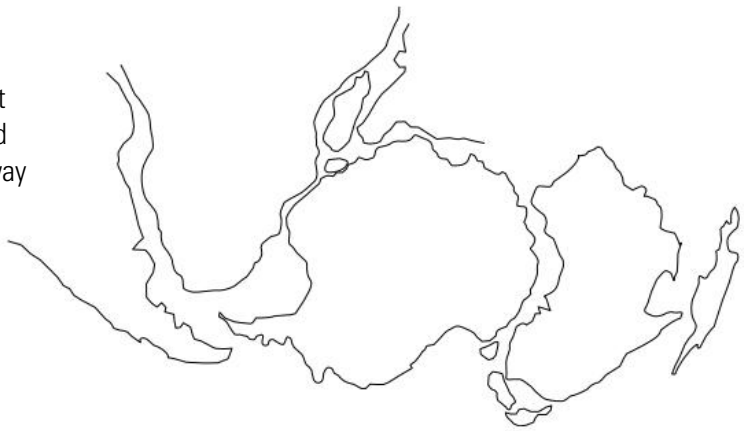
1. Where do geologists infer Australia was 100 million years ago? What is the evidence for this?
2. What type of climate would Australia have had at this time compared to today?
3. What adaptations did the polar dinosaurs have to help them survive the cold? What adaptations would they need to help them survive in a warm climate?
4. If the dinosaurs were adapted to the cold and thrived 100 million years ago, then what do you think killed them? What evidence is there to support your ideas?
5. The dinosaur species found at Dinosaur Cove was called *Allosaurus*. A similar dinosaur called *Cryolophosaurus* (cry-o-LOF-o-SAW-rus) was found near the South Pole. How do you think Wegener would explain this?

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INQUIRY 6

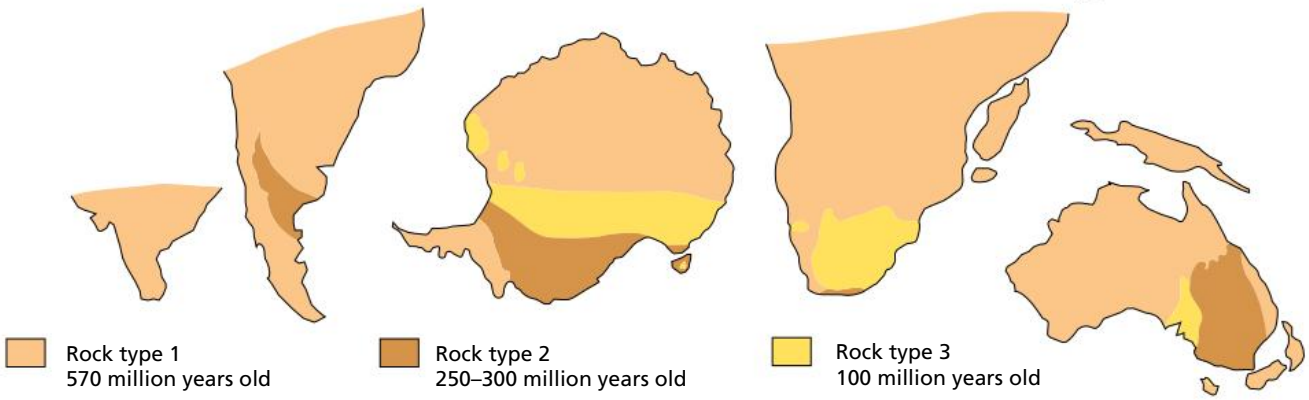
Evidence for continental drift

You will need: a larger copy of the continents that formed Gondwana (as shown right), atlas

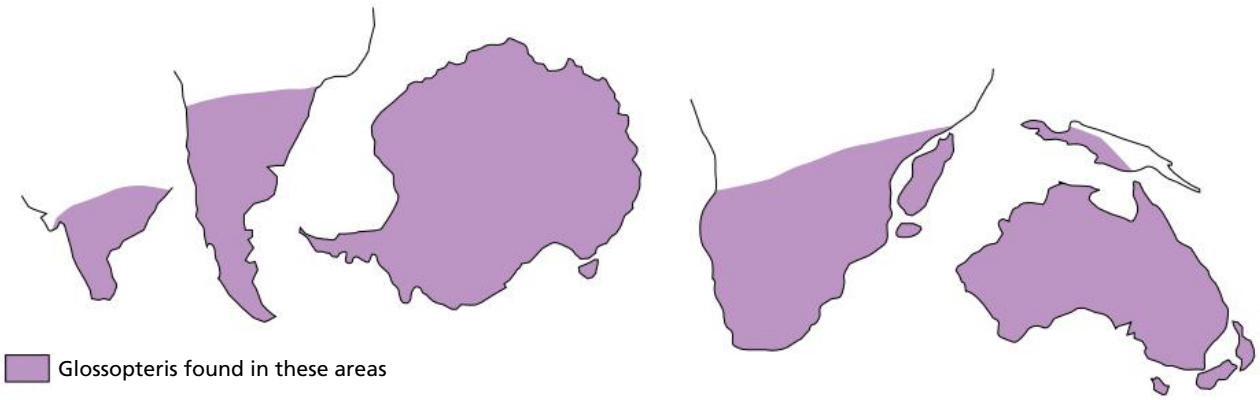


1 The diagram on the right shows the continents that formed Gondwana. Use an atlas to label these land masses. Do the shapes of the coastlines and the way they are positioned support Wegener's theory?

2 Look at where evidence of different ancient rock types has been found on the continents. Copy these areas onto your map of Gondwana. Explain whether this evidence supports the theory of continental drift.



3 Look at the diagram below of where *Glossopteris*, a fern which lived 250 million years ago, has been found on the continents. Copy these areas onto your own map. Does this support the theory of continental drift?



Over to you

1 What conclusions did Ortelius and Bacon draw from their observations of the continents of the world?

2 What was the 'supercontinent' called and what did it break up into?

3 How did Wegener explain how the continents moved?

4 Alfred Wegener's idea of continental drift was not taken very seriously at the time. Why not?

5 List the evidence that convinced Wegener that millions of years ago the continents were in different positions from where they are today.

6 What would you say to Wegener about his theory if he was still alive today?

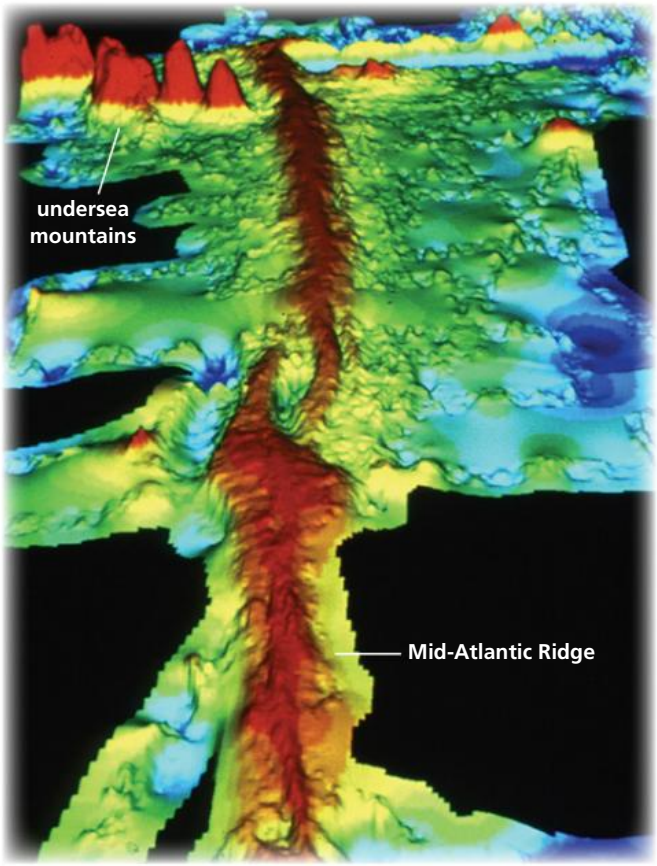
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11.3 Plate tectonics

Scientists today have modified Wegener's idea of drifting continents. They infer that the continents and oceans are part of huge flat pieces of the Earth's surface, called *plates*. As the plates move, the continents also move. This plate movement can be as much as 15 cm per year in some places and as little as 2.5 cm per year in others.

The idea that the crust is broken up into plates was introduced as a theory known as **plate tectonics** in the 1960s. Tectonics comes from the Greek word *tectonikos* that means to build or construct. So the Earth's crust is built of plates. These plates are moving because of the mobile, semi-solid material they sit on. They are pushing and grinding against one another in some places and moving apart in others. The Earth's plates are shown on the map on the next page.

The theory of plate tectonics supports Wegener's theory because the continents move with the plates. It also provides an explanation of *how* they move, which Wegener could not answer.



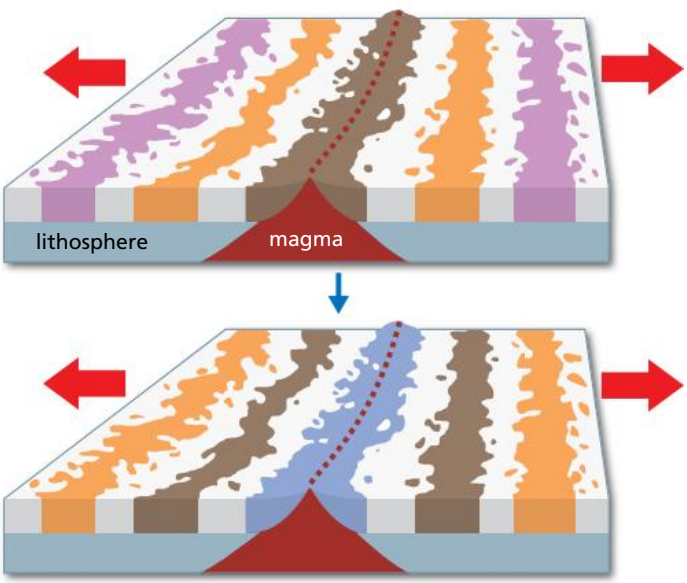
On either side of the Mid-Atlantic Ridge two Earth plates are slowly moving apart.

Evidence for the theory

What evidence do scientists have to support the theory of plate tectonics? How do they know that plates exist and that they are moving? Scientists have used sonar devices, bathymetric surveys (which indicate the depth of the ocean), and computers to map the ocean floor. On the floor of the Atlantic ocean there is a mountain range called the Mid-Atlantic Ridge (see diagram top right).

Scientists infer that the Mid-Atlantic Ridge is where two plates are moving away from each other. Magma from deep within the Earth comes up through the middle of the ridge, pushing the plates apart. As the magma between the plates hardens it forms new ocean crust, causing the floor of the ocean to spread.

Scientists infer the plates are moving apart along the mid-ocean ridge, from observations of the basalt (an extrusive igneous rock) that lies on the ocean floor. Basalt contains magnetite, a magnetic mineral. When the magnetite forms, the tiny particles inside it act like little magnets, aligning themselves with the Earth's magnetic field. The Earth's magnetic field has changed over the years and this has caused magnetic banding patterns in the basalt.



Magnetic banding patterns formed in the middle of the ridge are pushed out from the centre, forming identical magnetic banding patterns in the basalt on either side of the ridge. Notice how the brown ocean floor created in the top diagram has moved outwards in the bottom diagram.

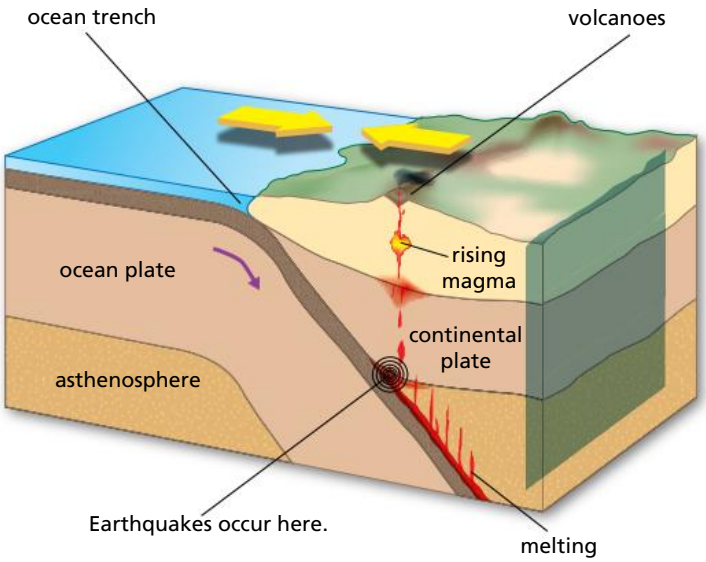
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The magnetic patterns on either side of the Mid-Atlantic Ridge are identical, suggesting that the basalt is created in the middle of the ridge and then pushed from the centre out to both sides. This theory is also supported by the observation that the rocks near the centre of the ridge are the youngest. The magnetic banding patterns in the youngest rocks match the Earth's present magnetic field.

Further evidence came from offshore oil exploration. In the search for oil, core samples were taken from the ocean floor. Using radioactive dating (see Chapter 2), the ages of these samples were estimated and they supported the hypothesis of seafloor spreading.

If seafloor spread is occurring, then the Earth's crust should be getting bigger. This isn't the case. So just as the crust under the oceans is created along oceanic ridges, somewhere else it must be destroyed.

If one plate rides over the top of another plate, the bottom plate sinks into the semi-solid material beneath it and is destroyed. This process is called **subduction**. The point near the Earth's surface where the two plates meet forms an ocean trench. Trenches like this are created in subduction zones and plates are destroyed deep under these areas. You also learnt in Section 11.1 that as a plate sinks under the trench, it drags the rest of the plate behind it, moving the plate along. So zones of subduction help drive plate movement.

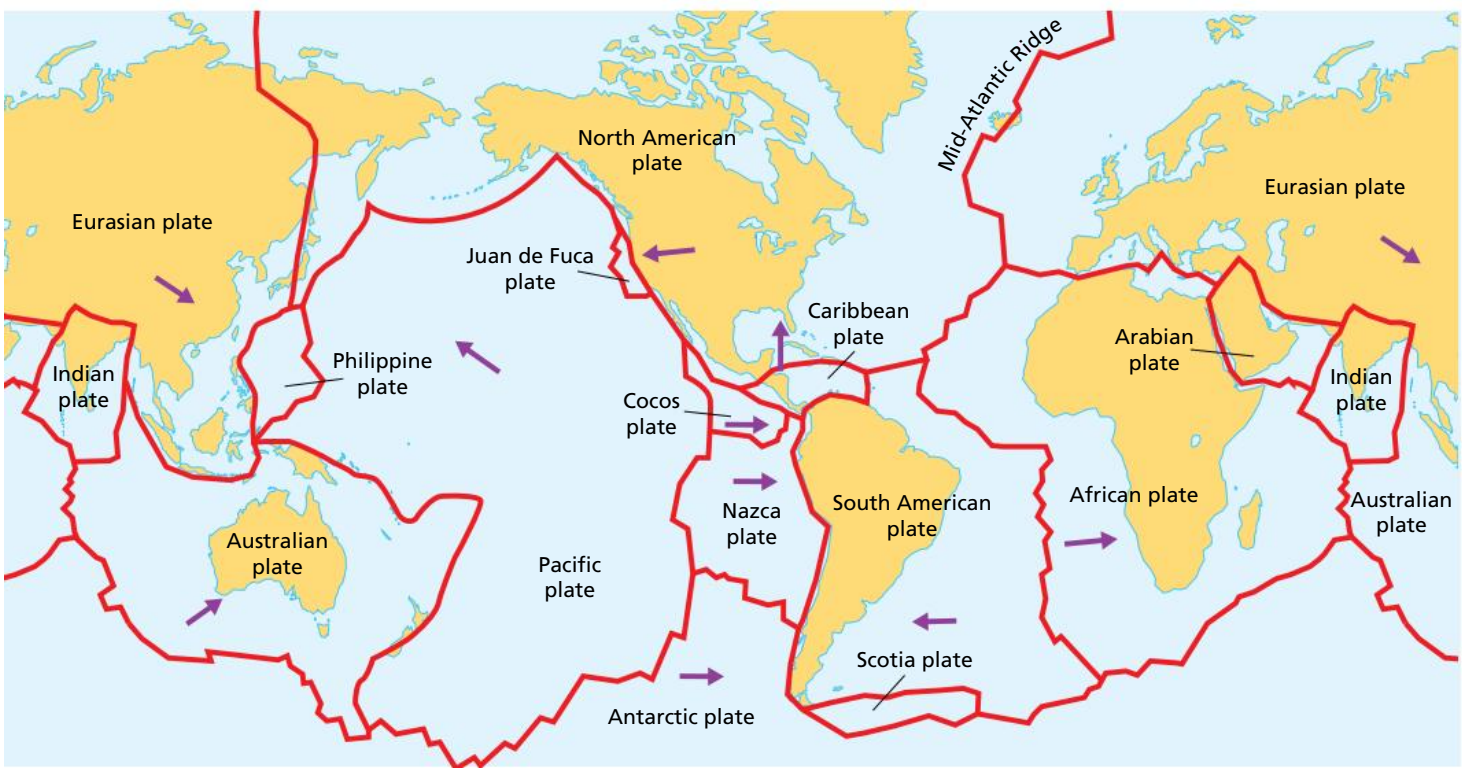


In subduction one plate sinks beneath another plate.

Further evidence

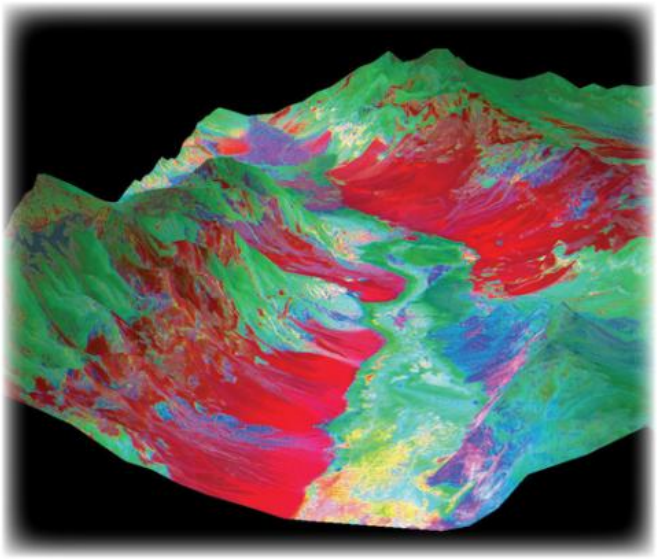
If the crust is being created and destroyed, then the crust should not be as old as the Earth itself. This was found to be the case. The oldest rocks on the ocean floor are only 180 million years old, less than the estimated age of the Earth (4.6 billion years).

Scientists have mapped the ocean floor and used satellite images to determine the distribution and location of rocks on the Earth, as the photo on the next page shows.



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GPS (Global Positioning System) has been used to map plate boundaries and monitor plate movement. GPS satellites send out signals to receivers on Earth. The returned signals can be used to pinpoint the location of the receivers. So far the evidence collected from all these sources supports the theory of plate tectonics.



Scientists use the information they gather from satellite images to determine the distribution and location of rocks. This satellite image shows Death Valley in the USA. The red areas are quartz sandstones and the green areas are limestones.

Earthquakes, volcanoes and mountains

If magma bursts through from ridges under the sea where plates move apart, do volcanoes also occur on the continents where plates meet? The answer is yes. Volcanoes do occur at plate boundaries, which are weak spots in the Earth's crust. The diagram top right on the previous page shows how volcanoes occur in subduction zones. Volcanoes also occur where plates move past one another. A lot of earthquake activity around the world occurs at plate boundaries.

Subduction zones are also areas where mountains form. For example the subduction of the Cocos and Nazca plates under the South American plate has formed the Andes Mountains. A lot of pressure and volcanic activity occurs here because of the trench formed where these three plates meet. There are many active volcanoes in the Andes, and it is also one of the most earthquake-prone places in the world.

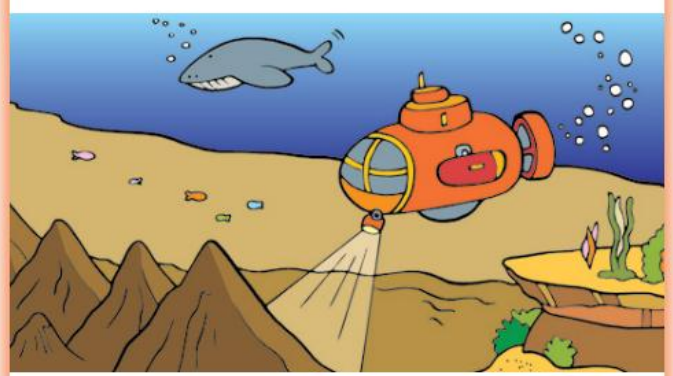
INQUIRY 7 Cartoon captions

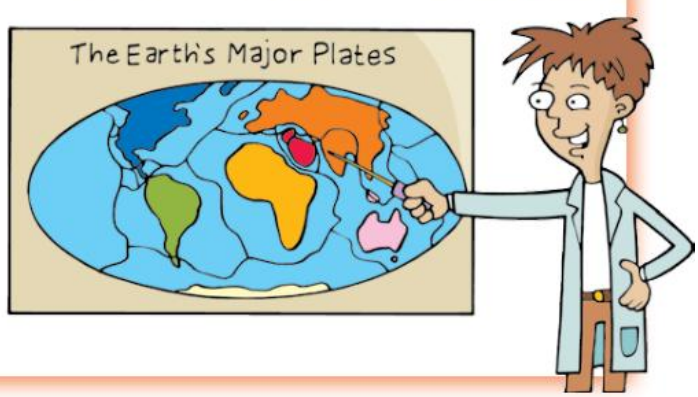
You will need: a copy of the cartoons below, scissors

Cut out each cartoon and stick it in your notebook. Write a caption for each cartoon, tracing the development of plate tectonics as a theory.









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INQUIRY 8

Plotting earthquakes and volcanoes

You will need: an enlarged copy of the map below

1 The coordinates in the table below show some of the earthquake and volcanic activity that has taken place around the world. Plot these on a copy of the map below. Use a blue pen for earthquakes and a red pen for volcanoes.

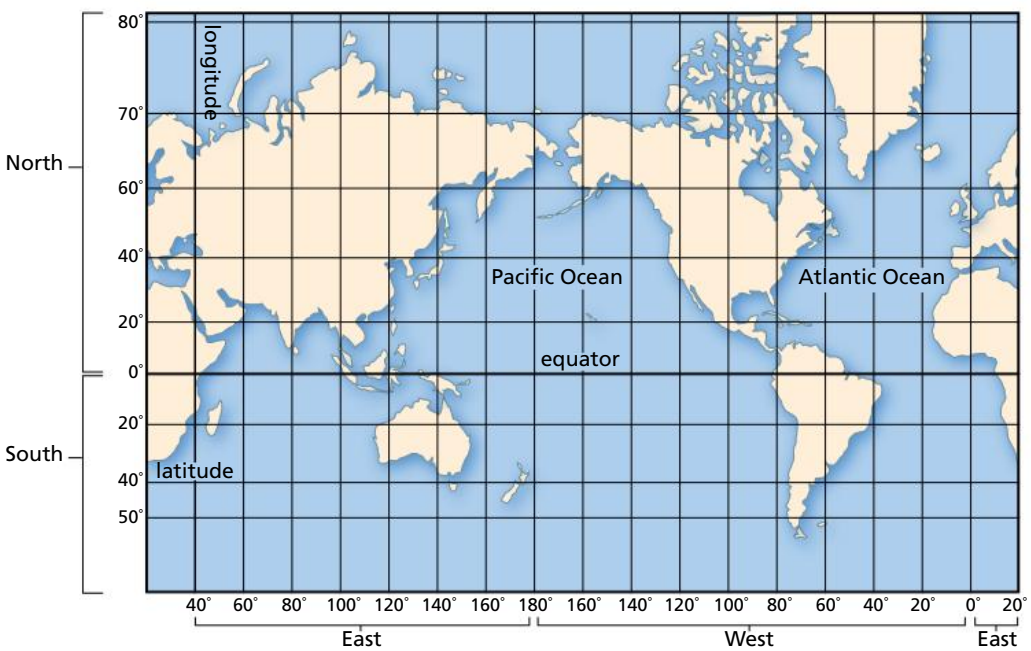
2 Describe any patterns you see in the position of the earthquakes and volcanoes. Suggest a reason for any patterns that you see.

3 Explain whether the information you have gathered here supports the theory of plate tectonics.

4 80% of earthquakes and 70% of volcanic activity occur around the edges of the Pacific Plate. This area is called the 'Ring of Fire'. Find this on your map. Why do you think it was given this name?

5 Use an atlas to indicate the major mountain ranges on the Earth. Can you see any pattern? Explain. You may need to refer back to the map on page 243.

Earthquakes		
Place	**Latitude**	**Longitude**
Kuril Islands	44° N	148° E
Panama	10° N	80° W
Peru	13° S	70° W
Philippine Islands	10° N	125° E
China	38° N	101° E
Hokkaido, Japan	41° N	144° E
Chile	52° S	76° W
Aleutian Islands	51° N	176° E
Western Caroline Islands	11° N	121° E
Sumatra, Indonesia	3° N	96° E
Russian–Mongolian border	50° N	88° E
Mid-Atlantic Ridge	30° N	41° W
New Guinea	6° S	147° E
Off the Mexican coast	8° N	102° W
Alaska	65° N	167° W
Northern Chile	18° S	70° W
Turkey–Iranian border	38° N	45° E
Afghanistan	36° N	71° E
Dominican Republic	20° N	71° W
Kamchatka	55° N	163° E
North Atlantic Ocean	57° N	33° W
Northern California	41° N	125° W
Santa Cruz Islands	13° S	166° E
Greenland Sea	79° N	2° E
South of New Zealand	45° S	167° E
Indonesia	5° N	126° E
Myanmar	20° N	96° E
Volcanoes		
Place	**Latitude**	**Longitude**
Hakone, Japan	35° N	139° E
Mayon, Philippines	13° N	124° E
Bezymianny, Kamchatka	56° N	161° E
Etna, Italy	38° N	15° E
Kilauea, Hawaii	19° N	155° W
Pinatubo, Philippines	15° N	120° E
Popocatepetl, Mexico	19° N	98° W
Shiveluch, Kamchatka	57° N	161° E
Soufriere Hills, West Indies	17° N	62° W
Tungurahua, Ecuador	2° S	78° W
Villarrica, Chile	39° S	71° W



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INQUIRY 9 Earthquakes in Australia

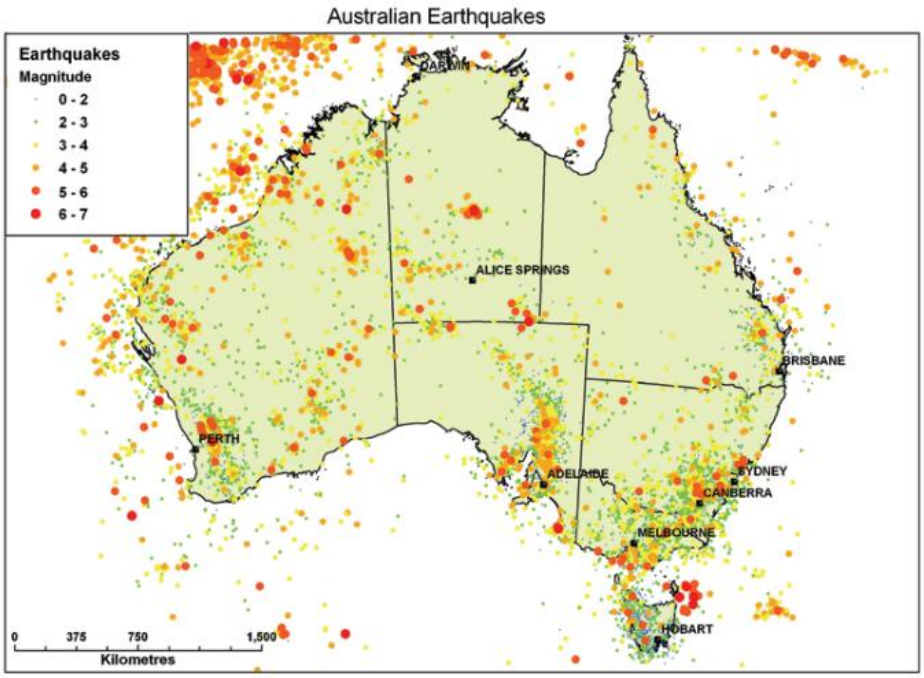
Read the following article and then answer the questions below. **You will need:** an atlas and a dictionary

The area around Cadoux, in south-west WA, is currently the hottest spot in Australia for earthquake activity, according to earthquake researcher Spiro Spiliopoulos.

Spiro and a team of scientists at Geoscience Australia plot all earthquake activity in Australian territory. In a typical year there are about 200 that have a magnitude of more than 2.5 on the Richter scale. At this level, quakes can be felt by humans. Smaller earthquakes occur almost every day, and larger ones that cause damage—above a magnitude of 5.0—occur about once a year.

Spiro said the team is not sure why south-west WA seems to have had more earthquake activity than other areas. 'The whole of Australia is under stress because we're moving north at about 7 cm a year, and there are certain parts of the country that relieve that stress better than other parts,' he said. 'We're trying to identify active faults, but we still seem to know so little.'

He said another earthquake hotspot is around the Flinders Ranges in SA.



1. Locate Cadoux on a map of Western Australia and the Flinders Ranges in South Australia. Does the map support the statement that these are hotspots for earthquake activity in Australia?
2. Why do you think people in Australia rarely notice earthquakes?
3. Use a dictionary to find the meaning of the word 'fault'. How could a fault cause an earthquake?
4. Australia is not near the edge of a plate, so why do you think earthquakes occur on our continent?

INQUIRY 10 Core sampling

Core samples are used to study the composition of the Earth's crust. They are obtained by driving a hollow drill into the ground and examining the rock cores that are taken out of it. Core samples were taken of the moon's surface during Apollo missions. Core tubes 2–4 cm in diameter were used. They were driven to a depth of 70 cm into the moon's surface with a hammer. An electric drill was used to obtain samples up to a depth of 3 m. Search the internet to find out how core sampling is carried out. Draw a diagram to explain your findings.

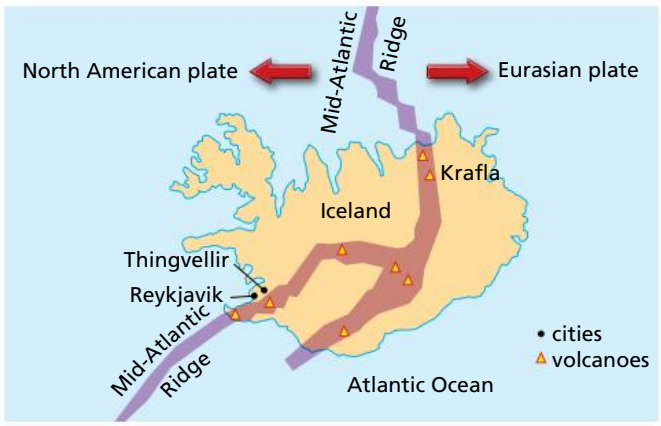
Over to you

1. How do the following provide evidence to support the theory of plate tectonics?
   - **a** mid-ocean ridges
   - **b** basalt on the ocean floor
2. The rocks on the Earth are much younger than the Earth itself. How does this observation support the theory of plate tectonics?
3. Give three examples of how the use of technology has provided evidence for the existence of Earth plates.
4. If the Earth's crust isn't getting bigger, how is crust disappearing?
5. How does the position of earthquake and volcanic activity support the theory of plate tectonics?

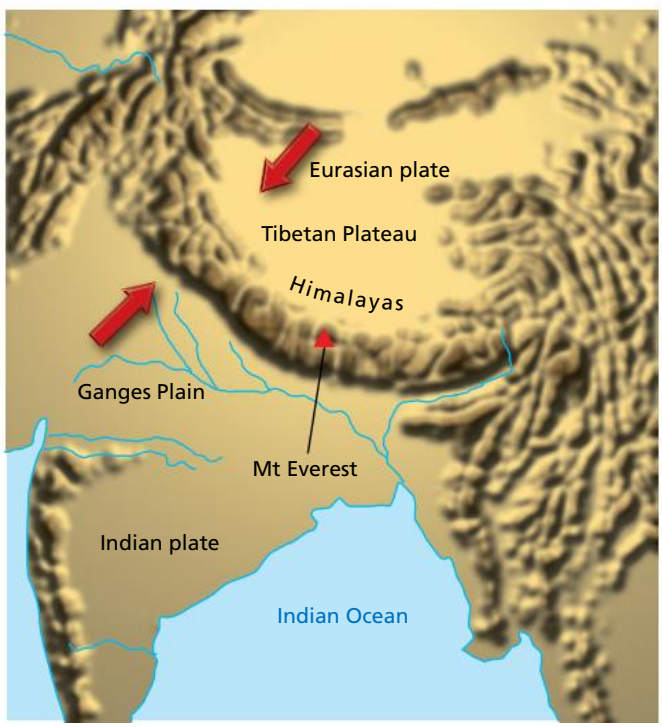
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11.4 Folding and faulting

There are different types of movement that can occur at plate boundaries. You already know that the plates on either side of the Mid-Atlantic Ridge are being pushed apart and that new crust is being made as magma comes up between them. This action causes earthquakes and volcanic activity along the ridge. It is also dividing the country of Iceland in half because it sits right in the middle of the ridge.



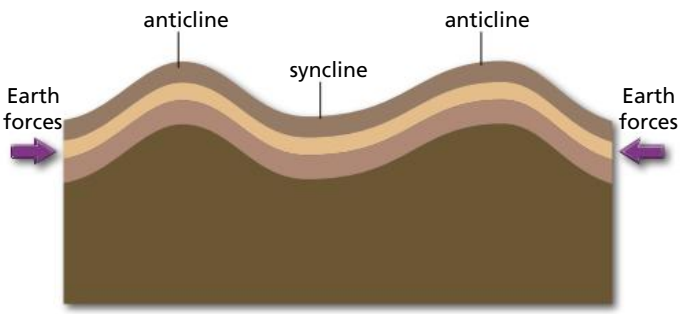
You have also learnt that volcanoes occur near subduction zones. The Ring of Fire that circles the Pacific Ocean is one example. It is called the Ring of Fire because of the volcanic activity that occurs around the edges of the Pacific plate. In subduction zones the sinking plate is under tremendous stress and pressure, so earthquakes occur here too.



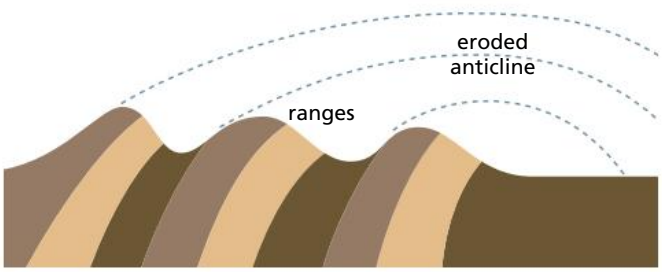
It is also possible for plates to be pushed upwards. When this occurs the plates buckle and crumple under tremendous pressure, forming mountain ranges. The Himalayas are an example of this. Over millions of years the collision of the Indian plate with the Eurasian plate has caused this mountain range to form. The Himalayas are getting higher because the Indian plate continues to move northwards, pushing into the Eurasian plate.

Folding

When rocks buckle and bend because they are pushed under pressure deep in the Earth, this is called **folding**. This can happen anywhere on the Earth's surface that is under stress and pressure. Rocks can be bent upwards forming an **anticline**, or downwards forming a **syncline**, as shown below. Over millions of years, rocks can be pushed upwards, tilted on an angle, or even turned upside-down from the pressure built up deep in the Earth.



Many Australian landscapes have been formed by folding. Over time the rocks weather and erode away to form interesting land structures. Uluru (Ayers Rock) is an example. It is made up of layers of sandstone that have been folded, so the layers are no longer horizontal. This giant fold has then been shaped by weathering and erosion.



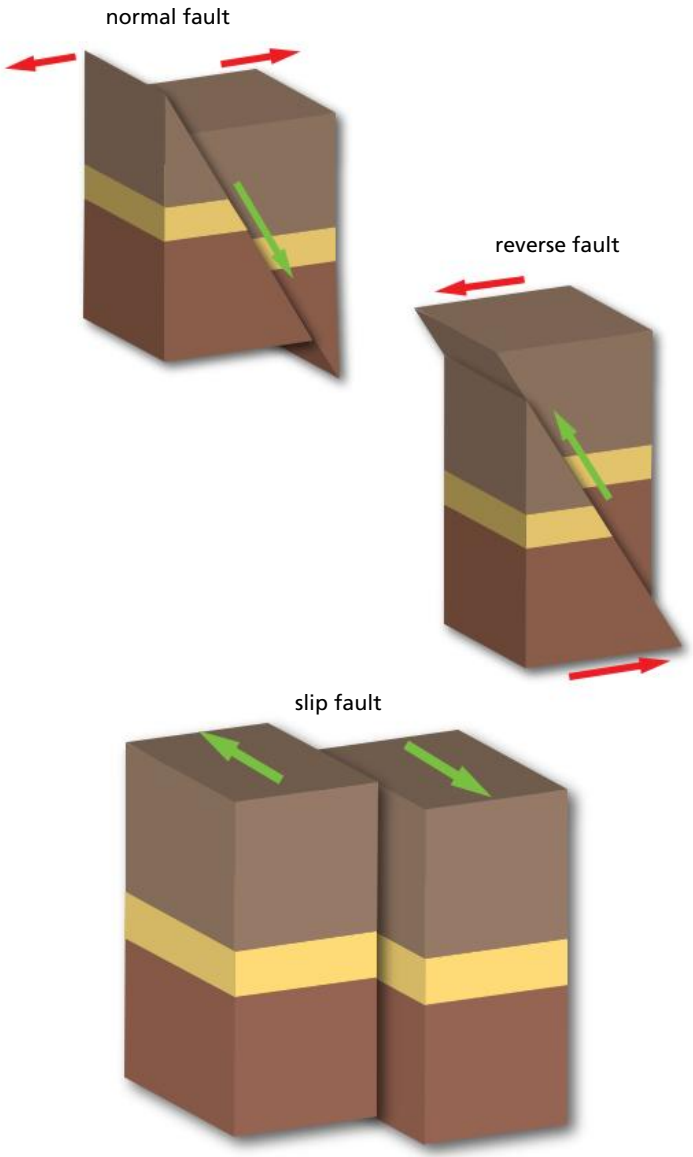
These ranges are all that is left of an anticline that has been weathered and eroded away over millions of years.

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Faulting

A **fault** is a break in the Earth's crust along which rock slides. Faults can occur wherever there is enough force to make the rock break. The blocks of rock on either side of the break move in opposite directions. The Mt Lofty Ranges in South Australia and the Grampians-Gariwerd in Victoria have all been formed as a result of faulting.

Three different types of faults are shown in the diagrams below.



A *normal* fault is the result of stretching forces, causing one block of rock to slide downwards against the other. A *reverse* fault is the result of pushing forces, causing one block of rock to slide upwards. In a *slip* fault, blocks can slide past each other.

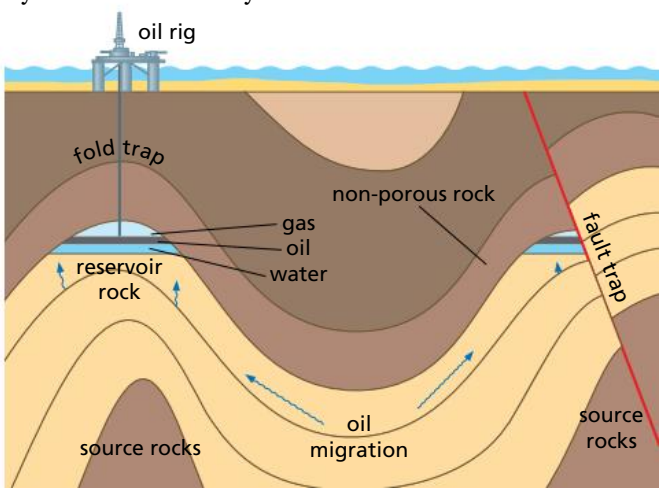
Faults often occur at plate boundaries, where blocks of rock slip and slide horizontally past one another, as well as slide under and over one another. This is occurring along the coast of North America near San Francisco and Los Angeles, where the North American plate is sliding past the Pacific plate. This movement has produced a huge fault known as the San Andreas Fault, which has been the source of many earthquakes. One of the worst occurred in 1906 in San Francisco. On page 235 there is a photo of some of the damage caused by an earthquake in Christchurch, New Zealand, in 2011. This occurred along a fault at the boundary of the Pacific and Australian plates (see map on page 243).

Finding minerals

Minerals are often found near faults and folds. Rocks may be squeezed under such pressure during folding that new minerals are formed.

Oil and gas are hydrocarbons that are made from organic material such as bacteria that have been trapped in sediments. Over millions of years, the organic material changes with extreme heat and pressure. The rock that contains the hydrocarbons is called the source rock. However the oil and gas can move or migrate upwards away from the source rock.

Oil and natural gas can rise through porous rocks such as sandstone. Porous rocks have spaces in between the rock grains that allow oil to move through them. However, rocks such as shale are non-porous and oil and gas cannot move through them. Anticlines can trap oil and gas between layers of non-porous rock as shown. In the same way, oil can be trapped against a fault if it is surrounded by non-porous rock. Mineral solutions can also be trapped by fault lines and crystallise to form minerals.

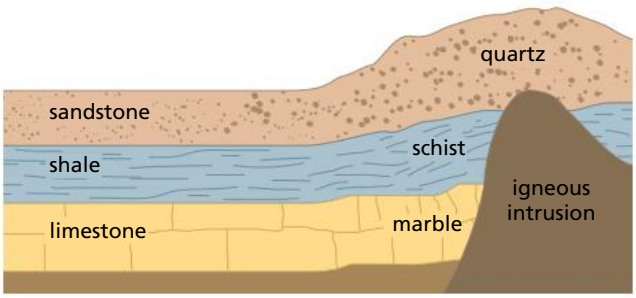


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SKILL

Drawing rock diagrams

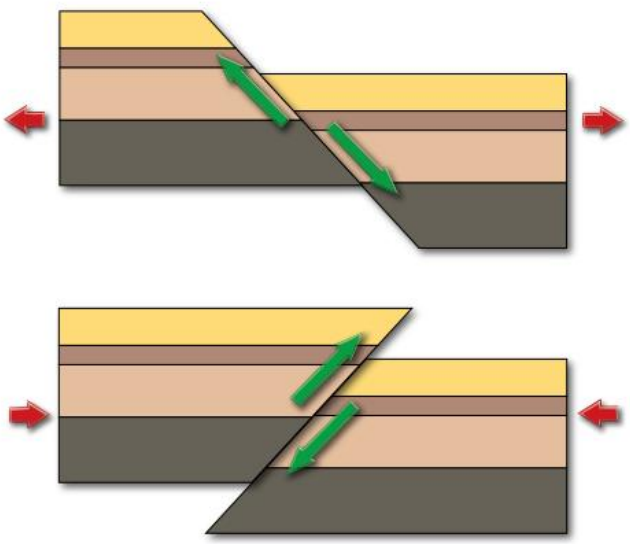
You will notice from the diagrams on the previous page that when folds and faults are drawn, the different layers or *strata* under the Earth's surface are shown. The drawings are cross-sections of the Earth, as if somebody has somehow sliced down through the layers and drawn what they see. The names of the rocks are usually shown on the layers. Here is an example.



1 Look at the two diagrams below showing faults. Which is a reverse fault, and which is a normal fault?

2 What do the red arrows represent? What do the green arrows represent?

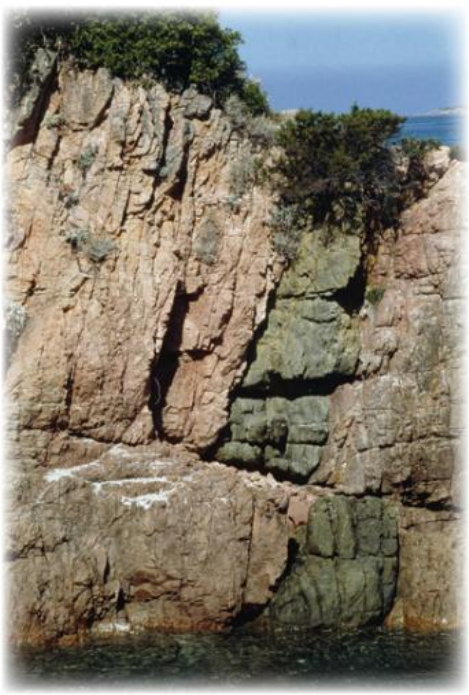
3 How do you think diagrams like this can help record the history of the Earth?



4 Look at the photograph below. Draw this as a diagram. Label any synclines and anticlines.



5 Draw a labelled diagram of the following photograph. What rock formation does it show?



Over to you

1 Name three different types of movement that can occur at plate boundaries. State what natural events are produced because of this movement.

2 What is the difference between a fold and a fault?

3 Why are minerals likely to be found near folded rocks and faults?

4 Describe how some interesting rock formations such as Uluru form.

5 How can there be igneous rocks in Australia when there are no active volcanoes?

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11.5 Impact of Earth movements

You have seen how plate movements, earthquakes and volcanoes affect the lithosphere. But how do plate movements, earthquakes and volcanoes affect the *biosphere* (life on this planet), the *hydrosphere* (the oceans) and the *atmosphere*?

Often Earth movements are hardly noticed. For example, in June 2001 Sydney was hit by a **tsunami** (tsoo-NAH-me). This Japanese word is formed from the words *tsu* which means harbour and *nami* which means wave. The wave was 30 cm high and people probably thought it was only a high tide. The wave was created by an earthquake in South America that measured 8.1 on the Richter scale.

Tsunamis can occur when earthquakes, volcanoes and landslides in or near the sea cause the sea floor to move, producing a series of waves. These waves can travel as fast as 960 km/h. As the water depth decreases near land, the height of the wave increases. Sydney was such a long way from the earthquake that the tsunami formed was no real threat. The north-west coast of Australia is under greater threat from tsunamis because it is closer to Indonesia, which is an earthquake-prone area.

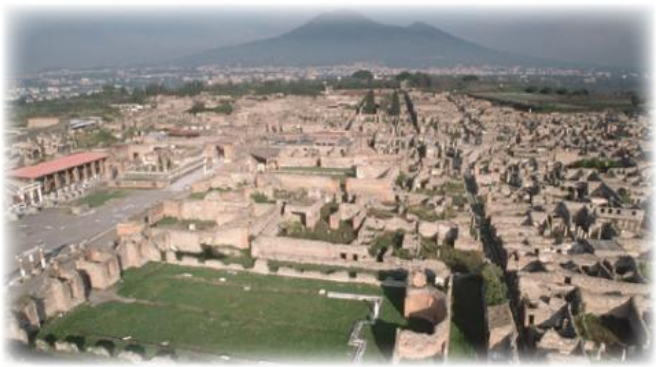
Some of the major earthquakes in the world have been followed by tsunamis. When Krakatoa erupted in 1883, 36 000 people were killed by the tsumanis that hit Java and Sumatra. On Boxing Day 2004 a major earthquake occured in Sumatra causing tsunamis to crash into Indonesia, Thailand and Sri Lanka, killing almost 300 000 people. Some Australian holiday-makers were among the dead.



The tsunami that devastated Indonesia, Thailand and Sri Lanka in 2004

Volcanic eruptions

In 79 AD, Mt Vesuvius in Italy erupted. It buried the city of Pompeii in mountains of ash and lava. The city is still being excavated today. The eruption also buried Stabiae and Herculaneum. These towns were covered by a cloud of burning hot ash and gas that burnt people alive, before pumice and ash covered them. These towns were not discovered until 1709, and provide an amazing insight into the life of people at the time.



Pompeii with Vesuvius in the background

In recent years there have been many volcanic eruptions. For example, Mt Pinatubo in the Philippines erupted on 15 June 1991, killing 1000 people, destroying 42 000 homes and covering 80 000 hectares of crops in ash. Closer to home, on 19 September 1994 in Rabaul, Papua New Guinea, the volcanoes Vulcan and Tavurvur erupted. A cloud of ash, gas and molten lava exploded 15 km into the air, covering the local area with more than a metre of ash. The area had been evacuated and only three people died.



Ash rains down on local villagers fleeing the eruption of Mt Pinatubo in 1991.

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Volcanic ash clouds

One major consequence of volcanic eruptions is the effect clouds of volcanic ash have on the atmosphere. In the photo on the previous page (bottom right), the skies were filled with ash for weeks after the 1991 eruption of Mt Pinatubo. It took this long for the ash that had been exploded into the air during the eruption to settle. So much ash and gas was sent into the stratosphere that it caused lower than normal temperatures across the world. In some places there was a drop of almost 0.5°C. This occurred because the sulfur dioxide in the ash dissolved in water in the atmosphere, forming sulfuric acid. This sulfuric acid stopped sunlight from reaching the Earth's surface.

In the last 30 years, 90 planes have encountered ash in the atmosphere. Sometimes the ash just scratches the exterior of the plane. However it can cause engine failure, which is what happened when a British Airways 747 encountered an ash cloud over Jakarta, Indonesia. The plane was without its engines for 12 minutes and fell 2000 metres, but the pilots managed to restart the engines.

Scientists at CSIRO have designed a detector that can tell the difference between clouds of ash and clouds of water. The tiny silicate particles in ash scatter infrared radiation differently from the way water and ice do. So by monitoring infrared frequencies, the device can indicate what type of cloud is ahead, giving the pilot enough time to change course.

Earthquakes

On 28 December 1989 an earthquake hit the city of Newcastle in New South Wales. It measured 5.6 on the Richter scale and caused $4 billion damage. One hundred and sixty two people were hospitalised and 13 people lost their lives. This loss is small compared to some of the major earthquakes that have occurred worldwide.

Many earthquakes have occurred in the state of California because it lies on the San Andreas Fault. Movement along this fault line caused the Loma Prieta earthquake in October 1989 which measured 7.1 on the Richter scale, took 62 lives and caused a damage bill of $6 billion. On 17 January 1994 an earthquake hit the area north of Los Angeles causing $30 billion in damages and taking 60 lives.



An ash cloud detected over the Kliuchevskoi volcano in Russia

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Benefits of volcanoes

There are some good things that come from volcanoes and earthquakes. Copper, silver, lead, zinc and gold are mined from extinct volcanoes located near subduction zones. Soils around volcanoes are also very fertile because they have been formed by the breakdown of igneous rocks.

Underground water can be heated by hot volcanic rocks near it. In some places the hot water rises and gushes out through vents or openings in the Earth's surface. Sources of hot water formed like this are called geothermal springs. They can occur on land, as in New Zealand, or through vents in the ocean floor. The water in these vents can be as hot as 380°C and contains minerals such as iron, copper, zinc and nickel. Geothermal springs that occur deep underwater on the floor of the ocean and contain dark coloured minerals are called 'black smokers'. These geothermal springs contain such rich mineral deposits they may be mined in the future.



Artist's impression of a black smoker

The heat from the Earth can provide energy called *geothermal energy*. Heat can be harnessed from active or recently active volcanoes and used to power turbines to produce electricity. In Iceland, the heat from active volcanoes warms 70% of homes. It is also used as heat for greenhouses and industry. Steam produced from geothermal activity is used to generate electricity in New Zealand and parts of Europe.

INQUIRY 11 *Impact of volcanoes and earthquakes*

The following table lists some major volcanic eruptions and earthquakes that have occurred. Search the internet to find out more about one of these events. What impact did it have on the biosphere, the lithosphere, the atmosphere and the hydrosphere? Prepare a fact sheet or a 2 minute presentation to the class on your findings.

Volcanic eruptions	
Date (AD)	**Volcano and Place**
79	Vesuvius, Italy
1104	Hekla, Iceland
1792	Unzen, Japan
1815	Tambora, Indonesia
1883	Krakatoa, Indonesia
1902	Mont Pelee, Martinique
1973	Heimaey, Iceland
1980	Mount St Helens, USA
1982	El Chichon, Mexico
1983	Kilauea, Hawaii
1985	Nevado Del Ruiz, Colombia
1991	Mt Pinatubo, Philippines
Earthquakes	
Date	**Place**
1755	Lisbon, Portugal
1906	San Francisco, USA
1960	Valdivia, Chile
1970	Chimbote, Peru
1976	Tangshan, China
1985	Mexico City, Mexico
1995	Kobe, Japan
2004	Sumatra, Indonesia (and tsunami)
2008	Sichuan, China
2011	Tohoku, Japan (and tsunami)

PROBLEM SOLVING

After reading this chapter you should have lots of ideas to choose from to complete your chapter task. For example, you could make a model of the Mid-Atlantic Ridge, show how the Himalayas were formed, construct Gondwana and show how it split up, use plasticine to model folding or model the San Andreas Fault. What ideas do you have? What are you going to do?

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Streets buckled during the 1995 Kobe earthquake in Japan

Over to you

1 Look at the following photographs that show a local village after the eruption of the volcanoes Vulcan and Tavurvur in Rabaul, Papua New Guinea. What are the likely effects of this eruption upon the hydrosphere, the biosphere, the atmosphere and the lithosphere?



This aircraft was buried in ash from the volcanoes.

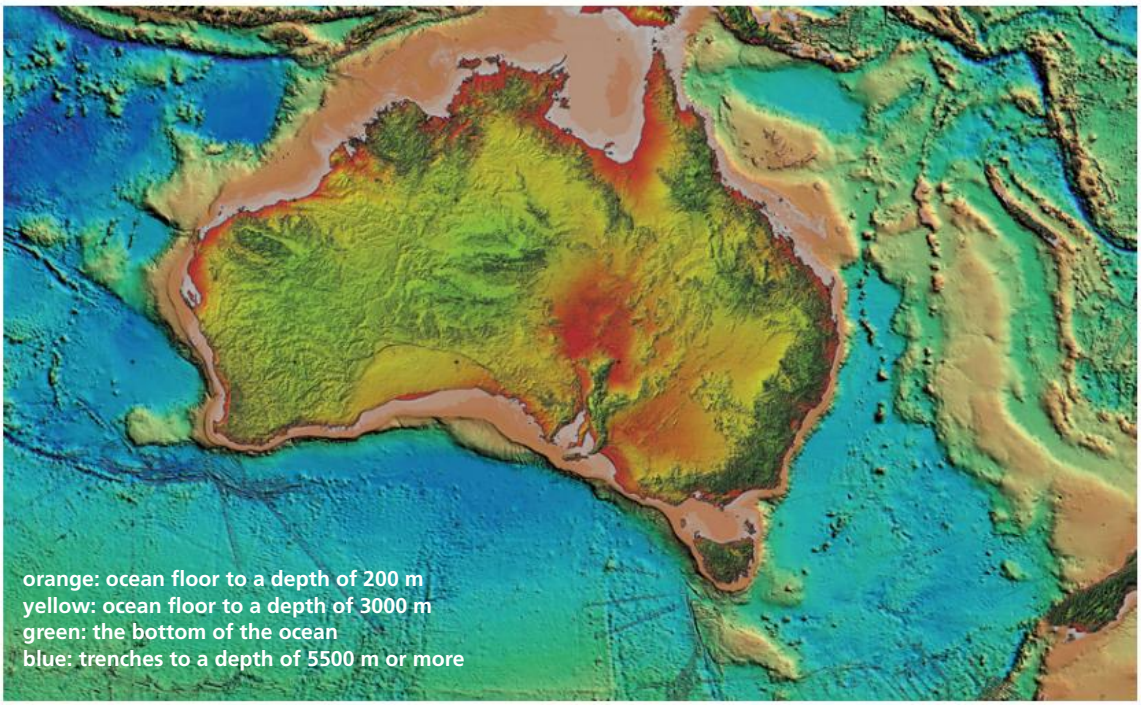
2 Explain whether there would be any advantages from such an eruption.



The volcanoes Vulcan and Tavurvur erupt in 1994

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THINKING SKILLS



1 Look at the image of Australia above prepared from satellite and ship surveys.
   - **a** How does this image show that the continents are not isolated pieces of land in the ocean?
   - **b** How does it provide evidence to support the theory of plate tectonics?

2 Much of Australia is made up of granite, which is an intrusive igneous rock. However, granite is formed underground. Explain how you think these granite formations called Murphy's Haystacks located on the Eyre Peninsula in South Australia came to be formed.



3 Australia's indigenous people are supposed to have come from Indonesia. How could this have happened?

4 Use the internet to find how a volcanic pyramid forms in the middle of the ocean.



These volcanic pyramids rise up out of the Pacific Ocean.

5 On your own world map, show earthquake and volcanic activity in the last month. You can investigate current earthquake and volcanic activity by looking up the following websites or sites you find yourself:

   www.iris.edu/sm2/
   www.volcano.si.edu

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 The crust and upper part of the mantle form the solid topmost layer of the Earth called the _____. It floats on a very hot, semi-solid part of the mantle called the _____.

2 The lithosphere is divided into _____ which move and slide under, over and past one another. The plates move because the mantle underneath them moves due to _____.

3 The theory of _____ suggested that all the continents of the world were once joined together to form a large 'supercontinent' called _____ which broke up more than 200 million years ago.

4 Magnetic band patterns on either side of the Mid-Atlantic Ridge and GPS mapping have provided some of the evidence to support the theory of _____.

5 Earthquakes and _____ can occur at plate boundaries where plates are moving relative to each other.

6 _____ occurs when rocks are pushed together and buckle under tremendous forces in the Earth's crust. _____ is the formation of a break in the rocks and the blocks on each side of the break move relative to each other.

7 Natural events such as earthquakes and volcanoes affect the hydrosphere, the atmosphere, the lithosphere and the _____.

asthenosphere

biosphere

continental drift

convection

faulting

folding

lithosphere

Pangaea

plates

plate tectonics

volcanoes

Self-management

Making a poem

Follow these three steps to help you write a poem that summarises the chapter.

1 Go through the chapter and write out all the words that appear in bold, with their meanings.

2 List three important points from each of the five sections in the chapter.

3 Write a poem to help you summarise the chapter. It should include some of the words in bold and some of the important points you have listed.



Folded rocks

For example:

Our planet is not a ball of rock,
there are layers inside, so it's said.
The *lithosphere* is the solid bit,
that floats on a semi-solid bed.

The crust is made up of many plates,
they move, and slide and shake.
And where they join scientists know,
there's likely to be a quake.

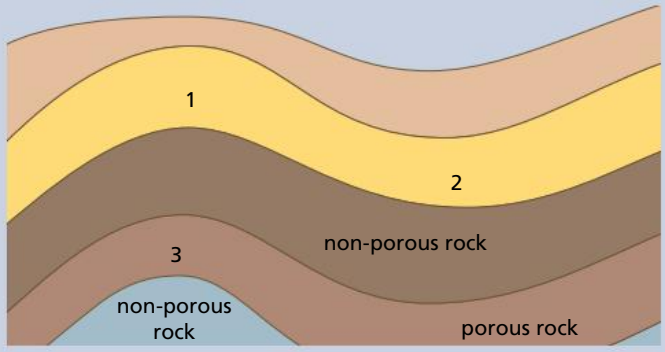
Rocks can tilt, and buckle and bend,
and some can be very old.
If they are squeezed with tremendous force,
the rocks are said to fold.

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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources
OneStopDigital

Look at the following diagram, then answer questions 1–3 below.

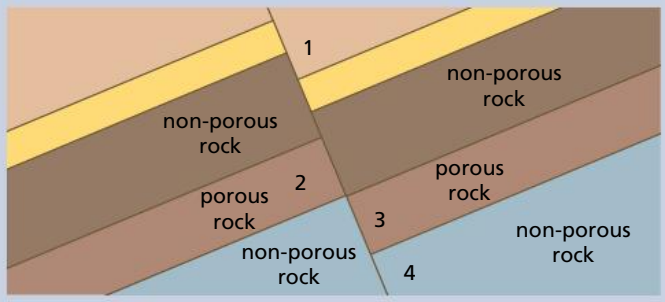


1 Point 1 on this diagram is:
- **A** an anticline
- **B** a syncline
- **C** a fault
- **D** a weathered rock

2 Point 2 on this diagram is:
- **A** an anticline
- **B** a syncline
- **C** a fault
- **D** a possible oil reservoir

3 Point 3 on this diagram is:
- **A** a weathered rock
- **B** a syncline
- **C** a fault
- **D** a possible oil reservoir

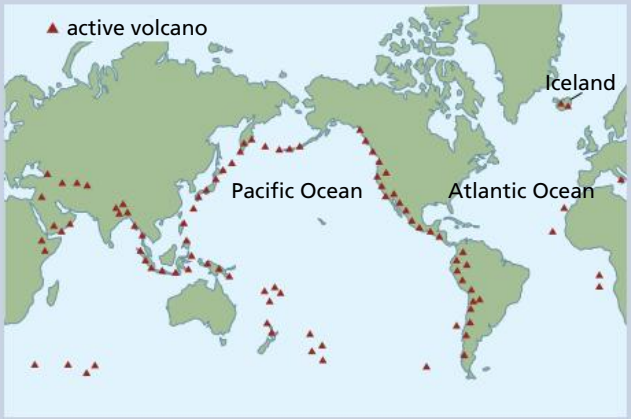
Use the following diagram to answer questions 4 and 5.



4 The diagram shows:
- **A** an anticline
- **B** a syncline
- **C** a fault
- **D** a fold

5 The most likely place on this diagram to find oil would be:
- **A** 1
- **B** 2 and 3
- **C** 2
- **D** 1 and 4

6 The map below shows where some of the world's most active volcanoes are located.



- **a** What other natural event would you also expect in these areas?
- **b** What geographical features would you expect in these areas?
- **c** Where is the Ring of Fire? Why is it called this?
- **d** Iceland is in the middle of the Atlantic Ocean. Why does this country have so much volcanic activity?
- **e** What scientific theory does the information presented here support? Explain.

7 This photo shows a sedimentary rock that initially formed in a river bed. Suggest a reason to explain how this rock is now high in the Blue Mountains.



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12



Going into space

By the end of this chapter you will be able to …

Knowledge and Understanding

- explain the transmission of sound in different mediums (PW1d)

Skills—Working Scientifically

- formulate questions or hypotheses about space that can be investigated scientifically (4a)
- select sources of information for a space experiment (5.1c)
- use the internet to access information on terraforming Mars (7.1c)
- apply critical thinking in considering a proposal to mine Mars (8f)
- propose coherent and logical ideas about space exploration (9d)

LITERACY FOCUS

Apollo
artificial gravity
asteroid
atmospheric pressure
atrophy
cosmic rays
free fall
geostationary orbit
Global Positioning System (GPS)
International Space Station
life-support system
microgravity
oxidiser
polar orbit
space elevator
space station
Sputnik
terraforming
thrust
weightlessness

Focus for learning

Very few people have travelled into space or lived there for any length of time. However, in the future it is possible that you could travel into space for a holiday or work there.

In this chapter you will learn what it is like to live and work in space, and you will learn about space tourism, which has already begun. Finally, you will consider the benefits of space travel, and whether we should continue to spend huge sums of money going into space.

PROBLEM SOLVING

Space experiment

A group of students at Glen Waverley Secondary College designed an experiment that was carried on board the space shuttle *Columbia* in 2003. The aim of their experiment was to find out whether spiders spin different sorts of webs in space, where they are weightless. The students used garden orb-weaver spiders, which are large, non-poisonous spiders common in gardens. These spiders build a perfectly symmetrical web overnight.

The students put eight spiders in a mini-ecosystem in a special box that was kept at a constant temperature in the payload bay of the space shuttle. It contained fruit fly larvae to provide a food supply of flies for the spiders. The students controlled their space experiment by having a second spider habitat at school, identical to the one in space except for the effect of weightlessness. The spiders on the space shuttle were monitored by video, and data was available to everyone on Earth via an internet site.

The spiders did spin webs in space but they were not as neat as on Earth. Tragically, the space shuttle broke up as it was re-entering the Earth's atmosphere and all seven of the astronauts were killed. None of the spiders survived.

Your chapter task is to design an experiment to be carried out on the International Space Station. First decide on something that would behave differently in the weightless conditions of space. Then devise a plan to carry out your experiment on the Space Station. The equipment you use must be compact and light, and the experiment needs to be simple and easily carried out by the Space Station crew. Write a detailed outline of your experiment, including diagrams of the equipment needed.



Four of the students involved in the project, with their teacher

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12.1 Getting into space

The first step in going into space is to launch the spacecraft using a rocket.

INVESTIGATION

1 Rockets

Aim

To make and test model rockets.

Risk assessment and planning

Read the investigation before you start. Both rockets must be launched outdoors and you must stand well back. Do not launch rockets without your teacher's supervision.

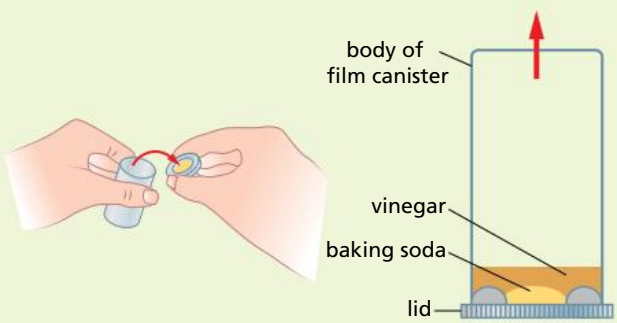
Part A: Film canister rocket

Apparatus

- film canister with lid
- vinegar
- baking soda
- teaspoon

Method

1. Take the lid off the film canister. Hold the body of the canister in one hand and the lid in the other. Practise quickly and firmly pressing the lid completely on and putting the canister down on a flat surface, as shown below.
2. Pour vinegar into the body of the canister until it is about 5 mm deep. Using the teaspoon, fill the recess on the inside of the lid with baking soda.
3. Now do what you practised in step 1 and move back quickly. What happens?
   - ✻ Explain in detail how this simple rocket works.
4. Experiment to find out how to make the best rocket. You could vary the amounts of baking soda and vinegar. You could try a quarter of an Alka-Seltzer with water. Or try launching the lid instead of the canister.



Part B: Water rocket

Apparatus

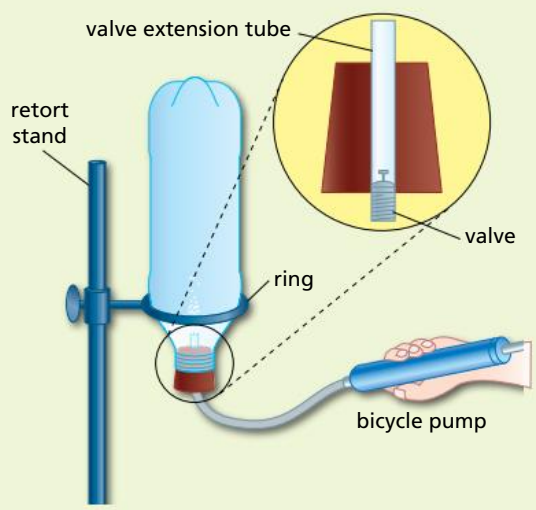
- plastic soft drink bottle
- rubber stopper with hole drilled for tyre valve (The stopper must fit firmly in the mouth of the bottle.)
- bicycle pump or foot pump
- car tyre valve and valve extension tube
- retort stand and ring

Method

1. Put the tyre valve in the hole in the rubber stopper to give an airtight fit. Attach the tyre valve to the pump, as shown.
2. Quarter fill the bottle with water. Push the rubber stopper firmly but not too tightly into the bottle.
3. Place the bottle upside-down on a launch pad like the one shown. Make sure everyone is well back.
4. Pump air into the bottle until the rocket lifts off.
   - ✻ Explain in detail how this rocket works.
   - ✻ Why does the rocket go faster after it is launched?
5. Experiment to find out how to make the best rocket.

Write your report

In your report, describe how successful your rockets were and any suggested improvements to their design.



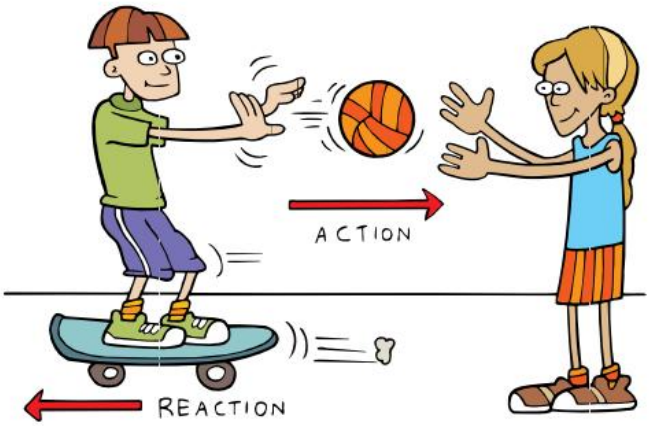
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Action and reaction

All rockets work on the principle of **action and reaction**. This is *Newton's third law of motion*: for every force (action) there is an equal and opposite force (reaction). Imagine you are on a skateboard and you throw a heavy ball to your friend. The ball goes in one direction and you and the skateboard go in the opposite direction. Some sea creatures, such as jellyfish, work this way too. They squirt water out in one direction to move in the opposite direction.

In the film canister rocket, the baking soda and vinegar reacted to produce carbon dioxide gas. As more gas was produced the pressure inside the canister built up, pushing on all sides of the canister and the lid. The lid could not go down, so the body of the canister went up.

In the water rocket the air you pumped into the bottle increased the pressure inside it, pushing out the stopper. The water rushing out of the bottle caused the bottle to lift off. As the water escaped, the bottle became lighter and the acceleration increased. This is *Newton's second law of motion* (F = ma): a force will give a greater acceleration to a small mass than it will to a large mass.



INVESTIGATION

2 Balloon rocket

Aim

To measure the maximum payload that can be lifted by a balloon rocket.

Risk assessment and planning

Read the investigation carefully to identify any possible hazards.

Apparatus

- large, long balloon
- fishing line
- plastic straw
- paperclips or other small masses
- adhesive tape
- balance
- small plastic cup

Method

Set up the apparatus as shown on the right. Use it to measure the maximum payload that can be lifted to the ceiling by the balloon rocket.

Try altering variables (e.g. the type of balloon) to increase the maximum payload.

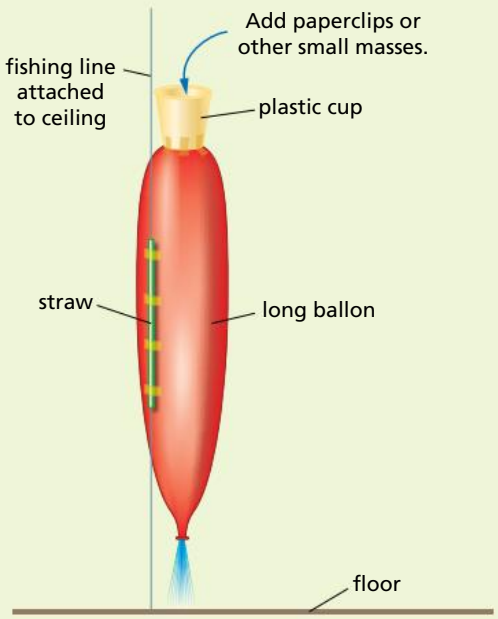
Write your report

Write a report explaining your method in detail, and giving your results.

Conclusion

1 What is the maximum payload that can be lifted by your balloon rocket?

2 The *thrust* of your rocket is the upwards force (reaction) due to the air escaping from the balloon (action). To launch the rocket this thrust must be greater than the weight of the rocket. Estimate the maximum thrust of your rocket.

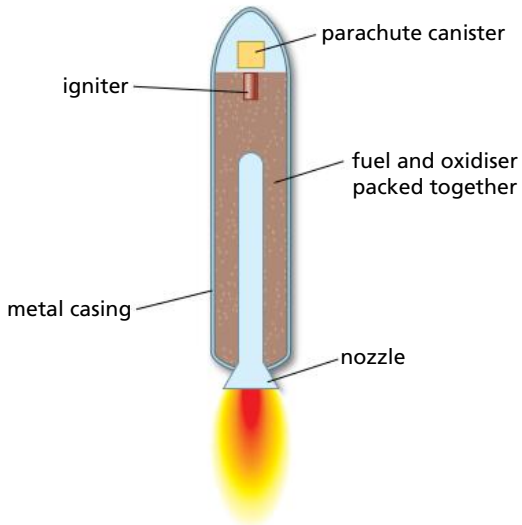


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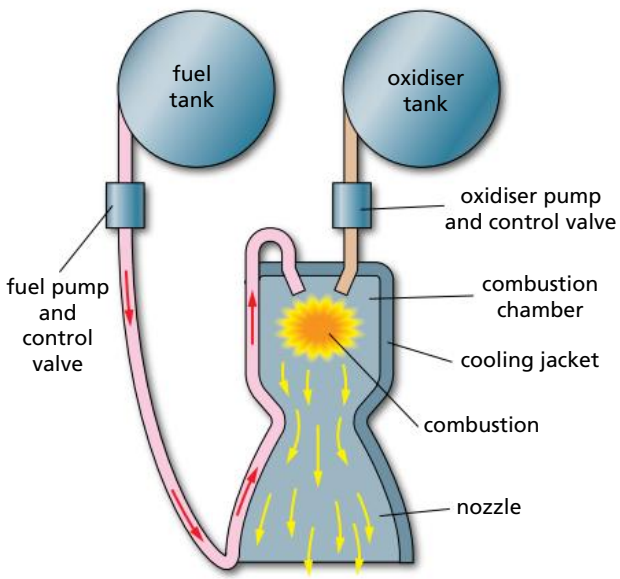
Rocket technology

Two types of rocket engine are used to launch spacecraft: the solid-fuel engine and the liquid-fuel engine.

A solid-fuel engine uses a solid fuel mixed with an *oxidiser*, like a fireworks rocket (see diagram below). A spark ignites the mixture, which burns very quickly but does not explode. High-speed gases are forced out of the nozzle. The space shuttle has two solid-fuel boosters on either side of its main engine. They use up their fuel in 2 minutes and then they are ejected. Parachutes enable the rocket casings to be recovered for reuse. The major disadvantage of a solid-fuel rocket is that once it is ignited it cannot be stopped or slowed down.



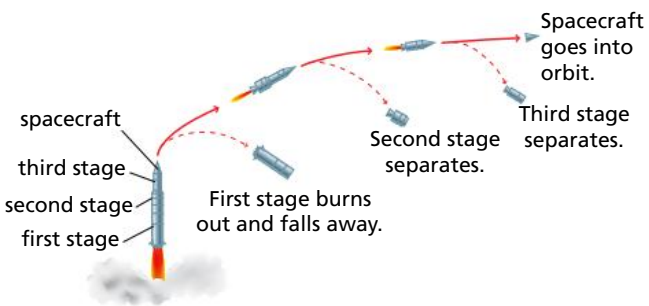
A solid-fuel rocket engine



A liquid-fuel rocket engine

A liquid-fuel engine has complicated pipework and pumps to force the liquid hydrogen fuel and the oxidiser (liquid oxygen) into a combustion chamber, where they are ignited and burn explosively. The advantage of this type of engine is that it can be turned on and off. You can also control the speed of the rocket by controlling the flow of fuel and oxidiser.

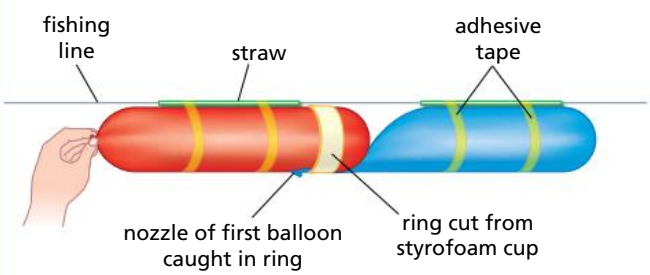
Rockets usually achieve the thrust required to send a spacecraft into orbit around the Earth by being built in stages, with several rockets on top of each other, as shown below. Each stage has its own fuel tanks and engines. The biggest challenge is getting the rocket to escape the gravitational pull of the Earth. For this reason very powerful engines and huge amounts of fuel are needed. However, once the first and second stages drop off, the mass is much less and the final stage can easily go into orbit around the Earth. The spacecraft then continues in a straight line according to Newton's first law of motion, but is continuously pulled back towards the Earth by gravity. In this way it stays in orbit.



INQUIRY 1 — *Two-stage balloon rocket*

You will need: 2 long balloons, fishing line, adhesive tape, 2 plastic straws, styrofoam cup, Stanley knife

1. Set up the two balloons on a fishing line tied across the room as shown.
2. Release the first balloon and observe what happens.
3. Can you make a three-stage balloon rocket?



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Over to you

1 Draw and label the forces on a rocket as it takes off.

2 Explain why a blown-up balloon shoots around the room when you release it.

3 When a person stands up in a stationary boat and moves forward to tie it to a jetty, the boat sometimes moves backwards. Why does this happen?

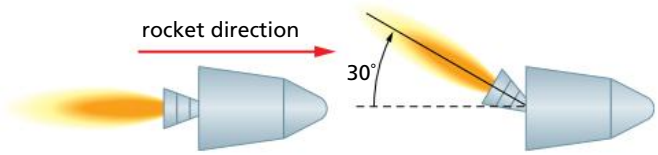
4 Describe the differences between solid-fuel and liquid-fuel rocket engines.

5 What is the advantage of using multi-stage rockets to launch spacecraft?

6 The manoeuvring rockets on spacecraft always use liquid fuel, never solid. Why?

7 Why does the space shuttle have to carry liquid oxygen (the oxidiser) but jet aircraft do not?

8 A rocket is accelerating in the direction shown. The rocket can change direction by rotating its engine, as shown. In which direction will it move? Use a diagram to explain.



9 A rocket of mass 12 000 kg is in deep space where gravity is virtually zero. It fires its rockets and accelerates at 5 m/s^2. Use the formula F = ma to find the thrust of its engines.



The Saturn V *rocket (right) used to launch the Apollo missions was over 100 m high. It burnt almost 2 tonnes of kerosene and oxygen every second. The rockets used today to launch the space shuttle (left) and satellites are much smaller than this.*

SKILL

Rocket equations

The force of the downward escaping gases from a rocket produces an equal and opposite reaction, which pushes a rocket upwards. This force is called the *thrust*. Using Newton's second law of motion (F = ma), the thrust of a rocket is equal to the mass of the escaping gases multiplied by the acceleration of the gases. The rocket will lift off the launch pad if there is a net upwards force. To calculate this force, subtract the weight of the rocket from the thrust:

net force = thrust of engines – weight

For example, the space shuttle's total mass was 2 000 000 kg and the thrust of its engines at lift-off was 33 000 000 N (Newtons). To calculate the weight (W) of the space shuttle, use the formula W = mg, where m is its mass in kilograms and g is the acceleration due to gravity (9.8 m/s^2).

Weight of space shuttle $= 2\,000\,000\text{ kg} \times 9.8\text{ m/s}^2$
$= 19\,600\,000\text{ N}$

Net upwards force $=$ thrust – weight of shuttle
$= 33\,000\,000 - 19\,600\,000\text{ N}$
$= 13\,400\,000\text{ N}$

To calculate the upwards acceleration, rearrange the equation F = ma to a = F/m.

Upwards acceleration of space shuttle $= \dfrac{13\,400\,000\text{ N}}{2\,000\,000\text{ kg}}$
$= 6.7\text{ m/s}^2$

Questions

1 Use the example above to solve this problem. A lunar lander with a mass of 3000 kg lands on the moon. When the astronauts are ready for lift-off, they fire the lander's rockets with a thrust of 15 000 N.

- **a** If g = 1.6 m/s^2 on the moon, what is the weight of the lander on the moon?
- **b** Is the thrust sufficient to lift the lander off the surface? How do you know?
- **c** What is the net force on the lander at lift-off?
- **d** What is the acceleration of the lander at lift-off?

2 Suppose the space shuttle lifted off from the moon, where g = 1.6 m/s^2, instead of from the Earth.

- **a** Predict whether its acceleration would be greater than, smaller than or the same as on Earth. Explain your prediction.
- **b** Calculate the acceleration to check your prediction.

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12.2 Living in space

Weightlessness

One day when Albert Einstein was thinking about the universe, this thought occurred to him: 'If a person falls freely he will not feel his own weight'. This seemingly simple thought made a deep impression on him. It eventually led him to his theory of gravitation.

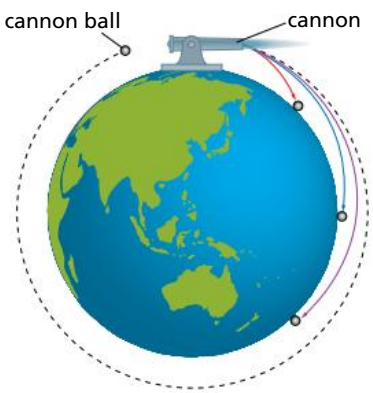
Suppose you are standing on bathroom scales in a lift on the 30th floor. Suddenly the lift cable breaks and the lift falls. You and everything in the lift also fall. The reading on the scales will soon reach zero. At this point you are *weightless*. You and the lift are in free fall.



Astronauts in free fall in the Vomit Comet

Astronauts in space experience weightlessness, and to train for this they use the *Vomit Comet*. This special aircraft climbs steeply, levels out, then dives. This is like a roller-coaster in the sky, and at the top of the loop the astronauts experience zero gravity for about 25 seconds.

When a spacecraft goes into orbit around the Earth it is also in free fall. Amazingly, Isaac Newton worked this out over 300 years ago by doing this 'thought experiment'. Imagine a cannon on top of a very high mountain. The greater the speed of the cannonball, the greater the distance it travels before landing. If fired at a high enough speed, the cannonball would reach a state where it is continuously falling towards the Earth yet stays in orbit.



Many people mistakenly think there is no gravity on astronauts in orbit. This is incorrect because the pull of gravity on them is about 90% as strong as the pull they would experience back on Earth. The further you go away from the Earth, the less the gravity. However, to reach a point of zero gravity, the spacecraft would have to travel 17 times further away than the moon.

Astronauts in orbit only *appear* to have no weight because they are in free fall and are falling continuously. The condition where astronauts in free fall experience reduced gravity and appear to be weightless is called **microgravity**.

INQUIRY 2 Weightless water

You will need: empty soft drink can, nail

1. Punch a hole in the can near the bottom.
2. Fill the can with water, holding your thumb over the hole. Remove your thumb from the hole and the water squirts out.
3. Now drop the can from a height as you remove your thumb from the hole. What happens?
4. What happens if you toss the can full of water through the air rather than letting it fall?

■ Write inferences to explain all your observations.

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Air and water

A spacecraft's life-support system supplies air at normal Earth pressure to enable the crew to survive. Water is produced in fuel cells that combine hydrogen and oxygen chemically and also produce electricity. The carbon dioxide and other gases produced by the astronauts are removed through filters.

Moving about

When you are weightless, every move you make must be carefully controlled. You can move in any direction with just a little push in the opposite direction. You can work upside down without the feeling of blood rushing to your head. Everything must be fastened down with Velcro straps or magnets or it will float around the spacecraft.

There is no need to wear a spacesuit inside the spacecraft. Astronauts wear in-flight coveralls which are close-fitting and fire-resistant. These have a lot of pockets as things cannot be left floating around.

Eating

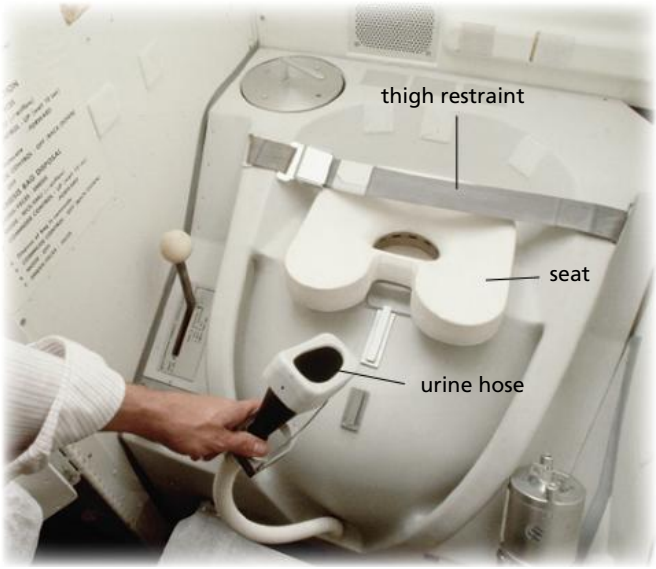
Most space food is preprocessed so that it can be stored for long periods in as small a space as possible. The food is processed and preserved in different ways (e.g. plastic or foil pouches, cans, freeze-dried). You can buy similar items in the supermarket. The food is carefully prepared to contain the vitamins, minerals and energy needed to keep the astronauts healthy. It is also designed to keep the production of body gases to a minimum.

On the space shuttle there are more than 70 different foods and 20 different drinks available. One of the most popular meals is freeze-dried prawn cocktail, which comes in a plastic pouch. To prepare the meal you have to add water from a needle dispenser into the plastic pouch. Once the water soaks into the food, it is ready for eating. Most meals have sauces to glue the food together and prevent it breaking into bits and floating around the cabin.

You do not need a table and chairs to eat at. The meals come in special trays that can be attached to your body or any surface by Velcro strips. You drink by sucking through a special straw that has a valve in it so the liquid cannot flow out of it.

Personal hygiene

To urinate astronauts do not need to sit down. They simply attach a personal funnel to a suction hose, then hold the funnel against their body. The urine is vacuumed away and stored. It is then dumped into space, where it immediately vaporises, producing an 'ice shower'.



A space toilet

To defecate is more complicated. Astronauts have to sit on a special toilet, making sure they are in the correct position. To avoid floating off the seat the astronaut uses foot restraints and a belt that is clipped across the thighs. This ensures a tight seal so that nothing escapes. Air suction removes the faeces into the compartment below. These wastes are returned to Earth. During launch, re-entry and spacewalks, astronauts wear adult-sized disposable nappies called maximum absorbency garments.

Astronauts can wash their hands in enclosed washing stations in which water is made to 'flow' by suction. To wash the rest of your body you use a wet cloth. After exercise any sweat must be wiped or vacuumed off to prevent drops of water floating around the cabin.

Sleeping

Because most spacecraft orbit the Earth in 90 minutes, there are 45 minutes of bright sunlight, followed by 45 minutes of total darkness. So sleeping can be difficult and astronauts often wear eyeshades and earmuffs. There is no 'up' or 'down' in space, so astronauts can sleep as comfortably in the vertical position as in the horizontal. They can sleep in their seats, in sleeping bags or in bunks, but they need to strap themselves in so they do not float around. They may simply attach themselves to a wall somewhere.

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Effects of space on the body

Before humans went into space, the effect of space on their bodies was unknown. As a precaution animals were first sent into space to see if they survived. Laika the dog was the first animal sent into space on the Russian *Sputnik II* in 1957. She survived. The first person in space was also a Russian, Yuri Gagarin, in 1961. Astronauts have now survived in space for long periods of time, but there are many changes that occur to their bodies.



Laika

In microgravity, with no 'up' and 'down', astronauts are weightless and float about the spacecraft. This affects the balance organ in the inner ear and astronauts experience space motion sickness, which is like carsickness or seasickness. This produces dizziness, sweating, vomiting and headaches. After a few days, however, the body adapts to space and the sickness goes away. To get an idea of what space motion sickness is like, sit in a chair that can spin in a full circle and spin around a few times. Then get out of the chair, close your eyes and stand on one leg.

Owing to the force of gravity on Earth, blood and body fluids are pulled down towards the legs. However, in microgravity, blood and fluids are redistributed throughout the body, away from the legs and feet. This results in puffy-faced or moon-faced astronauts because body fluids tend to fill in the usually empty facial cavities.

On Earth your body is adapted to gravity and your heart pumps blood to all parts of the body, including your legs. In microgravity blood does not flow naturally to your legs. Instead, the blood and fluids pool in your head and chest. This is similar to what would happen if you stood on your head for a few days. This fluid build-up can also lead to stuffiness similar to a head cold, and can affect your sense of smell and taste.

Your body responds as if there is excess blood, and blood volume can decrease by 10%. As well as your face swelling, your legs get thinner and astronauts call this 'chicken legs'. Also, your heart shrinks because it does not have to work as hard.

INQUIRY 3 A body in space

You can get some idea of what happens to the body fluids in space by using a balloon.

1. One-third fill a balloon with water and hold it up.
2. Now throw the balloon into the air.
   - What happens to the shape of the balloon?

In space, astronauts' muscles and bones are not used much and as a result they waste away, or *atrophy*. Bones lose calcium, making them weaker. To counteract this, astronauts must exercise regularly to keep their bones and muscles strong. When astronauts return to Earth they are sometimes so weak they cannot walk and need to be carried.

INQUIRY 4 Space bones

You will need: a chicken bone, vinegar, jar

1. Try to bend the chicken bone, but do not break it.
2. Put the bone in a jar, cover it with vinegar and leave it for two days.
3. Pour out the vinegar, replace it with fresh vinegar and leave another two days. Do this twice more until the bone has been in the vinegar for eight days.
4. Pour off the vinegar and rinse the bone in water. Now can you bend the bone?

The vinegar dissolves the calcium in the bone and makes it rubbery. This is similar to, but faster than what happens to astronauts' bones in space.

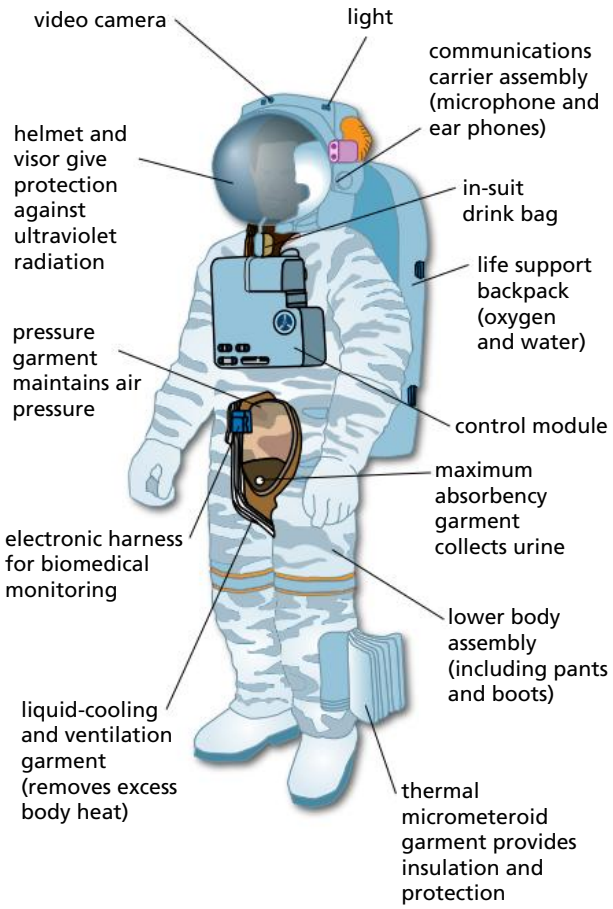
Astronauts get taller after spending time in space. The backbone is a series of vertebrae with intervertebral discs between them. These discs contain cartilage and have soft centres that act as cushions between the vertebrae. On Earth the force of gravity compresses the cartilage in these discs. In space, the discs expand because there is less gravity. As a result, astronauts can grow taller by as much as 5 cm. Once back on Earth they return to their normal height.

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Spacesuits

The lower the air pressure, the lower the boiling point of a liquid. So to go outside the spacecraft astronauts wear a pressurised spacesuit which prevents their body fluids boiling in the low pressure of space. The spacesuit protects the astronaut from bombardment by micrometeoroids—tiny specks of matter travelling through space at high speed. It also shields the astronaut from the extreme temperatures in space, from 120 °C to –120 °C. Oxygen is supplied through the helmet.

The spacesuit has 13 layers of material cemented together to form the suit. There is an inner cooling garment (two layers), a pressure garment (two layers), a thermal micrometeoroid garment (eight layers) and an outer layer. Each suit weighs 127 kg and costs $16 million.



INQUIRY 5 Spacesuit models

Part A: Teacher demonstration

You will need: balloon, bell jar, vacuum pump

1 Slightly inflate the balloon and tie off the nozzle. This is a model of a human body.

2 Put the balloon inside the bell jar and use the vacuum pump to slowly extract the air from the jar to simulate the low pressure of space.

- What happens? Write an inference to explain your observation.

3 Predict what will happen when air is allowed to return to the bell jar. Try it. Was your prediction correct?

Part B: Bending a spacesuit

You will need: 2 long balloons, 3 thick rubber bands

A spacesuit must have the proper pressure to work properly. You can use a long inflated balloon to model a spacesuit. The more pressure there is in the balloon, the more difficult it is to bend. Space engineers have therefore built in joints to make spacesuits more flexible.

Use the rubber bands to make joints in an inflated balloon. Does this make it more flexible?

Over to you

1 Describe at least six effects of weightlessness on astronauts.
2 Why is it that astronauts lose muscle and bone mass in space?
3 Why is exercise so important when living in space?
4 Why is it necessary for an astronaut to move about very carefully in a spacecraft?
5 When outside the spacecraft, astronauts need to wear a spacesuit. Describe the dangers in space that the spacesuit is designed to protect the astronauts from.
6 Why do all floating crumbs and drops of liquid in a spacecraft need to be collected?
7 Using the terms 'free fall' and 'weightlessness', write a sentence to describe microgravity.
8 Astronauts often experience back pain. Suggest a reason for this.

PROBLEM SOLVING

Have you decided on an experiment for the International Space Station? What you have learnt about microgravity (weightlessness) in this section may give you some ideas.

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SCIENTISTS AT WORK

Dr Andy Thomas

Andy Thomas was born in Adelaide, South Australia, in 1951. He knew early in life that he wanted to become an astronaut. In an interview he said 'The *Apollo* landings were just absolutely mesmerising for a young teenager. I think it was at this time that I got this passion of the idea of space flight, and I thought *Wouldn't it be wonderful to be an astronaut?* Of course, it wasn't a very high probability that I'd ever get to achieve it, but with the right kind of education and focus, you can.'



Andy received a degree and a PhD in mechanical engineering from the University of Adelaide, and in 1977 he started working as a research scientist for Lockheed Aeronautical Systems in Georgia, USA. He later headed a research team that solved aerodynamic and flight test problems. He then got a job at NASA's Jet Propulsion Laboratory, where he studied microgravity on board the *Vomit Comet* (see page 263). Finally, in 1992 he was selected to join America's Astronaut Corps and trained to be a mission specialist.

In 1996 Andy spent his first day in space on board the space shuttle *Endeavour*, which put two satellites into orbit. He next trained at the Gagarin Cosmonaut Training Centre in Russia, and in 1998 he spent 141 days on the Russian space station *Mir*. During this time he completed 2250 orbits of the Earth.

In 2001 Andy was again in space in the space shuttle *Discovery*, which docked with the International Space Station. He performed a 6½ hour spacewalk, installing components on the outside of the space station. The photograph shows the space shuttle with its robotic arm docked with the space station.



After the *Columbia* disaster in 2003, the space shuttle fleet was grounded, but in 2005 space shuttle *Discovery* returned to space with Andy on board. Its mission was to take supplies such as food, water and science equipment to the International Space Station. They also tested a new safety system and checked the outside of the shuttle carefully to avoid another disaster like the *Columbia*.

Andy is married to Shannon Walker, who is also an astronaut. He enjoys horse riding and jumping, mountain biking, running, wind surfing and playing classical guitar. He also likes to tinker in his garage, building things and repairing cars.

Questions

1. What subject did Andy Thomas study at university?
2. How do astronauts get to the International Space Station?
3. How many times has Andy been into space?
4. What do you think the robotic arm on the space shuttle is for?
5. Would you like to be an astronaut? Do you think you could?
6. Would you have been brave enough to go into space in the space shuttle after the *Columbia* disaster as Andy did? Explain.

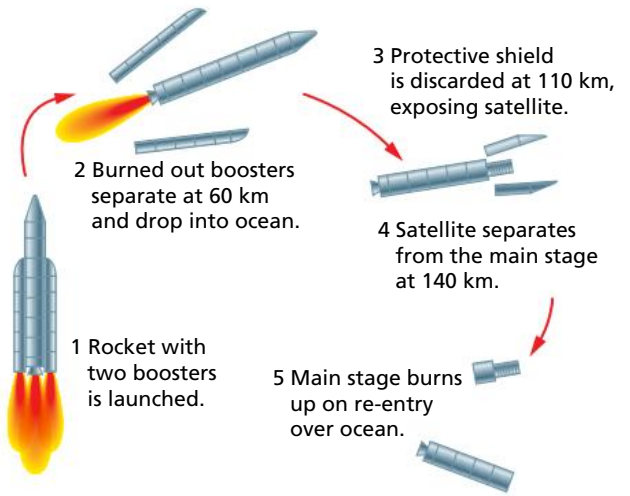
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12.3 Using space

Satellites

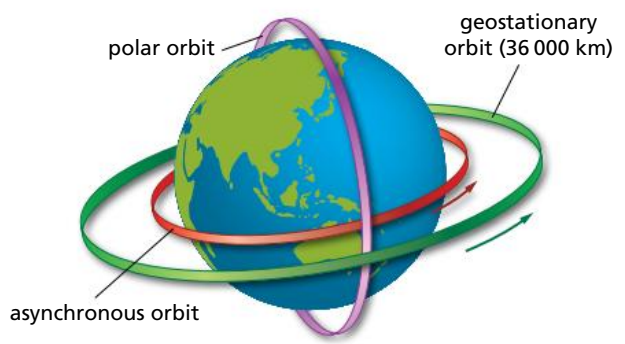
The Russian *Sputnik* satellite was the first to orbit the Earth in 1957. There are now about 5000 satellites in orbit around the Earth, many of them obsolete (no longer in use).

Satellites can be placed in Earth orbit in two different ways. They can be carried into space in the cargo bay of the space shuttle. Most, however, are carried into space on top of large rockets, as shown.



Satellites can be placed in several types of orbits. Most communication satellites are put into synchronous or **geostationary orbit**, 36 000 km above the Earth. This means they move in the same direction as the Earth rotates and take exactly one day to complete an orbit. During this time the Earth rotates once on its axis. This means the satellite stays over the same point on the Earth's surface. These satellites relay information such as telephone calls, television signals and internet data.

Remote-sensing and spy satellites orbit closer to the Earth in *asynchronous* orbit. They move at high speed in the same direction as the Earth rotates and do not stay over the same point.



In *polar* orbit, a satellite moves on a path at right angles to the rotation of the Earth, ensuring complete coverage of the planet over time as the Earth rotates under the satellite.

The weather satellites that take the pictures we see on television weather reports are either in geostationary or polar orbits. The Global Positioning System (GPS) consists of 24 navigation satellites spread in six different asynchronous orbits. GPS uses three or more satellites to locate objects with an accuracy of 10–20 m.

Space stations

A space station is a large orbiting structure where people can live and work in space. In 1973 the Americans put *Skylab* into orbit and in 1986 the Russians put *Mir* into orbit. Both of these have since re-entered the Earth's atmosphere and burnt up.

The International Space Station (see below) is a joint project between 16 countries—United States, Russia, Japan, Canada, Brazil and 11 European countries. It was assembled from modules taken into space by the space shuttle or by rocket. It took over 100 space flights to complete, and is 109 m long and 73 m wide, with 4000 m^2 of solar panels to provide power. It moves at about 3000 km/h in asynchronous orbit 400 km above the Earth.

It has laboratories for doing experiments in space, and can accommodate six astronauts. It is seen as a stepping stone to outer space. The hardest part of getting into space is leaving the Earth's surface. However, if the Space Station is used as a base, it is much easier to travel further into space (for example, Mars and beyond).

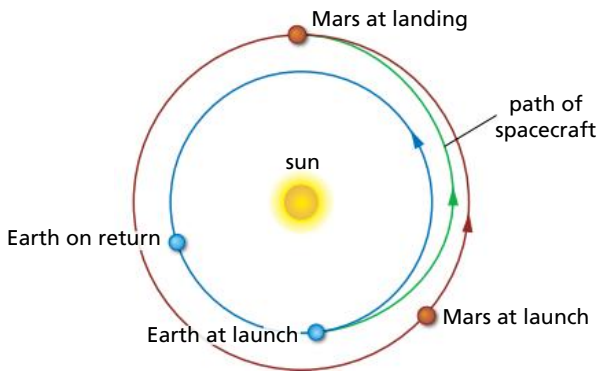


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Going to Mars

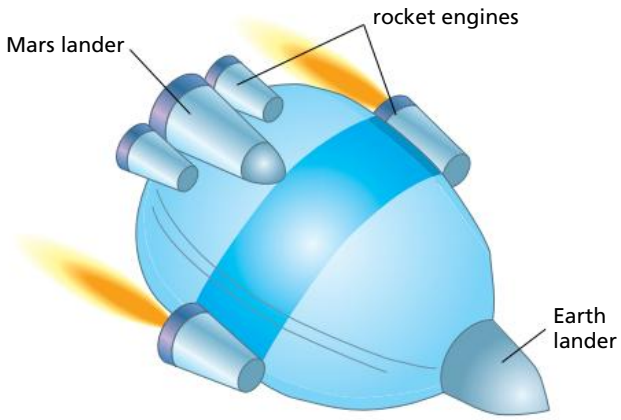
Mars is our nearest planet, and scientists now think it may be possible to go there in the future.

Sometimes the Earth and Mars are on the same side of the sun and sometimes they are on opposite sides. The best position for launch is when both are on the same side of the sun, as shown. This happens every 26 months. The trip takes about 260 days (about 9 months) using today's technology. The spacecraft has to be launched as shown to give it a greater speed around the sun. This greater speed is needed to get further out and catch up with Mars. While it travels from Earth to Mars, the spacecraft is in an elliptical (oval-shaped) orbit around the sun so it does not need to use its rocket engines.



The round trip to Mars would take about 2 years, so a large spacecraft would be needed to carry the huge amounts of fuel, air, water, food and equipment. The spacecraft would also need to carry smaller craft to land on Mars and to land back on Earth. It would therefore need to be built in orbit bit by bit, like the International Space Station. It has been estimated that a crew of six would need a million kilograms of supplies. So, given that the space shuttle can carry only about 20 000 kg, it would take many trips to get these supplies into orbit.

Once the spacecraft has been assembled and is orbiting the Earth at about 30 000 km/h, it fires its rocket engines and increases speed to 40 000 km/h. Once well away from the Earth it can shut down its engines and its inertia will carry it to Mars. During this part of the trip the crew are weightless and the effects of microgravity on the human body for long periods are still not properly understood. It may be possible to create artificial gravity by using special rockets to spin the spacecraft. During the flight the astronauts would need to be protected from the sun's radiation, especially during solar flares.



As the spacecraft approached Mars it would begin to come under the influence of Mars' gravity. It would begin to gain speed and fall towards Mars, so the spacecraft's engines would need to slow it down and point it in the right direction to go into orbit around the planet.

It is unlikely that the huge spacecraft would be designed to land on Mars since it would be too difficult to get it off again for the return flight. Instead it would carry its own landing module which would be detached from the main spacecraft, land on Mars and carry enough fuel to lift off again. This is how the *Apollo* landings were made on the moon.

Mars is half the diameter of Earth and only one-tenth the mass. Having a smaller mass means that the gravity is less than half what it is on Earth. Its atmosphere is 95% carbon dioxide, with only traces of oxygen. The atmospheric pressure is only one-hundredth what it is on Earth. It is also very cold, varying from –133°C to 27°C. So astronauts would need to wear spacesuits.

Mars has a rocky, cratered surface and is covered with reddish soil. There is a huge canyon 4000 km long and 2–7 km deep. There are wind storms and the sky is pinkish-yellow. The day is about the same length as on Earth, and there are two tiny moons.

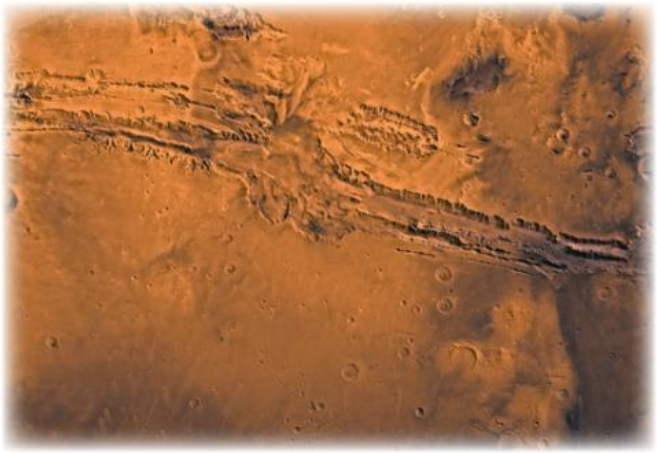
Because of the low gravity, less force would be required to lift the landing module off Mars than off Earth. The lander would go into orbit around the planet and dock with the main spacecraft, which would then fire its engines to escape Mars' gravity and head back towards Earth.

Landing on Earth is more difficult than landing on Mars because the gravity is much greater, and the atmosphere is thicker. The Earth lander would therefore have to be coated with a special heat-resistant material, like the space shuttle, or it would melt or burn away on re-entry.

ISBN 978 1 4202 3246 2

Terraforming Mars

There are more than six billion people on Earth and the number continues to grow. This overcrowding, or the possibility of a planetary disaster, may force us to consider new homes in our solar system. The most likely place is the planet Mars.



Mars showing the huge canyon Valles Marineris

NASA probes have discovered frozen water at the poles of Mars, and underground. There is also evidence of flowing water on the surface, and life might have existed there in the past. Mars is a cold, dry planet, but there are amazing similarities between the Martian atmosphere that exists today and the atmosphere that scientists infer existed on Earth billions of years ago. A number of people have therefore suggested the idea of **terraforming** Mars—making it more like Earth. This is a huge undertaking and would take hundreds of years, or more.

The first step in terraforming Mars is to warm it up, and various methods have been proposed. Large mirrors with a diameter of 250 km could be built in orbit around the planet. These would reflect the sun's radiation and heat the surface, especially the poles, where scientists infer there is frozen water and carbon dioxide. The mirrors could be constructed from material mined in space.

Another option is to build solar-powered factories to produce greenhouse gases, which could raise the planet's temperature as they have on Earth. CFCs and methane would be effective. Factories could be made out of materials mined on Mars. Another way to introduce greenhouse gases on Mars would be by drilling to release water vapour.

A more drastic method to warm up Mars would be to capture large, icy asteroids containing ammonia. These could be towed from the asteroid belt and hurled at the planet. Each asteroid would raise the temperature by 3°C and produce huge amounts of greenhouse gases and water. This method, however, would delay human settlement for centuries.

Once the temperature of Mars has risen above freezing (0°C), bacteria and primitive plants could be introduced. These would gradually convert the carbon dioxide in the atmosphere into the oxygen necessary for life. Eventually humans would no longer need to wear spacesuits and could begin growing crops for food.



This picture of the Martian surface was taken by the Mars rover Curiosity *in August 2012.*

INQUIRY 6 Terraforming Mars

1. Explain what terraforming Mars means. What are the reasons for doing this?
2. How do scientists plan to raise the temperature of Mars? Suggest other ways of doing this.
3. How is it planned to make Mars' atmosphere breathable for humans?
4. Where could the water needed to form rivers, lakes and small oceans on Mars come from?
5. A scheme has been proposed for building human habitats under vast glass ceilings in the canyons on Mars. Using what you know about Mars, describe what would need to be done to make the canyon habitable for humans. Include a sketch.
6. Use the internet to find out more about Mars and plans for terraforming it.
7. Write a letter to the editor of a newspaper explaining your opposition to or support for terraforming Mars.
8. Design a poster advertising holidays on Mars in the year 2200.

ISBN 978 1 4202 3246 2

Mining in space

In *Star Wars* the universe is teeming with massive spaceships—battle cruisers, interstellar transports and death stars the size of small moons. Many people predict that such massive spaceships will exist one day, but how?

The problem with building large spaceships here on Earth is gravity. It takes a huge amount of energy to get things off the ground and into orbit. The solution, therefore, seems to be to build spaceships on moons, planets or asteroids where the gravity is much weaker. Also, there are huge quantities of useful materials in space. For example, many of the asteroids between Mars and Jupiter are almost pure metal. Sometimes these asteroids stray from their orbits and come near Earth, like in the movie *Armageddon*. One of these near-Earth objects is called 1986DA. It is about 1 km in diameter and is literally a mountain of stainless steel. It has been estimated that there are more precious metals such as platinum in one asteroid than we could hope to mine from all the crust of the Earth! To mine these asteroids, however, mining machinery that operates in a microgravity environment is needed.

There are many useful materials that could be mined from the moon. For example, the lunar basalt could be used as a building material. The fine dust on the surface contains silicon and aluminium, which could be used to make solar cells for generating electricity in space. The lunar dust also contains helium-3, which can be used as a fuel for nuclear fusion, to help solve Earth's energy crisis. The mineral armalcolite, named after the *Apollo 11* astronauts (Armstrong, Aldrin and Collins), contains the metal titanium.



An electric rail gun for shooting ore into space

Mining has also been proposed for Mars. It has low gravity and it would be comparatively easy to launch materials into orbit for export to Earth or for use in space. The red dust is rich in iron and could be scooped up in buckets and accelerated along a track by magnetic waves to reach a high enough speed to escape from Mars' gravity. The buckets would then be stopped suddenly, causing the ore to be thrown into space where it could be caught and carried by space tugs to a construction site (see diagram). It should also be possible to mine ice from the poles and melt it for drinking water for a colony on Mars. The water could also be electrolysed to produce hydrogen (rocket fuel) and oxygen.

INQUIRY 7 Mining Mars

Work in groups of four for this activity. A new space station is to be built in space and the metal needed is to be mined on Mars. Your task is to investigate the feasibility of sending 100 people to live on Mars for 5 years to mine the ore. Your team consists of an engineer, a medical specialist, a food technologist and a manager. Choose one of these four jobs, answer the questions and discuss them with your group. Then present a joint report on whether the project is feasible.

Engineer

1. What type of living quarters will you build?
2. Will you process the ore on Mars or on Earth?
3. How will you transport the ore or the metal to the space station?

Medical specialist

1. What characteristics would the people on the project need?
2. How will you keep 100 people healthy and happy on the trip to Mars and during their time on the planet?

Food technologist

1. How will you feed 100 people on the voyage to Mars and while they are working on the planet?
2. How much food will you need to take with you?
3. Will you be able to grow food on Mars? How?

Manager

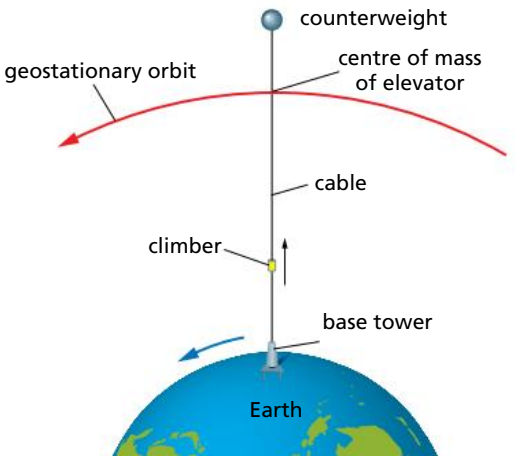
1. What could go wrong with the mission?
2. In your opinion, who owns Mars and has a right to its mineral resources?
3. Should you try to prevent environmental damage on Mars?

ISBN 978 1 4202 3246 2

Space elevator

The space elevator is an idea used by science fiction writers that may soon become reality. It consists of a cable about 47 000 km long, yet no more than a few centimetres thick, stretching from the surface of the Earth into orbit. The top of the cable is in geostationary orbit so that it stays in the same place above the Earth's surface. The base tower would be about 50 km high, probably built on a platform out at sea. The top of the cable would be tied to a counterweight, perhaps a small captured asteroid. The cable could be made from nanotubes, hollow cylinders made from sheets of hexagonally arranged carbon atoms. These are 100 times stronger than steel but very expensive at present. The climber would be like the car on a cable car, and would work like a maglev train, only vertically.

Using a space elevator, payloads could be put into orbit for as little as $2 a kilogram, compared with $30 000 a kilogram on a rocket.

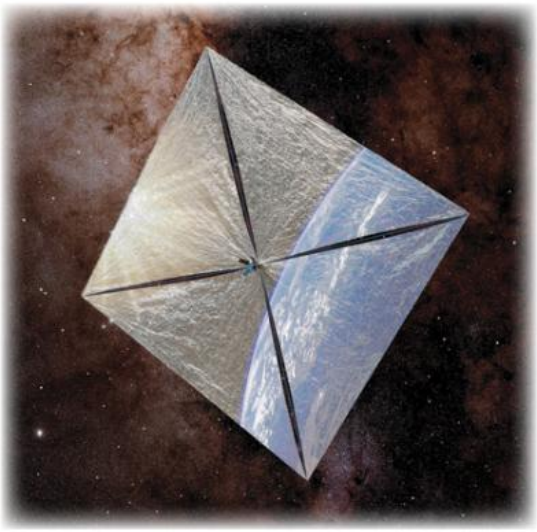


New rocket technology

If we are to explore the solar system beyond Mars, we will need faster spacecraft than we have now. This is why there is so much research into new rocket technology.

NASA is developing a spacecraft called *Prometheus*. It has a nuclear reactor that produces heat, which is converted to electricity. This electricity then powers an *ion thruster*, which produces a fast-moving beam of positive ions that propel the spacecraft in the opposite direction.

The Planetary Society is currently building a solar sail spacecraft as shown. It has four triangular sails and will be propelled by the pressure of light particles from the sun. The big advantage of this type of spacecraft is that it does not have to carry fuel.



A proposed solar sail spacecraft

Another idea is to use antimatter, as used by Star Trek's *Enterprise*. Antimatter consists of particles with charges opposite to that of ordinary matter. In antimatter, protons have a negative charge and electrons have a positive charge. When antimatter and matter combine, both are destroyed and huge amounts of energy are released. However, at this stage less than a billionth of a gram of antimatter has been produced.

Over to you

1 Describe four uses of satellites.

2 **a** What are the advantages of having a satellite in geostationary orbit?

b Why are most communication satellites in geostationary orbit, whereas many remote-sensing satellites are in polar orbit?

3 Draw a diagram showing how three weather satellites can cover the whole of the Earth's surface.

4 Which of the three proposed methods of rocket propulsion described on this page do you think is the most promising? Why?

5 What could be mined on:

a asteroids? **b** the moon? **c** Mars?

6 What is the big advantage of the space elevator over rockets?

7 It is cheaper to launch a satellite-carrying rocket in an easterly direction than in the opposite direction. Why?

8 The science fiction writer Larry Niven wrote a story about an asteroid that had been converted into a starship. What would need to be done to make this sci-fi idea a reality?

ISBN 978 1 4202 3246 2

12.4 Space tourism

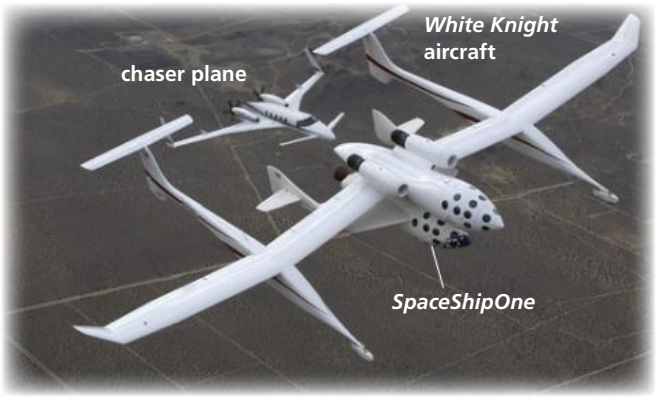
In 2001 American businessman Dennis Tito became the world's first space tourist. Tito flew into space aboard a Russian *Soyuz* rocket and spent several days on the International Space Station. He paid about $16 million for the trip. Six other people have been on similar flights since then.



Dennis Tito's flight was arranged by a company called Space Adventures.

Until recently space travel has only been possible with huge government-funded programs. However, the creators of *SpaceShipOne*, the first non-government manned spacecraft, have set out to change that. In 2004 they won the US$10 million prize for the first group to put three people into space twice in 2 weeks in a reusable spacecraft. *SpaceShipOne* was slung underneath the belly of the *White Knight* aircraft, which took off from a runway like a normal aircraft. At 16 000 m the spaceship dropped off the aircraft and its rocket motor fired. It used a mixture of tyre rubber and nitrous oxide (laughing gas). The rubber was the fuel and the laughing gas was the oxidiser. The spaceship climbed to 110 km above the Earth. It then levelled out and those on board experienced weightlessness. The spaceship then dived and returned to Earth as a normal aircraft.

Richard Branson, the billionaire owner of Virgin Blue, has announced a contract with the designer of *SpaceShipOne* to build a five to eight passenger spaceship, the *VSS Enterprise* or *SpaceShipTwo*. Virgin Galactic are offering suborbital flights above 11 km for a cost of about US$200 000 per seat. Thousands of people have expressed a strong interest in buying tickets.



INQUIRY 8 Would you go?

Read the description of the proposed flight into space with Virgin Galactic. Do you think it would be worth $200 000? Why?

Your journey out of this world begins not on the launch pad like a conventional space rocket but on a runway. Virgin Galactic craft are carried under a mother ship to 16 km above sea level. Then the countdown begins.

5, 4, 3, 2, 1 . . . *SpaceShipTwo*, your spaceship, is released from the mother ship (*White Knight Two*). Almost immediately, as your astronaut pilot ignites the engine, you will hear the roar of the rocket behind you as the enormous power accelerates you at 4 g to a speed faster than a bullet …

As you hurtle through the edges of the atmosphere, through the panoramic individual windows you will be able to see the cobalt blue sky turn to mauve and indigo and finally black. Out will come the stars, clear and bright … even though it is daytime! Soon the rocket motor cuts out. Now, from the rush of adrenalin and the rocket motor, everything is quiet. You are weightless … You are in space!

The ship will manoeuvre, so you can look for the first time back at the planet you have just come from. The view will be almost 2000 km in any direction …

After these precious minutes soaking up the thrill of space, you will start your return to Earth. Your seats will recline to make the journey through the atmosphere as comfortable as possible. At around 15 000 m the spaceship will return to a glider-like configuration for the landing back at the spaceport.

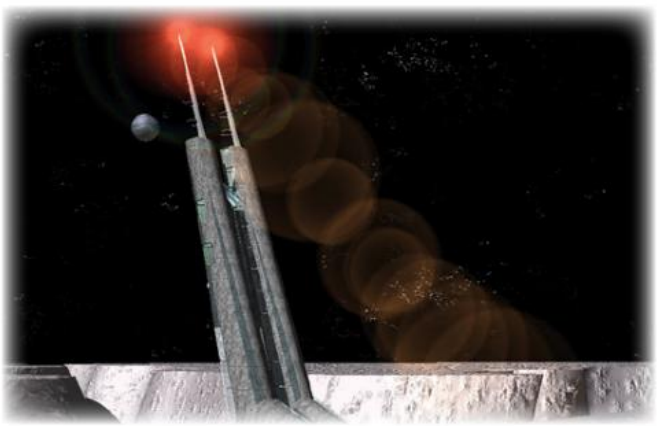
www.virgingalactic.com

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Holidays in space

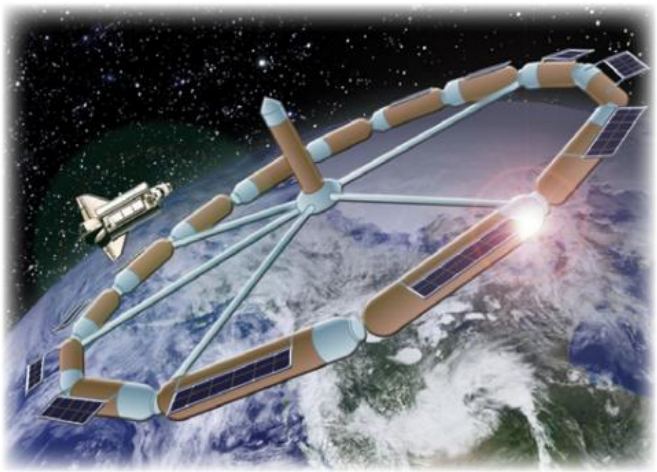
In the future it may be possible to build permanent accommodation or hotels in space. These would be incredibly expensive to build, but people are probably prepared to pay large amounts of money for such trips.

Several large hotel chains are investigating the feasibility of building a hotel on the moon. The Dutch architect Hans-Jurgen Rombaut designed the hotel below. The structure has two 160 m needle-like towers that soar over the rim of a deep canyon. This is possible because of the one-sixth Earth gravity and the absence of wind. To shield the interior, Rombaut designed 50 cm thick walls with two outer layers of moon rock and a 35 cm layer of water between glass plates. The water absorbs dangerous cosmic rays and helps keep the temperature constant. Suspended from the towers are teardrop-shaped 'habitation capsules' designed to look like little spaceships. The towers also provide ample space for low-gravity games, such as indoor mountaineering, abseiling and 'hang-gliding' using bat-like wings.



Moon hotel designed by Hans-Jurgen Rombaut

Space hotels have also been proposed to orbit around the Earth. These can be built any size and shape because of the microgravity environment. A common design is a wheel shape, like those in the movies *2001: A Space Odyssey*, *Star Trek*, *Deep Space 9* and *Babylon 5*. The Space Island Group has developed the design shown top right for Hilton International. It would be made from discarded main fuel tanks from the space shuttle. These normally separate from the shuttle, fall into the Earth's atmosphere and burn up. However, they could be left in space to make a space hotel, like a giant bicycle wheel with the tanks connected end-to-end to form the rim. It is proposed to rotate the hotel once every minute to create *artificial gravity*.



INQUIRY 9 Artificial gravity

You can easily demonstrate artificial gravity using a small billy-can or an empty tin can with a wire handle. Do this activity outside.

Half-fill the can with water and whirl it around your head.

- What is the force that keeps the water in the billy-can?
- How does the size of the artificial gravity change when you increase the speed of rotation?
- What is the lowest speed at which you can spin the can without spilling the water?



The water in the spinning can in Inquiry 9 seems to be pushed outwards, away from the centre of the circle. What actually happens is that the can is being pulled in towards the centre by your hand. The water stays in the can because of its inertia. The artificial gravity seems to pull the water towards the bottom of the can, just as gravity keeps you on the Earth.

In the rotating space hotel pictured above, the gravity on the rim would be about one-third Earth's gravity. So people and any other unattached objects would be pulled towards the outside rim of the space hotel. Moving towards the centre of the space hotel the gravity would decrease, and would be zero at the centre.

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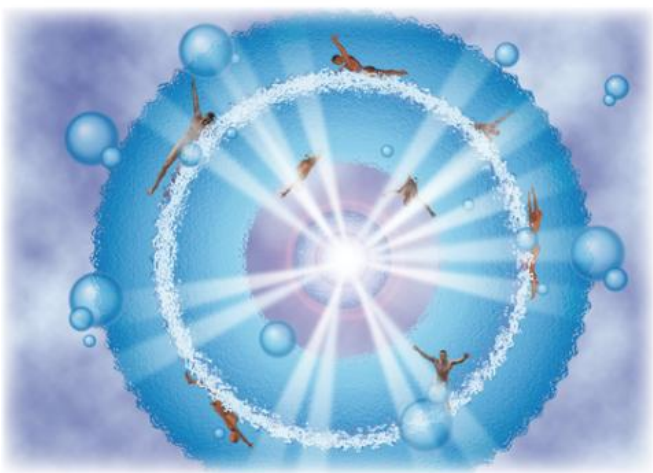
Space sports

In microgravity you float around and this allows you to play all kinds of sports. The astronauts who lived on board the US space station *Skylab* said they could not resist making acrobatic movements, somersaults, spins and so on. Whenever they had to move some distance they tried to spin and still land on their feet, like an Olympic gymnast, but at low speed. So space hotels are likely to have zero-gravity (zero-g) playrooms.

Eventually zero-g sports stadiums may be built in space. Zero-g versions of existing terrestrial sports could be played there, as well as completely new sports suited to zero-g. In rotating space hotels the ball would follow a kind of spiralling path, adding a new dimension to throwing and catching.

Astronauts in microgravity have also been fascinated by the way blobs of water float in the air inside a spacecraft. Some people have imagined a zero-g 'water room' with large blobs of water that you can throw at each other, or through which you can dive. This would provide a lot of unique entertainment.

In a rotating hotel you could even have a rotating swimming pool. You could swim around the outside of the pool, then dive out to float in the zero-g in the centre. Because there is no gravity, there are no buoyancy forces pushing you to the surface. This means that if you dive to the bottom of the pool, you will not float back up as you do on Earth. You will need to swim to get back to the surface. For this reason you will probably need mini scuba equipment. Water polo would be an interesting sport. In Earth's gravity, water polo is very tiring because you have to lift your body above the surface of the water. However, in a microgravity pool it would be quite easy to lift yourself out of the water.

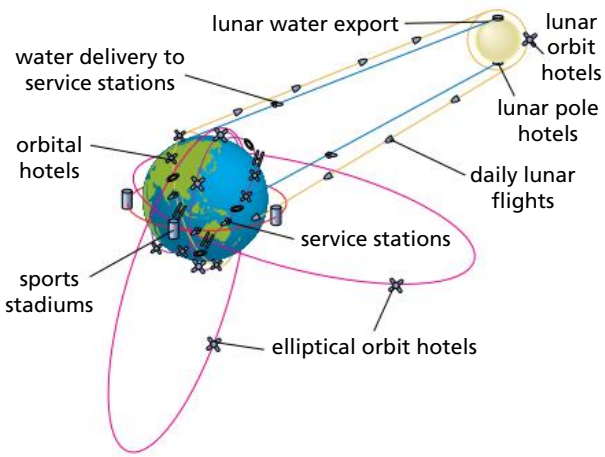


Artist's impression of a rotating swimming pool in a space hotel

Space tourism business

Patrick Collins, editor of the *Space Future* website, has described what the space tourism business might be like in the year 2030 (see diagram below). He has envisaged 100 or so hotels in orbit around the Earth, mostly in polar orbits. Some would be in large elliptical orbits to provide guests with more distant views of the Earth. There would also be sports stadiums in orbit. He has also proposed hotels on the moon and in orbit around it.

Collins imagined there would need to be at least one 'service station' in each of the main hotel orbits supplying water, oxygen and hydrogen. He suggested the water could be obtained from the poles of the moon, where astronomers think there could be water. This water could be electrolysed to produce hydrogen and oxygen for rocket fuel. Daily flights between Earth and the moon might be possible.



What space tourism might be like in 2030

Over to you

1 **a** Draw a diagram of a rotating space hotel, using stick figures to show the people in it.
   b How could you change the strength of the artificial gravity?

2 In a group, discuss how much you would be prepared to pay for a:
   a short suborbital flight (a few hours)
   b holiday in orbit (a week or more)
   c trip around the moon
   d holiday on the moon
   e trip to Mars (18 months minimum).

ISBN 978 1 4202 3246 2

12.5 Should we go into space?

The benefits

Satellites affect our daily lives in many ways. They allow us to see sporting and other events live anywhere in the world. They also save lives. For example, in 1997 three sailors participating in a round-the-world race for single-handed ocean-going yachts were rescued from the Southern Ocean by Australian boats and aircraft. The yachts were fitted with satellite location beacons that continuously transmit radio signals, which are picked up and relayed back to Earth by satellites. When the beacons were switched to distress mode, the yachts' positions could be determined to within 100 m, even among waves 8–10 m high.



English sailor Tony Bullimore was rescued after his yacht overturned in the Southern Ocean.

More than 30 000 new products and materials have been developed as a result of the space program. Here are some examples.

Cordless drills, shrub trimmers and Dustbusters are products made possible by NASA's *Apollo* program. Astronauts needed a way to drill down beneath the moon's surface to collect rock samples. Like everything else that went to the moon, the drill had to be small, lightweight and battery-powered. A computer program was used to design the drill's motor to use as little power as possible.

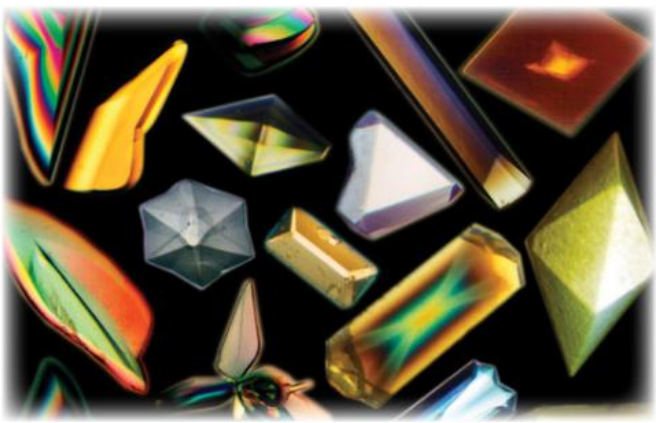
Hopefully, you have never been woken by a smoke detector. It would be bad enough in your home, but imagine having a fire in your spacecraft. In the 1970s NASA needed a smoke and fire detector for their *Skylab* space station. They developed the smoke detectors people have in their homes (see page 43). These have saved many lives.

In the 1980s NASA researched materials that filter out harmful welding light. This led to the development of polarised sunglasses, which block the ultraviolet rays in sunlight. They also developed scratch-resistant lenses. They were not trying to improve sunglasses but trying to find coatings to protect spacecraft from the harsh environment of space.

Other products and materials that have come from the space program are:

- voice and eye controls for wheelchairs
- Kevlar, an extremely strong polymer used to make racing bikes, yacht sails and bullet-proof vests
- convenience foods (e.g. freeze-dried ice-cream)
- pacemakers that can be implanted in a person's chest to control the rhythm of their heart.

Before the International Space Station was built, science experiments in microgravity had to be conducted on the space shuttle and could only last two weeks. Now scientists can conduct longer experiments on the Space Station. For example, many disease-causing bacteria contain enzymes that the bacteria need to reproduce and spread in the body. These enzymes must be a particular shape to work. If their shape can be changed by designing drugs that attach to the enzyme, the enzyme will no longer work, thus preventing the disease spreading. The only way to work out the exact shape of an enzyme is to grow crystals of it and then determine their structure using X-rays. But to do this large, perfectly shaped crystals are needed, which cannot be grown on Earth. If perfect crystals can be grown in space, better drugs may be developed.



A variety of protein crystals that were grown in space

ISBN 978 1 4202 3246 2

Problems

Space around the Earth is becoming more and more crowded, particularly in the region 36 000 km above the surface. So-called 'space junk' is made up of such things as old satellites no longer under control, discarded rocket boosters, payloads that have been lost and debris from exploded rockets. It is estimated that there are over 20 000 objects large enough to be tracked by radar in orbit around the Earth. These are potentially dangerous to astronauts and spacecraft because they travel at speeds up to 40 000 km/h. The International Space Station is designed so that it can be moved to avoid collisions with space junk.

There is also a risk of space junk returning to Earth. Most is small enough to burn up in the Earth's atmosphere, as meteors do. However, large pieces of junk have survived re-entry. For example, in 1979 NASA's *Skylab* space station broke up into fragments over Esperance in Western Australia. Fortunately, these fragments landed on an isolated sheep station on the Nullarbor Plain. The Russian *Mir* space station plunged back to Earth in 2001. Pieces as large as 700 kg landed somewhere in the Pacific Ocean between New Zealand and Chile.

In 1978 a Russian satellite with a small nuclear reactor on board crashed in Northern Canada. It scattered radioactive material over a wide area. As a result nuclear reactors cannot be used in orbit around the Earth. However, in 1996 a Russian space probe to Mars crashed near Chile in South America carrying radioactive plutonium batteries. They have never been found.

Another negative aspect of the space program is the loss of life. For example, in 1986 the *Challenger* space shuttle exploded shortly after lift-off, killing all seven astronauts on board. Then in 2003 the *Columbia* space shuttle broke up as it re-entered the Earth's atmosphere.

Finally, satellites are used to spy on other countries, so there is always the possibility of wars fought from space.



The Columbia *space shuttle disaster in 2003*

Science as a Human Endeavour

Space program inquiry

Imagine you are required to participate in a space program inquiry. The task of this inquiry is to decide whether we should continue spending huge amounts of money on the space program, given the number of people on Earth suffering from starvation and disease, and given the state of our environment. On the basis of this decision you are to decide whether further funds should be allocated to the space program.

1 Each person in the class must choose a role from this list:

- **a** five judges who hear the reports and rule on whether further funding should be allocated
- **b** members of research teams in the following areas:
  - NASA
  - Russian and European space agencies
  - satellites
  - the moon and Mars
  - space tourism
- **c** spokespersons for each of the research teams.

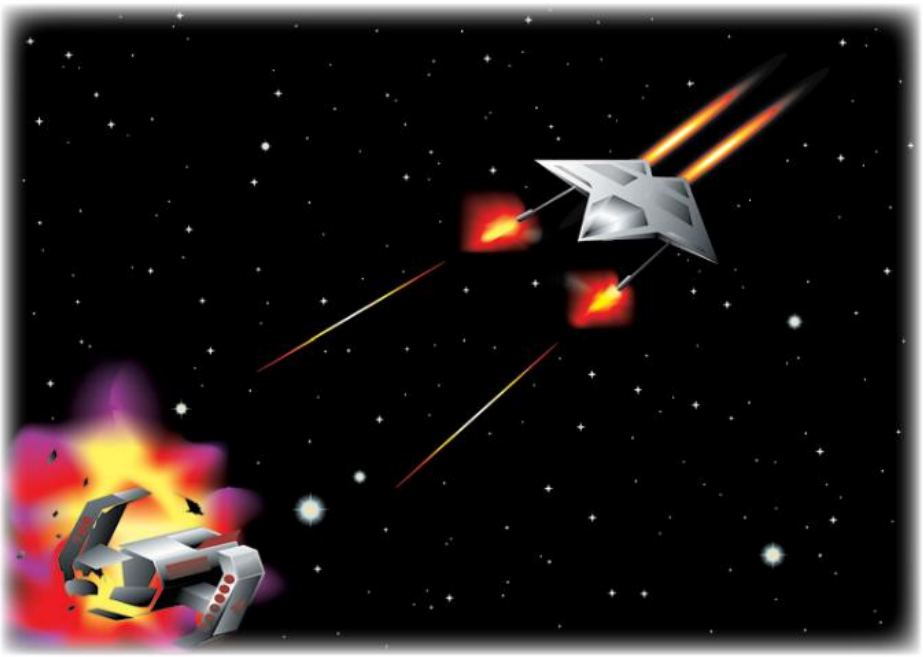
2 All class members must play their part in the inquiry. The judges must prepare questions that will help them assess the effectiveness of the space program. The research teams must provide their spokespersons with evidence to submit to the judges. The spokespersons will need to put the information together in a suitable manner for presentation.

3 Once the research teams are finished, the spokespersons present their material to those assembled for the inquiry. Following each report the judges can ask questions of either the spokesperson or the research team.

4 On the basis of the evidence received, the judges make their decisions.

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Science fiction



Sound in space

When the sci-fi horror movie *Alien* was released, it was advertised with the tagline 'In space no one can hear you scream'. However, in *Star Wars* you could hear plenty of things—like the whooshing sound made by a spaceship zipping across the screen, or an enemy spaceship exploding in a flash of colour and sound. So which movie is scientifically correct? Can you hear things in space?

Here on Earth sound travels as mechanical (longitudinal) waves transmitted through a solid, liquid or gas medium—like the air around us, the water in the ocean or the ground. (See *Science Essentials 7 for NSW* Chapter 8.) Pluck a guitar string and it vibrates. The vibration of the string pushes against the molecules of air around it. These molecules in turn push against other air molecules, which push against others, creating oscillation of pressure in the air, called a sound wave.

However, space is a nearly perfect vacuum, and there are no air particles to vibrate and carry the sound, so space is silent. A rocket launched from Earth makes a very loud sound, but once it travels out of the Earth's atmosphere into space, it makes no sound. As a spacecraft zips across the universe, it does so perfectly silently. And if it explodes in a space battle you won't hear anything. However you will see the light, because it is electromagnetic, not mechanical, and can travel through a vacuum. (See page 191.)

Radio waves are also electromagnetic and can therefore travel through space. Once a radio in a spaceship or an astronaut's spacesuit receives a signal, it converts it into sound, which travels through the air inside the ship or the helmet to the astronaut's ears.

Laser beams in space

Laser beams in space movies are also shown incorrectly. If you have ever seen a laser pointer in use you will know that you can't see the beam of light. You only see a dot of red or green light reflected from the surface the laser beam has hit. The beam can only be seen if there is smoke, dust or fog. When this happens the light reflects off the tiny particles of smoke, dirt or water in the air, scattering the light to your eyes. You are not actually *seeing* the laser beam, just the tiny particles illuminated by it.

In the vacuum of space there is no air to scatter the light, and laser beams are therefore invisible. Also, it is impossible to see a laser beam travelling from its source to its target, because it is travelling at the speed of light (300 000 km/s). The human eye could not possibly detect such fast motion. So sci-fi movies with laser blasts whizzing past the hero's head like tracer bullets are fun, but scientifically incorrect!

Over to you

1. Why can no one hear you scream in space?
2. Why can radio waves travel through space but sound can't?
3. Use the diagram on page 184 to explain the difference between transverse light waves and longitudinal sound waves.
4. A laser beam is invisible, yet when someone blows smoke into the path of the laser you can see the beam. Why is this?
5. A TV advertisement shows a very nimble robber working her way through a maze of security laser beams. Is there anything scientifically inaccurate about this? Explain.
6. Suppose you are floating in space wearing a spacesuit when you bump your head on the outside of the spaceship. Would you hear the bump? Explain your answer.

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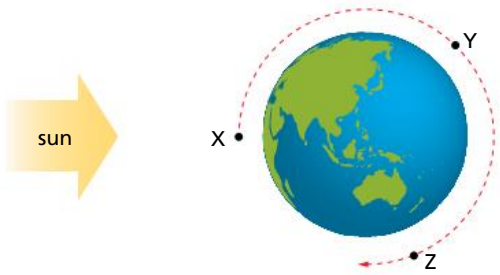
THINKING SKILLS

1 Arthur C. Clarke wrote a story called *The Wind from the Sun* about solar yachts that used the pressure of light particles from the sun to propel them. They had sails about 5 km^2 in area. The yachts started their race at point X and did one lap of the Earth, as shown.

a If the yachts had an acceleration of 0.001 g (about 130 km/h per hour), how long did it take them to reach a speed of 1000 km/h?

b At point Y the yachts continued to orbit the Earth but their acceleration dropped to zero. Why?

c How did the yachts travel from Z to X in the opposite direction to the light particles?



2 Calculate how long it would take a spacecraft launched from Earth to reach each of the planets, travelling at a speed of 48 000 km/h (the average speed of the *Voyager* spacecraft). The distances of each planet from the sun are listed in the table.

Planet	Distance from sun (million km)
Mercury	58
Venus	108
Earth	150
Mars	228
Jupiter	779
Saturn	1429
Uranus	2871
Neptune	4504
Pluto	5914

3 It is an advantage for spacecraft to be launched as close as possible to the equator. Suggest a reason for this.

4 When a spacecraft is travelling between Earth and Mars the astronauts are 'weightless'. How can you explain this?

5 Use the internet to find the latest news on current and future space missions.

6 Here are some ideas for colonising space:

- Establish a base on one of the moons of Jupiter or Saturn.
- Tap the hydrogen from the sun or from the giant gas planets to fuel nuclear-powered spaceships.
- Mine the asteroids.
- Build an artificial world orbiting the sun.

Work out a plot for a science fiction story using one or more of these ideas.

7 Design a new game or sport to play in the microgravity of space.

8 Research some proposals for space stations. Work in a group to construct a model of a space station. Seek help from your art teacher if necessary.

9 Use the internet to research the different animals that have been sent into space, and why they were sent. Debate whether animals should be used in space experiments.



Ham, the first chimpanzee in space

PROBLEM SOLVING

Have you designed your experiment for the International Space Station? Remember your experiment can be a long-term one. Try to investigate something that may benefit humans.

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Knowledge and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

1 All rockets work on the principle of action and reaction—they push hot _____ in one direction and go in the opposite direction.

2 Rockets need a fuel and an _____. There are two main types of rockets—solid-fuel rockets and _____-fuel rockets.

3 Astronauts who are in orbit around the Earth appear to be weightless because they are in _____. This condition is called _____.

4 Microgravity has a number of effects on the human body (e.g. the _____ does not work as hard and muscles and _____ waste away).

5 Satellites and space stations _____ the Earth. Other proposed uses for space are establishing a colony on Mars and mining the moon, Mars and _____.

6 In the future, space _____, with spaceflights and holidays in space hotels, may become big business.

7 The benefits of going into space need to be weighed up against the _____ and the risks involved.

asteroids
bones
costs
free fall
gases
heart
liquid
microgravity
orbit
oxidiser
tourism

Self-management

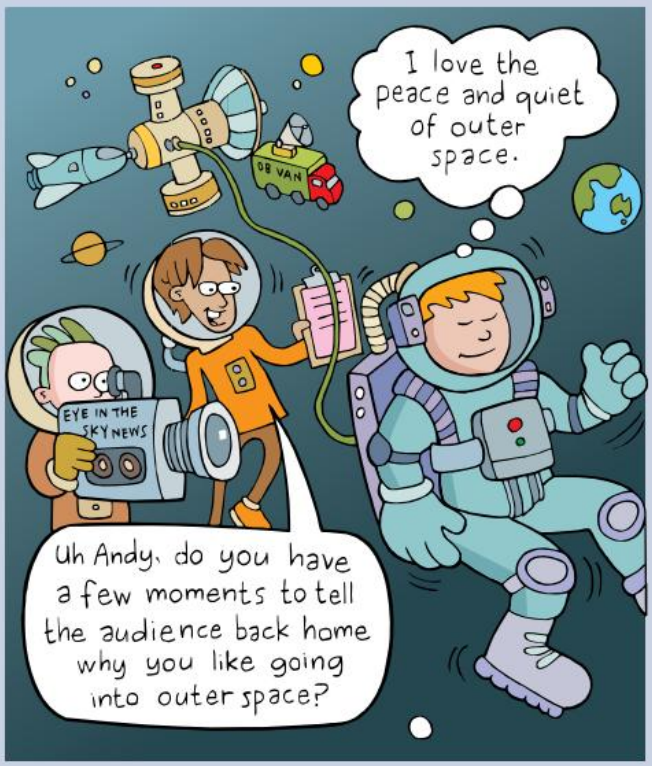
Interview with Dr Andy Thomas

Imagine you are a newspaper or television reporter. You have been given the job of interviewing Andy Thomas after his trip on the *Discovery* space shuttle to the International Space Station in July 2005.

1 Work in a small group to prepare a series of questions to ask Andy. Look through the chapter and think of two or three questions based on each of the five sections:
   - **a** the launch into space
   - **b** living and working in space
   - **c** how we can use space
   - **d** space tourism
   - **e** whether we should continue going into space.

2 Now prepare the answers you think Andy might give to each of your questions.

3 Finally, put the questions and answers together to make the interview. You could record the interview on audio or video. Alternatively, you could perform it for the class.



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Checkpoint

Remember to look at
www.OneStopDigital.com.au
for extra resources
OneStopDigital

1 You are standing on some bathroom scales in a lift. The lift suddenly moves downwards. The reading on the scales will:



A increase

B decrease

C stay the same

D decrease then increase again as the lift accelerates

2 On the rim of a spinning wheel-shaped space hotel the gravity is the same as on Earth. This gravity is the result of:

A the large mass of the space hotel

B the motion of the space hotel as it orbits the Earth

C the spinning of the space hotel around its central hub

D the gravitational attraction of the Earth

3 You are in a space shuttle in orbit 300 km above the Earth. Which of the following statements correctly explains why you feel weightless?

A The acceleration due to gravity 300 km above the Earth is zero.

B As it moves in its orbit the shuttle is free-falling towards the Earth, so the effect of gravity cannot be felt.

C The force of gravity decreases to zero when a spacecraft enters space.

D The force of gravity is balanced by the force of the shuttle's engines pushing it away from the Earth.

4 The space shuttle uses both solid-fuel rockets and liquid-fuel rockets.

a What is the advantage of using solid-fuel engines for lift-off?

b The engines in the space shuttle itself are the liquid-fuel type. Suggest why.

5 A spacecraft is cruising beyond the solar system with its engines turned off.

a What sort of motion will the spacecraft have? Why?

b What will happen if the rocket engines are fired in the normal way (backwards)? Use a diagram to explain.

c How could the spacecraft be slowed down? Use a diagram to explain.

6 **a** Firefighters often need to brace themselves or have extra help to hold a fire hose while it is on. Explain why.

b What would happen if they did not have this help?



7 Imagine you are a crew member on a space shuttle mission to the International Space Station. You make the following observations. Write an inference to explain each observation.

a Sleeping in a vertical position is as comfortable as sleeping in a horizontal position.

b After a week in space you notice that your face and neck become 'puffy' and you feel a fullness in the head.

c Inside the space station you sneeze and crash backwards into a wall.

d During re-entry you notice the tiles on the nose of the space shuttle glow red.

8 Buckley said 'Geostationary satellites do not move because they are so far from Earth that gravity has no effect. They just hang in space'. In simple language, explain why Buckley is wrong and why geostationary satellites only *appear* to be stationary.

9 Use Newton's second law of motion ($F = ma$) to explain why the acceleration of a rocket increases as its fuel is used up.

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Checkpoint answers

If your answer does not agree with the answer given here, go back to the chapter and re-read that section. Your answers may be slightly different from the answers given here. If you aren't sure about your answers, check with your teacher.

Chapter 1 Everyday reactions

1 **A** and **C** (see page 8)

2 **A**, as it is basic

3 **a** **B**, because it turned green in sodium hydroxide, which is alkaline.

b **B** It turned orange in hydrochloric acid, but any acid would turn it orange.

4 **a** C (highest pH)

b A (lowest pH)

c G

5 **a** exothermic (produces energy)

b exothermic (produces heat energy)

c endothermic (needs energy of UV radiation to break down O_2 moleclules)

d endothermic (needs energy of sunlight)

See pages 3–5.

6 **a** acid + base → salt + water (see page 21)

b acid + metal → salt + hydrogen (see page 8)

7 The carbon dioxide found naturally in the air dissolves in water vapour to form carbonic acid, making the rain slightly acidic.

8 Metals produce hydrogen gas and carbonates produce carbon dioxide gas. To test whether the unknown was a carbonate you would need to test the gas with limewater, as in Part C on page 7.

9 The pH of your stomach is about 1.5, much more acidic than in your oesophagus, throat and mouth. When you throw up, the acidic contents of your stomach produce a burning sensation in your oesophagus, throat and mouth.

10 To neutralise the formic acid injected by the ant, you need to rub on a weak base like baking soda, not a weak acid like vinegar.

11 **A** is the strongest acid since it makes the bulb glow brightly, indicating there are many ions in the solution.

12 You need to mix sodium hydroxide (**E**) and hydrochloric acid (**C**). These two will neutralise each other to produce sodium chloride, a salt (see page 21).

sodium hydroxide + hydrochloric acid → sodium chloride + water

Chapter 2 Atomic structure

1 **B**, because the number of electrons must be the same as the number of protons.

2 **B**

3 **A**, see page 39

4 **D**, see page 40

5 In the nucleus there are protons (positive charge) and neutrons (no charge). Around the nucleus are much smaller fast-moving electrons (negative charge).

6 **a** Gamma rays are stopped only by a thick sheet of lead (see page 38).

b Beta particles can pass through your hand but are stopped by a thin sheet of aluminium.

c Alpha particles are stopped by your hand or a few layers of paper.

7 **a** In nuclear fission a large nucleus splits into two smaller nuclei. In nuclear fusion two small nuclei such as hydrogen join together.

b The nuclear reactions in bombs are uncontrolled. It has been possible to control nuclear fission in a nuclear power station. However, it has not yet been possible to produce a controlled fusion reaction.

8 **a** The numbers 1, 2 and 3 indicate the mass number of the isotope (total number of protons and neutrons in the nucleus).

b All three isotopes have the same atomic number (just one proton in the nucleus).

c Hydrogen-1 has no neutrons in its nucleus, hydrogen-2 has one neutron, and hydrogen-3 has two neutrons.

d You would expect hydrogen-3 to be radioactive because there are twice as many neutrons as there are protons. This makes the nucleus unstable.

9 *Similarities:*

- They both use steam to turn turbines to generate electricity (see diagram on page 36).
- They both produce wastes that can harm the environment (see page 45–46).

Differences:

- Nuclear power stations use uranium as fuel, whereas coal-burning power stations use coal.
- Nuclear power stations don't produce carbon dioxide (a greenhouse gas), whereas coal-burning power stations do.
- Nuclear power stations produce radioactive wastes which must be stored safely for many years.

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10 The half-life is 6 minutes, so after 6 minutes there will be 400 g left. After another 6 minutes (that is, after 12 minutes) there will be 200 g, and so on. After 30 minutes there will be only 25 g.

Now	6 min	12 min	18 min	24 min	30 min
800 g	400 g	200 g	100 g	50 g	25 g

11 Ming is considering only Australia's position and his view is rather short-sighted. Uranium mined in Australia and exported to other countries can be used in nuclear power stations. An accident in a nuclear power station overseas could affect many countries, even Australia. And of course the uranium could be used to make nuclear weapons.

12 **a** Cancer is caused by uncontrolled cell growth, so radiation can be used to destroy cancer cells.

b Radiation can damage the rapidly dividing cells in your reproductive organs, and the rapidly growing cells in an unborn baby.

Chapter 3 Health and nutrition

1 **a** peristalsis
b deficiency disease
c absorption
d villi
e digestion

2 **A** mouth
B oesophagus
C stomach
D duodenum
E pancreas
F large intestine
G small intestine

3 **a** F
b C
c A
d D

4 Plants are able to make their own food from sunlight, and the minerals and water they obtain from the soil. They do not need to eat other organisms and they break down this food to produce simpler substances. They can make everything that they need.

5 Boxes 2 and 5 are in the incorrect positions and should be swapped. Boxes 3 and 9 should also be swapped. The correct table is as follows:

Organ	Activity	Substance produced
Box 1 mouth	**Box 5** The food is churned, mixed with saliva and rolled into a ball.	**Box 3** salivary amylase
Box 4 oesophagus	**Box 2** Food moves down to the stomach by the action of peristalsis.	**Box 6** Nothing is produced.
Box 7 stomach	**Box 8** The food is churned and mixed with acid and enzymes. The breakdown of protein starts here.	**Box 9** pepsin
		Box 10 rennin
		Box 11 hydrochloric acid
		Box 12 mucus
Box 13 duodenum	**Box 14** Bile is secreted into the duodenum to break down fats. Pancreatic enzymes continue digestion.	**Box 15** Does not produce anything, but receives substances from other areas.

6 Alexander is still eating foods that are high in fat and not exercising to use up the energy contained in the fat that he eats. He will not lose a lot of weight because he is still consuming more energy than he needs. He is hungry because he is missing out on an important food group by not eating carbohydrates. The effect of skipping breakfast will lower his basal metabolic rate. This means he will lose even less energy than before and so not lose much weight.

7 The photo is a close-up of the finger-like villi that line the wallls of the small intestine—as in the diagram on page 57.

Chapter 4 Body balance

1 **a** auxin
b excrete
c metabolism
d synapse
e hormone
f homeostasis

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2 **B** is correct.

A is incorrect because amino acids are not excreted.

C is incorrect because blood cells and amino acids are not excreted.

D is incorrect because glucose and amino acids are not excreted.

3 **C** is the correct answer. **A, B** and **D** are incorrect because they describe incorrect links.

4 **A** is correct, but not the best way to distinguish between these two systems.

B is incorrect because muscles, bones and nerves are needed to move your body. This was not what the question was asking.

C is correct and the best response to the question.

D is correct, but the question was asking for a difference, not a similarity.

5 Animals have a nervous system because they have to respond quickly to external stimuli. They have an endocrine system to maintain internal control. Plants rely on hormones to coordinate their bodies.

6 The skin around the horse's nostrils must be where the horse receives most stimuli. This would explain why such a large area of the brain is needed to control this area of skin.

7 This is a motor neuron because the cell body and its branching dendrites can be seen. The cell body is like the nucleus in other cells. It controls the cell's functions.

8 **A** pituitary gland—thyroid-stimulating hormone

B thyroid gland—thyroxine

C pancreas—insulin

D adrenal glands—adrenalin

E ovaries—oestrogen

F testes—testosterone

Other possible hormones are shown in the table on page 85.

9 **a** The ureter is the tube that leads from each kidney to the bladder. The urethra is the tube that leads from the bladder to the outside of the body.

b The cloaca is a chamber through which substances from the excretory, digestive and reproductive systems pass. The urethra is the tube that leads from the bladder to the outside of the body.

c A sensory neurone connects a receptor to the brain. A motor neurone connects the central nervous system to an effector.

d Secretion is the release of useful substances in the body. Excretion is the removal from the body of unwanted substances made in chemical processes in cells.

Chapter 5 Disease

1 **B** Correct

A Incorrect: A disease doesn't always make you feel sick. For example, people can have hepatitis and not know they have the disease.

C Incorrect: Only some diseases can be controlled by vaccination. So you can't always be vaccinated.

D Incorrect: Not all diseases are passed on by coughing or breathing. Some are passed on by direct contact with infected fluids (e.g. blood).

2 **C** Correct: Hepatitis is caused by a virus.

A Incorrect: Cancer is not caused by micro-organisms.

B Incorrect: Heat disease is a lifestyle disease.

D Incorrect: Anorexia nervosa is a lifestyle disease.

3 **A** Correct: A bacterium has a cell wall but a virus doesn't.

B Incorrect: Both are made up of protein.

C Incorrect: Both have DNA.

D Incorrect: Both cause disease.

4 **a** Fungi have a nucleus, whereas bacteria have a nuclear region.

b A bacterial cell has a cell wall and a nuclear region. A normal body cell lacks a cell wall and has a proper nucleus.

c Protozoa are unicellular organisms that can reproduce on their own. Viruses are not considered to be cells and cannot reproduce by themselves.

5 It is important to have the required vaccinations before travelling overseas to safeguard yourself from getting sick. You also need to prevent a disease spreading to others if you arrive home infectious.

6 A tapeworm is able to absorb body fluids directly from the host and has no need for a digestive system. It has a long, thin, ribbon-like body to absorb fluids easily. It produces thousands of eggs daily to ensure that some of the eggs survive and grow.

7 People who inject themselves with drugs are more likely to expose themselves to disease because a needle penetrates the skin and could carry pathogens.

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8 The pathogen was probably contained in the cattle's faeces, which were washed into the river and infected the platypuses.

9 New strains of bacteria and viruses are being passed on from animals such as bats and monkeys to humans. They are also developing when bacteria and viruses mutate or change as they reproduce.

10 **a** Gillray was showing that there were terrible side-effects to being vaccinated by Jenner. Since the vaccine for smallpox contained cowpox, the side-effects were that you could grow cow parts.

b The cartoonist was biased against vaccination because he didn't show any good things about having the smallpox vaccination.

c The attitude of the cartoonist is very similar to the attitudes held today about childhood vaccinations. Many people do not get their children vaccinated because they have heard about side-effects of vaccines.

d Vaccinations have lowered the death rate for many infectious diseases. In the case of smallpox, vaccination has eliminated this disease from the world.

Vaccines are the only way to protect yourself from viruses.

Side-effects of vaccines occur only in very rare cases. You are more likely to die from the disease itself than from any side-effects that vaccination causes.

11 **a** The mice were living in the place where the jar was placed. Over time, the mice discovered the food in the jar and fell into the jar trying to get to the food. The smell of the dirty clothes may have attracted them too.

b Redi was trying to show that life did not just spring to life. It already existed. He noticed that maggots came from fly eggs. They did not just suddenly appear.

c You would need to know whether Redi's experiment was a fair test. You would need to know what variables he controlled and whether he tested one variable at a time.

d Louis Pasteur showed that living things did not automatically spring to life from non-living things. He carried out many experiments that showed that we are surrounded by micro-organisms. So Pasteur's findings supported the tests of Redi.

Chapter 6 Ecosystems

1 **a** False—An ecosystem is a system of feeding relationships between organisms and their interactions with the non-living environment.

b True

c False—This is mutualism.

d False—Hiding behind rocks to avoid a predator is a behavioural adaptation.

e True

f True

2 **a** ecosystem

b habitat

c adaptation

d herbivore

e decomposers

3 A community is a variety of *different* organisms living together. A population is a group of the *same* organisms living together.

4 **a** a tapeworm in the intestines of a human

b epiphytes on eucalypt trees

c spines on an echnida

You may have other examples. Check with your teacher.

5 **a** The fish population is highest in October–November and lowest in April. The penguin population is highest in December–January and lowest in June.

b In general, if the small fish numbers increase, so do the penguins, and if the small fish numbers decrease, so do the penguins.

c In the warmer weather of spring and summer there is more sunshine and therefore more producers at the bottom of the food web providing food for the fish and penguins.

d A decrease in the numbers of fish and penguins would be caused by a decrease in the numbers of organisms lower in the web.

e The food web is delicately balanced. One penguin eats many fish, so if there were too many penguins the fish would all be eaten.

6 **a** diatoms

b small fish and small crustaceans

c baleen whales, large fish, dolphins and sharks

d large fish

e dolphins, sharks, squid and killer whales

f dolphins and sharks, dolphins and squid, sharks and squid

Chapter 7 Electrical energy

1 **C**, see page 157 (B is a microphone)

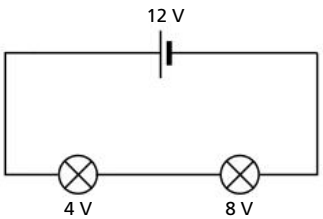
2 **A**, **C** and **D**. In B and E there is no relative movement between the magnet and the coil, so no electric current is generated.

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3 **D** glows because there is a complete circuit.
A—both connections to same terminal on battery
B—both connections to same terminal on bulb
C—only one connection between battery and bulb

4 **a** B—because there are two batteries in series, and only one bulb
b C—because there is only one battery and two bulbs in series
c D

5 The total voltage drop across the two bulbs will be 12 V, the same as across the battery. In a series circuit the voltage drops add up, so the voltage across the second bulb will be 4 V.



6 The wires are made of copper because copper is a good conductor of electricity. They are covered in plastic because plastic is a good insulator and won't allow electricity to escape.

7 **a** Only A will work because it has the positive terminal of one battery connected to the negative terminal of the other.
b The batteries are connected in series.
c 3 volts (2 × 1.5 V)

8 **a** Bulbs A and B glow.
b All three bulbs glow.
c All three bulbs go out.

9 **a** power = $\frac{1500\,\text{W}}{1000}$ = 1.5 kW
b electricity used = 1.5 kW × 3 h = 4.5 kWh
cost = 4.5 × 15 cents = 67.5 cents

10 **a** The knife is a conductor and electricity could flow to the ground through your body.
b If there is a fault in the electric drill, electricity can flow through your body. Because water is a good conductor, the electricity can flow through your feet to the ground more easily.
c 15 A is the maximum safe current in this circuit. A 20 A fuse will allow a greater current to flow before the fuse blows. This may cause overheating of the wires and a fire may occur.

Chapter 8 Light energy

1 **A**

2 **B**, see page 181

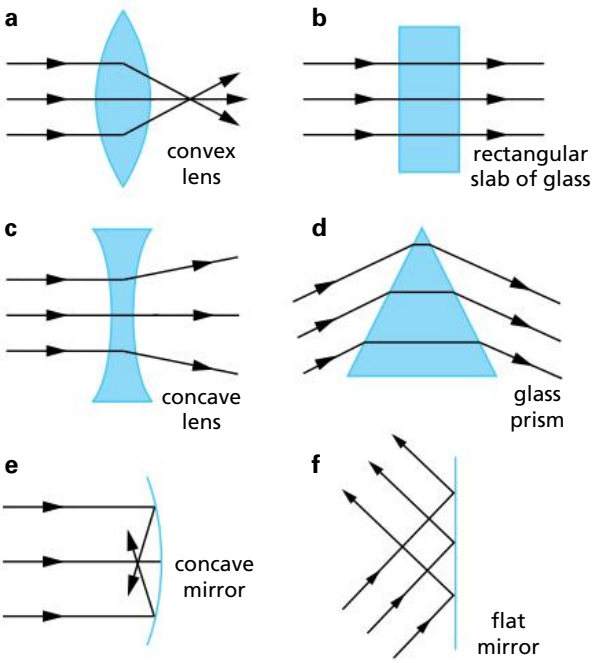
3 **B** (The pupil won't change unless the lighting conditions change.)

4 **D** Colour blindness is due to a problem with the light-sensitive cells in the retina.

5 **a** **C** The side of the bowl is acting like a lens. As light passes from the bowl to the air outside the bowl, it is refracted, producing an enlarged out of shape image of the hand.
b **D**, because the bowl curves outwards.

6 **a** Only blue light is passing through the filter and striking the screen.
b The red and yellow beams are being absorbed by the filter.
c The filter is blue, since it lets only blue light through (see page 182).

7



8 If the glasses have concave lenses, then the person is short-sighted (see page 177). If the glasses have convex lenses, then the person is long-sighted (see page 178).

9 Laser light is light of a single wavelength, so it cannot be dispersed into a spectrum of colours. It will be refracted (bent) but not dispersed.

Chapter 9 Using radiation

1 **D**

2 colour—visible light
communications—radio
heat—infrared
medicine—X-rays
radioactivity—gamma rays
sunburn—ultraviolet

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3 a gamma rays
X-rays
ultraviolet
visible light
infrared
microwaves
radio waves

b All are transverse electromagnetic waves.
All are transfer energy.
All travel in straight lines at the speed of light.

c Radio waves have a lower frequency than X-rays, but a longer wavelength.

d red–orange–yellow–green–blue–indigo–violet (ROYGBIV—see page 182)

e microwave ovens and satellite, radar and mobile phone communications

f detecting cancer in the body
destroying cancer cells
sterilising food and medical equipment
finding leaks in pipes

4 a Five waves go past in 10 seconds, so the frequency is 0.5 hertz (½ wave per second).

b The wavelength (distance between crests or troughs) is about 14 mm.

c The amplitude (height of wave) is about 9.5 mm.

5 a capacitor

b light-dependent resistor (LDR)

c resistor

d transistor

e diode

6 a speaker

b phosphor

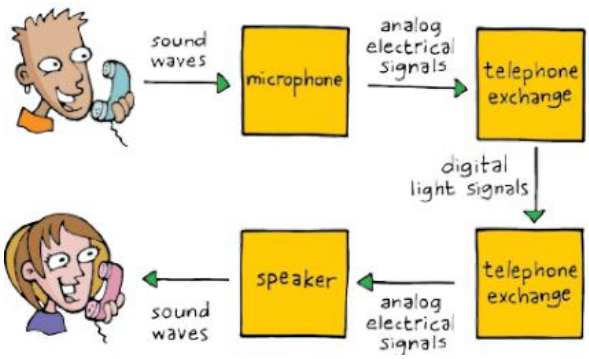
c LCD

d antenna

7 a The wavelength and frequency stay the same, but the amplitude increases.

b The amplifier keeps the sound the same, but makes it louder.

8



Chapter 10 Forensic skills

1 **D** is correct.

A and **B** are incorrect because a comparison microscope is not used to examine a single bullet or a single hair, but to compare two bullets or hairs.

2 **A**; **B** is partly correct, but knowing what the criminal touched is only useful if you can identify the fingerprints.

3 **D**

4 **C** Because there is such a small amount of DNA you would need to obtain a larger sample by replicating it.

5 a P = whorl, Q = composite, R = loop, S = arch

b Yes, the suspect could be placed at the crime scene because his fingerprint matches Q (composite).

c Because no two individuals have the same fingerprints, this evidence would be very damning. However, it is likely that other evidence besides the fingerprint would be needed to convict the suspect.

6 *Forensic science* uses different fields of science to help with forensic investigations. *Forensic medicine* uses medical practitioners or doctors. *Forensic pathology* uses medical practitioners to study the wounds and injuries on dead bodies.

7 a Gas chromatography (see page 229)

b Accelerants such as kerosene, petrol, diesel and turpentine

8 a The bands on the profile represent where fragments of DNA have moved to in electrophoresis.

b These bands are created by putting the DNA fragments at one end of a plate of thick gel. When an electric field is applied, the fragments move towards the other end of the plate. The lighter fragments move faster than the heavier ones. When the gel is stained the fragments show up as bands.

c 10 sites

d No, a minimum of 4 matching sites would be needed to determine paternity.

e Suspect 2 could be placed at the scene of the crime because his DNA profile matches the crime scene DNA profile.

f The chance of having all 10 matching sites is one in hundreds of millions. Only an identical twin of Suspect 2 is likely to have the same DNA profile.

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Chapter 11 Plate tectonics

1 **A**

2 **B**

3 **D**

4 **C**

5 **C**

6 **a** Earthquakes

b Mountain ranges

c The Ring of Fire surrounds the Pacific Ocean bordered by Japan, New Guinea, North and South America. It is called this because subduction zones surround the Pacific plate and volcanic activity occurs there.

d Iceland sits right on the middle of the Mid-Atlantic Ridge. Here two plates are moving apart and magma is coming to the surface through the middle, producing volcanic activity.

e This information supports the theory of plate tectonics, because volcanoes are occurring at the edges of plates.

7 Sedimentary rocks form when sediment carried by rivers builds up. Over time the layers of sediment undergo compression within the Earth and form rock. For this sedimentary rock to be exposed in the mountains, it must have been lifted to the surface by Earth movements such as folding. Since it was exposed at the surface it has undergone weathering and erosion to produce the rock formation seen today.

Chapter 12 Going into space

1 **B**

2 **C** (see page 274)

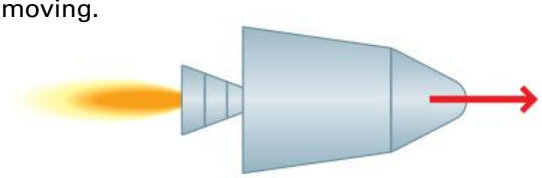
3 **B** (see page 263)

4 **a** Solid-fuel engines are simpler than liquid-fuel engines. They use up their fuel quickly, giving the space shuttle the thrust needed for lift-off. The burnt-out casings then fall back to Earth (page 261).

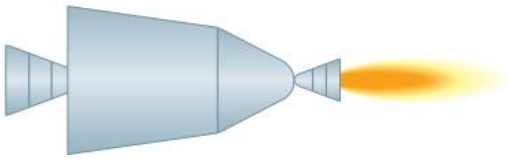
b To go into orbit, to dock with the International Space Station and to return to Earth, the space shuttle needs to manoeuvre by turning its engines on and off. This can be done with a liquid-fuel engine but not with a solid-fuel engine.

5 **a** Because the spacecraft is beyond the solar system, there are no gravitational forces acting on it. Its inertia will cause it to continue to move in a straight line, according to Newton's first law of motion.

b Firing the rocket engines (backwards) will accelerate the rocket in the direction it is moving.



c To slow the spacecraft down you would need to fire a rocket engine from the front of the spacecraft—in the opposite direction to the way the spacecraft is moving.



6 **a** The force of the water rushing out of the fire hose (action) has an equal and opposite reaction, pushing the firefighter backwards.

b It often takes several firefighters to hold the hose, as in the photograph. Otherwise the firefighter would be forced backwards—in the opposite direction to the jet of water.

7 **a** On the International Space Station astronauts experience microgravity (weightlessness), in which there is no up and down.

b In microgravity, blood and fluids are redistributed throughout the body, away from the legs and feet. These body fluids fill in the usually empty facial cavities, causing a moon-face (see page 265).

c Sneezing causes a small explosion of air and fluid from your nose and mouth. This causes an equal and opposite reaction, which forces the astronaut backwards.

d During re-entry there is enormous friction between the shuttle and the air of the Earth's atmosphere. This friction produces heat, which causes the nose of the shuttle to become red hot.

8 Geostationary satellites move in the same direction as the Earth rotates and take exactly one day to complete an orbit. During this time the Earth rotates once on its axis, so the satellite stays over the same point on the Earth's surface. Gravity affects the satellite and if it did not move it would fall back to Earth.

9 Rearranging the formula $F = ma$ gives $a = F/m$.

As the fuel is used up the mass (m) decreases. So if the force stays the same, the acceleration (a) increases, because you are dividing the force (F) by a smaller number.

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Glossary

The words in this list occur in bold type throughout the book. The number after each entry gives the page where you will find more information. For some words the pronunciation is given. The syllable in capitals should be stressed; for example, tsunami (tsoo-NAH-me).

abiotic factors (AY-by-OT-ik) physical or non-living factors which affect organisms, e.g. climate and weather 119

absorb (referring to digestion) to take the products of digestion into the bloodstream through the walls of the small intestine 57

AC (alternating current) current that flows first in one direction and then in the other 159

acid a substance that reacts with many other substances, including metals; it forms hydrogen ions (H^+) in solution 6

acid rain rain which is acidic due to dissolved air pollutants; it can damage plants and building materials 5

action and reaction Newton's third law of motion states that objects exert forces on each other that are equal and opposite in direction 260

adaptations the characteristics that an organism has that help it survive in the place where it lives 122

alkali a solution of a soluble base 8

alpha particles positively charged helium nuclei (two protons and two neutrons) given off during radioactive decay 38

ammeter (AM-eat-er) instrument used to measure electric current 145

amperes unit used to measure electric current (abbreviation amps, symbol A) 145

amplitude modulation (AM) a way of broadcasting radio and TV waves, where the frequency of the wave is kept the same but the amplitude (height of wave) varies 204

analog signal a type of telecommunication where the signal is a continuously changing wave that can have any value 200

antibodies substances made by the body to fight foreign substances in it, e.g. antigens 98

anticline layers of folded rocks that arch upwards 247

antigens substances in the body that are normally not recognised as part of the body 98

appendix a finger-like extension of the large intestine; in herbivores it helps break down cellulose and plant material 53

atomic number the number of protons in the nucleus of an atom; equal to the number of electrons 31

autopsy a medical examination of a body to determine the cause of death 213

autoimmune disease a disease caused when the body's own immune system attacks its own body tissues 96

auxins group of plant hormones that are produced by the growing tips of roots and shoots 88

axons nerve fibres that carry impulses, usually from the cell body of one nerve cell to the dendrites of the next cell 82

base a substance that neutralises an acid; it forms hydroxide ions (OH^-) in solution 8

beta particles high-speed electrons given off during radioactive decay 38

binary numbers numbers which use only ones and zeros; they are used for digital telecommunication 200

biotic factors biological or living factors that affect organisms, e.g. predators and availability of food 119

capacitor electronic device used to store electric charge in a circuit 196

carbohydrates a food type that supplies energy for the body; carbohydrates include sugars and starches 52

cataract a condition of the eye in which the lens gradually becomes cloudy, causing blurred vision 179

cellular respiration chemical reaction which occurs in living cells to release energy from food 4

central nervous system the brain and spinal cord 83

chain reaction the process in which one nuclear reaction produces particles that start off a chain of similar reactions 34

circuit diagram a standard way of drawing an electric circuit, using symbols 151

commensalism a relationship between organisms where one benefits without harming the other 129

community a variety of different organisms living in the same place at the same time 131

concave lens lens that is thinner in the middle than at the edges 174

concave mirror mirror with a surface that curves inwards, like the inside of a spoon 170

conservation of mass this law says that the total mass of the reactants in a chemical reaction is always equal to the total mass of the products; matter cannot be created or destroyed 33

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continental drift theory that says all the continents of the world were once joined and have been drifting apart ever since 239

convex lens lens that is thicker in the middle than at the edges, like a discus 174

convex mirror mirror with a surface that curves outwards, like the back of a spoon 170

cornea the clear transparent cover at the front of the eye 176

coroner a magistrate who investigates the cause of any unnatural death 215

DC (direct current) current that flows in one direction only 159

deficiency disease a disease that occurs when the body is lacking a particular nutrient; for example scurvy is caused by a lack of vitamin C 63

digital signal a type of telecommunication where the signal is a series of numbers (1 or 0) or pulses (on or off) instead of a wave 200

diode electronic device made from two pieces of semiconductor, which allows current to flow in one direction only 196

dispersion the splitting up of white light into the colours of the spectrum 181

DNA deoxyribonucleic acid, a complex molecule which carries the genetic code for your body 223

duodenum (du-O-DEE-num) the first part of the small intestine 53

earth (electrical) a safety wire connecting the metal case of an appliance to the ground 162

ecology the study of how living things are linked with each other and with their surroundings 138

ecosystem a system of relationships among organisms and the way they interact with the non-living things in their environment 119

effector a part of the body, such as a muscle or gland, which produces a response to a stimulus 82

electrical resistance a measure (in ohms Ω) of how difficult it is for an electric current to flow through a conductor; good conductors have low resistance 147

electric cell a device for producing an electric current from a chemical reaction; two or more cells connected together is called a battery 158

electric circuit a continuous path around which an electric current can flow 144

electric current continuous movement of electrons in a conductor; it is measured in amperes (A) 145

electric generator device that converts kinetic energy into electrical energy; it is the opposite of an electric motor 159

electromagnetic radiation radiation consisting of electric and magnetic fields; it includes gamma rays, X-rays, ultraviolet and visible light, heat, microwaves and radio waves 38

electromagnetic spectrum the family of all electromagnetic waves, including light 191

electronics the use of devices such as resistors, capacitors, diodes and transistors which control the flow of electrons in electric circuits 196

endocrine glands ductless glands which secrete hormones straight into the bloodstream 85

endocrine system a system of ductless glands throughout the body 85

endothermic a chemical reaction during which energy is absorbed; energy must be supplied to keep the reaction going 3

environment all the conditions that affect an organism where it lives 119

excretion the removal of unwanted substances made by your cells 77

exothermic a chemical reaction that releases energy 4

faeces leftover material that comes from the intestines; it is made up of bacteria and undigested material 57

fats a food type that supplies a large amount of energy and which can be stored in the body 52

fault a break in the Earth's crust along which rock slides in opposite directions 248

focal length distance from the centre of a mirror or lens to its focus (the point where the light rays meet after being reflected or bent) 170

folding the buckling and bending of rocks when they are pushed together by huge forces within the Earth 247

food chain a diagram which shows a chain of organisms in which each organism is eaten by the next in the chain 124

food web interconnected food chains showing many feeding relationships among the organisms present 124

forensic medicine specialist medical fields involved in the examination of evidence for use in courts of law 215

forensic pathology a study of the cause of unnatural death, as well as wound and injury interpretation of deceased individuals 215

forensic science scientific fields such as entomology involved in the examination of evidence for use in courts of law 215

forgery the crime of falsely making or altering documents 229

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frequency modulation (FM) a way of broadcasting radio and TV waves, where the amplitude (height of wave) is kept the same but the frequency varies 204

fuse a safety device containing a piece of wire that melts and breaks the circuit if too great an electric current passes through it 161

gamma rays very high-energy electromagnetic radiation given off during radioactive decay 38

geostationary orbit an orbit at a particular altitude such that a satellite remains over the same point on the Earth's surface 268

gland an organ that produces a substance that is used somewhere in the body 85

glycogen a compound built up of many glucose molecules and used to store carbohydrates in the body 74

half-life the time required for half the atoms of a sample of a radioisotope to break down (decay) 39

homeostasis (ho-me-o-STAY-sis) keeping the internal conditions of the body constant 74

hormones chemicals that are produced by ductless glands and act on specific target areas of the body 74

humus decaying plant or animal material in soil 218

image a picture of an object formed by reflection from a smooth surface or by refraction through a lens 169

immune system parts of the body that protect body tissues from disease-causing organisms and their toxins 97

immunisation when a person is made immune to a particular disease through vaccination 105

immunity the body's ability to resist or destroy micro-organisms that cause disease 98

indicator (acid–base) a substance, e.g. litmus, that turns different colours in acidic and basic solutions 10

infectious disease disease caused by micro-organisms, such as bacteria and viruses, in the body 96

infrared radiation electromagnetic waves with frequencies below the red end of the visible spectrum 193

interdependence the idea that the parts of a system depend on each other—they are inter-dependent; for example the organisms in an ecosystem 124

interferon a type of protein produced by a body cell when a virus invades it; interferon inhibits the reproduction of viruses 103

iris the coloured part of the eye; it controls the amount of light that enters the eye 176

isotopes (EYE-so-topes) atoms of the same element that have the same number of protons, but different numbers of neutrons 31

kidneys organs that filter and remove waste materials from the blood 77

laser an optical device which produces light of a single wavelength, with the waves all in phase 184

law of reflection a law which says that the angle of incidence of a light ray is equal to the angle of reflection 170

liquid crystal display (LCD) electronic device used to display numbers on digital watches; also used for flat screens on laptop computers 207

long-sighted people with this eye problem find it difficult to focus on close objects 178

lymphocyte (LIM-foe-site) a type of white blood cell involved in the production of antibodies 98

macrophage a type of cell in the body that engulfs disease-causing organisms 98

mass number the total number of protons and neutrons in the nucleus of an atom 31

metabolism all the chemical reactions that take place in your body cells 77

microchip an electronic circuit on a single chip of silicon crystal 199

microgravity a term that describes the apparent weightlessness of an object that is in orbit 263

microwaves electromagnetic waves with wavelengths shorter than radio waves; used for mobile phones and satelite TV 194

minerals naturally occurring chemical compounds found in foods; they contain essential elements your body needs for good health 62

modem a device that converts digital computer signals to analog telephone signals (modulation), and analog telephone signals to digital computer signals (demodulation) 202

motor neuron a nerve cell that carries impulses from the central nervous system to effectors such as muscles and glands 82

mutation the process where offspring become different from their parents because the DNA or genetic information has changed by chance 5

mutualism a relationship between two species in which both species benefit from the relationship 129

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neuron (NEW-ron) a nerve cell 82

neutralisation the reaction between an acid and a base to form a salt and water 20

neutrons neutral particles in the nucleus of an atom 30

nuclear fission the splitting of the nucleus of a large atom such as uranium into smaller parts, with the release of a huge amount of energy 34

nuclear fusion a nuclear reaction in which two small atomic nuclei (usually hydrogen) join to form a larger nucleus, with the release of a huge amount of energy; nuclear fusion occurs in the sun 36

nuclear reaction a type of reaction that involves changes to the nucleus of an atom; these reactions release huge amounts of energy 33

nuclear reactor a device in which nuclear reactions can be controlled 35

nucleus the positively charged centre of an atom; it contains protons and neutrons 30

oesophagus (uh-SOF-a-gus) the tube leading from the mouth to the stomach 52

optic nerve a bundle of nerves that carries electrical impulses from the retina to the brain 176

parallel circuit an electric circuit in which the parts are connected side by side, and the current can take different paths 149

pathogen a living organism that causes disease 95

peristalsis (per-i-STAL-sis) muscular contractions that move food along the length of the digestive tract 52

pH a scale from 0 to 14 which indicates how acidic or basic something is; pH stands for 'power of hydrogen' 11

phagocyte (FAG-o-site) a type of white blood cell, found mainly in the blood and lymph, that swallows up or engulfs disease-causing organisms or the toxins they produce 98

phloem (FLO-em) a series of tubes that carry the products of photosynthesis around a plant to the areas that need them 60

pixel a tiny dot of colour (red, blue or green) on a television or computer screen 182

plaque (PLARK) a layer of food particles, bacteria, acids and saliva that builds up on teeth 14

plasma a fourth state of matter; it is an extremely hot gas consisting of fast-moving electrons and positive ions 36

plate tectonics theory which states that the Earth's crust consists of plates that contain both continents and ocean floor, and that these plates are moving because of the mobile, semi-solid material they sit on 242

polarised light light that vibrates in one plane only 185

population a number of organisms of the same type living in a particular area at the same time 131

power (electrical) the rate at which an appliance uses electrical energy; it is measured in watts (W) 163

predators organisms that hunt and kill other organisms for food 122

proteins a food type that provides the materials for the growth and repair of cells 52

protons positively charged particles in the nucleus of an atom 30

pupil (eye) opening in the iris through which light enters the eye 176

quarks particles even smaller than protons and electrons; scientists infer that protons, neutrons and electrons are made from quarks 31

radioisotope an isotope that is radioactive 31

receptor a special sense organ that can detect a stimulus 82

refraction the bending of light as it travels at an angle from one transparent substance to another 172

refractive index a number which tells you how much light bends going from air into a transparent substance such as glass 172

retina inner lining at the back of the eyeball which contains receptor cells that are sensitive to light 176

salinity the accumulation of soluble salts in the soil, leading to land degradation and poor quality water 135

saliva fluid produced by glands in the mouth; it contains an enzyme called salivary amylase which starts the digestion of carbohydrates 52

salt an ionic compound formed when an acid reacts with a base, a metal or a carbonate 8

semiconductor a material such as silicon which conducts electricity, but not as well as metals do 196

sensory neuron a nerve cell that carries impulses from a receptor to the central nervous system 82

sepsis an invasion of the body by bacteria when a wound becomes infected 108

series circuit an electric circuit in which the parts are connected one after the other, without any branches 149

short-circuit what happens when an electric circuit takes a short cut; this short cut has very little resistance to the electric current 161

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short-sighted people with this eye problem find it difficult to focus on distant objects 177

solar cell a device that converts light energy into electrical energy 199

spectrum (plural spectra) continuous range of colours (red, orange, yellow, green, blue, indigo and violet) which make up white light; different stars have different spectra 181

strains (biology) varieties or types of organisms 113

subduction where one crustal plate rides on top of another plate, forcing the bottom plate to sink into the mantle 243

synapse (SIN-apse) a gap between the axon of one neuron and the dendrites or cell body of another neuron 82

syncline layers of folded rocks that arch downwards 247

terraforming changing the surface and atmosphere of a planet (e.g. Mars) so that the conditions there are similar to those on Earth 270

total internal reflection occurs when light hits a boundary between two transparent substances at a large angle of incidence and is reflected, with none transmitted 173

transistor electronic device made from three pieces of semiconductor, which can act as a switch or as an amplifier 197

transpiration the process by which water is lost from a plant by evaporation from the surface of the leaves 61

tsunami (tsoo-NAH-me) a giant wave caused by an underwater earthquake or volcanic eruption 250

ultraviolet radiation electromagnetic waves with frequencies beyond the violet end of the visible spectrum 192

ureters tubes that connect the kidneys to the bladder 78

urethra a tube that allows wastes to drain from the bladder to outside the body 78

urine waste produced by the kidneys; made up of urea, excess water and salts 78

vascular plants plants which have a series of tubes, called phloem and xylem, running through their bodies to transport materials 60

villi (singular villus) finger-like projections that cover the inside walls of the small intestine 57

vitamins a group of chemicals that come from living things; they are needed in small quantities for good health 63

voltage electrical potential energy lost across part of a circuit or gained across a cell or battery; it is measured in volts 150

voltmeter instrument used to measure electrical voltage, in volts 150

volts unit used to measure electrical voltage (symbol V) 150

xylem a series of tubes that carry water from the roots to the leaves of a plant 60

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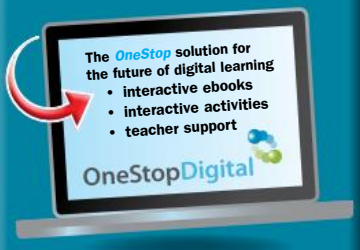
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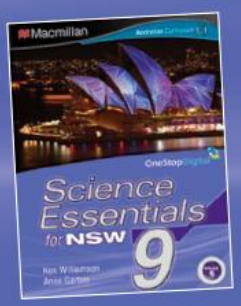
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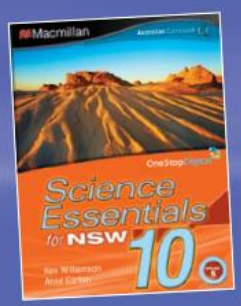
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