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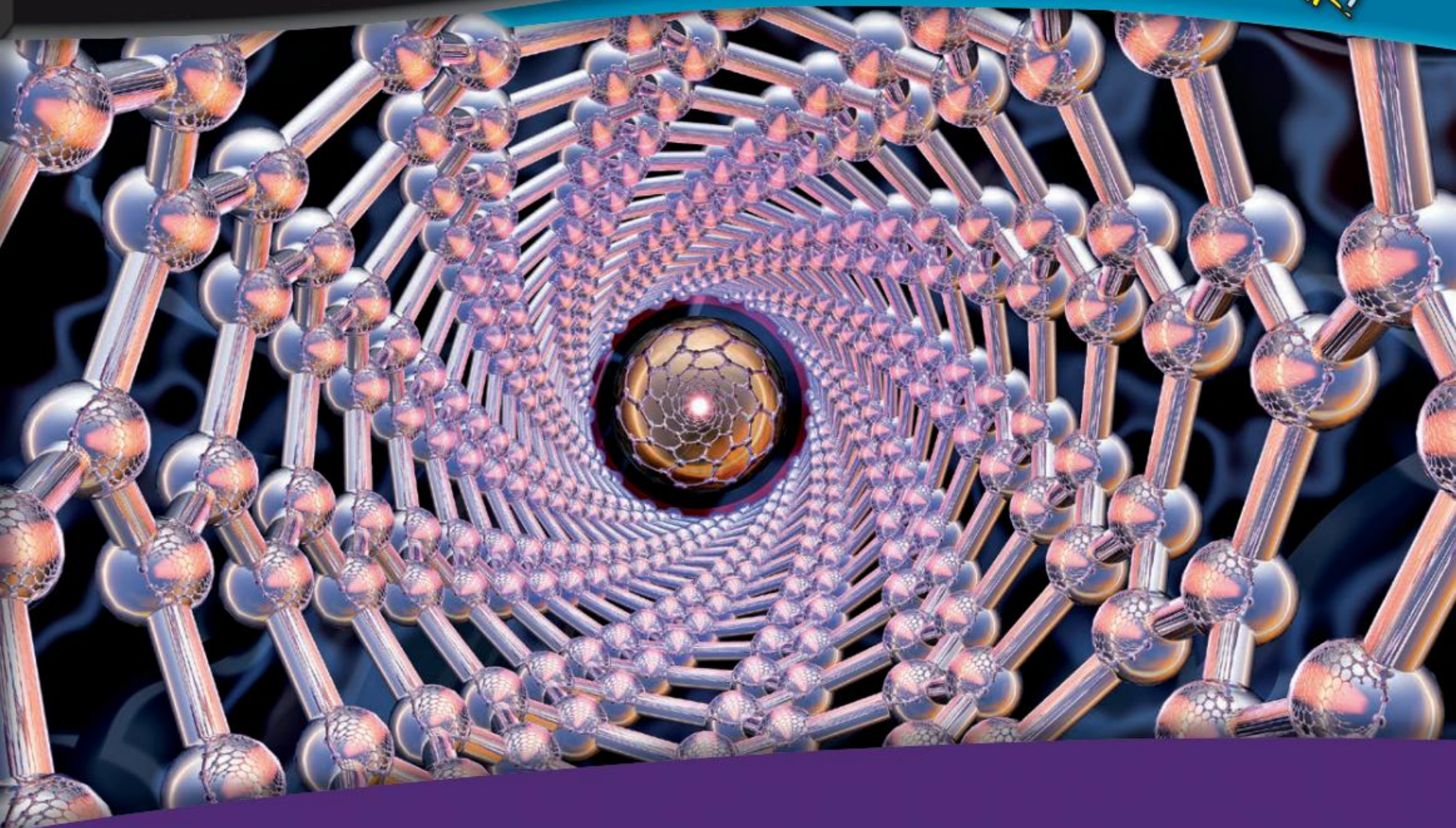

Science Essentials 10

Australian Curriculum edition

Ken Williamson Anne Garton

macmillan education

Australian Curriculum

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Australian Curriculum edition

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Internet addresses
At the time of printing, the internet addresses appearing in this book were correct. Owing to the dynamic nature of the internet, however, we cannot guarantee that all these addresses will remain correct.

Warning: It is recommended that Aboriginal and Torres Strait Islander peoples exercise caution when viewing this publication as it may contain images of deceased persons.

Contents

In most chapters there is a section called SCIENCE AS A HUMAN ENDEAVOUR which raises issues covered in the media. For example: Should scientists clone humans? Should scientists be allowed to bring dinosaurs back to life? Should we spend so much money on space research? Different people have different viewpoints on these questions and it is important that you form your own opinions.

As usual there is PROBLEM SOLVING in each chapter. For example in Chapter 11 you write a plot for a science fiction movie, using correct facts from the chapter or from your research.

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 5 on page 97 you have to write an essay about designing the perfect child. 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 11 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 in which you can record your results.

- Have a look at *Investigation* 1 on page 27.

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 5 you write a two-page argumentative essay discussing the following statement. 'Parents should be allowed to select the characteristics they want for their children.'

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 ?

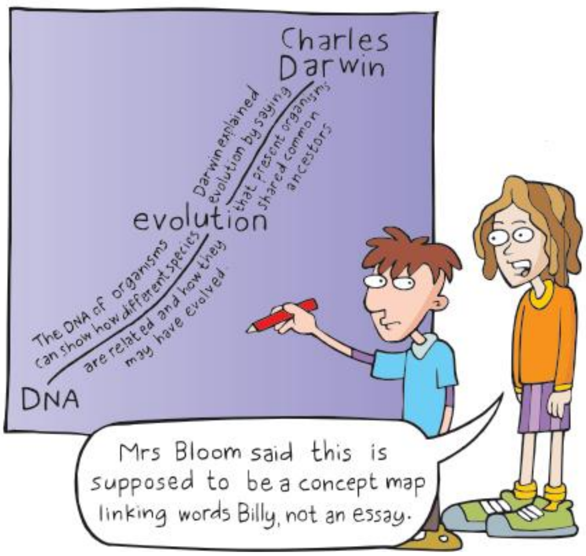
Towards the end of each chapter there is a section called *Thinking skills*. The exercises here are more difficult than those in *Over to you* and are designed to check how well you understand the chapter and whether you can think for yourself.

- Have a look at *Thinking skills* for Chapter 7 on page 168. 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 143. Check the *Knowing 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 143?



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 46.

- Try one or more of these questions. Then check your answers on page 266.
- 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 274. 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
  - the Big Bang theory
  - extracting DNA
  - El Niño and La Niña.

Check the page to see what information there is.

We hope you enjoy *Science Essentials.*

Ken Williamson and Anne Garton

Links to the Australian Curriculum

The content elaborations in the right-hand column are listed at the beginning of each chapter. They indicate *some* of the ways in which the Australian Curriculum content descriptions have been elaborated in *Science Essentials 10*.

Science Understanding	*Science Essentials 10* Elaborations
Science Understanding is fully integrated with Science Inquiry Skills, as indicated in the elaborations.	
Biological sciences The transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)	**Chapter 5 DNA and genetics** draw diagrams to show the difference between mitosis and meiosis use models and diagrams to represent the relationship between chromosomes, DNA and genes use Punnett squares to predict the results of dominant–recessive inheritance
The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (ASSSU185)	**Chapter 6 Evolution** outline the processes involved in natural selection, including variation in organisms and selection by the environment evaluate and interpret evidence for evolution, including the fossil record, comparative anatomy and DNA comparisons
Chemical sciences The atomic structure and properties of elements are used to organise them in the periodic table (ACSSU186)	**Chapter 3 The periodic table** describe the structure of atoms in terms of electron shells explain how the electronic structure of an atom determines its position in the periodic table and its properties investigate the chemical and physical properties of alkali metals **Chapter 4 Using chemistry** investigate the chemical reactivity of metals
Different types of chemical reactions are used to produce a range of products and can occur at different rates (ACSSU187)	**Chapter 2 Chemical reactions** design an experiment to investigate how reaction rate is affected by factors such as temperature, surface area and catalysts use word and symbol equations to represent chemical reactions test the law of conservation of mass for an everyday chemical reaction **Chapter 3 The periodic table** predict the products of a chemical reaction between solutions of two ionic compounds **Chapter 4 Using chemistry** describe how chemistry has been used to make a range of useful things, e.g. fireworks, matches, pure copper and batteries use equations to represent the loss or gain of electrons in chemical reactions use flow diagrams to show how materials such as sodium chloride are manufactured
Earth and space sciences The universe contains features including galaxies, stars and solar systems and the Big Bang theory can be used to explain the origin of the universe (ACSSU188)	**Chapter 11 The universe** describe the life cycles of stars, using terms such as supernovas, neutron stars, pulsars and black holes describe evidence supporting the Big Bang theory, including Hubble's observations and the detection of microwave radiation

continued >>>

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)	**Chapter 9 Earth systems** research interacting Earth systems and how human activities can affect them accurately describe the role of the carbon and nitrogen cycles in Earth systems understand the importance of the greenhouse effect to life on Earth discuss the importance of the ozone layer in protecting us from ultraviolet light **Chapter 10 Environment case studies** explore the problem of global warming and ways of combating it
Physical sciences Energy conservation in a system can be explained by describing energy transfers and transformations (ACSSU190)	**Chapter 7 Forces and motion** give examples to illustrate the law of conservation of energy use friction to explain why no system can be 100% efficient **Chapter 8 Alternative energy sources** distinguish between renewable (e.g. solar) and non-renewable (e.g. coal) energy resources
The motion of objects can be described and predicted using the laws of physics (ACSSU229)	**Chapter 7 Forces and motion** collect and record data on distance, time, speed and acceleration use Newton's three laws to analyse the motion of objects

Science as a Human Endeavour	*Science Essentials 10* Elaborations
Science as a Human Endeavour is integrated with Science Understanding.	
Nature and development of science Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community (ACSHE191)	**Chapter 5 Scientists at work** page 103 follow the historical development of the helix model for the structure of DNA **Chapter 6 Evolution** use the theory of evolution to illustrate that scientific theories are tentative and may need to be changed in the light of new evidence discuss how societal and religious values have had an impact on the development of the theory of evolution use the Mungo Man discovery to discuss the arrival of the ancestors of Aboriginal people in Australia **Chapter 11 Scientists at work** page 262 recognise the significance of Stephen Hawking's work to our understanding of the universe
Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE192)	**Chapter 2 Scientists at work** page 33 use the work of Perkin to illustrate how developments in technology are often linked to scientific discoveries **Chapter 11 The search for ET** pages 256–258 reflect on human attempts to search for extraterrestrial life
Use and influence of science People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions (ACSHE194)	**Chapter 3 Lead—valuable resource or deadly poison?** page 53 **Chapter 4 Dioxin—should we be worried?** page 92 debate how serious a threat dioxin is to our health **Chapter 6 Problem solving** pages 120, 123, 136, 140 **Chapter 8 Inquiry 2** page 174 investigate the energy needed to manufacture various shopping bags **Chapter 9 Inquiry 7** page 214 explore the social, political and economic aspects of using ethanol as a fuel

Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating career opportunities (ACSHE195)	**Chapter 1 Why study science?** pages 3–7 use the internet to research a range of careers in science **Chapter 5 Australia's Nobel Prize winners** page 106 research Professor Elizabeth Blackburn and other Australian Nobel Prize winners
The values and needs of contemporary society can influence the focus of scientific research (ACSHE230)	**Chapter 4 Matches** page 80 **Chapter 5 Cloning** page 115 **Chapter 6 What will happen in the future?** pages 139–141 consider arguments for and against applications of genetic engineering **Chapter 7 Youth and drink driving** page 167 consider issues relating to youth and drink driving **Chapter 8 Tidal power project** page 187 research the arguments for and against, then make a decision on whether to build a tidal power station **Chapter 10 Uranium inquiry** pages 227–228 participate in an inquiry to vote on a proposal to open another uranium mine in Australia

Science Inquiry Skills	*Science Essentials 10* Elaborations
Science Inquiry Skills are fully integrated with Science Understanding and can be developed through the various learning activities in *Science Essentials*—Problem Solving, Inquiry, Investigation, Skill, Over to you, Thinking Skills and Self-management.	
Questioning and predicting Formulate questions or hypotheses that can be investigated scientifically (ACSIS198)	**Chapter 1 Using science** design a series of experiments to test a range of brands of a consumer product, and write a report for consumers **Chapter 2 Investigations** pages 28–29, 31, 39 extend an investigation by suggesting further ideas to investigate
Formulate questions that can be investigated scientifically and develop testable hypotheses based on prior observations, scientific knowledge and primary and secondary sources (ACSIS209)	**Chapter 3 Investigation 1, Part C** page 67 apply a knowledge of ionic reactions to solve chemical problems **Chapter 10 Investigation 2** page 231 design, carry out and evaluate an experiment to investigate ways of cleaning up oil spills
Planning and conducting Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)	**Chapter 2 Investigation 3** page 31 plan, select and use appropriate methods to investigate exothermic and endothermic reactions **Chapter 8 Problem solving** pages 172, 181, 191–192 design an energy-efficient house

continued >>>

Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS200)	**Chapter 8 Inquiry 1** page 174 do a survey to find out the energy sources used by people in their homes **Chapter 11 Skill** page 255 identify constellations such as the Southern Cross and Orion in the night sky
Processing and analysing data and information Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS203)	**Chapter 7 Forces and motion** pages 151, 160 use the formula v = d/t or F = ma to calculate the third variable when you know the other two variables **Chapter 8 Alternative energy sources** page 173 compare energy use in Australia and other countries
Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204)	**Chapter 1 Using science** use an understanding of science to make informed choices about consumer products **Chapter 10 Environment case studies** use the internet and other resources to research an environmental case study discuss ways of solving the problem of albatrosses being caught by long-line fishing
Evaluating Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS205)	**Chapter 1 Using science** pages 9, 11 describe how to avoid errors in measurement and discuss whether the results of an experiment are reliable **Chapter 4 Investigation 3** page 77 suggest ways of improving an experiment to compare the reactivity of metals
Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems (ACSIS206)	**Chapter 1 Using science** research the methods used by scientists in studies reported in newspapers or on TV **Chapter 9 Earth systems** pages 211–212 evaluate claims that human activity is contributing to global warming
Communicating Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)	**Chapter 1 Right or wrong?** pages 19–21 discuss the pros and cons of an issue and carry out a debate or write an essay **Chapter 3** pages 59–64 write and balance symbol equations to represent chemical reactions **Chapter 5 Problem solving** pages 97, 100, 105, 108, 114 write an argumentative essay about whether we should create the perfect child **Chapter 10 Checkpoint** page 242 show understanding of a newspaper article by answering questions about it **Chapter 11 Problem solving** pages 244, 249, 258, 261 apply a knowledge of space to write a plot for a science fiction movie

1 Using science

Focus for learning

Most science teachers would probably wish they had a dollar for every time a student has said to them 'Why do I have to study science?' The answer is that science can help explain the world around you, and give you skills that you can use throughout your entire life. Science also gives you practice at thinking, questioning and analysing. Imagine what it would be like to live without the knowledge of science that we have today. For example, ancient humans observed day and night but did not understand *why* this happened.

Science also helps us to:

- solve problems in today's world
- provide for our needs in more efficient ways
- develop new materials and new technology
- make our world safer
- improve the health and wellbeing of society
- educate our children to use resources wisely
- protect and conserve the environment
- understand current events in the media
- make more informed choices about what we do and what we use in our daily lives.

This list could go on and on. As a class you might like to discuss the points listed and give examples. Inquiries 1–5 will help you with this.

Science can help you when you are shopping. When buying shoes you might ask: Are they leather or a synthetic material? Will they last a long time? Are they practical for what I want the shoes for? (Stilettos will not do for hiking.) What material are the soles made of? In making observations like these, asking questions and then trying to find answers to your questions (by looking at labels, feeling the material of the shoes, etc.) you have already started to use the *scientific method,* which is what this chapter is about.

PROBLEM SOLVING: Consumer testing

1 Choose a product to investigate. For example, which is the best weed killer to use, or the best stain remover for clothes?

2 Design a series of experiments to test a range of brands for the product you have chosen so as to determine which one is the best. For example: Does NapiSan remove stains from clothes better than White King?

3 Present your findings to the class and recommend which product should be used.

The rest of this chapter reviews how to design fair tests and presents other skills and examples that you might need to complete this chapter problem.

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

Science as a Human Endeavour

- use the internet to research a range of careers in science

Science Inquiry Skills

- design a series of experiments to test a range of brands of a consumer product, and write a report for consumers
- research the methods used by scientists in studies reported in newspapers or on TV
- use an understanding of science to make informed choices about consumer products
- describe how to avoid errors in measurement and discuss whether the results of an experiment are reliable
- discuss the pros and cons of an issue and carry out a debate or write an essay

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. In 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.

dependent variable	**interpret**	**objective**	**scientific method**
ethics	**investigation**	**quantitative**	**subjective**
fair test	**jargon**	**questionnaire**	**survey**
independent variable	**marine biologist**	**reliable**	**valid**

1.1 Why study science?

Scientific issues are often presented on the news or in the newspaper. Studying science will help you stay informed about new discoveries or current events that occur in the media.

Many television programs and movies focus on science themes. A science background will give you a greater understanding of these shows. You may even be able to detect some errors using your scientific knowledge. For example, in *Star Wars*, spaceships make a thunderous sound as they travel through space. But there would be no sound in space because there is no air to vibrate.

INQUIRY 2 Science on television

Use the internet to investigate some of the television show and movie mistakes. For example, use a search engine such as Google to investigate *CSI* myths or type in 'movie mistakes'. See how many examples of science you can find that are incorrect.

INQUIRY 1 What's in the news?

Read the following article and complete the questions below.

Hormone additives banned from beef

Beef pumped with growth hormones will be banned by supermarket giant Coles from New Year's Day in an Australian first, sending shock-waves through the meat industry.

Experts predict higher beef prices as more customers demand hormone-free meat, which makes up about half of all beef sold in Australia. Farmers have been able to use hormone growth promotants to boost muscle growth in cattle since 1979, backed by safety approval from health authorities. HGPs were banned by the European Union in 1988.

Regardless of the scientific backing, meat industry research has revealed a major consumer backlash against the additives. In a survey of 1000 people by Meat and Livestock Australia leaked to *The Sunday Mail*, almost half said they would consume less meat if it had added hormones, while 16 per cent would 'never touch again' and 15 per cent would also 'actively warn others'. Other research shows HGP-free beef is more tender than meat with the hormones.

Industry experts now fear a 'knock-on effect' from Coles' ban as other retailers are forced to fall into line, pushing up the price of the meat because hormone-free meat costs more to produce. Coles has vowed to spend tens of millions of dollars a year absorbing the extra costs incurred by farmers so that consumers will not pay more. Rival Woolworths supplies HGP-free beef through its Macro Wholefoods range but does not plan to extend that policy . . .

***The Sunday Mail* 25 December 2010**

1 Underline all the words in the article you do not know and find out their meaning. Use a dictionary or your previous *Science Essentials* books to help you.
2 What is a hormone?
3 What is Coles banning from its meat?
4 What do the experts predict this will do to beef prices?
5 How much meat sold in Australia contains hormones?
6 How do hormones get into the meat in the first place?
7 What are consumers attitudes about eating the hormone-free meat?
8 Is hormone-free meat different from meat with hormones How?
9 How does Coles plan to keep the costs down for consumers?
10 Do you prefer to eat meat with or without hormones? Why?

Science can help solve some of the problems we face today. These problems might be caused by natural events or ones that humans have caused

INQUIRY

3 Superfoods: How you can help eat cancer

Read the following article.

A fruit punch made of blueberries could be the key to stopping a range of the most deadly cancers.

Research conducted by the University of Sydney and Royal Prince Alfred Hospital has found that the cocktail—a blend of fresh olive leaf, grape seed, citrus skin, green tea, tumeric and ginger [added to the blueberry punch]—halted the growth of prostate cancer tumours in rats. Assistant Professor Qihan Dong, director of the hospital's department of endocrinology, said that the combination could have applications for patients with 16 different cancers, including the 'five major killers'—breast, colon, ovary, lung and prostate.

Associate Professor Dong said, if proven successful in a future human trial, it would be the first type of non-invasive treatment to halt the growth of prostate cancer cells. Its use would be ideal for patients with a low-grade, less aggressive form of the cancer who are under active surveillance by doctors, he said. 'We think that this chronic inflammation plays a role in pushing these cancer cells into a more aggressive stage, so if we combine these ingredients together, we think it will slow down this cancer progression,' he said . . .

***The Sunday Telegraph* 17 April 2011**

1 Which hospital carried out this research?
2 What does the fruit punch contain?
3 What do researchers claim the fruit punch does?
4 What is endocrinology?
5 What are the five major killers?
6 What is a non-invasive treatment?
7 What causes cancer cells to become more aggressive?
8 How is the fruit punch expected to slow down cancer?

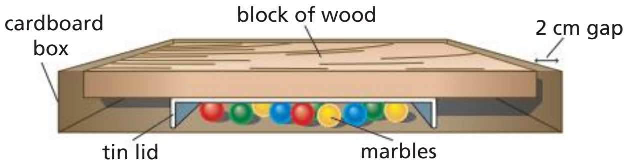
INQUIRY

4 Shudder and shake

Many people around the world live with the threat of earthquakes. Thus, scientists are trying to find ways to make buildings 'earthquake proof'. This may save lives and millions of dollars in damage when an earthquake hits. Scientists have found that buildings should not be made of brittle materials, such as brick and stone. A structure made of steel and aluminium is better. The walls of the buildings need to be braced evenly and tied to the roof. The foundations must also be tied to the walls. Buildings that are square or rectangular are better than L, T, H, U or O-shaped buildings.

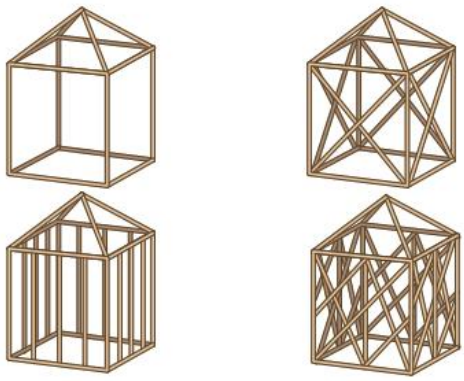
You will need: tin lid, nails, hammer, cardboard box, block of wood that fits loosely inside the box, 10 marbles, suitable building materials (e.g. staples, straws, paddle-pop sticks, Blu-tack)

1 Nail the top of the tin lid to the centre of the block of wood. Sit the block of wood inside the box so that it is resting on the 10 marbles under the lid. The block should be able to move back and forth, rolling on the marbles.



2 Use this shaker platform to simulate an earthquake to test one of the following hypotheses:
   a Square or rectangular buildings are better than other shapes for houses in earthquake-prone areas.
   b Walls that are braced are better than walls with no bracing in earthquake-prone areas.

Some house designs are presented below to help you.



SCIENTISTS AT WORK

Thomas Edison and electric light

American inventor Thomas Edison is known for developing the incandescent light bulb. However, during his life he patented 1093 inventions, such as the phonograph (an early version of the record player), the kinetoscope (a small movie viewer), a nickel–iron alkaline storage battery and an electric safety miner's lamp. He also made improvements to the telephone and telegraph, and demonstrated how entire cities could be lit by electricity when he set up the infrastructure for the first electrical power distribution company to light homes.

Thomas Edison is known for developing the light bulb but he did not invent it. In 1809 an English chemist called Humphry Davy placed a charcoal (carbon) strip between two wires that were attached to a battery. The charged carbon glowed. He had produced the first electric light.

Many inventors then followed Davy, trying platinum coils, carbonised paper or bamboo filaments instead of charcoal, and experimenting with glass bulbs and vacuums to improve the length of time the light glowed. By 1878 electric light bulbs could last up to 13.5 hours but this was still not long enough for practical use.

In 1879 Thomas Edison produced a light bulb that could burn for 40 hours. He created a vacuum inside a glass bulb and placed a small carbon filament inside the bulb. He then passed a small electric current through it to make the filament glow. In December 1879 Edison held a public demonstration of how electric light could be used by lighting his laboratory complex. To do this Edison had to invent a parallel circuit, light sockets, on and off switches, insulating materials for wires, and a device for maintaining a constant voltage. His demonstration was successful.

By 1880 Edison had improved his design to make a light bulb that lasted over 1200 hours. Then, on 4 September 1882, Thomas Edison's Pearl Street electricity generating station started operation in New York City. The station used about 5 kg of coal per kilowatt hour to service 59 customers. This was a huge development because Edison had made electricity possible and practical for everyday use. It was clean and easy to use and people no longer had to rely on gas lamps.

Edison created many more power companies to supply electricity across America. He eventually formed the Edison General Electric company in 1889, which became known as General Electric in 1892. Edison died a famous and wealthy man.

Edison's light bulb

Level 1 Knowledge

1 What does 'incandescent' mean?

2 When did the first electrical power distribution company start operation in America?

Level 2 Understanding

3 How did Edison improve the design of the light bulb?

4 In what ways do you think Edison's development of electricity changed people's lives?

Level 3 Apply your knowledge

5 Suggest a reason why Edison is credited with the development of the light bulb even though he did not invent it.

6 Edison has been called an entrepreneur. What does this mean? Does this title fit Edison?

INQUIRY

5 *Science careers*

Studying science can open up a world of different careers. This activity will show you some of these possible careers and explain why you might want to choose science for further study.

1 Use the internet to research different science careers. Using a search engine such as Google, search sites from Australia under 'job guide'. Look for the Australian Government Department of Education, Employment and Workplace Relations job guide. Alternatively, type in the following: www.jobguide.thegoodguides.com.au or www.jobguide.deewr.gov.au

2 Once you are in the text version of the job guide you can search by 'field of work', 'learning area' or 'alphabetically'. Select 'learning area'. You will then be given a list of subject areas, such as:

Art	Computing Studies
Biology	Economics
Chemistry	English

Select Biology.

3 You should now have a list of careers available to you if you study biology. These include

Ambulance Officer	Environmental Scientist
Animal Technician	Nurse
Botanist	Optometrist
Dentist	Park Ranger, etc.

4 Select one occupation to look at that you are interested in (e.g. marine biologist). Here you are given a description of the job, personal requirements, related jobs and state/territory specific information where you can find out what qualifications you need. An example of a job description for a marine biologist is given on the right.

5 Once you have read the job description and found out the education and training requirements for the occupation you have chosen, look up other biology occupations you are interested in. When you have finished, go back to the 'learning area' screen, select Chemistry and repeat steps 3 and 4. When you have finished, do this again for the 'learning area' of Physics.

6 List the careers that interest you in the area of science.

7 What subjects would you need to do to work in the area that interests you?

Marine biologist description

Marine biologists study the origin, structure, function and behaviour of all life in the sea, rivers and lakes. They look at the relationships organisms in the sea have with one another and how they are affected by the environment. Marine biologists may perform some of the following tasks:

- estimate the number of marine organisms and examine how these populations change over time
- observe different marine communities
- look at how introduced organisms affect marine communities
- monitor pollution in the ocean and how it affects marine organisms
- give information and make recommendations about marine conservation
- design experiments to assess the effect of change on marine ecosystems.

Marine biologists work in the laboratory, at sea and in field stations. Field work may include work on commercial fishing vessels and scuba diving. Most work involves office work, research, writing reports and spending long hours in laboratories. It is not all about swimming with dolphins and whales.

Adapted from Australian Government Department of Education Employment and Workplace Relations job guide

A marine biologist at work

INQUIRY 5 *continued*

8 Many girls think that science is only for boys but there are many women scientists. There are also some excellent websites on the internet that discuss women in science. Type ‘women in science’ into your search engine and examine some of the different jobs that women scientists are doing.

Over to you

1. Give three examples of observations you can make around you. For example, *The plant in the corner of the laboratory is dying*.
2. List two questions you could ask for each observation. For example, *Is the plant lacking in water? Does the plant need more sunlight?*
3. What would be the next step in planning an investigation to answer each question?
4. How do you use the scientific method when you buy an item of clothing?
5. Give three examples of how an understanding of science can help you in your daily life.
6. You are asked to explain why Year 10 students should choose to study science as a career choice. Write down what you would say.

INQUIRY 6 *Being informed*

By having an understanding of science, you can make informed choices about products, goods and services. Write down your answers to the following questions, even if they are a guess, *before* reading the article below.

1 a What is the difference between an alkaline battery and a normal zinc–carbon battery?

b Which has more power and lasts longer?

c How do their uses differ?

Bunnies and batteries

You have probably seen the fluffy pink Duracell bunny on television that lasts up to three times longer than the Eveready bunny. This advertisement convinced many people to buy Duracell batteries. But what the advertisement did not make clear was that the Duracell batteries used were alkaline and that the Eveready batteries used were zinc–carbon.

So what is the difference? Alkaline batteries have electrodes of zinc and manganese dioxide with an electrolyte solution of potassium hydroxide. They are designed for heavy or continuous power usage. On the other hand, zinc–carbon batteries use a slightly acidic electrolyte and are designed for light-to-moderate power usage. They are a much cheaper battery. So the test was an unfair comparison.

Energizer Australia, who make Eveready batteries, took Gillette Australia (Duracell) to court because they believed the advertisement was misleading and not comparing like products. They stated that Gillette should have compared their Duracell batteries with Eveready Gold batteries, which are alkaline. Gillette eventually won the case because the court ruled that consumers knew the difference.

2 Answer question 1 again. Have your answers changed? Has an understanding of science helped you?

3 Do you think the advertisement that shows an Energizer-powered bunny being defeated by a Duracell-powered bunny is a fair test? Explain.

4 Do you think the court ruling was correct? Give reasons for your answer.

5 Why did Energizer Australia believe the advertisement was misleading? Did it mislead *you*?

1.2 Making tests fair

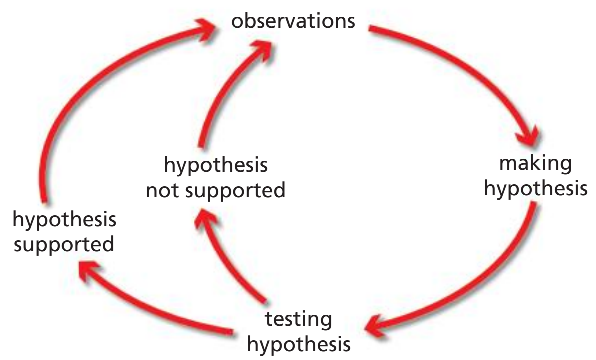
The first step in the scientific method is making *observations*. You do this on a daily basis. For example, you might observe that it is raining or the sun is shining. You might notice that your new puppy has not eaten its dinner. You might feel how good a clean dry towel is, or smell frangipani flowers. In doing these things you are using your senses to make observations about the world around you.

You may then begin to *ask questions* about your observations; for example, why hasn't my puppy eaten anything? This may lead you to make *inferences* to explain your observations and try to answer your questions. Perhaps the puppy is not hungry, or maybe it does not like that particular brand of dog food. You can then formulate a **hypothesis**, which is an educated guess based on the observations you have made and the knowledge you already have. For example, 'My puppy may like other brands of dog food'.

The hypothesis you make must be about something that can be observed and measured, and the data you collect will either support the hypothesis or show that the hypothesis is incorrect. For example, you can give your puppy different brands of dog food and measure how much of each brand it eats over a period of time. If your puppy eats a different brand of dog food, then your hypothesis is supported and you can make a *conclusion* about its eating habits. However, if it refuses to eat the other brands, you will have to revise your hypothesis and try again.

From your hypothesis you can also make *predictions* about the outcome of your tests. You might predict that the puppy will eat more of brand A than brand B because brand A is advertised as a better dog food. If your hypothesis is supported by the tests that you make, then this could lead to new questions and further testing. For example, 'Which dog food will my puppy eat that is the cheapest to buy?'

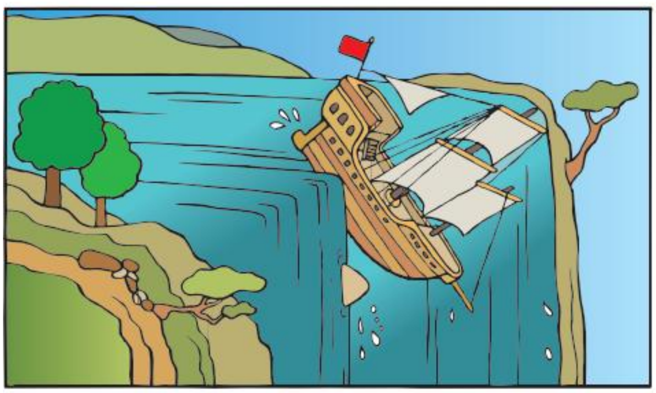
If you find that your hypothesis is not supported, then you will need to modify it in the light of the evidence you have collected. You can then design a new experiment that is able to test the new hypothesis. In this way the scientific method is not a linear process. In other words, it does not really have a starting point and finishing point. For example, on the diagram below, you can start with observations or you can start with a hypothesis. The scientific method is a cyclical process of observations, hypothesis making, testing, hypothesis modification and further testing.



Supported, not proved

You will notice that we said the evidence gathered can *support* a hypothesis. This is because you can never prove something and be 100% certain of the results. There might be a better test, a different explanation for the findings or a new technology developed that may show that the hypothesis is incorrect. For example, people once believed that food rotted because of spontaneous generation. This meant that organisms such as maggots just sprang to life in the food. But this idea did not explain why food rotted even without the presence of maggots. It took the invention of the microscope and the subsequent experimental work of Louis Pasteur to show that it was microorganisms that caused food to rot.

Hypotheses are also formed using the knowledge that exists in society at the time. Thus, the framework of thinking from which inferences are made may be wrong. For example, people once believed that the Earth was flat and that if you sailed too far east or west you would drop off the end of the world. We now know that this is incorrect. We know that it was probably the small boats, treacherous seas, and poor maps and navigation instruments that caused many failed expeditions.



Repeat, repeat, repeat

For the results of an experiment to be taken seriously they must be able to be repeated and produce the same results every time, no matter who does the testing. This is why it is important to record the results accurately and precisely, without error. It is also important to write down everything that you do to obtain the results. If your method is clearly written down, then somebody else can follow your method and check your findings.

If an experiment can be repeated over and over again and the same results obtained, then the results are said to be **reliable**. To obtain reliable results you must design a fair test.

Controlling variables

Many factors can affect the outcome of an experiment. These factors are called *variables*. To design a fair test you must change only one variable at a time and keep all the other variables the same. For example, Leisa and Peter were trying to decide which swim vest was best for their 1-year-old son Kurtis to use in their swimming pool. They asked some friends which swim vests their children used.

Cathy said the swim vests her girls used at the beach were great. They had panels in them that could be blown up. Bernie said he would not recommend the brand of vest he used. His son swam in their chlorinated pool every day and the straps of his vest had worn and the colour faded. Sandra said her son Austin had a great swim vest because he wore it each summer at the local swimming pool. It had a rubber ring sewn in it.

Peter said he would buy the vest that Sandra used. Leisa said that they could not really tell which vest was best because each vest was designed differently and had been tested under different conditions. Who was correct?

Leisa rightly pointed out that the vests were tested under different conditions. It would be impossible to make conclusions about which swim vest was best with so many uncontrolled variables. In a good experiment only one variable is changed at a time and all the other variables are controlled. It is then a fair test.

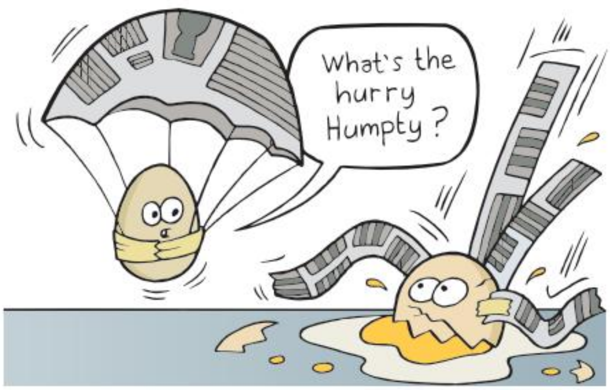
As well as being fair, the testing must also be relevant to what you are trying to find out to obtain **valid** results. For example, testing the swim vests for whether they smashed when dropped is not going to be relevant, since the swim vests are not made from a material that will break on impact.

Inquiries 7 and 8 will show you how important it is to change only one variable and to control all others when making fair tests.

INQUIRY 7 Egg drop

You will need: double page of newspaper (i.e. the size of *The Age* or *The Sydney Morning Herald*), one unboiled egg, sticky tape (1 m), string (1 m)

1 Form groups of three students.
2 Using only the materials provided, design a way to drop your egg from the height of a first floor veranda (balcony) so that it does not break.
3 Perform your tests. The winning team is the one that has an unbroken egg at the end of the activity.



4 Which design was the most effective in protecting the egg from breaking?
5 Which variables were controlled in this activity?
6 Which variables were not controlled in this activity? How did this affect the results?

Over to you

1 What is the difference between an observation, an inference and a prediction?
2 Give your own example of a hypothesis that can be tested.
3 What is meant by a 'fair test'?
4 What are variables? Why is it important to control the variables in an experiment?
5 Why should you never use the word 'proved' to describe the outcome of any test you perform?
6 What do the words 'reliable' and 'valid' mean?

INQUIRY 8 Choice testing

Read the two consumer tests below and, for each article, answer the questions that follow.

Choice magazine tested 20 brands of different knee-high stockings, involving 181 home testers in the trial. Each tester received two pairs of knee-high stockings in clear plastic bags with no brand names. Each brand of knee-high stockings was trialled by 16 people. The testers wore (and washed) each pair of knee-high stockings for five days, or until they could no longer be worn, whichever came first. They checked them for obvious manufacturing faults on opening and rated them on appearance and comfort when they first put them on and after the last day's wear. They also considered size, ability to stay up and leg band tightness. If one or more of these was unsatisfactory, the testers tended to give a lower overall rating.

Adapted from *Choice*

Choice magazine tested 39 hair conditioners that were placed in clear plastic bottles with no brands on them. Four different bottles of conditioner were tested by 423 people. The testers had to carry out their normal hair washing and styling routine, and use each product three times before trying the next. Each brand was tested by 40 people. They then had to rate the conditioners on fragrance, manageability of their hair after use, and on factors such as control, shine, body, softness and appearance of hair after use.

Adapted from *Choice*

1 Why do you think the testers received the products in clear plastic containers or bags without brand names?
2 Which variables were controlled in these tests?
3 Which variables were not controlled?
4 If *Choice* magazine made a recommendation to buy a particular product after these tests, would you buy the product based on their testing procedures? Explain.
5 How many people tested each product? Was this enough? Do you think the results are reliable? Explain.

1.3 Recording and presenting results

To obtain reliable results you must make precise measurements. You must also record and present the findings in a way that people reading the report will understand.

Errors in measurement

In some tests it is appropriate to record your results in a qualitative way using descriptions or words. For example, the *Choice* consumer testing of hair conditioner in Inquiry 8 was based on qualitative statements being made by the testers on how shiny, manageable and soft their hair was after using each conditioner.

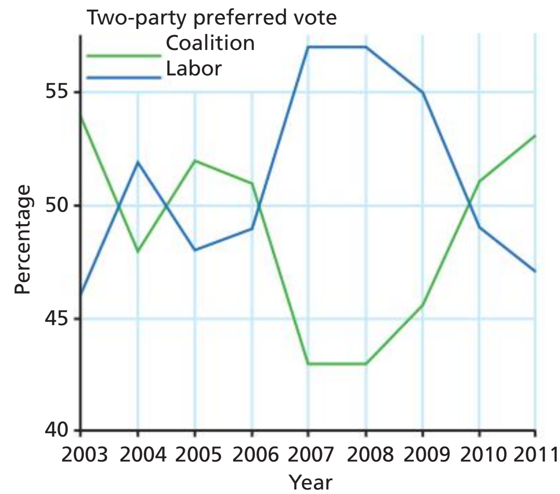
In some tests it is more appropriate to make quantitative measurements using numbers. However, you need to take care to avoid errors in recording your results. Errors can be made because the correct procedure is not followed for using a measuring instrument. For example, when a measuring cylinder is used, the scale must be read with your eyes level with the meniscus to avoid parallex error. Another example is using a balance to measure the mass of an object. The scales must be set back to zero for each measurement that is made.

Errors can also be made because of carelessness. For example, a person might measure from the wrong place. Errors can also be made by using the wrong measuring equipment. For example, you might want to see if a tiny amount of current is flowing in a circuit. If an ammeter is used instead of a *milli*ammeter, the results may not be accurate.

It is also important to remember what variable you are measuring. The *independent variable* is the one you choose values for. The *dependent variable* 'depends' on the values chosen for the independent variable and is the one you measure. For example, if you wanted to measure how fast water boils, you could decide to measure the water temperature at 2 minute intervals. In this case, time is the independent variable because you choose what the time intervals will be. The dependent variable is the temperature of the water because it depends on what time you choose to measure it. Remember that the independent variable is plotted on the x-axis and the dependent variable is plotted on the y-axis.

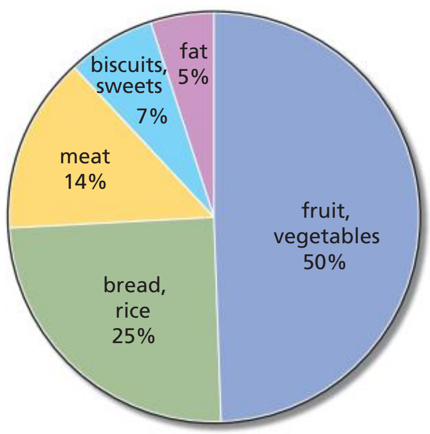
Which graph do I use?

Once the results are collected they need to be presented for others. This could be as a table, a spreadsheet or a graph. Column graphs (that run up and down) and bar graphs (that run across) are used when you want to make comparisons at a particular time. For example, how many votes each party polls on election day could be shown as a column graph because voting preferences are being compared at a particular time. However, if you wanted to look at the voting preferences of people over several years, a line graph would be used because the differences are being compared over a period of time.

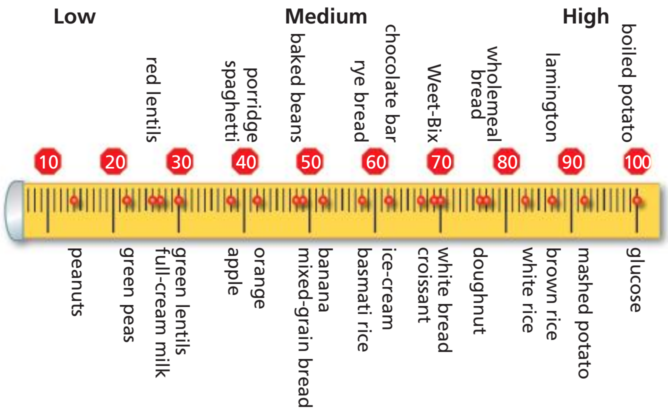


This line graph shows the Newspoll results from 2003 to 2011 for people's voting intentions for the Federal parliament.

Pie charts can be used if your results can be divided into a number of parts or segments to show how something is a percentage of the whole. Imagine you are investigating the amount of fruit, vegetables, meat, etc. you eat in a week. The results could be calculated as a percentage and a pie chart used to display the results.



You can also present your results in other ways that are a bit more creative. For example, the average glycemic index (GI) of some foods is shown below. (The GI is a ranking of foods based on their immediate effect on blood sugar levels.) This information could have been presented as a column graph. Instead, it has been presented as points along a tape measure because low GI foods are recommended for weight loss.



The average GI of some foods

INQUIRY 9 Drained mass of cans

For many products, such as canned fruit, the mass of the food indicated on the can includes the fruit (solid) and the juice (liquid). New labelling regulations require the drained mass of these products to be listed. In this activity you are going to check different brands of canned food to see what the mass indicated on each can refers to. Zero the balance for each measurement and record each mass in your notebook.

You will need: digital balance, can opener, sieve, 2 large bowls, different brands of canned fruit and vegetables

1 Measure the mass of each bowl, then the unopened can.
2 Open the can. Separate the liquid and the solid into separate bowls using the sieve.
3 Measure the mass of the liquid and then the mass of the solid. (Remember to subtract the mass of the bowl for each.)
4 Since most cans give the amount of mass as a percentage, convert the mass of the solid to a percentage by dividing it by the total mass of the can contents.
5 Is the labelled mass correct? Is the drained mass labelled on the can? Test other brands.
6 What type of graph would be best to display your results? Draw it.

INQUIRY 10 Displaying information

Andre asked, 'Why buy an expensive car? Won't parts for the car cost more if you have to get it repaired?' Complete this activity and see if Andre is right.

The most common car accident in Australia is one car hitting the rear of another. NRMA Insurance tested how well the bumper bars of the 10 top-selling small and medium cars protect them from damage in a simulated 10 km/h collision. They then assessed the cost of the repairs and used this to work out their insurance premiums. Here are their results.

	Purchase price ($)	Total repair costs ($)	Total as a percentage of purchase price
Hyundai Getz	14 980	6095	40.7
Suzuki Swift	15 980	9875	61.8
Toyota Yaris	18 180	6598	36.3
Ford Focus	22 020	4008	18.2
Mazda 3	22 970	5375	23.4
Toyota Corolla	22 980	3217	14.0
Mitsubishi Lancer	23 310	7040	30.2
Honda Civic	23 810	10 927	45.9
Holden Astra	24 020	4251	17.7
Subaru Impreza	26 510	8352	31.5

Source: NRMA Insurance 2007

1 Which graph would you draw to show the total repair costs of the cars compared to the purchase price of the cars. Draw this graph. Is Andre correct?
2 Which graph would you draw to show the relationship between total repair cost (as a percentage of purchase price) and the purchase price? Draw this graph. (*Hint*: To show a relationship you plot the dependent variable against the independent variable. Which is the independent variable?)
3 Are small cars (top of table) better value for money (i.e. are you spending less money on repairs as a proportion of the total cost of the car)?
4 Which car would you purchase if you were buying a car? Give reasons for your answer.

INQUIRY

11 Cloth or disposable nappies

Are cloth nappies cheaper to use than disposable nappies? Read the following information and answer the questions below.

Nappy type/ treatment	Wash	Dry	Weekly cost ($)	Cost over 2.5 years ($)
Cloth (front loader)	Cold	Line	7.00	908
	Warm	Dryer	8.19	1065
	Hot	Dryer	8.38	1089
Cloth (top loader)	Cold	Line	7.31	951
	Warm	Dryer	8.50	1103
	Hot	Dryer	9.25	1206
Cheap disposable			14.19	1843
Expensive disposable			24.13	3138

All the cloth nappies were washed with the same detergent and soaked in warm water and a stain remover before washing. An electric clothes dryer was used where indicated. Calculations were based on 9 cloth nappies and 6 disposable nappies per day. The cheap disposable nappies were 34 cents each and the expensive nappies were 58 cents each.

1 Draw a graph showing the cost over 2.5 years for the cloth and disposable nappies listed.
2 Which variables were controlled in these tests? Which variables were not controlled?
3 What other tests were not performed that could have been carried out to compare the cost of the nappies?
4 Can you draw a conclusion about the cost of using cloth nappies compared to disposable ones? Explain.
5 What other factors, besides cost, might influence which nappies a person used?

Over to you

1 What errors are possible when using scientific equipment and recording measurements?
2 When you are designing your own experiment, what variables do you measure?
3 When would you use a column graph and when would you use a line graph to plot your results?
4 Why is it important to make accurate measurements and record your results precisely?

INVESTIGATION

1 Testing saucepans

Aim

To measure how quickly different brands of saucepans heat water.

Risk assessment and planning

1 Review the safety rules for using a hotplate with your teacher.
2 List any other safety precautions you think are necessary after reading this investigation.
3 Draw up the following table to record your results. You may need to add more columns.

Brand of saucepan	Temperature of water at 2 minute intervals				
	0	2	4	6	8

Apparatus

- hotplate
- thermometer
- different brands of 1 litre saucepans (no lid)

Method

1 Form groups of three.
2 Add 500 mL of water to a 1 litre saucepan. Measure and record the temperature of the water before heating.
3 Place the saucepan on the hotplate and heat the water. Measure the temperature of the water every 2 minutes until it boils.
4 Remove the saucepan and let it cool before emptying the water on a garden bed in the school grounds.
5 Collate the results for each saucepan tested.

Results

Draw a graph showing the temperature results for all the brands of saucepans.

Discussion

1 Which variables were controlled in this experiment? Which variables were not controlled?
2 Do you think the results you obtained are reliable? Explain.

Conclusion

Write a sentence or two explaining which brand of saucepan you would recommend.

1.4 Designing your own test

Your chapter problem is to test different brands of a particular product to see which brand is the best. In doing this you are consumer testing. Your first step is to decide on the product you wish to test. For example, you might want to test soft drinks, batteries or liquid paper. Once you have chosen your product, you then need to work through the following steps.

1 *What features do consumers want from the product?* Let's say, for example, that you choose to test vacuum cleaners. You might ask the following questions:
   a Which vacuum cleaner removes dirt from carpet the best?
   b Which vacuum cleaner works the best on hard floors without scratching the surface?
   c Which vacuum cleaner cleans in the corners most efficiently?
   d Which vacuum cleaner is the quietest?

2 *Which of the listed features are you going to investigate?* For example, you might decide to investigate which vacuum cleaner removes dirt from carpet the best.

3 *What will you need to do the test?* To test a number of different vacuum cleaners, you might need to ask some friends if you can use theirs. You might also need a sample of carpet, some sand or dirt and a balance.

4 *List the variables that could affect the test and any possible problems.* For example, the type of vacuum cleaner head, the reach of the handle, the amount of suction and the power of the vacuum cleaner might affect the outcomes of the test. Think of any problems that could occur in the testing. For example, are there any possible dangers to you or others with the products you are testing?

5 *Design and carry out a fair test.* You must design a test that alters only one variable (the different brands being tested) and keeps all other variables the same. For example, to make this a fair test for all vacuum cleaners, the same head and speed would need to be used for all the vacuum cleaners. The same carpet would need to be tested and it would need to be vacuumed in a set pattern. The same amount of sand (e.g. 100 g) would need to be spread across the carpet. This could then be weighed and you could work out what percentage of the sand was collected by each vacuum cleaner.

6 *Repeat your test.* If only one test is carried out, the results may be inaccurate. To get more accurate results it would be better to carry out three trials and take an average. This is especially true for the vacuum cleaner example. You might push the vacuum cleaner across the floor slightly harder with some brands than others. If three trials are carried out and an average calculated, then you are reducing error in your procedure and obtaining more accurate results.

7 *Interpret and discuss your results.* For any experiment it is important to analyse the method used. You can then assess whether the results are reliable and the tests are valid. To do this, complete the following questions.
  a Explain whether the results were expected.
  b If the results were not expected, explain why you think they were different.
  c Which variable did you change purposely? Which variable did you measure and how?
  d Which variables were controlled?
  e Do you think there were any errors in the design of the experiment? Did you control all the variables except one? Why or why not?
  f If the variables were not all controlled and you need to repeat the experiment, suggest improvements you could make.

8 *Make a conclusion.* Once you have obtained your results and discussed them you need to make a recommendation about which brand to choose. This also includes a statement of where to go from here. Is further testing needed to check the results? Do the results suggest another test that could be done?

Writing your report

You can write up your investigation as a report in the format you are used to. You might like to discuss as a group which parts of a consumer test correspond to the aim, apparatus, method and so on.

The reports of consumer tests in *Choice* magazine are written up a little differently from those you write for investigations. Their reports start with a brief summary stating what the findings were (conclusion) and what the surprises or unusual outcomes of their testing were. This is to get people interested in reading what was done.

The reports often have pictures of six or eight of the best products tested, and explain the good and bad points of each. They also give a brief description of the non-performing products and state what was wrong with them. They provide a table of results and describe how each test was performed to get these results (method). The reports sometimes provide special segments or recommendations, for example, on which brand to buy if you have a disability or sensitive skin. They then make a final recommendation as to which product *Choice* thinks is the best to buy and why.

INQUIRY 12 Choice *magazine*

You will need: a variety of *Choice* magazines

Find a consumer test in *Choice* that interests you and answer these questions about it.

1 What consumer test are you looking at?
2 How was the test performed?
3 Which variables were controlled? Which variables were not controlled?
4 How are the results presented?
5 Are there any special features in the report?
6 How is the report different from the reports you write up for investigations?

Carrying out a survey

Consumer testing can be carried out in different ways and some of these do not require scientific tests. For example, you can carry out a **survey** to get the product information you need.

To carry out a survey, you could choose a particular product or topic and ask consumers a set of questions to determine their opinion. Many product advertisements on television ask people for their opinion. For example, Why do you shop at BI-LO? What do you think of NapiSan Oxy Action? Surveys like this have to be carefully written so that the questions are not misleading or produce false responses, and so that consumers can answer them quickly and easily. The questions also have to be written so that the information in the answers can be collated and interpreted. The skill section on the next page will show you how to do a survey.

You could also carry out a comparison survey so that you have a checklist of criteria you use to evaluate each product.

SKILL

Doing a survey

A survey is carried out when you want to find out facts, figures or opinions about a particular topic. For example, a bank may do a survey of its customers to find out how they view its service or whether it is meeting their needs. A written survey or a *questionnaire* is a useful tool for collecting information from a wide range of people in the community. The following hints will help you write a survey.

1 Ask yourself what information you want to find out or what area you are interested in sampling.

2 Limit your survey to no more than 10 questions.

3 Use everyday language so that all participants will understand. Avoid **jargon** or slang words.

4 Ask simple questions that have only one part to them. For example, 'Do you enjoy shopping at this centre and can you always get a park when you get here?' is too complicated a question because it requires two separate answers. You need to break it into two separate questions.

5 Arrange the questions so that they follow a logical sequence and do not jump around from one topic to another.

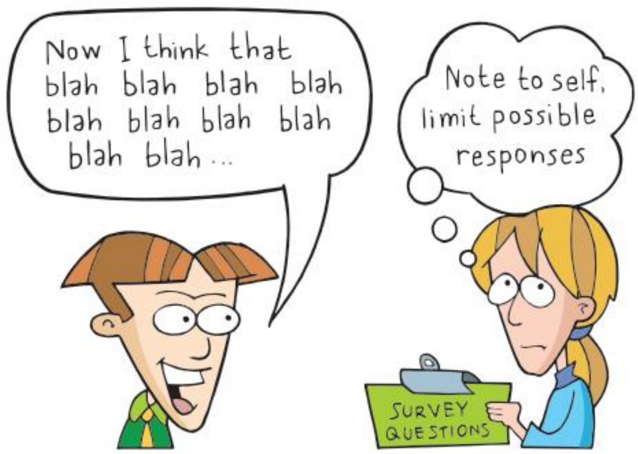
6 Decide whether you are going to present the survey as an interview or as a questionnaire. If you carry out an interview, avoid leading the participants to give you the answer you want. For example, you might really like the product you are surveying and want others to like it too. A question like 'Is this product the best for removing stains?' could influence the answers that you get. It would be better to ask 'How well do you think this product removes stains?' Pay close attention to what you say and your body language. Smiling and nodding your head when someone gives you an answer you like may influence the participant without you being aware of what you have done.

7 Limit the responses that participants can give you. When you ask for people's opinions you are getting a **subjective** or personal response. You could get a wide range of answers and find it very difficult to compare the information you receive from different people. If you limit the responses available, you will overcome this problem. You can do this by asking people to give a rating, such as:

excellent ↔ very good ↔ satisfactory ↔ poor ↔ terrible

When possible, obtain **objective** answers so that you can measure or count something, for example:

1 ↔ 2 ↔ 3 ↔ 4 ↔ 5
Always Never



8 Whatever scale you use for each rating, make sure that you use it consistently throughout the survey. Do not have one question with a response such as:

1 ↔ 2 ↔ 3 ↔ 4 ↔ 5
Always Never

and then change it to:

1 ↔ 2 ↔ 3 ↔ 4 ↔ 5
Never Always

You will find that participants will get confused and you will not get an accurate response.

SKILL continued

9 Make your possible responses mutually exclusive. For example, if you want to ask the participants their age, you could have age groups of:

15–20 years   20–25 years   25–30 years   30 years +

However, if the participant is 20, 25 or 30 years old it would be difficult to know which response to tick because these age groups are not mutually exclusive.

10 Trial your survey on your classmates before you ask the local community.

11 Finally, always remember to be polite when asking people if they want to participate in your survey, and be gracious if they say that they do not have the time.

Follow the steps below to conduct a survey.

1 Working in groups of three, design a survey to ask the students at your school what they think of the products sold at the school canteen. You could ask a variety of questions, such as:
   - **a** Are you happy with the range of products, food choices, sandwiches and so on?
   - **b** What would you like to see removed from sale?
   - **c** What would you like to see added to the list of products sold?
   - **d** Is there too much junk food?

2 Have your questions checked by your teacher once you have finished. Then, during lunchtime, each person in the group can survey three students.

3 Collate the results. Graph the data where possible and make a short presentation to the class of your findings.

INQUIRY 13 Shopping online

1 Carry out your own survey online to see which internet shopping organisation is the cheapest to use or whether internet shopping is cheaper than going to the supermarket yourself.

You could use the following internet addresses to carry out your survey: www.homeshop.com.au or www.colesonline.com.au. Do not register with these websites, just go into product survey to find the information you need.

2 To complete your survey, find the name and price of the cheapest brand for the 10 products listed below. Add up all the prices to get an overall shopping bill. Don't forget the delivery fee.
   - **a** canned dog food
   - **b** teabags
   - **c** toothpaste
   - **d** jam
   - **e** nappies
   - **f** toilet paper
   - **g** laundry detergent
   - **h** baked beans
   - **i** cereal
   - **j** facial tissues

3 Which variables were controlled in your survey?

4 Which variables were not controlled in your survey?

5 Is the survey fair? Are the results reliable?

6 Your survey did not include fresh foods, such as fruit and vegetables. Why? (*Hint*: What else would you need to assess with fruit and vegetables, other than price, that would make it difficult to compare these products?)

INQUIRY 14 Breakfast cereals

People who miss breakfast are four and a half times more likely to be obese (excessively overweight) than people who eat breakfast. And children who eat breakfast have less chance of becoming obese and are able to concentrate better throughout the day. Breakfast is also a good way to get the fibre you need. An adult should get 25–30 g of fibre each day. For students, add 5–10 g to your age to find out how much fibre you need a day. So, if you are 15 years old, your fibre intake should be 20–25 g. A good breakfast cereal is high in fibre and energy, and low in fat, sugar and salt. How do single serves of some breakfast cereals compare?

Brand name	Fibre (%)	Energy (kJ per serve)	Fat	Sugar	Sodium (salt)
Sanitarium Weet-Bix	18.5	580			
Uncle Tobys Vita Brits	13	390			
Kellogg's All Bran	27.5	630			
No Frills Just Bran	34	430			High
Kellogg's Oat 'n' Honey Bake	8.6	670	High		
Sanitarium Puffed Wheat	6.5	370			
Kellogg's Special K	4.0	470			
Kellogg's Nutri-Grain	2.5	480		High	High
Kellogg's Froot Loops	2.4	490		Very high	

Fat, sugar and sodium are noted only if the cereal contains high amounts.

1 Which breakfast cereal would you recommend from this list and why?
2 Which variables that could influence people's choice of breakfast cereal are not included in this table?
3 Look at the nutritional information on the back of the cereal you eat. How does this compare to the cereals above? Are they high in fibre, energy, fat, sugar and sodium? Are the breakfast cereals you eat good for you?

Over to you

1 In some tests it is recommended that you perform three trials and take an average. Why is it important to do this?
2 Why is it important to analyse the method used when you have finished consumer testing?
3 What do you think are the three most important things to do when designing your own experiment?

PROBLEM SOLVING

What have you learnt so far to help you with your chapter task? You have learnt how to design a fair test, and how to carry out consumer tests. You now need to decide what you are going to do. Here is a list of topics to help you, or you can think of your own. You could look through *Choice* magazines or go to the supermarket to get some ideas. Get your topic approved by your teacher before you start.

1 Which cleaner is best for removing graffiti from the walls of buildings?
2 Does the storage temperature of batteries affect how long the batteries will last?
3 Which is the best material to keep lunches fresh?
4 Which aluminium foil is the strongest?
5 Which shopping bag holds the most without breaking and is the kindest to the environment to produce?
6 Which paper towel is the most water absorbent?
7 Which type of milk lasts the longest?
8 Do washing powders work as well in cold water as in hot water?
9 Which brand of sunglasses gives the highest sun protection and the most true-to-life colour?
10 Which clothes dryer dries clothes the fastest?
11 Which brand of rubber bands can stretch the most without snapping?
12 By how much do the prices of food items vary in different shops?

1.5 Right or wrong?

You will see many scientific and technological changes in your lifetime. Scientists will come up with many wonderful inventions that will help people live better lives. But new scientific developments can have both a positive and a negative impact on society. For example, consider nuclear fission. When scientists discovered that they could split atoms and release massive amounts of energy, people thought that nuclear power could solve the world's energy needs. However, accidents in nuclear reactors, the dumping of nuclear waste and the potential to make nuclear bombs are some disadvantages associated with this scientific discovery.

Studying science helps you to discuss the advantages and disadvantages of scientific discoveries from an informed point of view. This is very important if you are going to make judgments about whether something is acceptable or not.

Science can open up a world of amazing discoveries, but at the same time these discoveries can conflict with the underlying framework of beliefs and values that society holds. For example, scientists have mapped the human genome, or all the genetic information contained in human cells. They have isolated parts of the genome that cause certain diseases and parts that produce the physical characteristics each person has. They have been able to replace parts of the genome that do not function properly and thereby correct diseases. They also have the ability to make an identical copy of an organism using the genetic knowledge they have acquired. This is called cloning.

Some people may say that this is wonderful. We have the ability to cure diseases such as diabetes and Alzheimer's disease. Others may say that the natural world dictates that those who are the best adapted to their environment survive. People with diseases are not adapted to their environment and should be allowed to die.

People may also oppose new scientific techniques on religious grounds. Some religions do not believe that a person who requires medical assistance to extend their life should receive it. They believe that we should not 'play god' by trying to fix things.

When you are asking whether something is right or wrong, based on the values and beliefs that society holds, you are talking about *ethics*. Each chapter of this book has a feature called 'Science as a Human Endeavour' that presents new scientific findings and asks you to discuss their advantages (pros) and disadvantages (cons).

Debating

One way to discuss the pros and cons of an issue is to carry out a debate. The steps for carrying out a debate are outlined below.

1. Your teacher will divide the class into two groups. One group will present the affirmative argument (they are *for* the issue presented). The other group will present the negative argument. Each person in the group must think of arguments your group can use and any counter or opposing arguments that can be made against the other group. This is called rebuttal. Use examples to support each point, as well as facts, figures and current events.
2. One person in the group is the recorder and writes down all the arguments. Put the most important arguments first and try to arrange them in a logical order so that each point leads onto the next. Make sure there is a relevant example for each argument.
3. Choose a team of three people to present your argument. Both the affirmative and the negative teams have three people.
4. Your teacher will choose a chairperson who is responsible for when each person speaks. Another person will be a timekeeper. Each team member is given 4 minutes to present their argument. The timekeeper will ring a warning bell at the end of 3 minutes and then a final bell at the end of the 4 minutes.

5 The first speaker for the affirmative goes first. They introduce the team and briefly outline the arguments each person will make. They then give two arguments of their own.
6 The first speaker for the negative then does the same, but they are also able to rebut the arguments made by the first speaker.
7 The second speakers for both teams present the body of the argument and rebut any arguments made by the opposite team.
8 The third speaker for the affirmative clarifies their team's argument and adds any further points they wish to make. They also rebut any points made by the speaker before them. They summarise their team's point of view and make closing remarks.
9 The third speaker for the negative does the same but cannot raise any new points because there is no chance for the other team to offer a rebuttal against them.

INQUIRY 15 *Practice debate*

Read the following article.

> The use of cannabis has been criticised because it causes depression, anxiety and mental disorders such as schizophrenia. However, it could be used to assist people who are in severe pain from long-term illness. Cannabis-based medicine (CBM) has been tested in patients with rheumatoid arthritis. In this disease the body's immune system attacks the lining of the joints, causing inflammation. (The joints swell, and become stiff and sore.) In a recent trial 31 patients were given CBM and 17 were given medicine with no cannabis (a placebo). Both were in the form of a mouth spray that patients could take themselves, with up to six sprays per day for a period of five weeks. The sprays were taken just before going to bed to reduce any intoxication effects. Patients taking CBM had significant improvements in pain when moving, pain at rest, quality of sleep, inflammation and intensity of pain. However, side effects included dizziness, light-headedness, dry mouth and nausea.
>
> **Adapted from *The Weekend Australian* 12 November 2005**

Debate the following: 'Cannabis should be freely available to people with long-term pain'.

Essay writing

Another way you can discuss the issues relating to scientific discoveries is to write an essay. You will have written essays in English and history. Here are a few steps to help you write an argumentative essay.

1 List all the pros and all the cons for the topic you are given.

2 Choose whether you are going to take the affirmative argument (for) or the negative argument (against). Choose the argument that you can think of the most points to discuss.

3 Write a draft of the essay with the following plan.

Paragraph 1: Introduction. A brief statement of the argument and a summary of some of the points you wish to discuss.

Paragraph 2: List the main argument and an example to support what you are saying. Think of any counter arguments that can be made against what you are saying and discuss them.

Paragraphs 3, 4, 5… : State one supporting argument with one clear example for each paragraph you write. Discuss any counter arguments that can be made against what you are saying.

Conclusion: Summarise what the main argument is. Think of a snappy ending to leave the reader convinced of your point of view.

4 Review any spelling and grammatical errors before writing a final copy of the essay.

Over to you

1 Give your own example of a scientific discovery that has had both a positive and a negative effect on our world.
2 What are ethics?
3 Find a newspaper article on one scientific discovery. Answer the following:
   a What is the science being discussed?
   b What are the advantages and disadvantages of the science being discussed?
   c Based on your own values, do you think that the use of the scientific discovery is right or wrong? Explain whether others would agree with you.

Newspaper articles

1 Read the article on this page and explain:
  a what the article is about and what the science being discussed is
  b why the article appeared in the newspaper
  c the advantages and disadvantages of the science being discussed
  d whether you think that the science is right or wrong, giving reasons for your answer.

2 Write an essay on one of the following topics:
  a How you could convince the Supreme Court that Mrs Edwards has every right to use her husband's frozen sperm.
  b Surrogacy should be freely available to couples unable to have a child.

Widow Jocelyn Edwards fighting to deliver her husband's IVF baby

Jocelyn Edwards

A woman fighting to have her dead husband's baby has launched a new court battle to take his frozen sperm outside NSW for use in IVF treatment.

A Supreme Court judge will decide soon whether to grant Jocelyn Edwards possession of her husband Mark's semen, which is held by IVF Australia. Mrs Edwards, 40, wants to travel interstate to have treatment because NSW law prevents her having an IVF baby without written consent from the donor. Mr Edwards, 39, died after falling from a balcony the day before the couple were to sign consent forms to undertake IVF treatment.

Mrs Edwards convinced Royal North Shore Hospital doctors, Westmead Fertility Centre, IVF Australia and a Supreme Court judge to take sperm from his body after his death on August 5 last year. But she has since had to apply to the Supreme Court to use the sperm in IVF treatment. Her lawyers dropped attempts to have a court rule she can use the sperm in NSW because NSW law expressly bans such a practice without the donor's written consent. Instead a Supreme Court this week heard an application from Mrs Edwards' legal team to make her husband's sperm her property.

The court heard the NSW Assisted Reproductive Technology Act bans a reproductive technology provider from exporting sperm outside the state. But it does not ban individuals from transferring sperm, the court heard. Mrs Edwards's lawyer Harry Freedman confirmed they believed IVF treatment could be undertaken legally by Mrs Edwards outside NSW. It is understood Mrs Edwards, from Lane Cove, might attempt to take the sperm to the ACT or overseas. 'It's a matter of the court's discretion,' Mr Freedman said. There are previous cases in which, in other states, sperm had been exported.

The Attorney-General's Department is not opposing or supporting Mrs Edwards's bid. Mrs Edwards refused to comment ahead of the judgment yesterday. But she said in October: 'Mark wanted us to have a baby, regardless of what happened, regardless of if I passed away or he passed away. It's our love, it's our union, it's our family.' Justice Robert Allan Hulme reserved his decision but noted: 'I appreciate Ms Edwards is undoubtedly keen to see a resolution and I will certainly bear that in mind.'

***The Daily Telegraph* 21 April 2011**

THINKING SKILLS ?

1 Look at the following table:

Type of potato	Fat (%)
Homecooked potatoes	
Boiled potato	<0.5
Jacket-baked potatoes	<0.5
Roast potatoes	4
Mashed potatoes with butter or margarine	5.5
Chips	8.5
Oven-baked varieties	
McCain Healthy Choice Country Style Wedges	3.0
McCain Crunchy potato chips	3.7
Logan Farm Golden Gourmet crinkle cut chips	3.2
McCain Superfries extra long French fries	4.4
Birds Eye Golden Crunch Chips	4.3
Birds Eye Golden Crunch Fries	5.7
Birds Eye Traditional Hash Browns	9.6
Birds Eye Potato Gems	7.5
Birds Eye Oven Roast Vegetable Mix	1.7
Fast food chips	
Takeaway chips	17.5

a Draw a graph showing the fat percentage in different types of potato.

b Which are the healthiest ways to prepare potatoes?

c Explain whether oven-baked varieties can be healthier for you than homemade types of potato.

d Which types of potato do you think should be avoided or eaten in moderation?

2 Read the following table:

Hot water system	Carbon dioxide produced each year (t)*
Electric hot water system	5
Natural gas hot water system	1.5
Solar hot water system (electric boosted)	<2
Solar hot water system (gas-boosted models)	0.5

* From producing the electricity or gas needed to run the appliance.

a Do solar hot water systems produce less carbon dioxide than electric or gas hot water systems? Explain.

b Why do we need to limit the amount of carbon dioxide that we produce?

c The average price of an electric hot water system is $1100, plus $900 to install. The average price of a two-panel solar hot water system ranges from $2500 to $3000, plus $1200 to install. Why do you think people still install gas and electric hot water systems instead of solar hot water systems? Which would you choose? Why?

d The average running cost of a gas hot water system is about $300 per year. Solar (boosted) hot water systems cost about 70% less to run. How much money do you save a year using a solar (boosted) hot water system compared with a gas one?

e How many years would it take you to pay for your solar (boosted) hot water system from the money you save in yearly energy bills?

3 Use the internet to find out about Australian inventions and how they have changed our lives. Some examples include:

a Hills Hoist

b Victa mower

c black box flight recorder.

d combine harvester

e Vegemite

4 Use the internet to find out what the food labelling laws are in Australia and what should go on a food label. Then find out:

a what flavours, colours, antioxidants, emulsifiers, food acids, vegetable gums and humectants are

b why these substances are added to food

c how these substance are labelled on food packages.

Knowing and Understanding

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

1 _______ helps solve problems, provides for our needs more efficiently and helps us make informed choices about what we do and what we use.

2 Making _______, _______ and trying to find answers to these questions are some of the first steps in the scientific method.

3 A _______ is an educated guess based on the observations you have made and the knowledge you already have. It is a statement that can be _______ by making observations and measurements.

4 If an experiment can be repeated and the same results obtained, then the results are said to be _______. To make the experiment _______, only one variable must be changed and all other variables controlled.

5 When carrying out scientific testing it is often necessary to do three trials and take an average. This minimises _______ that may occur in the procedure.

6 Not all consumer testing relies on scientific testing. Sometimes consumers can be asked questions about a topic. This is called a _______.

7 When you are asking whether something is right or wrong, based on the values and beliefs that society holds, you are talking about _______.

- asking questions
- errors
- ethics
- fair
- hypothesis
- observations
- reliable
- science
- survey
- tested

Self-management

Dicey stuff

1 Form groups of four.

2 Your teacher will give you three dice.

3 On the faces of dice 1 are the words 'what', 'when', 'where', 'how' and 'why'. One side is blank. On the faces of dice 2 are the words 'is', 'can', 'will', 'do' and 'are'. There is also one side blank. On the faces of dice 3 are the words 'variable', 'reliable', 'valid', 'fair tests' and 'errors'. Once again there is one blank side.

4 Roll the dice together. Use the words that appear on the top sides of the dice to make a question that helps review this chapter. You will need to add your own words too. You must always start with the word that appears on dice 1 but the other words can appear in any order. You can also use the plural of any words you roll. For example, you might roll the dice and get the words: 'what', 'is' and 'variable'. Possible questions could be: '*What is* a *variable*?' or '*What is* meant by controlling the *variables* in a scientific test?'

5 If you cannot think of a question from the words you have, roll the dice again.

6 If you roll a blank, choose any word you like to make the sentence.

7 Your teacher may also instruct you to change the word of any face on dice 3 during the activity. Other words could be: survey, hypothesis, scientific method, debate, ethics, essay.

8 Write answers to your questions on a separate sheet from the questions.

9 Swap your revision questions with another group and see if you can answer their questions. When you have finished, check your answers with the answer sheet.

Checkpoint

1 Which of the following statements are true and which are false?

a Science can provide new materials and new technologies.

b Thomas Edison is one scientist who helped provide for our needs in a more efficient way.

c Asking questions about your observations is called inferring.

d A type of test based on opinion is referred to as an objective test.

e The results of an experiment are said to be reliable when the test can be repeated many times and the same results are obtained.

f In designing a fair test all the variables must be controlled.

2 Eddie wanted to test which garden hose was best for his father to buy. He tested three features of garden hoses: test 1—squash resistance, test 2—kink resistance, and test 3—flexibility. For his squash resistance test, he got his father to sit the front tyre of his car on each hose for 20 minutes. He then timed how long it took each hose to return to its original shape. For kink resistance he bent each hose in a circle of about 80 mm diameter and rated how easy this was to do for each hose. Some hoses were difficult to bend into a circle so he tried to bend them as close to 80 mm as he could. For flexibility he rolled each hose up for 24 hours and then measured how long each hose was when it was uncoiled compared to before the hose was coiled.

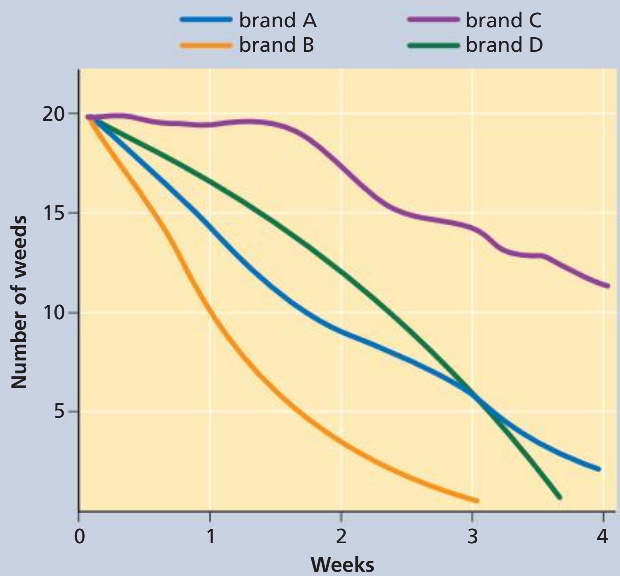
a List the variable Eddie was changing in each of his tests.

b For each of these three tests, list at least one variable that Eddie needed to control.

c Are there any errors in Eddie's procedures? Explain.

d Are Eddie's results reliable? Explain.

3 Than chose to test four brands of weed killer to see which one was best for use in her garden. She divided a large garden bed into four areas each a metre square. In each area she marked 20 weeds of approximately the same size with a red permanent marker. She then sprayed a different brand of weed killer in a set pattern across each area and resprayed 24 hours later. For the next 4 weeks she counted how many of the 20 weeds in each area were still alive. Her results are presented in the graph below.



The effect of different brands of weed killer

a Which brand of weed killer was the most effective? How long did it take to kill all the weeds in its test area?

b Which weed killer was the most ineffective? Give reasons for your answer.

c Why did Than draw line graphs? Is this the right type of graph to display her results?

d Which was the one variable Than was altering?

e Were all the other variables properly controlled? Explain.

f Can Than make valid conclusions?

4 Why is it usually necessary to repeat your testing when carrying out a scientific experiment?

5 Explain whether the scientific method is a linear or a cyclical process.

2 Chemical reactions

Airbag race

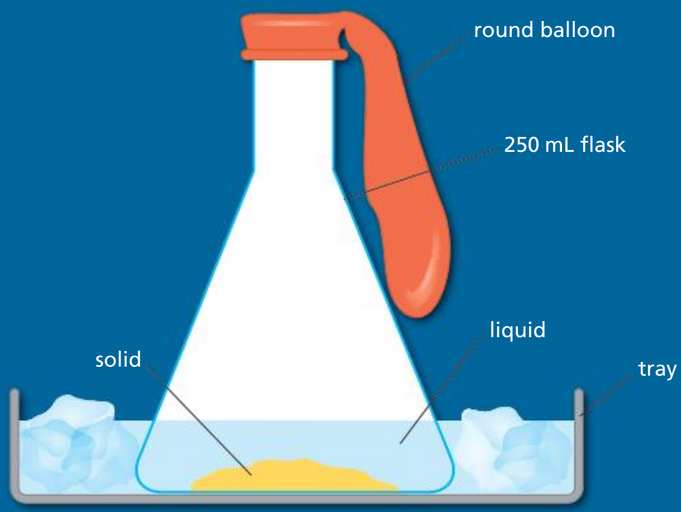
You can make your own airbag by mixing a solid and a liquid which react in a flask to produce carbon dioxide gas. This gas needs to inflate the balloon as quickly as possible.

The idea is to see who has the biggest balloon after a set time. You can choose from one of these solids: 8 Fruit Tingles or a packet of sherbet.

You also need to choose one of these liquids: 20 mL of water, 20 mL of vinegar, or 20 mL of freshly squeezed orange juice or lemon juice.

Also, you can leave the flask at room temperature, put it in a tray of iced water, or put it in a tray of hot water.

When your teacher gives the start signal, tip the solid and the liquid you have chosen into the flask and immediately put the balloon over the mouth of the flask. Put the flask in iced water or hot water, if you have chosen to do this.



Who is the winner?

Discuss the results. What was the winner's secret? What can you do to make a chemical reaction go faster? You will learn about this in this chapter and later you can have another race.

Focus for learning

Chemical reactions are all around us. Here are two examples.

When you swallow food you also swallow air. If you eat too much or too quickly you may feel bloated, due to the air trapped in your stomach. 'Fizzy drinks' (called antacids) may give you some relief. These drinks contain two chemicals which react to produce carbon dioxide gas when added to water. Drinking a fizzy drink releases even more gas into your stomach. This gas is released when you burp.

Airbags are a common safety device in cars. The inflator contains a mixture of chemicals that act like solid rocket fuel. In an accident this mixture is ignited by electricity and an extremely fast reaction occurs, releasing a large volume of nitrogen gas, which inflates the bag. This all happens faster than the blink of an eye. The gas then escapes through tiny holes in the bag, causing the bag to deflate.

An airbag to protect you from computer crashes

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

Science Understanding

- design an experiment to investigate how reaction rate is affected by factors such as temperature, surface area and catalysts
- use word equations to represent chemical reactions
- test the law of conservation of mass for an everyday chemical reaction

Science as a Human Endeavour

- use the work of Perkin to illustrate how developments in technology are often linked to scientific discoveries

Science Inquiry Skills

- plan, select and use appropriate methods to investigate exothermic and endothermic reactions
- extend an experiment by suggesting further ideas to investigate

LITERACY FOCUS

catalase
catalyst
catalytic converter
combustion
conservation of matter
corrosive
decomposition
endothermic
enzyme
exothermic
hydrochloric acid
inhibitor
oxygen
particle theory
phlogiston
photochemical
photosynthesis
precipitate
reaction rate
respiration

2.1 Investigating reactions

INVESTIGATION

1 Observing reactions

Aim

To observe a variety of chemical reactions.

Risk assessment and planning

1 Hydrochloric acid and sodium hydroxide (caustic soda) are both corrosive liquids. If you spill these onto your skin or the bench, wash the area *immediately* with lots of water and send someone to tell the teacher.

2 Always wear safety glasses when handling corrosive liquids. If liquid splashes into your eye, wash it *immediately* with lots of water and keep doing this for up to 30 minutes. Blink your eyelid under water. The laboratory will probably have a special eyewash fountain or bottle.

3 Several of the chemicals are toxic, especially lead nitrate in reaction 1, so wash your hands carefully after using them.

4 Follow the rules for your laboratory on the disposal of chemicals.

5 For more information you should check the Materials Safety Data Sheets (MSDS).

Apparatus

- *dilute hydrochloric acid (1 M)*
- *dilute sodium hydroxide solution (1 M)*

- 2 small pieces of magnesium ribbon
- *copper sulfate solution (0.1 M)*
- *lead nitrate solution (0.1 M)*
- *potassium iodide solution (0.1 M)*
- *phenolphthalein indicator*
- *copper nitrate*

- 5 test tubes in test tube rack
- Bunsen burner and heatproof mat
- test tube holder
- spatula

Method

1 Number the five test tubes.

2 Carry out the following five reactions. For each reaction record your observations, noting any new substances formed.

3 For reactions 1–4 feel the test tube to see if any heat was produced.

Reaction 1 (teacher demonstration)

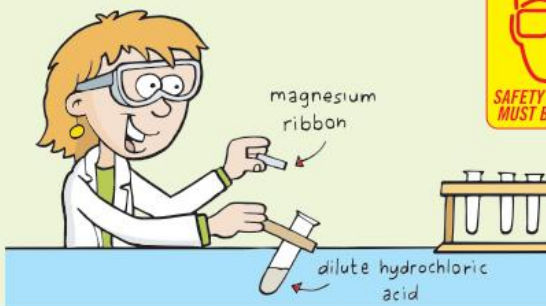
Add a small amount of potassium iodide solution to test tube 1, then a small amount of lead nitrate solution.

Reaction 2

One-third fill test tube 2 with copper sulfate solution, then add a piece of magnesium ribbon.

Reaction 3

Add a small amount of dilute hydrochloric acid (about 1 cm) to the bottom of test tube 3. Now add a piece of magnesium ribbon. Remember to point the test tube away from yourself and other people, as shown.



Reaction 4

Add a small amount of sodium hydroxide solution (caustic soda) to test tube 4. Then add a drop of phenolphthalein (FEE-nol-THALE-een).

Reaction 5

Use a spatula to put a small amount of copper nitrate in test tube 5. Light the Bunsen burner and use it to heat the test tube, gently at first, then more strongly. Don't forget to move the test tube from side to side as shown.

Do this reaction in a fume cupboard.

Write your report

Write your report using the usual headings. In your conclusion, summarise how you were able to tell when a chemical reaction had taken place.

Signs of a chemical reaction

In a chemical reaction the substances that react together are called *reactants*. The new substances formed are called *products*. There are five signs that tell you a reaction has occurred.

1 *You may notice the formation of a product*. For example, in Reaction 1 a bright yellow substance formed. Because it is insoluble in water it settled to the bottom of the test tube. It is called a *precipitate* (pre-SIP-it-ate). In Reaction 2 you would have noticed that brown copper metal collected on the bottom of the test tube. In Reaction 5 a brownish gas was formed.

2 *One of the reactants may be used up*. For example, in Reactions 2 and 3 the magnesium ribbon disappeared as it was used up.

3 *The colour may change*, as happened in most of the reactions.

4 *Bubbles of gas may produce fizzing*. This happened in Reaction 3 because the invisible gas hydrogen was formed.

5 *Heat and light may be produced*. You may have noticed that in Reactions 2 and 3 the test tubes became warm. In Reaction 5 you had to heat the test tube to get the reaction to go.

Rusting is an unwanted chemical reaction that causes iron and steel to go brown and break up. It occurs when iron reacts with water and with the oxygen in the air to form iron oxide (rust). To describe this reaction you can write a *word equation* with the reactants on the left and the products on the right.

iron + water + oxygen → iron oxide

reactants *product*

INVESTIGATION

2 Investigating rusting

Part A

Aim

To find out if water and air are both needed for rusting.

Risk assessment and planning

In the first part of the experiment you will put pieces of steel wool into small jars and vary the amounts of air and water in each.

- What variables will you need to control in this experiment?

You can get splinters from the steel wool, so it is a good idea to wear gloves when handling it.

Apparatus

Study step 1 of the Method and make a list of the apparatus you will need.

Method

1 Set up four small clear containers with lids such as baby-food jars as shown. Add a piece of unsoaped steel wool to each jar.

The anhydrous calcium chloride dries the air inside jar 1; that is, it removes the water from the air. (*Anhydrous* means 'without water'.)

Boiling the water (jars 3 and 4) removes air from it. The vegetable oil which floats on the water in jar 3 stops the air from getting into the water.

2 Observe the pieces of steel wool each day for about a week. Record all your observations. While you are waiting you can go on with parts B and C.

Conclusion

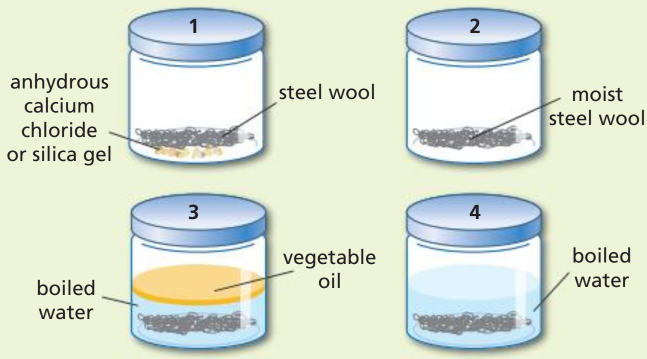
1 Which jar contained air but no water? Did rusting occur in it?

2 Which jar contained water but no air? Did rusting occur?

3 Which jar contained air and water? Did rusting occur?

4 How can you explain what happened in Jar 4?

Now write up your own conclusion about whether water and air are both needed for rusting to occur.



Part B

Design your own experiment to test the following hypothesis: *Iron rusts more rapidly in salt water than in fresh water.* Write a report of your experiment.

INVESTIGATION

2 continued

Part C

Aim

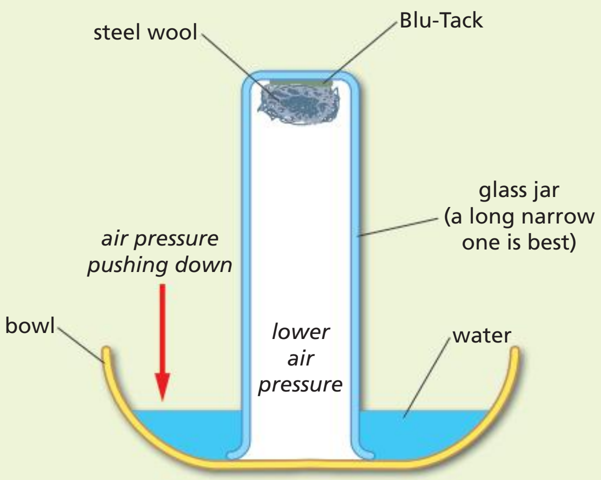
Air is a mixture of nitrogen and oxygen. When iron rusts it uses up the oxygen and leaves the nitrogen. The aim of this part of the experiment is to see what proportion of the air is oxygen.

Apparatus

Study the Method and make a list of the apparatus you will need.

Method

1 Use Blu-Tack to stick a piece of steel wool to the inside of the bottom of the jar.



2 Completely fill the jar with water then tip the water into a measuring cylinder.

✻ What volume of air does the jar hold?

3 Put the jar in the bowl as shown. Pour water into the bowl and leave it somewhere it won't be disturbed.

4 After two days you should find that water has moved up into the jar to take the place of the oxygen that is used up as the steel wool rusts. Use a marking pen to mark the water level carefully.

✻ Use air pressure to explain how the water moved up inside the jar. (Hint: See the diagram.)

5 Take the jar out of the bowl and measure how much water it takes to fill the jar to the mark. Subtract this from the volume of water it took to fill the jar (step 2) and you will have the volume of oxygen that was in the jar and that was used up in the rusting.

6 Divide the volume of oxygen used by rusting (step 5) by the volume of air in the jar (step 2) to find what proportion of the air is oxygen.

Discussion

1 Were the results what you expected?

2 If they were, say *why* you expected these results.

3 If the results were not what you expected, try to explain them.

4 Were there any problems or errors in the experiment? If so, describe them.

5 What could be done to improve the experiment?

Over to you

1 Copy and complete these sentences.
   a When a chemical reaction takes place new ________ are formed.
   b Fizzing means that a ________ has been produced.
   c ________ and light may be produced in a chemical reaction.
   d In the reaction **iron + water + oxygen → iron oxide** the reactants are ________, ________ and ________. The product is ________.

2 How can you tell whether a chemical reaction has taken place?

3 When orange juice is added to milk a precipitate is formed. What does this mean?

4 Which two substances are needed for rusting to occur?

5 Why does rusting occur faster near the coast than in inland areas?

6 Why does painting an iron object slow down its rusting?

7 Infer how rust bubbles form under the paint on a car.

8 When hydrogen is mixed with air and ignited it explodes to form water.
   a Name the reactants and products in this reaction.
   b Write a word equation for the reaction, like the one for rusting on the previous page.

2.2 Types of reactions

Exothermic reactions

Combustion is an everyday chemical reaction in which something burns in air to produce heat, light and sound energy. It is a chemical reaction between the substance that is burning and the oxygen in the air. This type of reaction which releases energy is said to be **exothermic**. You probably noticed in Investigation 1 that when you mixed magnesium and hydrochloric acid the test tube became warm. This was because the reaction was exothermic—it gave out heat energy.

A dramatic example of combustion

Exothermic reactions also occur in the hot packs used by skiers and campers to warm their hands in cold weather. One type of hot pack contains a mixture of iron powder, water, salt and sawdust. When you shake the packet the iron powder reacts rapidly with the salty water, releasing heat to warm your hands.

Respiration, which occurs in your body, is another exothermic reaction.

food + oxygen → carbon dioxide + water + ENERGY

The heat energy released in respiration keeps your body at 37°C, even when the outside temperature is much lower than this. When you exercise, the respiration that occurs in your muscles produces waste heat, which is why you feel hot.

While most exothermic reactions produce mainly heat, some produce mainly electrical energy. For example, the chemicals in a battery react to produce the electricity needed to run an appliance.

Some exothermic reactions produce mainly light energy. For example, light sticks that glow in the dark are popular at outdoor events at night. They consist of two parts: an outer plastic tube that contains a chemical called an ester and a fluorescent dye, and an inner glass vial that is thin and breakable and contains hydrogen peroxide (the chemical used to bleach hair). When you bend the light stick you break the inner vial and the solutions mix. An exothermic reaction occurs, which causes the fluorescent dye to give off light.

Light sticks or glow lights

Some living things can produce light by exothermic reactions. For example, the angler fish, which lives deep in the ocean, has a lure that dangles above its head. A chemical reaction causes this lure to glow. Smaller fish mistake this light for prey and swim into the angler fish's large mouth. Fireflies and glow-worms produce light by a similar reaction to attract mates and prey.

Endothermic reactions

A reaction that needs some type of energy to make it go is said to be **endothermic**. It takes in energy. For example, the sherbet you used for the chapter problem on page 25 is a mixture of baking soda and citric acid. When it is mixed with water in your mouth an endothermic reaction occurs, taking heat energy from your mouth and making it feel cooler.

Another example of an endothermic reaction is seen with the cold packs used by athletes to treat injuries. These packs usually consist of a plastic bag containing ammonium nitrate and an inner bag of water. By punching the bag you break the inner bag and the ammonium nitrate dissolves in the water. This process is endothermic—taking heat energy from the surroundings and cooling the injured part of your body. In this way the cold pack acts like an ice pack.

The reactions that occur in cooking are endothermic because you have to supply heat to make them go. Other reactions need electricity to make them go. For example, when recharging a battery electricity is needed to reverse the reactions that occurred when the battery was being used. Electroplating a piece of jewellery with silver or gold is another endothermic reaction. You place the piece of jewellery in a silver or gold solution and pass electricity through it. A reaction then occurs causing the silver or gold to move from the solution onto the jewellery.

Photochemical reactions

Some endothermic reactions need light to make them go. These are called *photochemical* reactions. The most important of these is photosynthesis, the process used by plants to make food. It requires energy from the sun.

carbon dioxide + water + ENERGY → plant food + oxygen

Black and white photographic film is made of plastic that is coated on one side with a jelly-like substance called gelatin. This gelatin contains silver chloride. When light falls on the film it turns black, because the silver chloride changes to form metallic silver. The film is black where the light fell on it.

INVESTIGATION

3 Hot or cold?

In this experiment you will add water to each of the following substances:

- anhydrous calcium chloride
- ammonium nitrate
- magnesium sulfate
- sherbet
- sodium thiosulfate

✱ Which reactions are exothermic and which are endothermic? Which is the most exothermic? Which is the most endothermic? How do you know?

1 Write an aim for the experiment.
2 Decide on a method. For example, how will you measure the temperature? What variables will you need to control? How will you do this?
3 Do a risk assessment.
4 Make a list of the apparatus you will need.
5 Carry out the experiment and write a report. Be sure to include a conclusion.

Challenge

Design an experiment to show that the rusting of iron is an exothermic reaction.

Over to you

1 a What is an *ex*othermic reaction? Give two examples.
  b What is an *endo*thermic reaction? Give two examples.
2 Decide whether the reactions described below are exothermic or endothermic.
  a When you add dilute hydrochloric acid to zinc, the test tube feels warm.
  b A candle burns.
  c When you eat sherbet your mouth feels cool.
  d Photosynthesis needs sunlight to make it go.
3 Name at least three forms of energy released by exothermic reactions.
4 Why is combustion an exothermic reaction?
5 Give three examples to show how we use the energy released in exothermic reactions.
6 Why do cold packs feel cold?
7 What is the difference between photosynthesis and respiration?

INVESTIGATION

4 Making photos

Aim

To investigate how photographic film works.

Risk assessment and planning

Be very careful not to spill any of the silver nitrate solution onto your skin or clothes, or onto the bench. It will stain and is difficult to remove. It is therefore best to wear a lab coat and gloves.

Any silver nitrate spills should be wiped up immediately with dilute ammonia solution.

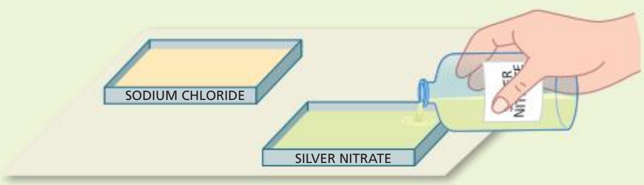
Apparatus

- 2 small trays, e.g. baking trays
- small piece of white paper to fit in tray (about 15 cm × 10 cm)
- sodium chloride solution (0.2 M)
- *silver nitrate solution (0.2 M)*

- metal tongs
- newspaper

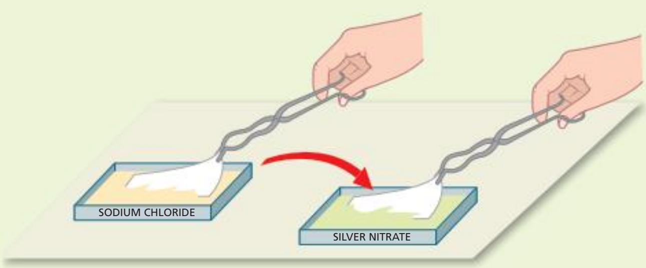
Method

1 First cover the bench with newspaper. Pour enough sodium chloride solution into one of the small trays to just cover the bottom. Put the same amount of silver nitrate solution into the second tray.

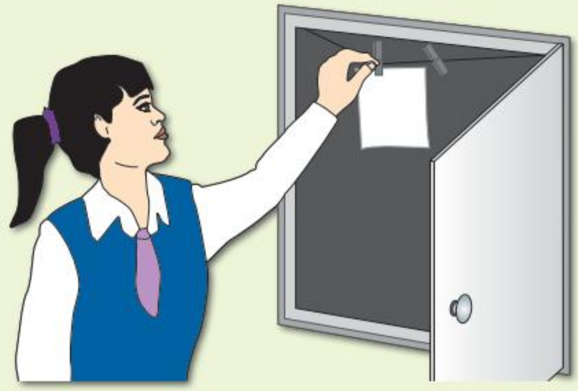


2 Use the metal tongs to dip the piece of white paper into the sodium chloride solution. Lift the paper out and let the excess solution drain back into the dish.

3 Now dip the paper into the silver nitrate solution. Lift it out and again let all the excess solution drain off. *Don't drip silver nitrate solution on the bench or yourself.*



4 Leave the paper to dry in a dark place such as a cupboard (about 30 minutes) or in a barely warm oven (about 10 minutes).



5 You can now use the paper you have prepared to make a photo.

In a darkened room, put several small objects such as paperclips, small leaves or coins on the dry paper. Put the paper in bright sunlight or close to a bright light for about 15 minutes.

6 Remove the objects and examine the paper.

Conclusion

1 Complete this word equation for the reaction that occurred in step 3.

sodium chloride + silver nitrate →

sodium nitrate + silver __________

2 Explain what happened in step 5.

3 How successful was your photographic paper?

SCIENTISTS AT WORK

William Henry Perkin (1838–1907)

When he was 14, William Henry Perkin watched a friend do experiments in chemistry and decided that was what he wanted to do with his life. Schools in those days didn't teach chemistry, so he went to a lunchtime course. He then enrolled at the Royal College of Science, London, in a course run by August Wilhelm von Hofmann. He did so well that he became Hofmann's assistant.

Hofmann was fascinated by the chemicals in coal tar, a sticky black substance made by heating coal in a container with no air in it. Coal tar is a mixture of many different chemicals. Hofmann was also interested in quinine, the drug used to fight malaria. Quinine was extracted from the bark of a South American tree. He wondered whether quinine could be made more cheaply from the chemicals in coal tar, and asked Perkin, who was only 18 at the time, to investigate this.

Perkin was not able to make quinine, but one day when he was working in his laboratory at home, he mixed aniline, one of the coal tar chemicals, with potassium dichromate. He was about to throw out the black gunk in his beaker when he noticed a purplish glint. He added some alcohol to see if he could dissolve anything out of the mess and the alcohol turned a 'strangely beautiful' purple. When he used a cloth to wipe up a spill on the bench, the cloth was stained purple.

Perkin called his new dye aniline purple. It was the first synthetic (made) dye. Until then all dyes had been made from plants and animals.

For example, the only purple dye at the time was Tyrian purple, which was made from a species of snail. This was so expensive it was used only by the very rich.

Perkin patented his process for making aniline purple. He decided to leave school and go into business. The banks wouldn't lend him any money, so his father and brother put their life savings into building a dye factory in London. Perkin couldn't get aniline, so he bought benzene and reacted it with nitric acid to make aniline. He even had to make his own nitric acid, and design all his own equipment.

Purple was all the rage in fashion at the time, especially in France, and Perkin was able to sell all the dye he could make. Suddenly, at the age of 19, he was rich and famous. He then went on to make a red dye called alizarin and at the age of 36 he sold his factory to do chemical research.

The following year Perkin made another synthetic chemical from coal tar. It had a pleasant odour and was the start of the synthetic perfume industry.

Thanks to the work of Perkin we now have thousands of dyes of every shade and tint. He opened up a chemical wonderland and for the first time people realised that the study of chemistry could make you rich.

Questions

1 What is coal tar?

2 How did Perkin become interested in chemistry?

3 Why was Hofmann so interested in making quinine from coal tar?

4 Why did Perkin add alcohol to the black gunk in his beaker?

5 What is the difference between a natural dye and a synthetic one?

6 What does it mean to 'patent a process'?

7 Write a word equation for the chemical reaction Perkin used to make aniline from benzene.

8 If you were a bank manager, would you have lent Perkin money to build his factory? Explain your answer.

9 Do you think it is still true that the study of chemistry can make you rich? Explain.

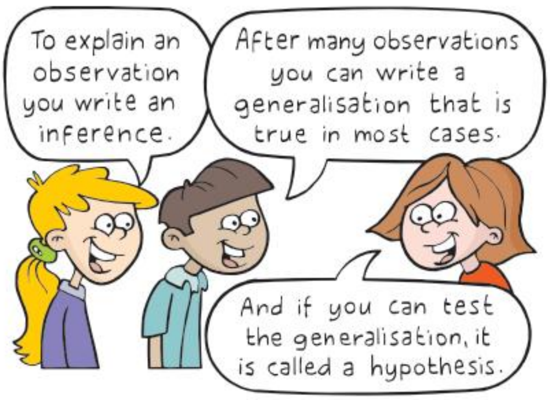
2.3 Reaction rate

Some chemical reactions are slow, like rusting. Others occur quickly, such as when you mix baking soda and vinegar. The reactions that cause fireworks to explode also occur very quickly, producing large amounts of light, sound and heat.

The speed of a reaction is called the **reaction rate.** A slow rate means the reaction takes a long time. A fast rate means it takes only a short time. In this section you will investigate the variables that can affect the rate of a reaction. Before doing this however, you need to check that you can write generalisations.

A slow reaction

SKILL Generalising



1 Look at the cartoon above. Use it to decide whether each of the following statements is an *inference* or a *generalisation*.

a Dogs tend to be smarter than cats.

b It usually rains when we are on holidays.

c The sun rises in the east and sets in the west because the Earth is rotating.

d This coffee tastes very sweet. I must have sugared it twice.

e The heavier you are, the faster you go down a water slide.

✳ Which of the generalisations are also *hypotheses*?

You can make a generalisation only after you have made many observations. And just because the generalisation is true for your observations, it doesn't mean it will always be true. For example, dogs usually seem to be smarter than cats, but your cat may be smarter than most dogs. This is why generalisations often contain words like *generally, normally, usually, as a general rule, most, tend to be …*

2 Generalisations often link two different variables. For example, the generalisation *Big cars generally use more petrol than small cars* links the size of the car to the amount of petrol it uses. Here are two other ways to write this same generalisation:

The bigger the car, the more petrol it uses.

***If** you drive a big car, **then** you will use more petrol.*

✳ Make up your own generalisation linking two variables.

3 When you do an experiment and collect data you usually look for a pattern in the data. You can then write your conclusion as a generalisation. For example:

Niketa did a science project on the solubility of various chemicals in water. Here are her results.

Grams that dissolve in 100 mL water at various temperatures (°C)

	0°	20°	40°	60°
potassium carbonate	105	110	117	127
sodium hydroxide	42	109	129	174
sodium sulfate	5	21	48	45
sodium thiosulfate	53	70	104	207
sucrose (sugar)	179	204	238	287

✳ Draw a line graph for each chemical, all on the one sheet of paper.

✳ Write a generalisation about the solubility of the chemicals at various temperatures.

INVESTIGATION

5 The hypo cross

Aim

To investigate how temperature affects the rate of the reaction between hypo solution and hydrochloric acid.

Risk assessment and planning

1 Do a risk assessment. What safety precautions will be necessary?

2 What are the two variables you will be investigating in this experiment?

3 Write a generalisation linking the two variables. (See the Skill section on the previous page.) Write the generalisation so that it can be tested. It is then a hypothesis.

4 Use your hypothesis to *predict* whether hypo and hydrochloric acid react faster at 20°C or at 60°C.

5 Design a data table in which to record your results.

Apparatus

- *dilute hydrochloric acid (1 M)*
- sodium thiosulfate (hypo) solution (0.2 M)
- 250 mL flask
- stopwatch
- 10 mL and 50 mL measuring cylinders
- Bunsen burner equipment or hotplate
- sheet of white paper
- black marking pen
- thermometer
- 500 mL beaker

Method

1 Use the measuring cylinder to put 50 mL of hypo solution into the conical flask. Measure the temperature of the solution.

✱ Record this temperature (called *room temperature*) in your data table.

2 Use a black marking pen to put a cross on the sheet of white paper. Put the flask on top of the cross. When you add hydrochloric acid to the hypo solution a reaction occurs which produces sulfur. This causes the solution to go cloudy and the cross will disappear as you look down through the top of the flask.

3 Measure out 5 mL of hydrochloric acid and pour this into the flask. Give the flask a quick swirl and start timing.

✱ When you cannot see the cross from above, record the reaction time in the data table.

4 Dispose of the contents of the flask and rinse it with water. Add another 50 mL of hypo solution to the flask. Use the Bunsen burner to heat it until its temperature is about 10°C above room temperature.

✱ Record this temperature.

5 Take the flask off the burner, put it over the cross and repeat step 3 in exactly the same way.

6 Do the experiment four or five times, steadily increasing the temperature of the solution up to 60°C or 70°C.

Results

1 Which was the independent variable in this experiment—the one you purposely varied?

2 Which was the dependent variable—the one that varied as you changed the independent variable?

3 Which variables did you control?

4 Display your results as a graph, with the independent variable on the x-axis and the dependent variable on the y-axis. Decide on a suitable scale for each axis, and mark each point on the graph with a small neat cross. Draw a *line of best fit* through the points.

5 Explain the shape of the graph. Does it agree with your hypothesis?

Other things to try

- Use your graph to predict the reaction times for temperatures you did not measure. You could *interpolate*—make predictions between the temperatures you used. You could also *extrapolate*—make predictions for temperatures higher or lower than those you used.
- Now test your predictions. For temperatures below room temperature you will need to use ice.

INVESTIGATION

6 Design your own

Aim

To design an experiment to answer one or both of these questions.

How is the rate of a reaction affected by:

- the concentration of liquid reactants?
- the particle size of solid reactants, that is, whether the solid is in powdered form or in larger lumps?

Risk assessment and planning

1. A suitable reaction to investigate is that between dilute hydrochloric acid and zinc or marble chips. You can measure the reaction time by how long it takes for the solid to disappear.
2. You can use different concentrations of hydrochloric acid, e.g. 0.5 M, 1 M and 2 M.
3. If you use zinc, you can use granular zinc, zinc foil and zinc powder. If you use marble chips, you can use a mortar and pestle to break them up into smaller pieces.
4. Write a brief outline of your experiment, including the hypothesis you are going to test, your method, how you will control variables, the apparatus you will need and a risk assessment.
   Get your teacher's approval before starting.

Write your report

Your report should include a conclusion, in which you answer the question you were investigating (the aim). Also include a discussion, in which you answer the six questions (a-f) listed in the *Interpret and discuss your results* section on page 15.

Temperature and reaction rate

In Investigation 5 you found that *the rate of a reaction generally increases as the temperature increases*. An everyday example of this is in cooking, where heat is needed to make reactions go. As you increase the temperature these reactions go faster.

Many of the reactions that occur inside living things also depend on temperature. For example, plants usually grow more rapidly in spring and summer than they do in colder weather, because the reactions needed for growth occur faster. The body temperature of all animals except birds and mammals is much the same as the temperature of their surroundings. This is why animals such as snakes, crocodiles and insects are inactive in winter and become much more active in warmer weather. Scientists have found that the chirp rate of crickets can be used to measure the temperature. The higher the temperature, the higher the chirp rate.

The chemical reactions used in many industries are done at high temperatures to increase the reaction rate. A slow reaction means slow production, and this can mean less profit.

Sometimes it is important to slow down reactions by decreasing the temperature. For example, food is spoiled because of chemicals produced in reactions caused by microorganisms. These reactions can be slowed down by keeping the food cool in a refrigerator.

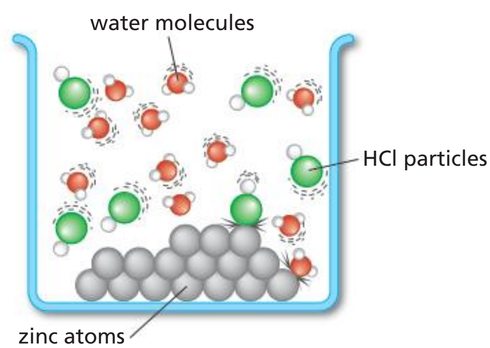
Speeding up reactions

Chemical reactions can be explained in terms of the **particle theory**, which says that:

1. All matter is made up of tiny particles too small to see with the unaided eye.
2. There are spaces between the particles.
3. There are attractive forces between the particles.
4. The particles are always moving.
5. The particles move faster at high temperatures than they do at low temperatures.

Consider what happens when dilute hydrochloric acid (HCl) reacts with zinc. For the reaction to occur the HCl particles must collide with the zinc atoms. The more often they collide and the harder they hit, the more likely it is that they will react. Anything that makes the HCl and zinc particles collide more often, or more violently, will therefore speed up the reaction.

If you heat the acid, its particles move faster. They will collide with the zinc atoms more often and more violently, and the reaction occurs more quickly.



Concentrated acid has more HCl particles and fewer water molecules than dilute acid. The HCl particles in it collide with the zinc atoms more often and the reaction is faster. So increasing the *concentration* of the reactants makes a reaction go faster. For example, concentrated acids 'burn' your skin more rapidly than dilute acids.

In a piece of magnesium ribbon, only the atoms on the surface of the ribbon can come into contact with the acid, so they are the only ones that can react. However, if you break the magnesium ribbon into smaller pieces, it will have a greater *surface area* and more of it can react. If the magnesium is powdered it reacts even faster. So the greater the surface area available, the faster the reaction.

An everyday example of the effect of surface area on reaction rate is in campfires. A log burns fairly slowly, because only the wood on the outside of the log can burn (react with the oxygen in the air). However small sticks burn much more easily, because there is more wood in contact with the fire. And fine sawdust thrown on a campfire burns instantly.

Some reactions can be speeded up by using light or UV (ultraviolet) radiation. For example, dentists use blue light or UV radiation to set composite resin fillings. This radiation speeds up the reactions that cause the materials in the filling to harden, and decreases your time in the dentist's chair.

Over to you

1 Put these reactions in order, from the fastest to the slowest.
  - a a metal can rusting
  - b an egg cooking in boiling water
  - c milk turning sour
  - d lead nitrate reacting with potassium iodide (Investigation 1)
  - e wood rotting

2 Write a complete sentence to explain each of the following statements.
  - a Antacid powders work faster than antacid tablets.
  - b Copper pipes carrying hot water corrode more quickly than those carrying cold water.
  - c Concentrated acids are more hazardous than dilute acids.
  - d Fresh food needs to be kept in a refrigerator.
  - e Vegetables cook more quickly if you cut them into small pieces.

3 Use the particle theory to explain why heating increases the rate of a reaction.

4 Green tomatoes can be picked and left in a warm place to ripen. However if they are put in a refrigerator, they ripen much more slowly. How can you explain this?

5 Look at the graph below, which shows the rate at which carbon dioxide is produced when acid is added to marble chips. Reactions A and B were carried out under different conditions.
  - a Which was the faster reaction? How do you know?
  - b Give three reasons why the reaction may have been faster.

PROBLEM SOLVING

You now have information to help you win the airbag race (see page 25).

- Which reacts faster—the Fruit Tingles or the sherbet? Why? Would it help to break up the Fruit Tingles?
- The carbon dioxide that inflates the balloon is produced by a reaction between baking soda and any acid. Sherbet and Fruit Tingles contain baking soda and citric acid. Orange juice and lemon juice both contain citric acid, and vinegar contains acetic acid. On the basis of this information, which do you think would react faster with sherbet and Fruit Tingles—water, orange juice, lemon juice or vinegar? Give a reason for your prediction, using what you have learnt in this section.
- For a fast reaction, should you do it at room temperature, in iced water or in hot water?
- Would shaking the flask make any difference? Explain.

Use your answers to these four questions to make your selections, then have another race.

2.4 Catalysts

INQUIRY 1 *Burning sugar cube*

You will need: 2 sugar cubes, ash from a fire or fine carbon, metal tongs, matches, heatproof mat

1 Stick a toothpick into a sugar cube. Can you burn the sugar cube by holding it in the flame of a match?

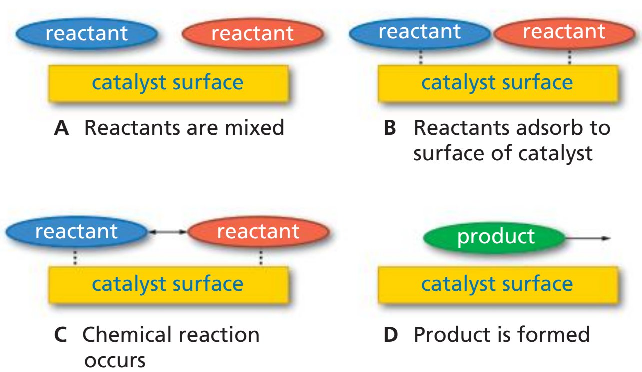
2 Take another sugar cube and dip it in the ash. Will it burn now?

- How can you explain your observations?

In the previous section you learnt that reactions can be speeded up by increasing:

- the temperature
- the concentration of the reactants, and
- the surface area of the reactants.

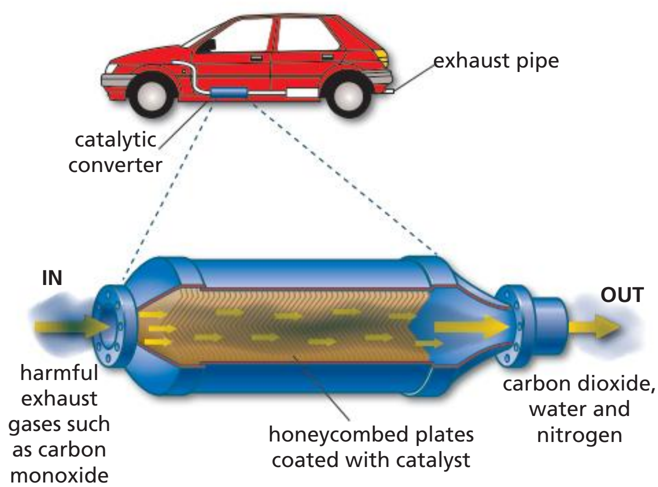
Reactions can also be speeded up by using **catalysts** (CAT-a-lists). As you saw in the inquiry above, a sugar cube will not burn in the flame of a match. But if you dip the sugar cube in ash it burns easily. This is because the ash acts as a catalyst for this particular reaction, speeding up the reaction without being used up itself. The reactants become attached (adsorbed) to the surface of the catalyst. In this position they react together more easily. The products that are formed are then released, leaving the catalyst unchanged.



Catalysts are used in industry to speed up reactions and therefore reduce the costs of producing chemicals. For example, a fine powder of nickel–aluminium catalyst is used to speed up the reaction between vegetable oil and hydrogen to make margarine. Self-cleaning ovens are coated with a catalyst that helps to burn small food particles that stick to the oven walls.

A catalytic cracker or 'cat' in an oil refinery. It uses a catalyst to 'crack' or split large molecules into smaller ones.

Cars are fitted with antipollution devices called *catalytic converters*. These devices are packed with plates coated with a platinum and rhodium catalyst. The plates have a honeycomb structure, giving them a surface area about equal to that of two football fields. The harmful exhaust gases react on the surface of the catalyst to form less harmful gases which are then released into the air through the exhaust pipe.



In Investigation 7 you will investigate the decomposition (break down) of hydrogen peroxide.

hydrogen peroxide → water + oxygen

This reaction normally occurs very slowly, but various substances can act as catalysts to speed up the decomposition.

INVESTIGATION

7 Peroxide catalyst

Aim

To investigate which substances act as catalysts for the decomposition of hydrogen peroxide.

Risk assessment and planning

Read the investigation carefully and do a risk assessment.

Apparatus

- *hydrogen peroxide solution (6%)*
- *manganese dioxide*
- *potassium iodide*

- 7 test tubes and a test tube rack
- wooden splint and matches
- piece of liver (or other red meat)
- measuring cylinder
- sand or dust
- spatula
- iron filings
- cabbage leaf
- liquid detergent

Method

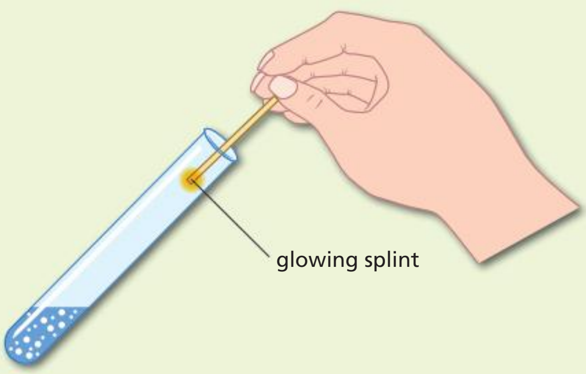
Part A

1 Add 5 mL of hydrogen peroxide solution to a test tube. Is there any evidence of decomposition; that is, are bubbles of oxygen formed?

2 Add a tiny amount of manganese dioxide—about the size of a rice grain. This is the catalyst.

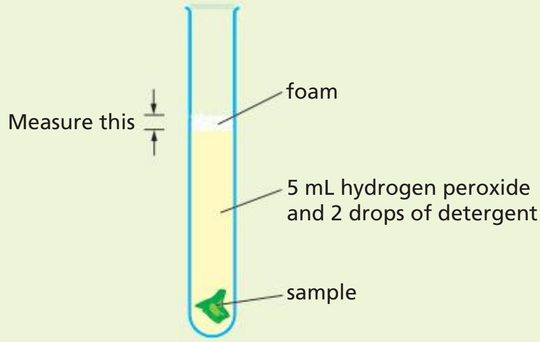
Describe what happens.

3 Light a wooden splint then blow it out, so that it still has a glowing tip. Immediately put the glowing splint into the test tube from step 2. The splint should burst into flame, showing that oxygen is present in the tube.



Part B

1 Prepare six test tubes, each containing 5 mL of hydrogen peroxide and 2 drops of detergent. When oxygen is produced the detergent will foam up. The height of the foam will then give you an idea of the rate of reaction.



2 Test various substances to see if they also act as catalysts for the decomposition of hydrogen peroxide. Add about the same amount of the following, one per test tube: manganese dioxide, iron filings, sand or dust, potassium iodide, a small piece of cabbage leaf, a small piece of liver (or other meat).

You could also try other plant and animal materials, e.g. blood from meat, small pieces of fruit and vegetables, and leaves. You may need to grind up some of these with sand in a mortar and pestle before adding them to the peroxide.

Using a mortar and pestle to grind up solids

Results

Which of the substances you tested was the best catalyst for the decomposition of hydrogen peroxide?

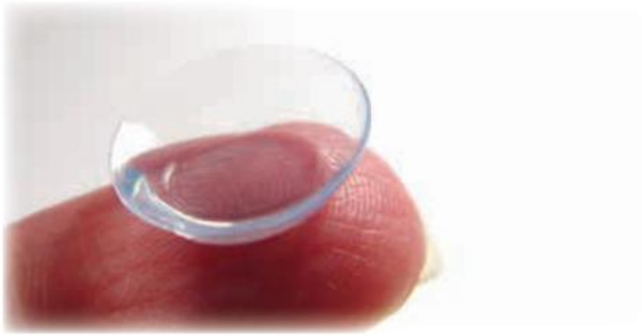
Other things to try

For each of these questions, predict what you think will happen, then try it.

- What effect does heating have on the decomposition of hydrogen peroxide?
- Does grinding up the substances make any difference?
- Is the manganese dioxide catalyst used up? How could you find out?

Decomposition of peroxide

The decomposition of hydrogen peroxide can be used to clean and disinfect contact lenses. One cleaning product uses a platinum catalyst. The lenses are placed in a small dish that contains a platinum-coated disc. When the peroxide is poured into the dish the oxygen that is released kills the microbes on the lenses.



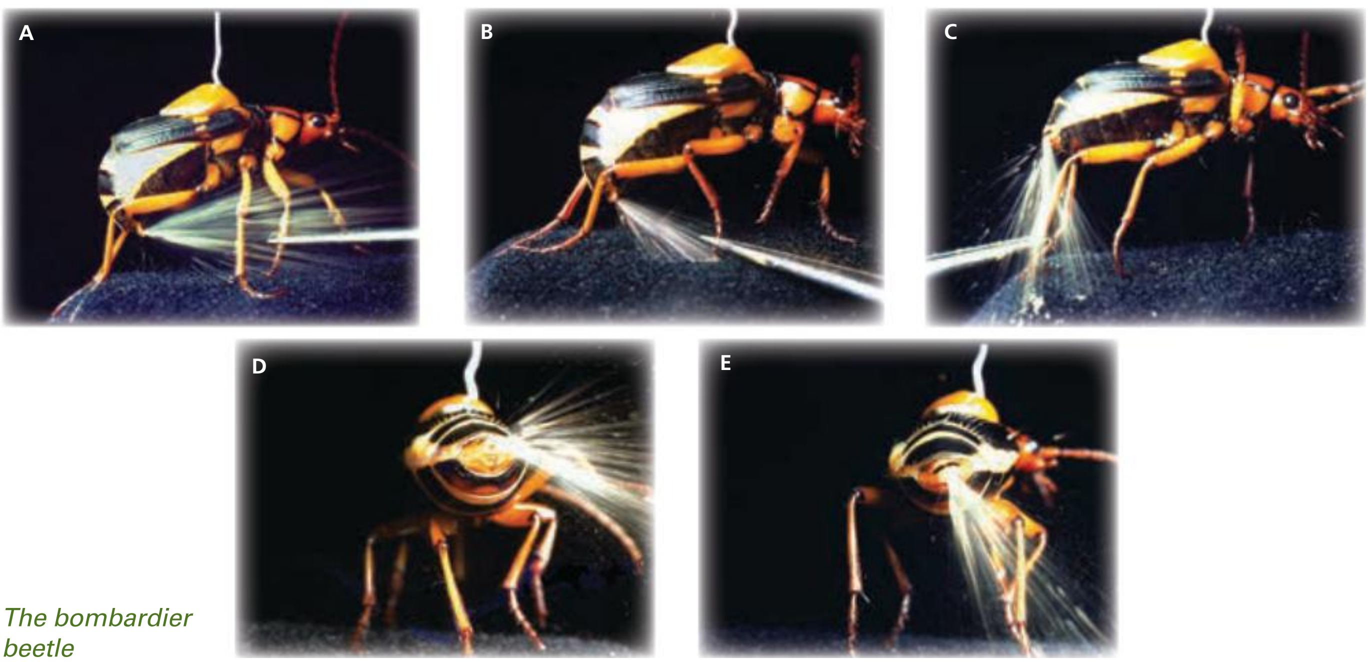
Enzymes

Hydrogen peroxide is produced in the body. For example, it is part of a system that helps you use the oxygen you breathe. But hydrogen peroxide is toxic, so the body produces a biological catalyst called an **enzyme** (EN-zime) to decompose the peroxide. This enzyme is called *catalase*. It is produced in the liver, and is found in nearly all animal cells, especially in blood. That is why blood and liver decompose hydrogen peroxide so readily. Catalase is also found in plant cells, and one molecule of it can decompose up to 100 000 molecules of hydrogen peroxide per second.

The bombardier beetle uses hydrogen peroxide as a weapon against its enemies. It has two glands at the tip of its abdomen and each of these has two separate chambers—a storage chamber and a reaction chamber. The storage chamber contains hydrogen peroxide and hydroquinone (a chemical that is used in photo developing). When the beetle is attacked, these chemicals are released into the reaction chamber where two enzymes (catalase and peroxidase) are added. These cause the hydrogen peroxide to decompose to oxygen. At the same time the hydroquinone decomposes to quinone, a foul-smelling substance. These reactions are exothermic and generate a lot of heat. The result is that a foul-smelling hot mist is sprayed towards the beetle's enemy.

Many chemical reactions occur in living things. These reactions need enzymes to control them, because otherwise they would occur much too slowly to keep the organism alive. Your own body contains thousands of enzymes, each one acting to speed up one type of reaction. Particular enzymes do particular jobs. Enzymes in your saliva, stomach and intestines control the digestion of food. Others assist in extracting energy from food.

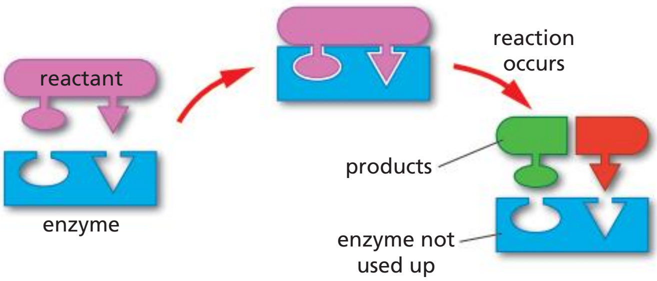
Biologists have worked out a theory to explain how enzymes work. Each enzyme has 'holes' of various shapes in it. The reactants are attracted to these holes and fit them perfectly, like a key in a lock. Each reaction needs a different enzyme, because the holes



The bombardier beetle

have to be exactly the right shape. While the reactants are in these holes the reaction occurs. The products are then released. The diagram below shows a breakdown reaction. Notice that the enzyme is not used up in the reaction.

Enzymes are also used to make complex molecules (e.g. proteins) from smaller molecules. In this case, the reaction would go in the opposite direction to that shown.



Some washing detergents contain enzymes. These are added to the detergent to remove stains made by proteins such as blood and eggs, and other biological stains. The large protein molecules are insoluble in water. The enzymes help to break down these large molecules into smaller more soluble ones that can be washed out.

Some washing powders contain enzymes.

Inhibitors

There are also substances which slow down reactions. These are called **inhibitors**. Rubber perishes as a result of a slow reaction with the oxygen in the air. To slow down this reaction an inhibitor is added to the rubber during the manufacturing process. An inhibitor is added to the radiator of a car to slow down rusting.

Inhibitors are also important in the body. They work by blocking the holes in the enzymes, or by changing the shape of the holes so that the enzyme no longer works. Such inhibitors are used in antibiotics to slow down reactions in bacteria. Scientists are also experimenting with an inhibitor that can be used as a drug against the AIDS virus.

Over to you

1 When manganese dioxide is added to hydrogen peroxide, oxygen gas and water are formed. The manganese dioxide is not used up.
- **a** Name the reactants, the products and the catalyst in this reaction.
- **b** Write a word equation for the reaction.
- **c** What is the test for oxygen gas?

2 Monique obtained these results in Investigation 7.

Substance	Mass (g)	Height of foam (cm)
granular manganese dioxide	0.1	4
powdered manganese dioxide	0.1	6
piece of liver	0.1	3
ground up liver	0.1	5
boiled liver	0.1	2
sand	0.1	0

- **a** Which substance was the best catalyst for the decomposition of hydrogen peroxide?
- **b** Suggest why powdered manganese dioxide is a better catalyst than the granular form.
- **c** What do the results for liver show?
- **d** Which variable did Monique control?

3 Hydrogen peroxide is best kept in a refrigerator. Why?

4
- **a** Explain in your own words how the catalytic converter in a car works.
- **b** Why do the plates inside the converter have a honeycomb structure?

5 Inhibitors are sometimes called *negative catalysts*. What are they and how do they work?

6
- **a** What are enzymes?
- **b** Why are enzymes added to some washing powders?

7 Water and hydrogen peroxide are both colourless, odourless liquids. What test could you do to tell the difference between them?

8 A candle burns faster in oxygen than in air. If catalysts speed up reactions, is it true to say that oxygen is a catalyst in the burning of the candle? Why or why not?

2.5 Conservation of mass

If you burn a log you are left with ash. This ash weighs less than the original log. In about 1700 scientists had a theory to explain this. They said that when something was heated it gave off a mysterious thing called phlogiston (flo-GIST-on). However when they were heated most metals *increased* in mass. The phlogiston theory predicted a *decrease* in mass. So a new theory was needed.

A French scientist called Antoine Lavoisier (la-VWAH-zee-ay) set out to solve the problem. He did many experiments which showed that air is one-fifth oxygen and four-fifths nitrogen. When a metal is burnt in air it combines with the oxygen in the air, and this is why its mass increases. The metal changes to a metal oxide.

Lavoisier now had a better theory than the phlogiston theory. However, during the French Revolution he was arrested and executed. This was because early in his career he had used his income as a tax collector to set up his laboratory.

INVESTIGATION 8 Combustion of magnesium

Aim

To weigh magnesium before and after it burns in air.

Risk assessment and planning

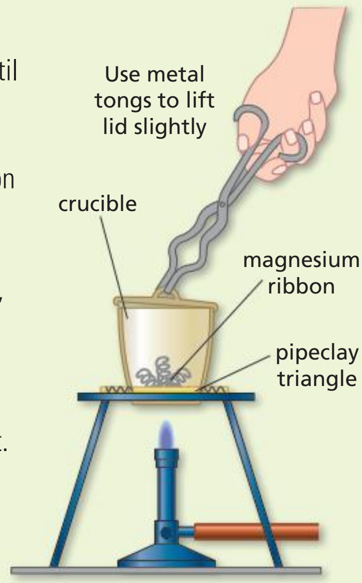
1 **Don't look directly at the burning magnesium.** The light produced is very intense and could damage your eyes.
2 Why is it essential not to touch the crucible with your hand during the experiment?
3 Why is a lid needed on the crucible?
4 Why do you think it is necessary to clean the magnesium before you start?
5 Predict whether the mass of the magnesium will increase, decrease or stay the same when it burns.

Apparatus

- 5 cm piece of magnesium ribbon
- Bunsen burner, heatproof mat and tripod
- pipeclay triangle
- metal tongs
- steel wool
- crucible with lid
- balance

Method

1 Clean the magnesium ribbon with steel wool.
2 Coil the ribbon into a loose open coil, like a spring.
3 Place the magnesium into the crucible, put on the lid and weigh the crucible.
   ✱ Record the starting mass.
4 Light the burner and open the air hole to give a hot blue flame.
5 Heat the crucible for 5–10 minutes using the metal tongs to carefully lift the lid a little from time to time, to allow air in but not let any reaction products out.
6 Continue heating until the contents of the crucible no longer glow and the reaction is finished .
7 Let the crucible cool, then inspect the contents.
   ✱ Describe the reaction product. It is called magnesium oxide.



8 Re-weigh the crucible and lid.
   ✱ Record the final mass.

Results

Was the prediction you made in Risk assessment and planning correct?

Conclusion

1 Explain your results.
2 Write a word equation for the reaction that occurred.

Lavoisier heated various metals in air and they all increased in mass, like the magnesium in Investigation 8. However, when he heated a piece of tin in a *sealed* flask, there was no change in the total mass of the flask. When he opened the flask, however, air rushed in and the mass of the flask increased.

From these observations, Lavoisier inferred that when tin was heated it reacted with the oxygen in the air. He then predicted that the mass gained by the tin should be the same as the mass of air used up. If this was true, then there should be no change in mass during any chemical reaction. To test this hypothesis Lavoisier made more careful measurements and was able to convince himself that 'matter cannot be created or destroyed'. It can only be changed during a chemical reaction.

Many different reactions have been studied to test Lavoisier's hypothesis, and the results have always supported it. The hypothesis is now called the law of **conservation of mass**.

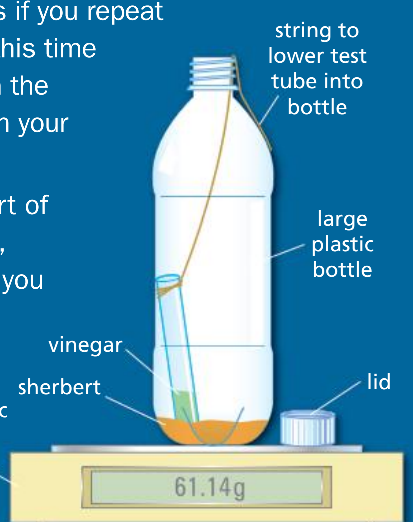
PROBLEM SOLVING

Does the reaction you investigated in the 'airbag race' obey the law of conservation of mass?

To investigate this you can use a large plastic soft drink bottle with a lid, and an electronic balance. In the bottom of the bottle you can put Fruit Tingles or sherbet, and in the test tube you can put water, vinegar, orange juice or fruit juice.

- What happens to the mass of the bottle when you tip it so that the solid and liquid mix? Explain your observations.
- What happens if you repeat the reaction, this time with the lid on the bottle? Explain your observations.

Write a full report of your experiment, describing what you did and what you found out.



Over to you

1 What is the law of conservation of mass? Why is it called a law?

2 When a campfire burns, the ash left after the fire weighs less than the wood that burnt.
  - a Why doesn't this reaction seem to obey the law of conservation of mass?
  - b Design an experiment to show that the burning of a campfire actually does obey the law.

3 Use the story of Lavoisier and phlogiston to answer these questions.
  - a What was phlogiston?
  - b Why was the phlogiston theory unsatisfactory?
  - c Complete this sentence. Lavoisier discovered that air is a mixture of ________ and ________. When you burn something in air, it reacts with the ________.
  - d What proportion of the air is oxygen?
  - e Lavoisier heated a piece of tin in a sealed flask. Why did the mass of the flask stay the same?
  - f When he opened the flask, air rushed in. How can you explain this?

THINKING SKILLS ?

1 Use what you have learnt in this chapter to explain why crocodiles are more active in warmer weather.

2 Blowing on a fire usually helps it to burn. Why?

3 When ammonia is made by reacting nitrogen and hydrogen the gases are under very high pressure—about 250 times atmospheric pressure. Suggest a reason for this.

4 Aluminium frypans can be used in cooking, yet the label on a container of very fine aluminium powder warns that the contents are highly flammable. Explain the difference.

5 Write a hypothesis saying why a cut apple turns brown. Design an experiment to test your hypothesis.

6 What are the similarities and differences between combustion and respiration?

7 Explain the following in terms of the particle theory.

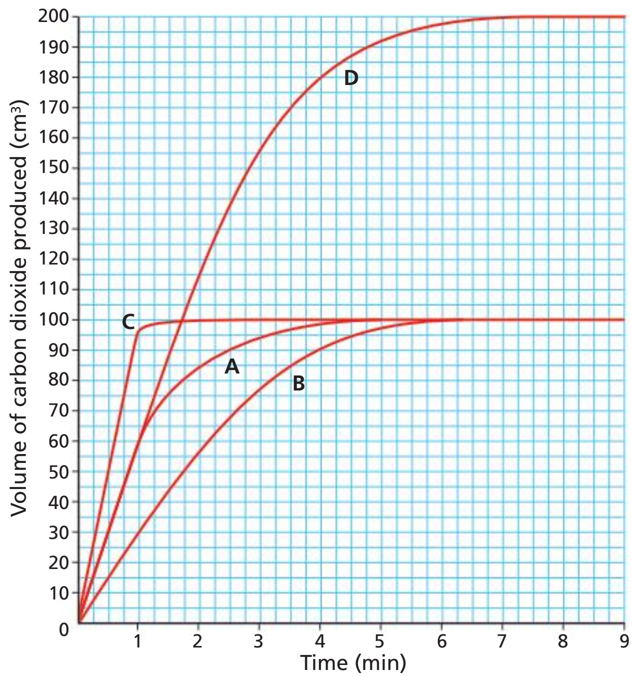
a Stirring usually speeds up a reaction.

b Sulfur burns more rapidly in oxygen than in air.

8 The table gives the results of an experiment involving four reactions between hydrochloric acid and calcium carbonate (marble chips). In each reaction there was leftover calcium carbonate.

Reaction	A	B	C	D
Volume of conc. acid (mL)	50	50	50	100
Volume of water added (mL)	0	50	0	0
Temperature (°C)	20	20	60	20

The graph below shows the results.



a Why do all the graphs flatten out?

b How much carbon dioxide was produced in reactions A, B and C?

c Why did reaction D produce twice as much carbon dioxide as the other reactions?

d Which was the fastest reaction? How do you know? Suggest why it was the fastest.

e Which was the slowest reaction? Why?

9 Sherbet is a mixture of two powders—baking soda and citric acid. However these powders don't react until you add water. How can you explain this?

10 A scientist heated a metal in a flask and noted that the mass of the flask and its contents increased.

a Was the flask open or sealed? How do you know?

b Do you think the new substance formed was a solid or a gas? Explain your answer.

11 Lavoisier found that metals increased in mass when heated, but a diamond (carbon) burnt away completely. Try to explain what happened, using word equations if possible.

12 Design and perform a short play to show why a chip of marble takes longer to react with hydrochloric acid than if it is crushed up.

Knowing and Understanding

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

1 In a chemical reaction the ________ are used up and products such as ________ and precipitates may be formed. This may cause a ________ change.

2 Some reactions occur slowly, while others occur ________. The speed of a reaction is called its ________.

3 Reactions like burning which release energy are called ________. Reactions which need energy to make them go are called ________.

4 The rate of a reaction usually ________ as the temperature increases. Similarly, the rate usually decreases as the ________ decreases.

5 Increasing the ________ of the reactants usually increases the rate of a reaction.

6 Increasing the ________ of the reactants usually increases the rate of a reaction.

7 A ________ is a substance that increases the rate of a reaction without being used up itself.

8 The law of ________ of mass says that the total mass of the reactants in a chemical reaction is always equal to the total mass of the ________.

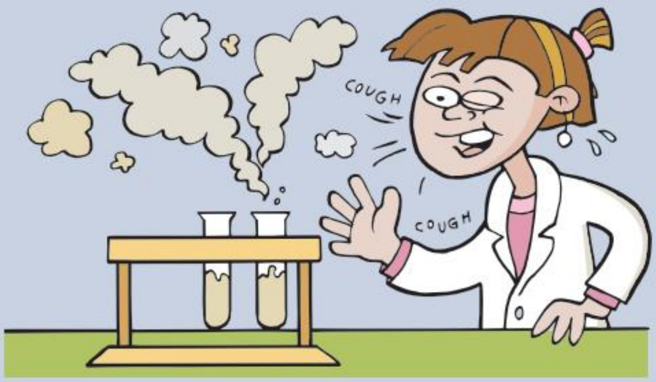
catalyst
colour
concentration
conservation
endothermic
exothermic
gases
increases
products
quickly
rate
reactants
surface area
temperature

Self-management

In this chapter you have learnt about many different types of reactions. To help you revise, look back through the chapter and find:

1 three reactions that produce a colour change
2 a smelly reaction
3 two very fast reactions
4 a slow reaction
5 six reactions that produce carbon dioxide gas
6 two reactions that produce hydrogen gas
7 three examples of combustion
8 three reactions that produce heat
9 two reactions that need heat to make them go
10 two reactions that need light to make them go
11 two reactions that produce light
12 a reaction that produces electricity
13 three reactions that can be speeded up using a catalyst
14 a reaction that is slowed down by an inhibitor.

Which is your favourite reaction? Why?



Checkpoint

1 Read the descriptions below of four reactions carried out by Saskia. For each, state how she knew a chemical reaction had taken place. Choose from these reasons:

There was a colour change.

A gas was produced.

A precipitate was formed.

Heat was produced.

a Two colourless solutions were mixed and a yellow solid settled to the bottom of the tube.

b After a while the test tube felt warm.

c Adding water caused the Fruit Tingles to fizz.

d The solution turned red when blue litmus was added.

2 Which one of the following is an example of a fast reaction?

A wood rotting

B milk going sour

C fermentation of wine

D adding hydrochloric acid to magnesium.

3 Does each of the following normally speed up or slow down a chemical reaction?

a cooling the reactants

b using a more concentrated solution of a reactant

c grinding up the solid reactants

d using a catalyst

e using an inhibitor

f adding water to the reactants

4 Some fruit juice was left in a closed plastic bottle on the kitchen bench. After a week or so the bottle started to bulge. What do you infer from this?

5 Explain why it is difficult to burn a telephone book, yet a single page burns easily if torn out?

6 Which of the following reactions are exothermic, and which are endothermic?

a respiration

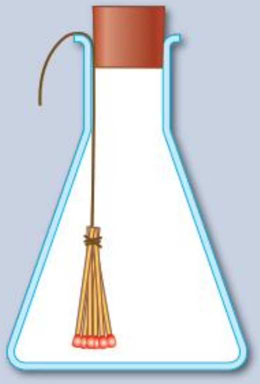
b sherbet dissolving in your mouth

c photographic film being exposed to light

d fireworks exploding

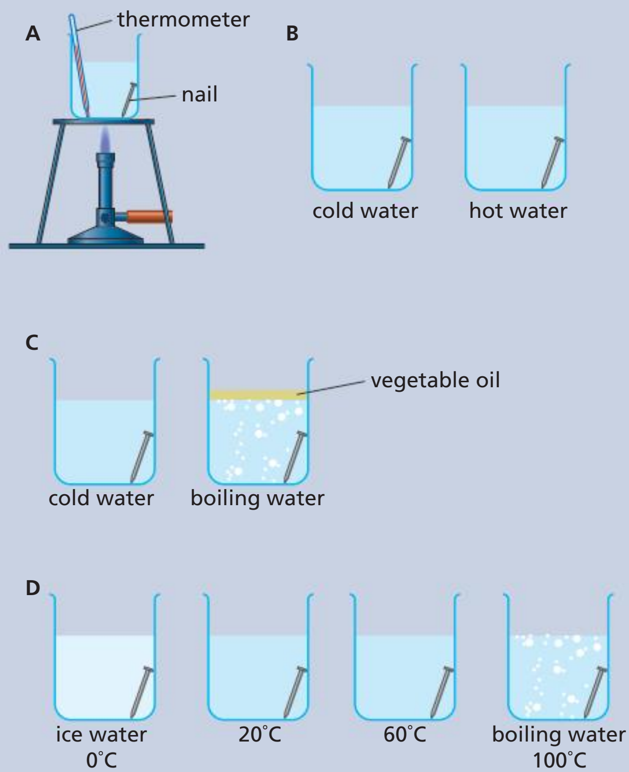
e electroplating silver

7 Matches are suspended inside a stoppered flask as shown. The mass of the flask is then found accurately. When the flask is heated strongly the matches catch alight and burn. The flask is then allowed to cool.



Will the mass of the flask have changed? Explain your answer.

8 Brandon wants to investigate if temperature has any effect on the rusting of iron. Which one of the following setups would be the best experimental design? Explain your choice.



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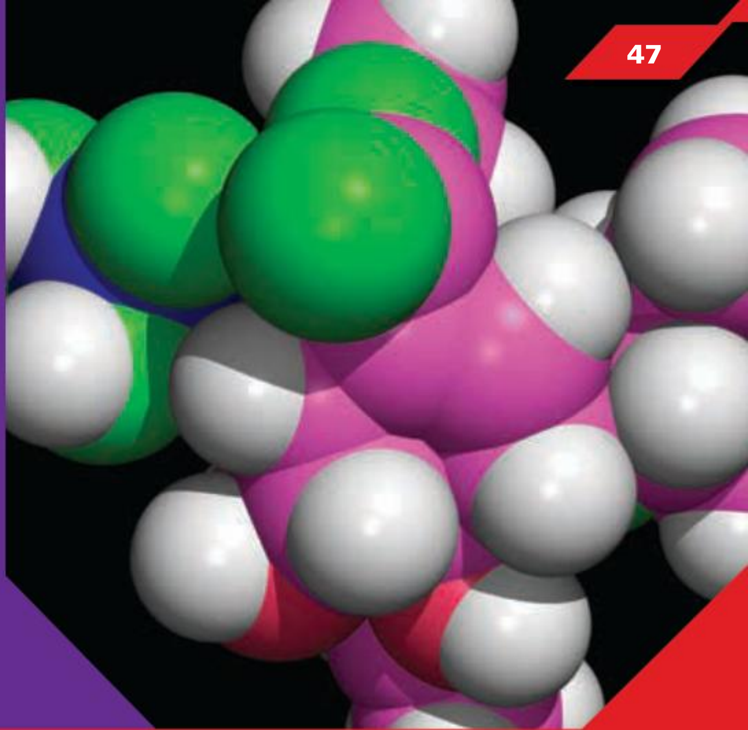


The periodic table

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

Science Understanding

- describe the structure of atoms in terms of electron shells
- explain how the electronic structure of an atom determines its position in the periodic table and its properties
- investigate the chemical and physical properties of alkali metals
- predict the products of chemical reactions between solutions of two ionic compounds

Science Inquiry Skills

- write and balance symbol equations to represent chemical reactions
- apply a knowledge of ionic reactions to solve chemical problems

LITERACY FOCUS

alkali metals
alkaline earth metals
atomic number
balanced equation
chemistry
compound ion
covalent bond
covalent lattice
electron shells
energy levels
halogens
ionic bond
ionic equation
ionic lattice
metallic bond
noble gases
periodic table
precipitate
transition metals
valency

Focus for learning

To understand why a leaf turns red in autumn, why diamonds are so hard or how soap gets rid of dirt you need a knowledge of chemistry. To design a synthetic fibre, a life-saving drug or a space capsule you also need an understanding of chemistry. The behaviour of atoms, molecules and ions can explain the sort of world we live in, how our bodies work, and even how we feel on a given day.

Chemists tackle the problems faced by our modern society. They may study how DNA in our bodies works, measure the amount of insecticide in drinking water, compare the protein content of meats, design a new antibiotic or analyse a moon rock.

When the weather changes in autumn, the green chlorophyll disappears from the leaves of deciduous trees and shrubs. As the green fades you begin to see the yellow and orange colours that were hidden by the green. The bright reds and purples are produced by chemical reactions in the leaves.

PROBLEM SOLVING

DHMO

Dihydrogen monoxide (DHMO) is colourless, odourless and tasteless. We use it every day, yet it kills thousands of people every year. Most of these deaths are caused when DHMO enters the lungs. Prolonged exposure to its solid form can cause loss of fingers and toes. In its gaseous state it causes deadly burns. Swallowing DHMO can cause excessive sweating and urination and possibly a bloated feeling, nausea and vomiting. We are all dependent on DHMO and its withdrawal means certain death.

DHMO is the major component of acid rain and contributes to the greenhouse effect. It causes massive erosion of our natural landscape and accelerates the corrosion and rusting of metals. It can cause electrical short circuits and is found in cancerous tumours.

DHMO is in every river, lake and reservoir in the world and large quantities are found in Antarctica. DHMO has caused millions of dollars of property damage, often associated with cyclones.

Despite these dangers, DHMO is still used as an industrial solvent and coolant, in nuclear power stations, in the production of styrofoam, as a fire retardant and in the manufacture of biological and chemical weapons. It is also the most common food additive. To make matters worse, DHMO is allowed to escape into rivers and the ocean, and nothing can be done to stop this because the practice is still legal.

The Australian government has refused to ban the production, distribution or use of DHMO owing to its importance to the national economy. In fact, the Navy is presently designing multimillion dollar devices to control and utilise it during warfare.

Use the internet to find out as much as you can about DHMO. From your research, would you support a ban on DHMO?

3.1 The periodic table

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Caesium	56 Ba Barium	57–71	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Ti Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

The key to an understanding of chemistry is the **periodic table**. It arranges all the elements in order according to the size of their atoms. Hydrogen is the smallest atom, with atomic number 1. The biggest atoms are at the bottom of the table, towards the right.

The periodic table groups together those elements with similar properties. Each vertical column in the table is called a *group*—a chemical family. The elements in a group are all different but they look alike and all behave in a similar way. To the left of the zigzag line in the table above are the metals and to the right of this line are the non-metals. Hydrogen is a special element. Sometimes it behaves like a metal and sometimes it behaves like a non-metal.

The metals on the left become more reactive as you go down the group, and less reactive as you go from left to right across the *periods* (the horizontal rows). So the most reactive metal of all is francium (Fr) in the bottom left-hand corner of the table. The non-metals become *less* reactive as you go down the group and *more* reactive as you go from left to right across the periods, except for the noble gases in Group 18 (see p. 50). So the most reactive non-metal is fluorine (F) in the top right-hand corner.

Alkali metals (Group 1)

The metals in Group 1 on the left of the periodic table are the **alkali metals**. They all have similar properties. They are so reactive that they are never found in nature as elements, only as compounds. They are called alkali metals because they react with water to form alkaline solutions. For example, sodium reacts violently with water to form sodium hydroxide (an alkali) and hydrogen gas.

sodium + water → sodium hydroxide + hydrogen

INQUIRY 1 Teacher demonstration

You will need: pneumatic trough, scalpel, paper towel, small samples of lithium and sodium in paraffin oil, phenolphthalein

Students should wear safety glasses. Do the demonstration in a fume cupboard or behind a perspex screen.

1. Half fill the pneumatic trough with water and add a few drops of phenolphthalein.
2. Use a dry scalpel to cut a small amount of lithium—*no bigger than a rice grain*. Blot up any paraffin oil with a paper towel.
3. Carefully place the lithium in the centre of the pneumatic trough. Do not get the scalpel wet.
4. Repeat steps 1–3 for sodium. Use fresh water.
   - Which was more reactive—lithium or sodium?
   - Why did the lithium and sodium disappear?
   - Why did the water turn pink each time?

Alkaline earth metals (Group 2)

These metals are not as reactive as the alkali metals. They are called **alkaline earth metals** because, when they combine with oxygen to form oxides, these oxides are alkaline. As the oxides are unreactive, the alchemists (ancient chemists) called them earths. This group contains two of the most biologically important metals: magnesium, which is found in chlorophyll in plants, and calcium, which is found in bones and teeth.

Transition metals

The metals in the middle of the periodic table are called **transition metals**. They are hard and have high melting points. The transition metals all have similar properties, especially those close together in the periodic table. For example, iron, nickel and cobalt, next to each other in the same horizontal period, are all magnetic. Metals near the top of the table (e.g. aluminium and zinc) are generally more reactive than those towards the bottom (e.g. silver, gold and lead).

Many of the compounds that transition metals form with non-metals are coloured. For example, copper sulfate is blue and cobalt chloride is red. These compounds are used to produce the bright colours of fireworks and to colour glass. The compounds are also responsible for the different colours of human hair.

Halogens (Group 17)

The **halogens** are very reactive non-metals on the right-hand side of the periodic table. Fluorine and chlorine are gases at room temperature, bromine is a liquid and iodine is a solid. The word *halogen* means ‘salt former’ because the halogens readily combine with metals to form salts. For example, chlorine reacts with sodium metal to form sodium chloride.

sodium + chlorine → sodium chloride

Noble gases (Group 18)

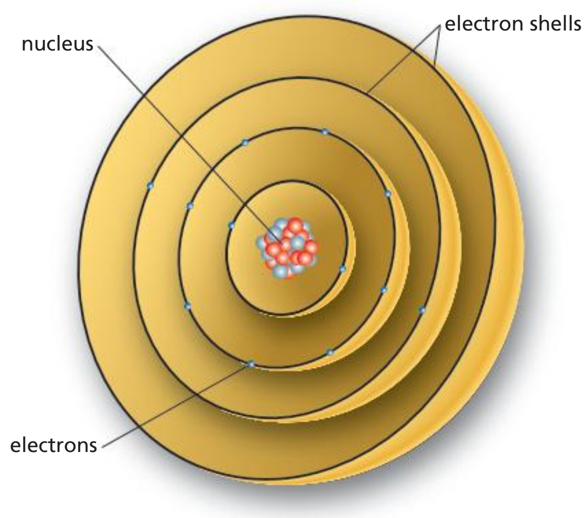
These are all colourless gases that are found in very small amounts in the atmosphere. They are called **noble gases** because they do not react with other elements, except under extreme conditions. This is because we tend to think of nobles (royalty) as having nothing to do with the common people, like us.

Helium, the lightest gas, is used to fill balloons. It is also mixed with oxygen for divers to breathe. Neon is used in neon signs and lasers because it gives a coloured light. Argon is used in light bulbs and in welding to stop hot metals from burning.

Electron shells

To make more sense of the periodic table you need to understand more about atoms. As you know, each atom has a nucleus containing protons and neutrons. This nucleus is surrounded by electrons. The number of electrons is the same as the number of protons in the nucleus—the *atomic number*. The bigger the atomic number, the bigger the atom because it has more protons in its nucleus.

The electrons are arranged in **electron shells** or *energy levels*. If you think of the nucleus of the atom as a pea, then the pea sits in the middle of a table tennis ball. This is the first shell. All this sits inside a tennis ball (the second shell), which sits inside a basketball (the third shell), which sits inside a beach ball. The electrons move rapidly around the surface of the shells. The electrons in the second shell have more energy than those in the first shell. Those in the third shell have more energy than those in the second shell, and so on.



When you put a metal compound in a flame you see a flash of colour. This can be explained by saying that the energy that the electrons absorb from the flame enables them to jump to a higher energy shell for a short time. When they return to their original shell, they release their extra energy as coloured light.

Filling the shells

Electron energy levels are a bit like floors in a high-rise car park. Cars drive into the car park at ground level. Usually they fill all the parking spaces on this level before moving up to find a parking space on the next level. There are only a certain number of cars that can fit on each level. For atoms, chemists have found that:

- Electrons normally fill the energy shells in order, starting with the inner lowest energy shell.
- There is a maximum number of electrons allowed in each shell:

  first shell 2
  second shell 8
  third shell 18
  fourth shell 32
- The maximum number in the outer shell is eight. For example, the third shell can only hold 18 electrons when it is not the outer shell.

Using these rules, scientists inferred that electrons are arranged in this way for the first 20 elements.

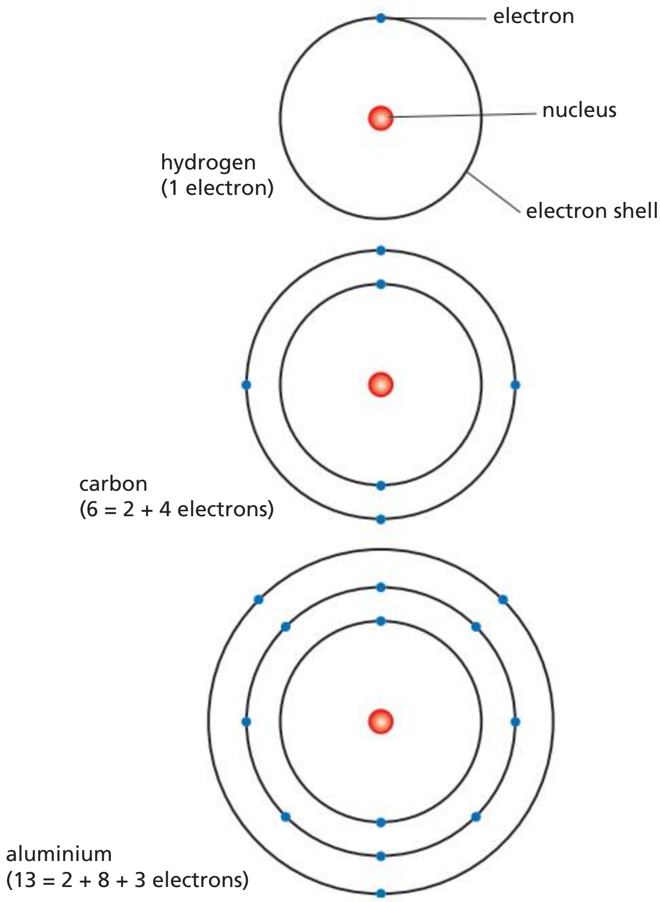
Element	Symbol	Atomic number (number of electrons)	First shell	Second shell	Third shell	Fourth shell
Hydrogen	H	1	1			
Helium	He	2	2			
Lithium	Li	3	2	1		
Beryllium	Be	4	2	2		
Boron	B	5	2	3		
Carbon	C	6	2	4		
Nitrogen	N	7	2	5		
Oxygen	O	8	2	6		
Fluorine	F	9	2	7		
Neon	Ne	10	2	8		
Sodium	Na	11	2	8	1	
Magnesium	Mg	12	2	8	2	
Aluminium	Al	13	2	8	3	
Silicon	Si	14	2	8	4	
Phosphorus	P	15	2	8	5	
Sulfur	S	16	2	8	6	
Chlorine	Cl	17	2	8	7	
Argon	Ar	18	2	8	8	
Potassium	K	19	2	8	8	1
Calcium	Ca	20	2	8	8	2

Periodic table patterns

Now you can see some interesting patterns in the periodic table. For Period 1(hydrogen and helium) the first shell is being filled. For Period 2 (lithium to neon) the second shell is being filled. For Period 3 (sodium to argon) the third shell is being filled. And so on.

Also, chemists have found that the chemical properties of an element are determined by how many electrons there are in the outer shell of its atoms. In the table on this page you will notice that lithium, sodium and potassium all have a single electron in their outer shell. This is why these elements are in Group 1. They all have similar properties. You would expect the other elements in Group 1 to also have a single electron in their outer shell, and they do. Similarly, the Group 2 elements (beryllium, magnesium, calcium) all have two electrons in their outer shell, and so on until the Group 18 elements (helium, neon, argon) which have filled outer shells.

Diagrams can be used to show how the electrons are arranged in shells.



Electron shell arrangements

INQUIRY

2 Alkali metals

1 Use the table below to plot a graph of melting point against atomic number for the alkali metals. On the same graph, plot the boiling points. Write a sentence describing what patterns the graph shows.

Element	Atomic number	Melting point (°C)	Boiling point (°C)	Density (g/cm^3)
Lithium	3	180	1331	0.53
Sodium	11	98	890	0.97
Potassium	19	63	766	0.86
Rubidium	37	39	701	1.5

2 Would the alkali metals listed in the table float or sink in water? Would you say they are typical metals? Explain your answers.

3 Look at the table on the previous page. Write down the electron arrangements for lithium, sodium and potassium. How does this explain why these metals have similar properties?

Over to you

1 What does the atomic number of an element tell you?

2 Use the periodic table on page 49 to find out which element has the atomic number of:

a 6 **c** 47

b 17 **d** 88

3 Explain the difference between a period and a group in the periodic table.

4 Draw a periodic table and put in the first 20 elements. Label the following groups:

a alkali metals **d** halogens

b alkaline earth metals **e** noble gases

c transition metals

5 Use the periodic table to decide which three of the following elements have similar properties: argon, carbon, copper, gold, platinum, silver, zinc.

6 Use the periodic table to decide which element would be more reactive:

a magnesium or calcium

b sodium or magnesium

c carbon or oxygen

d fluorine or bromine.

7 What are electron shells? Why are they also called energy levels?

8 Draw the electron shell arrangements for the following atoms (see diagram on p. 51).

a helium **b** oxygen **c** argon

9 Name the elements that have these electron arrangements:

a 2, 1 **c** 2, 8, 6

b 2, 5 **d** 2, 8, 8, 2

10 Name those elements in the first 20 elements that have:

a a full outer electron shell

b three electrons in their outer shell

c an outer shell needing one electron to be full.

11 Which atom is represented by the electron shell diagram on page 50?

12 How many electrons are there in the outer shell of an atom of:

a magnesium? **b** silicon? **c** nitrogen?

13 What is the maximum number of electrons allowed in the outer shell of an atom?

14 What information about the electron arrangement is given by the group number of an element?

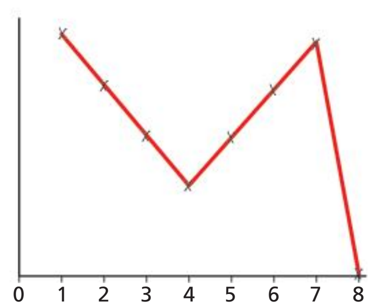
15 **a** Write a word equation for the reaction of potassium (Group 1) with water.

b Suggest why you did not try this reaction in Inquiry 1 on page 49.

16 **a** If an element has two electrons in its outer shell, is it a metal or a non-metal? Explain.

b If an element has seven electrons in its outer shell, is it a metal or a non-metal? Explain.

17 The chemical reactivity of an element is related to the number of electrons in its outer electron shell. Elements with one or seven electrons in the outer shell are more reactive than those with two or six electrons. In turn, these are more reactive than elements with three or five electrons, which are more reactive than those with four. The graph below summarises this information. Copy the graph and label the two axes. Give the graph a title.



Science as a Human Endeavour

Lead—valuable resource or deadly poison?

From the age of 20 the great composer Ludwig van Beethoven had a mysterious illness that changed his personality and caused him endless suffering. He saw dozens of doctors but nobody could cure his abdominal pain, digestive trouble, depression and irritability. When he was 23 he wrote in a letter 'After my death, if Dr Schmidt is still alive, ask him in my name to discover my disease'. He died at the age of 57 and a music student kept some of his hair. This hair was eventually sold at an auction in 1994 and it was given to scientists, who bombarded it with a high-energy beam of X-rays. When this happens each atom releases energy of a particular wavelength, which allows it to be identified.

They found that Beethoven's hair contained more than 60 parts per million of lead—about 100 times the normal amount. So Beethoven's illness was no longer a mystery, although where the lead came from is not known.

Beethoven composing

Lead has been used for at least 7000 years. It is easy to extract from its ore, easy to work with and resists corrosion. The Romans used it to line the aqueducts that carried their water, they drank from lead goblets, put lead compounds on their faces and added them to food and wine.

Lead pipes were widely used in plumbing. In fact, the term 'plumbing' comes from the Latin word for lead—*plumbum*. This is where the symbol for lead, Pb, comes from. The solder used to join pipes is an alloy containing 40% lead.

Lead is still widely used today, for example, in paint, car batteries, glass, ceramics, coverings for electrical cables, protective shielding against X-rays and radioactive substances, and as flashing on roofing to protect joints from rain. Up until the 1950s paint in homes could be as much as 50% lead compounds, but since 1997 it has been reduced to less than 0.1%. However, lead paint is still used to protect steel bridges against corrosion. For example, every five years 90 tonnes of red lead paint are used to paint the Sydney Harbour Bridge. Also, many old houses still have lead paint, perhaps under layers of newer paint. In the past, many children developed lead poisoning by chewing on the rails of lead-painted cots or on windowsills.

Up until 2002 a compound called tetraethyl lead was added to petrol to make it burn more efficiently. However, the use of this leaded petrol caused an increase in lead concentrations in the atmosphere and in roadside dust. Since leaded petrol has been phased out, these lead levels have fallen.

The element lead is not itself poisonous to humans but lead compounds, such as lead oxide, are. The metal gradually becomes coated in these compounds. Lead is also slightly soluble in water, which is why lead pipes used for water supply were a cause of lead poisoning. Once lead compounds enter your body they disrupt bodily functions and can remain in bone for 25 years. They can cause brain disorders and can affect learning in young children.

Birds and fish are also at risk from lead. Hunters use lead shot and people fishing use lead sinkers. Water birds or fish that take this lead into their bodies sicken and die. When they are eaten by predators, the lead is passed along the food chain. Alternatives such as steel shot are now being used.

1 Why do you think the doctors 200 years ago did not know that Beethoven was suffering from lead poisoning?

2 What properties of lead make it such a useful resource?

3 If you are fishing, what precautions should you take when handling lead sinkers?

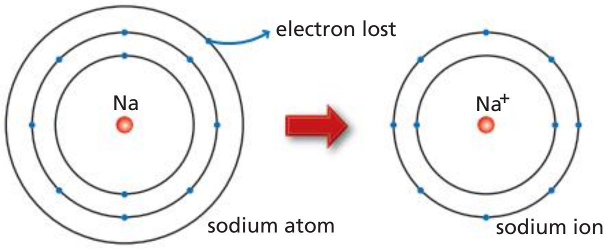
4 Should we continue to use lead or should its use be totally banned? Discuss this in a group.

3.2 Bonding

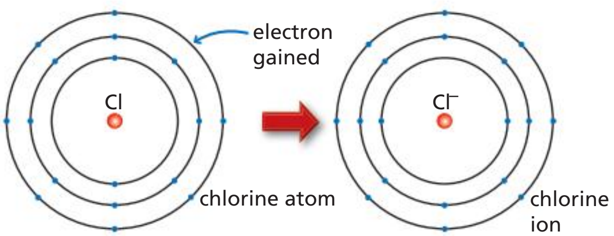
Ionic bonds

When atoms react with each other to form compounds, the electrons in their outer shells determine the type of reaction that occurs. Chemists have always been interested in the noble gases because they are so unreactive or stable. They infer they are so stable because their outer electron shell is full. All other atoms react because their electron arrangements are not as stable as those of the noble gases. Atoms can become more stable if they can get electrons to fill their outer shells.

As an example, consider a sodium atom. It has two complete shells and a single electron in its outer shell (see diagram). This is a very unstable arrangement. Sodium, therefore, has a strong tendency to lose the single electron in its outer shell so that it ends up with a full outer shell of eight electrons, like the noble gas neon. When a sodium atom loses its outer electron like this, it is no longer neutral. It becomes a positively charged ion Na^+.

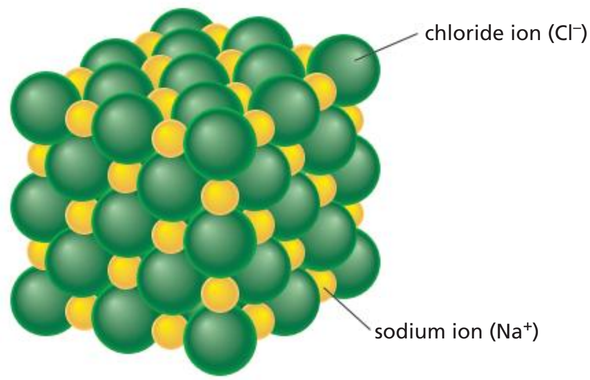


Now consider a chlorine atom. It has an outer shell with seven electrons and needs one more electron to have a full outer shell, like the noble gas argon. Chlorine, therefore, has a strong tendency to gain an electron. When this happens it becomes a negatively charged chloride ion Cl^-.



What is likely to happen when sodium and chlorine atoms come together? A sodium atom wants to lose an electron and a chlorine atom wants to gain one. So both atoms can become stable if the sodium atom gives up an electron to the chlorine atom. The 1+ charge is balanced by the 1– charge to form a neutral compound.

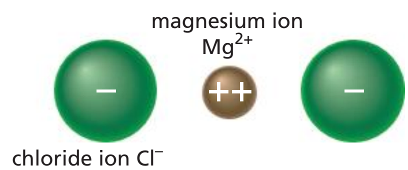
You can see what happens if you watch sodium metal burning in chlorine gas in a gas jar. The sodium burns brightly and a white solid forms on the sides of the gas jar. This solid is table salt—the compound sodium chloride (NaCl). The sodium atoms form positive ions and the chlorine atoms form negative ions. These positive and negative ions are very strongly attracted to each other and arrange themselves in a regular three-dimensional pattern, as shown below. This is called an *ionic lattice*. The force of attraction between the ions is called an **ionic bond**.



The compound sodium chloride (NaCl) consists of a lattice of positive sodium ions and negative chloride ions held together by ionic bonds.

All the elements in Group I of the periodic table behave in much the same way as sodium. When they react they tend to lose one electron to form an ion with a single positive charge. Similarly, all the elements like chlorine in Group VII tend to gain an electron to form an ion with a single negative charge.

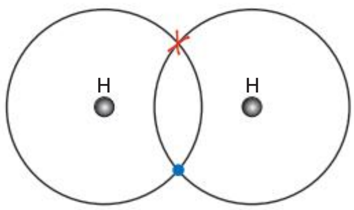
Elements in Group II tend to lose *two* electrons when they react. For example, a magnesium atom tends to lose both the electrons in its outer shell to form an ion with two positive charges Mg^{2+}. It can combine with two chloride ions to form magnesium chloride $MgCl_2$, as shown below. (Two Cl^- ions are needed to balance one Mg^{2+} ion.)



Covalent bonds

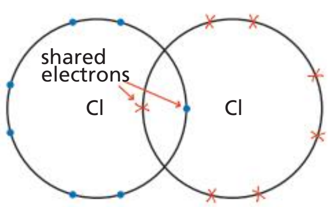
Instead of gaining or losing electrons, atoms sometimes get a stable outer shell by *sharing* electrons. This type of bonding is called **covalent bonding**. When two or more atoms share electrons a molecule is formed. The atoms in the molecule may be the same or they may be different.

When two hydrogen atoms approach each other, both nuclei attract each other's electrons. As a result, the two atoms end up sharing the electrons. In this way they both have a full outer shell of two electrons. The electron from one atom is shown as a dot and the electron from the other atom as a cross, as shown.

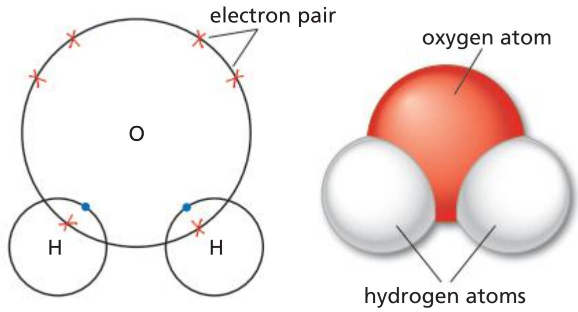


A hydrogen molecule has the formula H_2 and can be represented by H—H. The molecule can be represented as a model. In the model on the left below the spring represents the covalent bond. In the model on the right the two atoms fit together.

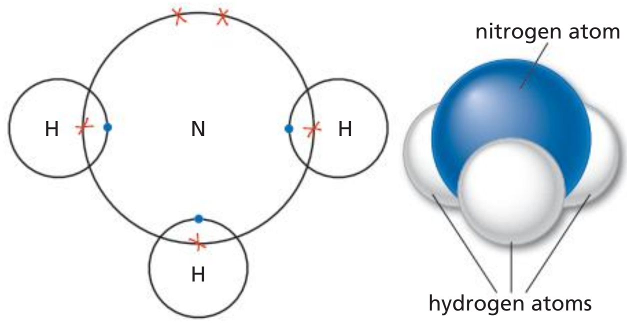
When two chlorine atoms come together to form a chlorine molecule by sharing electrons, each atom ends up with a full outer shell of eight electrons. For simplicity only the electrons in the outer shell are shown below. Chemists have found that the electrons tend to pair up.



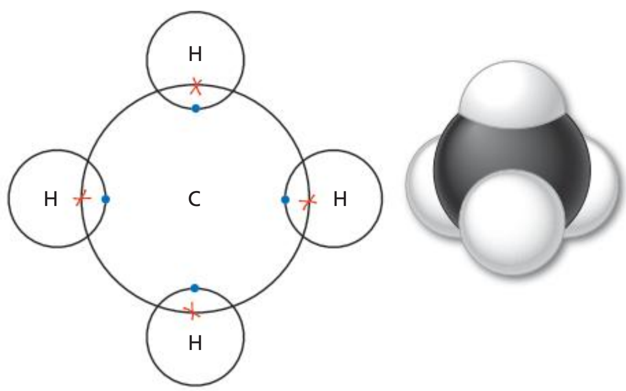
An oxygen atom has six electrons in its outer shell. So if it combines with two hydrogen atoms to form water (H_2O) it ends up with a full outer shell of eight electrons. The bent shape is the most stable and keeps all the electrons as far apart as possible, as shown below.



Nitrogen has five electrons in its outer shell so it needs to bond with three hydrogen atoms to form an ammonia molecule (NH_3). The lone pair of electrons at the top forces the molecule into the shape of a pyramid, as shown below.

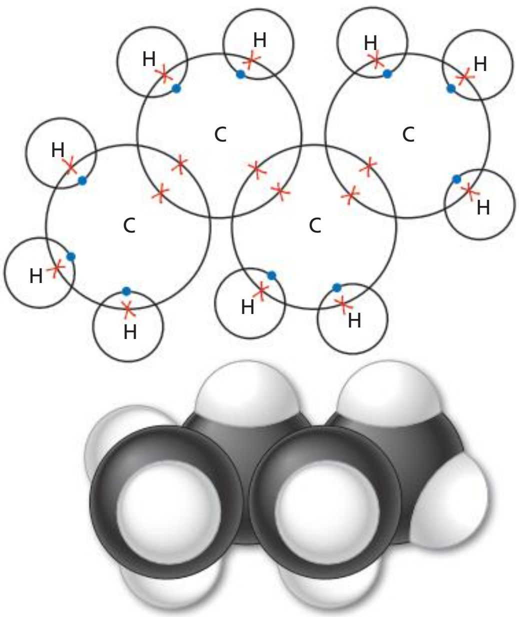


Carbon has four electrons in its outer shell so it can form four covalent bonds with hydrogen. The methane molecule formed (CH_4) has the shape of a tetrahedron, as shown below.



Carbon compounds

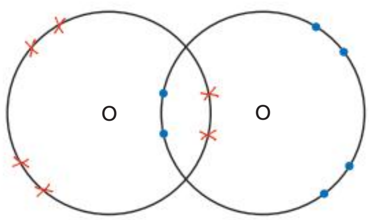
As well as bonding to hydrogen atoms, a carbon atom can also bond to other carbon atoms. Thus, each carbon atom has a complete outer shell of eight electrons. As a result, carbon can form the many complex molecules found in living things, as well as the long chains in plastics.



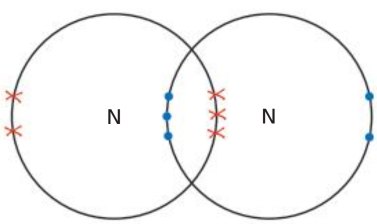
A butane molecule (C_4H_{10})

Double and triple bonds

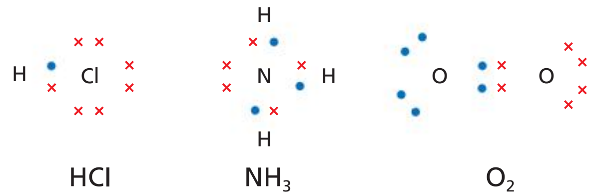
When two oxygen atoms combine they can share *two* pairs of electrons. This gives each atom a share of eight electrons in its outer shell, as shown below. Chemists say there is a *double bond*, between the two oxygen atoms.



When two nitrogen atoms combine they share *three* pairs of electrons to form a *triple bond*, as shown.



When you leave out the circles representing the outer electron shells of the atoms, you end up with *electron dot formulas*. This is a quick and neat way to show the electron arrangement of a molecule. Here are some examples.



INQUIRY 3 *Molecular models*

You will need: molecular models kit, Smarties (optional)

1 Use molecular models to make models of some of these molecules:

Single bonds:

hydrogen H_2
chlorine Cl_2
fluorine F_2
hydrogen chloride HCl
water H_2O
hydrogen sulfide H_2S
ammonia NH_3
methane CH_4
carbon tetrachloride CCl_4
butane C_4H_{10}

Double bonds

oxygen O_2
carbon dioxide CO_2
carbon disulfide CS_2
ethylene C_2H_4

Triple bonds

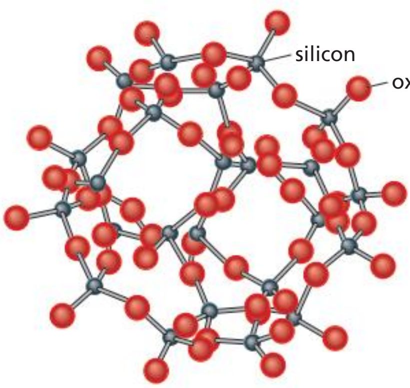
nitrogen N_2
acetylene C_2H_2

2 For each molecule you make, write down its name and formula. Also draw it in three dimensions, indicating any double or triple bonds. If possible, draw its electron dot formula.

To work out the electron dot formula you can use Smarties of different colours to represent the electrons from different atoms. You can move them around until you get the bonding pairs right.

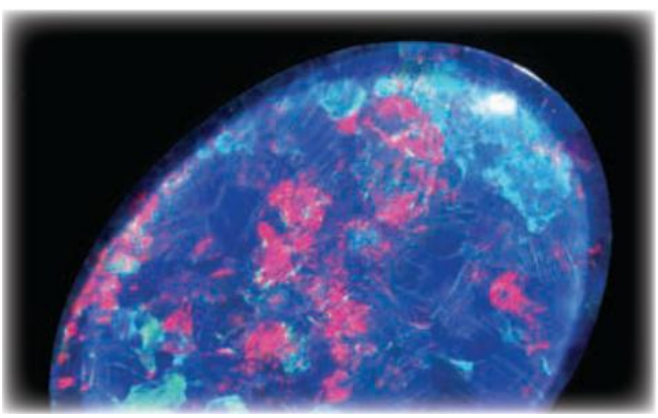
Covalent lattices

Just as ionic compounds form ionic lattices (see p. 54), some covalent elements and compounds form *covalent lattices*. For example, carbon (as diamond) and silica (silicon dioxide) form these lattices. Silicon is in the same group as carbon, with four electrons in its outer shell. Each silicon atom can therefore form four bonds with four oxygen atoms. Each oxygen atom can also bond to two silicon atoms, in a continuous three-dimensional lattice, as shown. The strong bonds throughout the structure make diamond and silica very hard, with high melting points. Because the electrons are all so tightly involved in bonding, there are no free electrons that can move through the lattice and carry an electric current. Thus, diamond and silica do not conduct electricity.



The covalent lattice of silicon dioxide (silica)

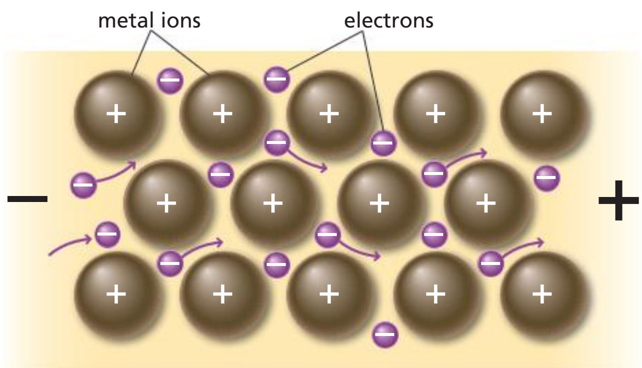
Silica makes up 87% of the Earth's crust. It forms the common mineral quartz and gems such as opal and agate. Opal contains thousands of tiny grains of silica, which scatter and bend the light hitting it, causing the beautiful colours.



Opal is considered a gem because of its beautiful colours.

Metallic bonding

The atoms in a metal are held together in a three-dimensional lattice. The electrons in their outer shells are easily lost and move freely throughout the metal without being bound to any one atom. This results in a lattice of positive ions held together by a 'sea' of electrons. This is called a **metallic bond**. When an electrical voltage such as a battery is connected to the metal, an electric current flows because the electrons are free to hop from atom to atom, as shown.



Over to you

1 Why is sodium more stable as an ion than as a neutral atom?

2 Why does magnesium always form ions with a double positive charge Mg^{2+}?

3 Use the table on page 51 to predict the type of ions formed by these elements:
- **a** lithium
- **b** calcium
- **c** fluorine
- **d** aluminium.

4 **a** Give two examples of non-metals in Group VI.
b How many extra electrons do these non-metals need to share to have a full outer electron shell?

5 **a** Draw a diagram to show what happens to the electron arrangement of lithium (see the table on p. 51) when it loses an electron.
b Draw a diagram to show what happens to the electron arrangement of fluorine when it gains an electron.
c Predict what will happen when lithium metal burns in fluorine gas.

6 What is the difference between a single, double and triple covalent bond in terms of the number of electrons involved?

7 Describe what happens when two hydrogen atoms collide to form a molecule.

8 Why don't the noble gases form covalent bonds?

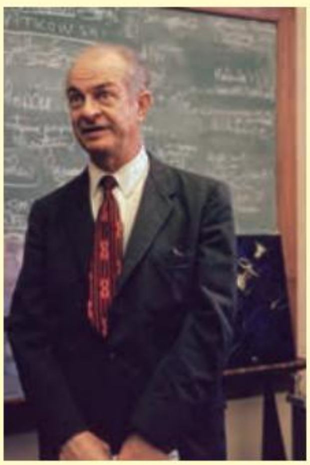
9 Use the cartoon below to explain the difference between an ionic bond and a covalent bond.

SCIENTISTS AT WORK

Linus Pauling

Linus Pauling was born in Portland, Oregon, USA in 1901. At 11 he began an insect collection and at 13 he set up a laboratory in his home.

He graduated from university with a degree in chemical engineering and began work on the structures of crystals. He used X-rays to work out how the invisible atoms in the crystals were arranged. He measured the distances and angles of the bonds in the three-dimensional structures. He realised that these bonds could be explained in terms of electrons, as you have learnt in this section.



Pauling became interested in biological molecules. For example, he studied the structure of haemoglobin, the substance in the blood that carries oxygen. He also studied DNA and in 1953 he proposed that it was made up of three chains, twisted around each other. Soon after, the British scientists Watson and Crick saw that there was a mistake in Pauling's structure. It was a double helix, not a triple helix. However, Watson and Crick had seen some X-ray photographs of DNA taken by Rosalind Franklin, which Pauling had not seen. Pauling was, however, awarded the Nobel Prize in Chemistry in 1954.

During World War II Pauling was asked to work on the Manhattan Project to develop the atomic bombs that were dropped on Hiroshima and Nagasaki in 1945. He refused because he was concerned about the dangers of atomic weapons and radiation. He showed that the radiation caused by weapons tests could cause miscarriages, stillbirths, physical and mental defects in children, and increases in cancer. In 1958 Pauling and his wife presented the United Nations with a petition signed by more than 11 000 scientists calling for an end to nuclear weapons testing. He lost many friends because of this and lost his job at the California Institute of Technology. His passport was also taken from him for two years, and he risked going to prison. However, public pressure led to the Partial Test Ban Treaty, signed in 1963. On the day the treaty came into force Pauling was awarded the Nobel Peace Prize, only the second person after Marie Curie to receive two Nobel Prizes.

Pauling wrote a number of books, including *No More War!*, *Vitamin C, the Common Cold and the Flu*, and *How to Live Longer and Feel Better.* He believed that taking very large doses of vitamin C could prevent colds and even cancer, but this has never been proven.

1 Some people thought that Pauling was guilty of treason (betraying his country). Suggest why.

2 What did Linus Pauling achieve during his life?

3 What do you think was his greatest achievement? Why?

3.3 Formulas

Covalent formulas

The chemical formula of a compound shows the symbols of the elements that have combined to make the compound. It also gives the ratio in which the atoms have joined together. For example, the formula for methane (found in natural gas) is CH_4. This means that a molecule of methane contains one carbon atom and four hydrogen atoms. The 4 is written as a subscript, slightly smaller and a little below the line.

The formulas for some common covalent compounds are listed below. You should be able to remember most of these.

hydrogen H_2	carbon monoxide CO
oxygen O_2	carbon dioxide CO_2
chlorine Cl_2	silicon dioxide SiO_2
water H_2O	sulfur dioxide SO_2
hydrogen chloride HCl	sulfur trioxide SO_3
hydrogen sulfide H_2S	methane CH_4
carbon disulfide CS_2	carbon tetrachloride CCl_4
ammonia NH_3	propane C_3H_8

You will notice that the ending of the second non-metal name changes when it forms a compound. For example, chlorine becomes chlor*ide*, sulfur becomes sulf*ide*, hydrogen becomes hydr*ide* and oxygen become ox*ide*. In carbon monoxide, each carbon atom is combined with one oxygen atom. So the *mono-* means one. Similarly *di-* means two, *tri-* means three and *tetra-* means four. Thus, dihydrogen monoxide (DHMO) indicates a compound containing two hydrogen atoms and one oxygen atom (H_2O). However, it is easier to use its common name—water. Similarly, the common name of ammonia is used instead of nitrogen trihydride, and CH_4 is called methane.

Valency

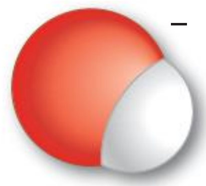
As you learnt in the previous section, the properties of an element are largely determined by the electrons in the atom's outer shell. Atoms react to fill or empty their outer shell. They do this by gaining, losing or sharing electrons with other atoms.

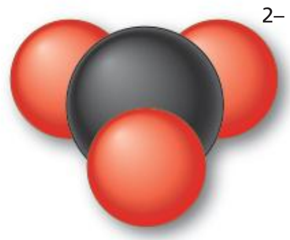
The number of electrons an atom normally gains, loses or shares is called its **valency** or combining power. This can be positive or negative. Metals have a positive valency because they tend to lose electrons to form positive ions. Non-metals have a negative valency because they tend to gain electrons to form negative ions.

Compound ions

Many ions are formed from single atoms, for example, Na^+ and Cl^-. However, many important ions are formed from *groups* of atoms that have an overall charge. Some of these are shown below. These are called *compound ions*. Look at the hydroxide ion. The oxygen and hydrogen are bonded together and act as a single unit with a charge of –1.

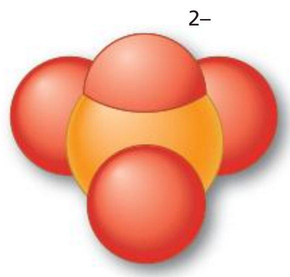
hydroxide OH^-

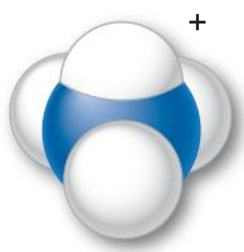




carbonate CO_3^{2-}

sulfate SO_4^{2-}





ammonium NH_4^+

Compound ions can combine with other ions to form ionic compounds. For example, hydroxide ions OH^- can be combined with sodium ions Na^+ to form sodium hydroxide NaOH (caustic soda).

The table on the next page lists the valencies of some of the common ions, including the compound ions.

Ion	Symbol	Charge on ion (valency)
Ammonium	NH_4	1+
Hydrogen	H	1+
Potassium	K	1+
Silver	Ag	1+
Sodium	Na	1+
Calcium	Ca	2+
Copper	Cu	2+
Iron	Fe	2+ or 3+
Lead	Pb	2+
Magnesium	Mg	2+
Zinc	Zn	2+
Aluminium	Al	3+
Bromide	Br	1–
Chloride	Cl	1–
Hydrogen carbonate	HCO_3	1–
Hydroxide	OH	1–
Iodide	I	1–
Nitrate	NO_3	1–
Carbonate	CO_3	2–
Oxide	O	2–
Sulfate	SO_4	2–
Sulfide	S	2–
Phosphate	PO_4	3–

Patterns in the valencies

You will notice that metals in Group 1 (e.g. sodium and potassium) have a valency of 1+. Metals in Group 2 (e.g. calcium and magnesium) have a valency of 2+. Aluminium in Group 13 has a valency of 3+. Non-metals in Group 16 (e.g. oxygen and sulfur) have a valency of 2–, and non-metals in Group 17 (e.g. chlorine and bromine) have a valency of 1–. Transition metals such as iron have variable valencies, but most form ions with a 2+ charge.

PROBLEM SOLVING

Did you work out that DHMO is just a fancy name for plain old water? This shows how important it is to critically evaluate everything you read on the internet and elsewhere. It is very easy to agree with something without thinking about it carefully for yourself. You may want to read the description of DHMO on page 48 again. You could draw up a DHMO fact sheet and see how many signatures you can get on a petition to ban it.

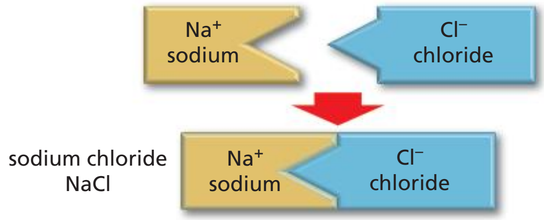
Writing formulas

Metals (positive valencies) combine with non-metals (negative valencies) to form a range of ionic compounds. When naming these compounds the metal ion is listed first, followed by the non-metal ion (e.g. sodium chlor*ide*).

INQUIRY 4 *Formula cards*

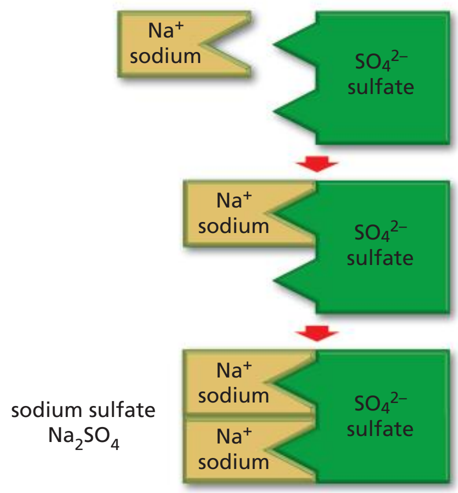
You will need: cardboard and scissors

Make cardboard cut-outs to represent various positive and negative ions. You could make them different colours.



Fit the cards together to make compounds. For example, one sodium ion fits with one chloride ion to make sodium chloride. So the formula for sodium chloride is NaCl.

Make cut-outs for sodium sulfate. This time you need two Na^+ ions to balance the double negative charge on the sulfate ion (SO_4^{2-}). So the formula for sodium sulfate is Na_2SO_4.



Make cut-outs for a range of positive and negative ions from the table on this page. Then put them together to make ionic compounds. For each compound you make write down its name and correct formula. You could have a competition to see who can make the most compounds.

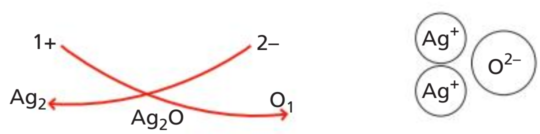
To write the formula for an ionic compound, follow these rules.

Example 1

1 Write down the symbols of the ions. Note that the positive ion (usually a metal) goes first. Write the valencies above the symbols.

silver	oxide
1+	2–
Ag	O

2 Crisscross the valencies to get the correct subscripts. Leave out the + and – signs.

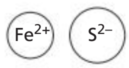


3 Write the correct formula with subscripts, leaving out the 1. Check that the charges are balanced. You need two Ag^+ ions to balance one O^{2-} ion.

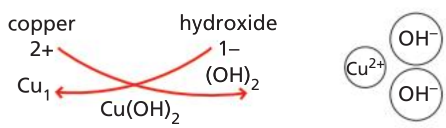
Example 2

iron sulfide FeS

Fe^{2+} balances S^{2-} $(2^+) + (2^-) = 0$.

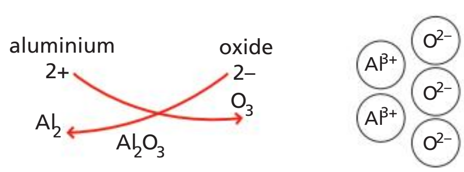


Example 3



In this example you put the compound ion in brackets to indicate that it acts as a single unit. The subscript 2 refers to everything inside the brackets. In other words, there are two oxygen atoms and two hydrogen atoms. When there is only one unit of the compound ion, the brackets are not needed, e.g. $CaCO_3$ instead of $Ca(CO_3)$.

Example 4



You need two Al^{3+} ions to balance three O^{2-} ions: $(2 \times 3+) + (3 \times 2–) = 0$.

> Formulas for common acids:
> - hydrochloric acid HCl (not hydrogen chloride)
> - sulfuric acid H_2SO_4
> - nitric acid HNO_3

Over to you

1 Write down the symbols for the following ions:
- **a** ammonium
- **b** nitrate
- **c** oxide
- **d** zinc

2 How many sodium ions (Na^+) will combine with:
- **a** a chloride ion Cl^-?
- **b** a carbonate ion CO_3^{2-}?
- **c** a phosphate ion PO_4^{3-}?

3 When carbon burns in oxygen, carbon combines with oxygen to form carbon dioxide. Name the compound formed when:
- **a** potassium burns in chlorine gas
- **b** sodium burns in air (oxygen)
- **c** silver tarnishes by reacting with sulfur in the air.

4 Aluminium sulfate, used in sewage treatment and water purification, has the formula $Al_2(SO_4)_3$. How many atoms of aluminium, sulfur and oxygen are represented by this formula?

5 Copy this table and complete the formulas.

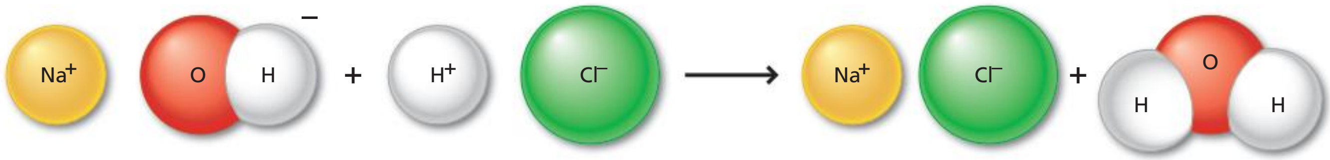
	iodide I^-	oxide O^{2-}	phosphate PO_4^{3-}
potassium K^+			
copper Cu^{2+}			
aluminium Al^{3+}			

6 Name the following compounds:
- **a** $FeCl_3$
- **b** HCl
- **c** $(NH_4)_3PO_4$
- **d** ZnI_2
- **e** $CaCO_3$
- **f** HgO
- **g** UO_2
- **h** $NaNO_3$

7 Write down the formulas for these common compounds:
- **a** ammonium sulfate (fertiliser)
- **b** calcium hydroxide (lime)
- **c** calcium phosphate (in bones)
- **d** magnesium sulfate (Epsom salts)
- **e** silver chloride (used in photographic film)
- **f** sodium hydrogen carbonate (baking soda)
- **g** sodium hydroxide (caustic soda)
- **h** zinc chloride (used in batteries)

8 The following formulas are incorrect. Correct each one and say *why* it is incorrect.
- **a** $NaCl_2$
- **b** Na_1HCO_3
- **c** $CaOH_2$
- **d** Mg_2O_2
- **e** $(NH_4)Cl$
- **f** H_2NO_3

3.4 Writing equations



NaOH + HCl ⟶ NaCl + H_2O

When you mix hydrochloric acid and sodium hydroxide they neutralise each other to form sodium chloride (a salt) and water. The word equation for this reaction is:

sodium hydroxide + hydrochloric acid → sodium chloride + water

Now that you know how to write chemical formulas, you can write a symbol equation like the one above.

This equation tells you how many of each kind of atom react together. Notice that the NaOH, HCl and NaCl are all ionic compounds, made up of positive and negative ions. During the reaction the ions swap partners. Look closely at the equation and you will see that there is a Na^+ ion (yellow) and a Cl^- ion (green) on both sides of the equation. Similarly, there is an oxygen atom (red) on both sides of the equation. Also, there are two hydrogen atoms (white) on the left-hand side, which both end up in the H_2O molecule on the right-hand side.

An equation like this, in which the numbers of each kind of atom are the same on both sides, is called a *balanced equation*. Equations must always be balanced because of the law of conservation of matter. Atoms cannot disappear and they cannot appear from nowhere.

To balance some equations you need to write numbers in front of the formulas. Here are three examples that show how to do this.

Equation 1

Magnesium metal reacts with hydrochloric acid to produce hydrogen gas and a solution of an ionic compound called magnesium chloride.

Step 1: Write the word equation

magnesium + hydrochloric acid → magnesium chloride + hydrogen

Step 2: Write down the formulas

You next write down the formulas of the reactants and products. For the element magnesium you simply write down its symbol Mg. It is best to remember that the formula for hydrochloric acid is HCl. For magnesium chloride you can work it out using valencies from the table on page 60. In hydrogen gas, however, the molecules are diatomic, meaning that they consist of two hydrogen atoms (H_2). Other diatomic molecules are oxygen (O_2), nitrogen (N_2) and chlorine (Cl_2).

$$Mg + HCl \rightarrow MgCl_2 + H2$$

Step 3: Balance the equation

In a chemical reaction the atoms are rearranged but you end up with the same number of atoms as you started with. So the final step in writing an equation is to make sure that the numbers of atoms of each element are the same on both sides of the equation.

In this case, there is one magnesium atom on each side of the equation, so the magnesium atoms are balanced. There are two hydrogen atoms on the right-hand side but only one on the left. You can balance the hydrogen atoms by putting a 2 in front of the HCl on the left-hand side. This means two molecules of HCl.

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

The 2 refers to every atom in the molecule. So 2HCl means that there are two atoms of H and two atoms of Cl. Now the chlorine atoms are also balanced. Never change formulas to balance an equation. The balancing numbers always go in front of the formulas.

Note that the balancing numbers you use should be the smallest number possible. For example, the equation $2Mg + 4HCl \rightarrow 2MgCl_2 + 2H_2$ is balanced but can be simplified to $Mg + 2HCl \rightarrow MgCl_2 + H_2$.

Equation 2

When you add silver nitrate solution to copper chloride solution (blue) you get a **precipitate** (pre-SIP-it-ate) of white silver chloride. This is an insoluble solid that settles to the bottom of the test tube.

copper chloride + silver nitrate → silver chloride + copper nitrate

$$CuCl_2 + AgNO_3 \rightarrow AgCl + Cu(NO_3)_2$$

To balance the two Cl^- ions on the left-hand side you need to put a 2 in front of AgCl.

$$CuCl_2 + AgNO_3 \rightarrow 2AgCl + Cu(NO_3)_2$$

You then need a 2 in front of the $AgNO_3$ to balance the $Cu(NO_3)_2$ on the right-hand side.

$$CuCl_2 + 2AgNO_3 \rightarrow 2AgCl + Cu(NO_3)_2$$

To check the balancing you can count the numbers of atoms.

Left	Right
Cu 1	Cu 1
Cl 2	Cl 2
Ag 2	Ag 2
N 2	N 2
O 6	O 6

Equation 3

When propane (LPG) burns it reacts with the oxygen in the air to form carbon dioxide and water.

propane + oxygen → carbon dioxide + water

You need to know the formulas for propane, carbon dioxide and water.

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

To balance the carbon atoms you need to add a 3 in front of CO_2.

$$C_3H_8 + O_2 \rightarrow 3CO_2 + H_2O$$

To balance the hydrogens on the left-hand side you then need to add a 4 in front of H_2O.

$$C_3H_8 + O_2 \rightarrow 3CO_2 + 4H_2O$$

This makes 10 atoms of oxygen on the right-hand side. So to balance the oxygens you need to add a 5 in front of O_2 on the left-hand side.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Left		Right	
C	3	C	3
H	8	H	4 x 2 = 8
O	5 x 2 = 10	O	(3 x 2 = 6) + 4 = 10

INQUIRY 5 Balancing Smarties

You will need: large packet of Smarties, molecular models kit (optional)

Would you believe that you can use Smarties to balance equations? Consider this equation:

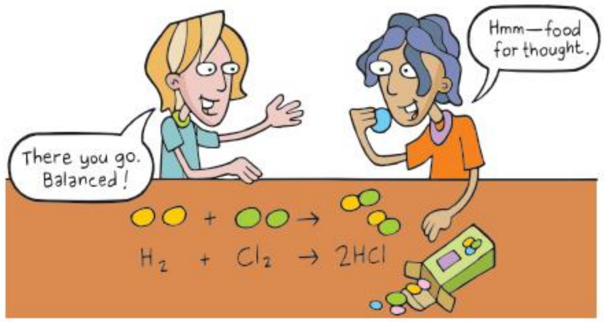
hydrogen gas + chlorine gas → hydrochloric acid

First, write the formulas for the reactants and products:

$$H_2 + Cl_2 \rightarrow HCl$$

Now use the Smarties to make models of the molecules. Decide which colours to use for the various atoms. For example, hydrogen could be represented by a pair of yellow Smarties, chlorine by a pair of green Smarties, and hydrogen chloride by a yellow–green pair. Once you have done this you will see that you will need a second yellow–green pair to balance the equation.

Try this for yourself. Before you break up the Smarties molecules, make sure you have written down the balanced equation. Don't eat the Smarties yet—you still need them.



Here are some other equations you can try to balance using Smarties.

nitrogen (N_2) + oxygen (O_2) → nitrogen dioxide (NO_2)

hydrogen (H_2) + oxygen → water

magnesium + oxygen → magnesium oxide

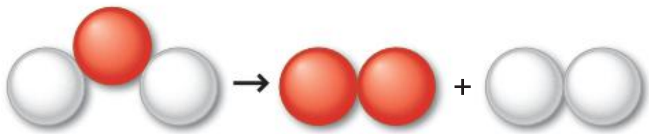
nitrogen + hydrogen → ammonia (NH_3)

If they are available you could use molecular models instead of Smarties.

Over to you

1 Why is it necessary to balance equations?

2 When electricity is passed through water it decomposes (breaks up) into hydrogen gas and oxygen gas. Kye used Smarties to make an equation for this reaction.



a Is this equation balanced? What does Kye need to do to balance it?

b Write the balanced equation.

3 Describe in your own words what happens in the reactions represented by these equations:

a $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$

b $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

4 Write balanced equations for these reactions between two elements to form a compound:

a potassium and iodine to form potassium iodide

b hydrogen and oxygen to form water

c carbon and hydrogen to form methane

d nitrogen and hydrogen to form ammonia

e nitrogen and oxygen to form nitrogen dioxide

5 Balance these equations. No numbers bigger than 2 are needed. (*Note:* Some equations may be balanced already.)

a $NaBr + Cl_2 \rightarrow NaCl + Br_2$

b $Ba(NO_3)_2 + H_2SO_4 \rightarrow BaSO_4 + HNO_3$

c $CaCO_3 \rightarrow CaO + CO_2$

d $H_2 + I_2 \rightarrow HI$

e $CH_4 + O_2 \rightarrow CO_2 + H_2O$

f $AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + Ag$

g $NO + O_2 \rightarrow NO_2$

h $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

6 Write balanced equations for the following reactions.

a Zinc reacts with sulfuric acid (H_2SO_4) to produce zinc sulfate and hydrogen.

b Hydrogen peroxide (H_2O_2) decomposes on heating into water and oxygen.

c Sulfur dioxide burns in oxygen to produce sulfur trioxide.

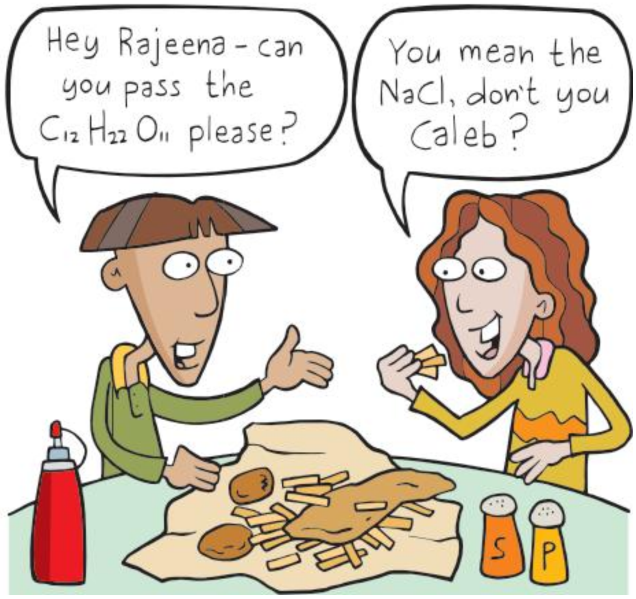
d Sodium reacts with water to produce sodium hydroxide and hydrogen (see Inquiry 1, p. 49).

e Iron reacts with the oxygen in the air to form iron oxide Fe_2O_3 (rust).

f During respiration, glucose ($C_6H_{12}O_6$) reacts with oxygen to produce carbon dioxide and water.

g When heated, table sugar ($C_{12}H_{22}O_{11}$) decomposes to carbon and water.

7 Choose two of the equations from question 6 and draw diagrams of the atoms, molecules and ions to show what is happening.



8 Each of the following equations is incorrect. First check the formulas. Then rewrite the equations correctly and balance them.

a $H + Cl \rightarrow HCl$

b $Cu + O_2 \rightarrow CuO_2$

c $H_2 + F_2 \rightarrow HF + HF$

d $Pb(NO_3)_2 + NaI \rightarrow PbI + Na(NO_3)_2$

e $K + H_2O \rightarrow KOH + H_2$

9 Balance these equations. (The formulas are correct.) You may need to use the numbers 2, 3, 4 or 6.

a $C + Fe_2O_3 \rightarrow Fe + CO$

b $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$

c $HCl + O_2 \rightarrow Cl_2 + H_2O$

d $Al + HCl \rightarrow AlCl_3 + H_2$

e $(NH_4)_2CO_3 + Fe_2(SO_4)_3 \rightarrow Fe_2(CO_3)_3 + (NH_4)_2SO_4$

f $Pb_3O_4 \rightarrow PbO + O_2$

g $KClO_3 \rightarrow KCl + O_2$

h $CH_4 + Cl_2 \rightarrow CCl_4 + HCl$

i $Pb(NO_3)_2 \rightarrow PbO + NO_2 + O_2$

3.5 Predicting precipitates

A colourful precipitate

When you mix lead nitrate and potassium iodide (both colourless solutions), an amazing thing happens. An eye-catching yellow solid is formed (see photograph), which settles to the bottom of the beaker as a precipitate. You can explain what has happened from what you have learnt in this chapter.

Lead nitrate and potassium iodide are both ionic compounds. When they dissolve in water the ionic lattice is broken up. The ions separate and move freely throughout the solution. Lead nitrate $Pb(NO_3)_2$ breaks up to form a lead ion with a double positive charge and two nitrate ions with a single positive charge.

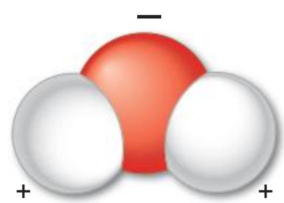
$$Pb(NO_3)_2 \rightarrow Pb^{2+} + 2NO_3^-$$

In the same way, the potassium iodide KI breaks up into K^+ ions and I^- ions.

When the two solutions are mixed, the four ions also mix—a bit like the different coloured Smarties in a box. The ions are constantly moving and bump into each other. The positive ions are attracted by the negative ions and repelled by other positive ions.

This means that the Pb^{2+} ions are attracted to the I^- ions as well as to the NO_3^- ions. The K^+ ions are attracted to the NO_3^- ions as well as to the I^- ions. So there is the possibility that the ions could change partners.

The ions are also attracted to the water molecules. This is because the hydrogen and oxygen in the molecule do not share their electrons equally. The oxygen is greedier for electrons than hydrogen is. As a result, the oxygen atom has a slight negative charge and the hydrogen atoms have a slight positive charge, as shown. This is why water dissolves so many different ionic compounds. It interacts with ions, breaking them apart.



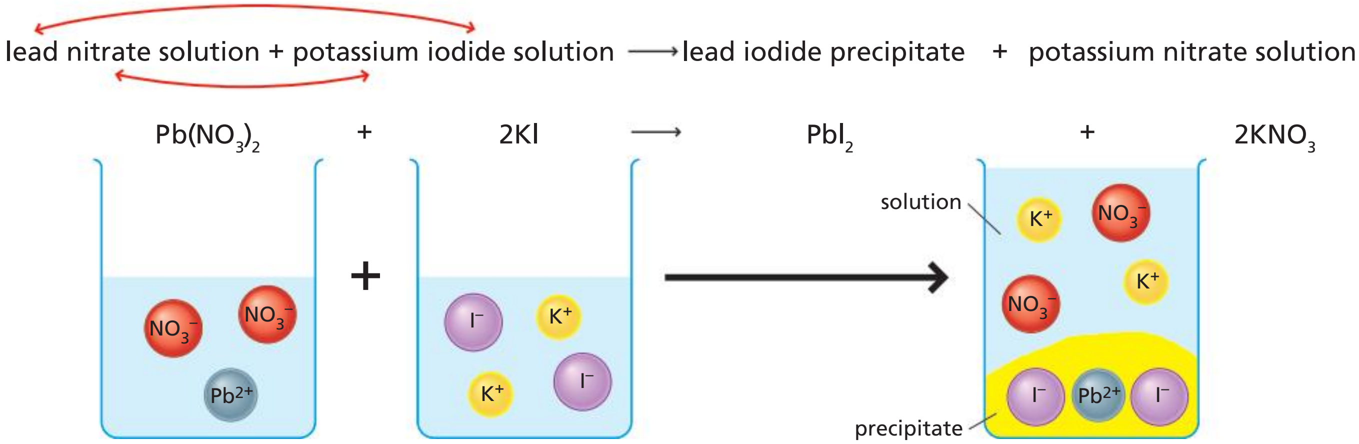
Changing partners

Look at the diagram below showing what happens when you mix lead nitrate and potassium iodide solutions. The ionic compound lead iodide is insoluble in water and forms a precipitate. This is because lead ions are more strongly attracted to iodide ions than they are to nitrate ions or to water molecules. These ions join together to form solid lead iodide. The potassium and nitrate ions are left in the clear solution.

Notice that each Pb^{2+} ion combines with two I^- ions to form PbI_2. Hence, there is a 2 in front of the KI so that there are the same numbers of ions on both sides of the equation.

The equation can be written more simply by showing only the ions that form the precipitate. The ions that do not take part in the reaction are left out. This is called an *ionic equation*.

$$Pb^{2+} + 2I^- \rightarrow PbI_2$$



Solubilities of ionic compounds

Using what you have learnt on the previous page, it is possible to predict whether a precipitate will be formed when two ionic solutions are mixed. If a soluble compound is formed, it will remain in solution. If the compound is insoluble, it will form a precipitate.

1 All ionic compounds containing sodium, potassium, ammonium or nitrate ions are soluble in water. For example, NaCl, K_2SO_4, NH_4Cl and $AgNO_3$ are all soluble.
2 Compounds containing chloride, bromide or iodide ions are soluble, except when they contain Ag^+, Pb^{2+}, Cu^+ or Hg^{2+} ions. For example, $MgCl_2$, NaBr and KI are soluble but AgCl, PbI_2, CuI and $HgBr_2$ are not.
3 Compounds containing sulfate ions are soluble, except for $CaSO_4$, $BaSO_4$ and $PbSO_4$. For example, Na_2SO_4 and $(NH_4)_2SO_4$ are soluble.
4 Compounds containing carbonate ions are generally insoluble, unless they contain Na^+, K^+ or NH_4^+ ions. For example, $PbCO_3$ is insoluble, but Na_2CO_3 is soluble.
5 Compounds containing hydroxide ions are generally insoluble unless they contain Na^+, K^+ or NH_4^+ ions. For example, $Cu(OH)_2$ is insoluble but NaOH and NH_4OH are soluble.
6 Some compounds are *slightly* soluble, for example, $Ca(OH)_2$, $PbCl_2$, $CaSO_4$ and Ag_2SO_4.

INVESTIGATION

1 Predicting and mixing

Aim

To predict whether a precipitate will form when pairs of ionic solutions are mixed, then to test these predictions.

Risk assessment and planning

The solutions you will be using are toxic, especially lead compounds. For this reason you should wear gloves at all times, and wash your hands when you are finished.

The leftover solutions must not be washed down the sink. They must be placed in a clearly marked waste bottle for proper disposal.

Apparatus

- 0.1 M solutions of the following:
  - *ammonium carbonate* $(NH_4)_2CO_3$
  - *barium chloride* $BaCl_2$
  - *copper sulfate* $CuSO_4$
  - *lead nitrate* $Pb(NO_3)_2$
  - *potassium iodide* KI
  - *sodium hydroxide* NaOH

- 2 test tube racks
- white tile and black tile (optional)
- 15 test tubes
- marking pen

Method

Part A: Making your predictions

1 There are six solutions and you will be mixing them two at a time. How many different combinations are there? Write them in your notebook, leaving a space to record your prediction and observation. Number each pair.
2 Look at your first pair of solutions (e.g. ammonium carbonate and barium chloride). The ions can swap partners, as shown on the previous page.

ammonium carbonate + barium chloride ⟶ ammonium chloride + barium carbonate

According to the solubility generalisations above, barium carbonate is insoluble, so you would predict a precipitate.

✱ Consider each pair in this way and record your predictions.

Part B: Testing your predictions

1 Number the test tubes to match your solution pairs from Part A.
2 Mix your first pair of solutions. To do this, add 10 drops of the first solution to a test tube, then 10 drops of the second. If necessary, hold a black or white tile behind the test tube to make it easier to see any precipitate.

✱ Record your observation next to your prediction.

3 Repeat for all the different combinations of solutions.

Results

Check how many of your predictions were correct. If your prediction is wrong, either do the prediction again or mix the two solutions again.

INVESTIGATION

1 continued

Part C: Solving problems

Use what you have learnt in this practical to solve one or more of these problems. Work out what tests you could do to solve the problem using the solutions from Part B, then carry out your tests. Make sure you use the same safety precautions as you did in Part B.

1 You are given three containers labelled A, B and C. The solutions are copper sulfate, sodium chloride and water. Your problem is to work out which is which by adding any of the solutions you used in Part A. For example, copper sulfate reacts with sodium hydroxide to give an insoluble blue precipitate, but nothing happens with sodium chloride.

2 Imagine you are an investigator called out to investigate a suspected poisoning. In the victim's bathroom are three bottles containing colourless liquids. Someone has pulled all the labels off the containers. You test the solutions and find them to be lead acetate (a poison), magnesium sulfate (Epsom salts) and sodium chloride (table salt). The pathologist has given you a sample of fluid from the stomach of the victim. Your problem is to test this sample to see if it contains the poison lead acetate. In other words, how can you test for lead acetate?

3 You have colourless solutions of four different sodium salts—sodium carbonate, sodium chloride, sodium nitrate and sodium sulfate. How can you work out which is which?

4 Imagine you have been captured by terrorists. They are holding you in an abandoned laboratory that was once used to manufacture poisons. You are dying of thirst and the terrorists have given you two containers—one containing water and the other a poisonous substance called mercury nitrate. How can you use the chemicals in the laboratory to identify which container is safe to drink?

5 Design an experiment to test which brand of potato chips is the saltiest, using one of the solutions from Part A.

Over to you

1 Use the solubility generalisations on the previous page to classify the following compounds as soluble or insoluble:

aluminium hydroxide	lead carbonate
ammonium bromide	mercury chloride
barium carbonate	potassium hydroxide
chromium nitrate	silver nitrate
gold sulfate	zinc chloride

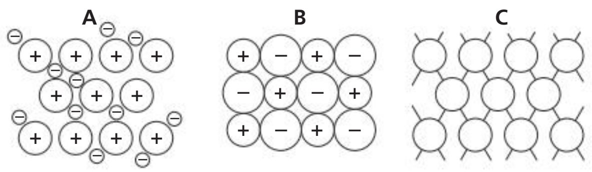
2 Write equations like the one on page 65 to describe what happens when the following ionic compounds dissolve in water:
- **a** copper sulfate $CuSO_4$
- **b** sodium carbonate Na_2CO_3
- **c** aluminium chloride $AlCl_3$
- **d** ammonium sulfate $(NH_4)_2SO_4$

3 What precipitate is formed when the following solutions are mixed?
- **a** silver nitrate and sodium chloride
- **b** copper sulfate and ammonium hydroxide
- **c** calcium nitrate and lithium carbonate
- **d** barium nitrate and sodium sulfate

4
- **a** You want to make some copper carbonate. What two solutions could you mix to do this?
- **b** Write a balanced equation for the reaction.
- **c** Write an ionic equation showing how the copper carbonate is formed.

THINKING SKILLS

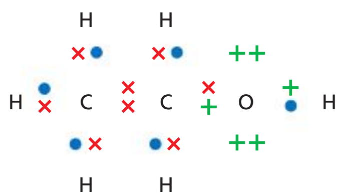
1 Look at the three diagrams below. Which one represents an ionic lattice, which is a covalent lattice and which is a metallic lattice? Explain your answers.



2 A metal M forms many different compounds. For example, it forms an oxide with the formula M_2O_3. Given this information, which of the following formulas are correct?

a M_2SO_4
b $M_2(NO_3)_3$
c M_2Br_3
d MPO_3
e $M(OH)_3$
f M_3S_2

3 The diagram shows the electron arrangement in a molecule of ethanol (alcohol).



a What is the formula for ethanol?

b What do each of the three types of symbols (×, • and +) represent?

c Which type of bonding is present in this molecule?

d How many bonds does each carbon atom form?

4 Why do oxygen and hydrogen exist as diatomic molecules (O_2 and H_2) but helium exists as single atoms?

5 Which type of bonding would you expect to find in the following substances (covalent, ionic or metallic)?

a sodium
b sulfur dioxide
c chlorine
d aluminium
e silicon dioxide
f sodium nitrate
g lithium oxide
h nitrogen dioxide
i silver chloride

6 Elements X and Y form two different compounds with carbon. Their formulas are CX_4 and CY_2.

a Predict the formula of a compound of X and Y. Explain how you worked it out.

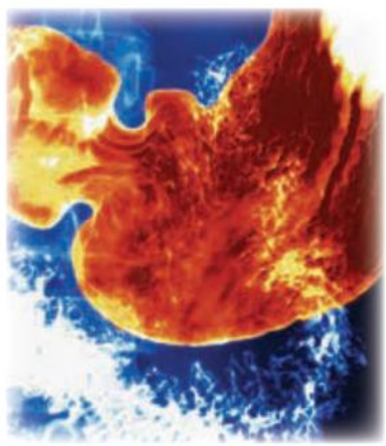
b If carbon forms a compound with both X and Y, what would its formula be?

7 Predict what shapes you would expect the following molecules to have. Draw them.

a Br_2
b H_2S
c PCl_3
d HF
e CCl_4

8 A salt solution conducts electricity but a sugar solution ($C_{12}H_{22}O_{11}$) does not. Use what you have learnt in this chapter to explain the difference.

9 A person with a problem in their digestive tract may be asked to swallow a porridge containing a very insoluble substance called barium sulfate. X-rays cannot pass through this substance and any problem in the digestive tract can be identified.



a Suppose the hospital does not have any barium sulfate. Which two compounds could they mix to make it?

b Suggest why no toxic barium ions are absorbed into the patient's bloodstream.

10 Imagine you are an electron in the outer shell of a sodium atom in a piece of sodium. Describe your experience as the sodium is burnt in a gas jar of chlorine gas.

11 Felicia wants to learn the names of the first 10 or 20 elements in the periodic table. Design a jingle to help her remember them. (A jingle is a sentence or rhyme to help you remember facts; for example, **M**y **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**achos for the planets in the solar system.)

Knowing and Understanding

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

1 The periodic table arranges the elements in order according to the size of their ______. Elements with similar properties are in the same vertical column or ______.

2 The metals are on the left and in the middle of the periodic table, with the ______ on the right.

3 The electrons surrounding the nucleus of an atom are arranged in ______ or energy levels. The number of electrons in the ______ shell determines the chemical ______ of the element.

4 Metals tend to lose electrons to form ______ ions, and non-metals tend to ______ electrons to form negative ions. These positive and negative ions combine to form ______ compounds.

5 When atoms share electrons they form a ______ bond. For example, two oxygen atoms combine to form a ______ with the formula O_2.

6 Metals consist of a lattice of positive ions held together by a 'sea' of ______. This is called a metallic ______.

7 The ______ of an atom is the number of electrons it gains, loses or ______ with other atoms.

8 Chemical equations must be ______, with the same number of each type of atom on each side of the equation.

atoms
balanced
bond
covalent
electrons
gain
group
ionic
molecule
non-metals
outer
positive
properties
shares
shells
valency

Self-management

Chemical riddles

1 Use the clues next to each set of blanks to fill in the missing word. Now transfer the corresponding letters to the numbered blanks at the bottom to give the answer to the riddle.

2 As a group, make up your own chemical riddle based on this chapter. Check through the chapter for important words and use the riddle on the right as a model. Check carefully that you have all the right letters, then try it out on another group.

_ _ _ _ _ _
1 2 3 4 5 6
This atom normally forms four covalent bonds.

_ _ _ _ _ _ _
7 8 9 10 11 12 13
This man won two Nobel Prizes.

_ _ _ _ _
14 15 16 17 18
Number of electrons that atoms like to have in their outer shell.

_ _ _ _
19 20 21 22
A heavy poisonous metal in Group IV.

You sit at one of these on a regular basis.

_ _ _ _ _ _ _ _   _ _ _ _ _
7 20 3 11 5 22 15 1   18 8 4 19 14

Checkpoint

1 Which one of the following substances is an ionic compound?

A copper **C** calcium carbonate
B water **D** carbon dioxide

2 Covalent compounds usually form when:

A non-metals react together.

B metals react together.

C metals and non-metals react together.

D ions are present.

3 Which one of the following is the correct formula for the ionic compound calcium iodide?

A CaI_2 **B** CaI **C** Ca_2I_2 **D** $Ca(I)_2$

4 When hydrochloric acid is added to zinc, hydrogen is produced and zinc chloride is left in solution. Which one of the following is the correctly balanced equation for this reaction?

A $Zn + HCl \rightarrow ZnCl_2 + H_2$

B $Zn + HCl \rightarrow ZnCl + H$

C $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

D $2Zn + 2HCl \rightarrow 2ZnCl_2 + H_2$

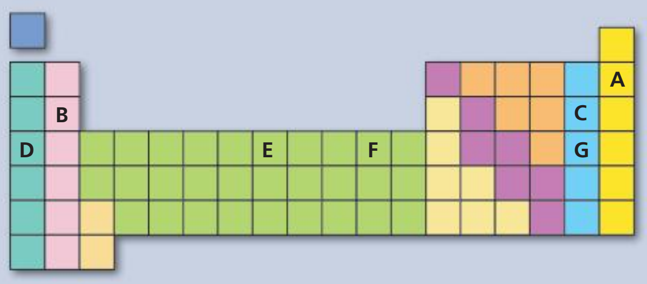
5 The formula for magnesium sulfate (Epsom salts) is $MgSO_4$.

a How many different elements are there in magnesium sulfate?

b Which ions are formed when magnesium sulfate dissolves in water?

c Is magnesium sulfate an ionic or a covalent compound? Explain.

6 This question refers to the outline of the periodic table below. The letters in the table are not the symbols for the elements.



a Which two elements would you expect to have very similar chemical properties? Why?

b Name two elements that are in the same period. Explain your answer.

c Which element is an alkaline earth metal?

d Which element is a very unreactive gas?

e Which two elements are transition metals?

f Which element reacts violently with water?

g Which element has only one electron in its outer shell?

h Name two elements that are likely to react with each other?

7 The table gives the solubility (shown by a tick) of some ionic compounds in water. Use the table to work out which of the following generalisations are true.

Ions	potassium	sodium	calcium	lead
nitrate	✓	✓	✓	✓
chloride	✓	✓	✓	✗
sulfate	✓	✓	✗	✗
carbonate	✓	✓	✗	✗

a All carbonates are soluble.

b All compounds are soluble when they contain nitrate ions.

c All calcium compounds are insoluble.

d Lead compounds are insoluble except for lead nitrate.

e Calcium sulfate often forms a precipitate.

8 Calcium chloride and sodium hydroxide react to form calcium hydroxide and sodium chloride.

a Write a word equation for this reaction.

b Write an equation using the formulas for each substance.

c Add numbers in front of the formulas if necessary to balance the equation.

9 Lead nitrate solution $Pb(NO_3)_2$ is mixed with sodium carbonate Na_2CO_3.

a Which ions would be in the mixture?

b Would a precipitate be formed? Explain.

c Write a balanced equation for the reaction you predict.

10 These diagrams represent the electrons in the outer shells of carbon and hydrogen. Use them to explain how covalent bonds are formed to hold a molecule of methane (CH_4) together.
Draw an electron dot formula.

4 Using chemistry

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

Science Understanding

- describe how chemistry has been used to make a range of useful things, e.g. fireworks, matches, pure copper and batteries
- use equations to represent the loss or gain of electrons in chemical reactions
- investigate the chemical reactivity of metals
- use flow diagrams to show how materials such as sodium chloride are manufactured

Science as a Human Endeavour

- debate how serious a threat dioxin is to our health

Science Inquiry Skills

- suggest ways of improving an experiment to compare the reactivity of metals

LITERACY FOCUS

activity series	electrochemical cell	fuel cell	properties
anodise	electrodes	fuels	redox reaction
corrosion	electrolysis	galvanising	reduction
dioxin	electrolyte	oxidation	sacrificial protection
displacement reaction	electroplating	phosphorus	sublimation

Focus for learning

The materials we use are made using a knowledge of chemistry. For example, the oxygen given to accident victims is manufactured by heating liquefied air to evaporate the nitrogen. A match burns when struck because the side of the matchbox contains phosphorus. Electricity is used to electroplate jewellery with gold or silver, or to make aluminium cooking foil from bauxite ore. Batteries contain chemicals that react together to produce electricity.

Objects being lowered into an electroplating vat

Accident victim recieving oxygen

PROBLEM SOLVING

Researching a substance

As you work through this chapter you will find examples of many different substances that people use at some time during their lives. These substances may be very common, such as carbon dioxide, which is used to make soft drinks fizzy, or they may be new materials with unusual properties. For example, Australian coral is being used to make artificial eyes, and polymers are being used to make medical implants, such as heart valves.

Your chapter problem is to select a substance, research it in detail, and write a report. You can find information on new materials in science magazines such as *The Helix* (CSIRO) or *Australasian Science* (Control Publications). You may even be able to design controlled experiments to explore the properties of your substance. Present your findings in a well-organised and well-presented report.

This report must:

- give details of how the substance is made (e.g. chemical equations for any reactions)
- describe the properties of the substance
- relate the uses of the substance to its properties
- describe the production, uses and impact on society of your chosen substance.

Australian coral is being used to make artificial eyes.

4.1 Everyday gases

INVESTIGATION

1 Making hydrogen gas

Aim

To make and test hydrogen gas (H_2).

Risk assessment and planning

Read the skill carefully before you start so that you know exactly what you have to do. What hazards could there be?

Apparatus

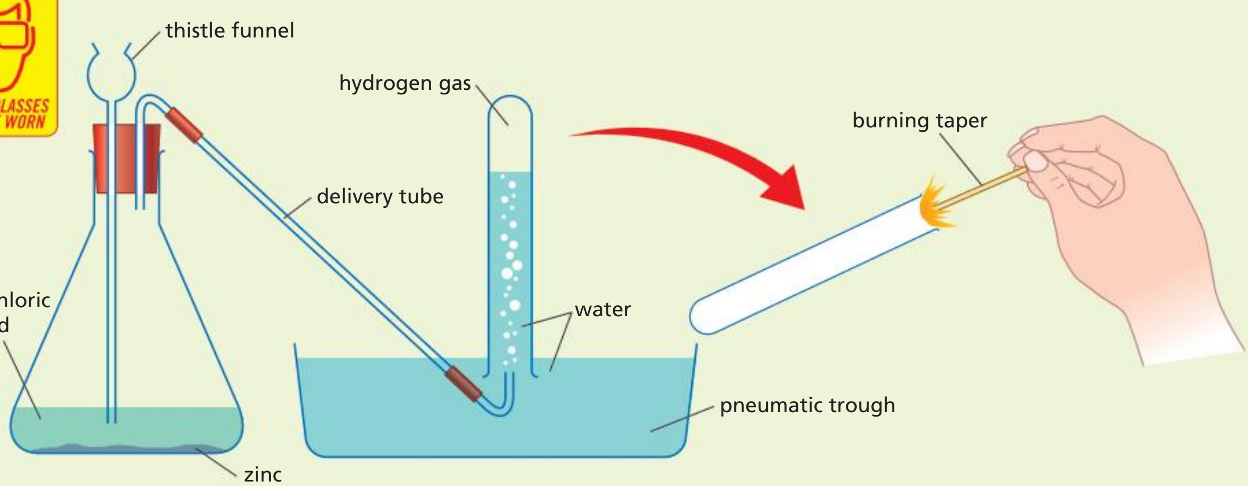
- *dilute hydrochloric acid (2 M)*
- conical flask (e.g. 250 mL)
- two-holed stopper fitted with thistle funnel and delivery tube
- pneumatic trough or large ice-cream container
- taper and matches
- 3 test tubes
- zinc
- large metal lid
- detergent

Method

1. Half fill the pneumatic trough with water. Lie two test tubes in the trough so that they fill with water. You will use these to collect the hydrogen gas you make.
2. Put a few pieces of zinc in the flask.
3. Carefully fit the two-holed stopper into the flask. Put the delivery tube under one of the test tubes full of water, as shown.
4. Add dilute hydrochloric acid to the thistle funnel until the zinc and the bottom of the thistle funnel tube are covered with acid.
5. Collect a test tube of gas but do not use it since it may contain air from the flask.
6. Collect a second test tube of gas, take it away from the apparatus, tilt it slightly upwards as shown and immediately put a burning taper near its mouth.
   - What happens?
   - What do you notice on the inside of the test tube?
7. Your teacher will demonstrate what happens when you bubble hydrogen gas into a large metal lid filled with water containing detergent, then light the bubbles of hydrogen.

Results

1. What colour is hydrogen gas?
2. How do you know that the hydrochloric acid (HCl) reacted with the zinc?
3. Write a word equation for the reaction that occurred in the flask. You know one of the products but you will need to infer what the other one is.
4. Write a balanced symbol equation.
5. Why do you think you tilted the test tube upwards before bringing the burning taper near its mouth? Is hydrogen lighter than air or heavier than air?
6. How can you explain the presence of water inside the test tube after you 'pop' the hydrogen? What does the hydrogen react with?
7. Write a balanced equation for the reaction that occurs when hydrogen explodes when mixed with oxygen.



Uses of hydrogen

The sun and other stars are mainly made up of hydrogen, and it is thought that hydrogen makes up about 90% of the total universe. Hydrogen atoms are the smallest of all atoms, and hydrogen is 15 times lighter than any other substance. This is why it was used in the early airships, such as the *Hindenberg*. It is still used today to fill weather balloons, but modern airships use helium because it is not flammable. In the presence of a flame, hydrogen reacts so rapidly with the oxygen in the air that it explodes, producing water.

hydrogen + oxygen → water

$$2H_2 + O_2 \rightarrow 2H_2O$$

Hydrogen is used in the rockets of the space shuttle and in oxy-hydrogen flames for cutting and welding steel under water. It is also used in the manufacture of ammonia, which in turn is used to produce fertilisers. The hydrogen combines with nitrogen at high temperatures in the presence of a catalyst.

nitrogen + hydrogen → ammonia

$$N_2 + 3H_2 \rightarrow 2NH_3$$

When liquid vegetable or animal oils are heated in the presence of hydrogen, solid fats are produced. These can then be converted to soap, candles or margarine.

INVESTIGATION

2 Making carbon dioxide

Aim

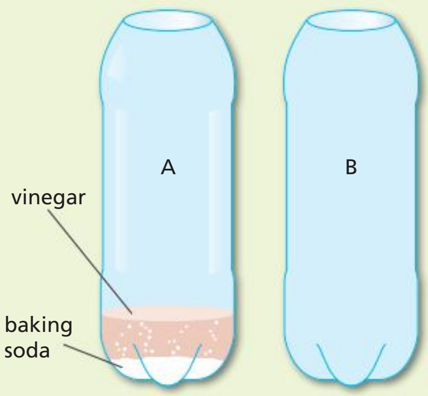
To investigate the properties of carbon dioxide gas (CO_2).

Risk assessment and planning

Read the investigation and do a risk assessment.

Apparatus

- two 2 L soft drink bottles with their tops cut off, as shown
- taper and matches
- baking soda
- vinegar
- marking pen
- tablespoon
- cup



Method

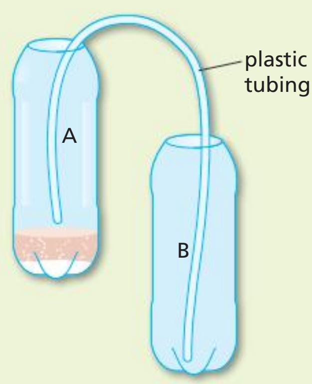
1 Label the two bottles A and B.
2 Put two tablespoons of baking soda into bottle A, then add half a cup of vinegar. Allow a minute or so for the reaction to finish.
3 Light the taper and lower it into bottle B. What happens?
4 Now lower the lit taper into bottle A. What happens now?
   * How can you explain your observations in steps 3 and 4?
5 Pick up bottle A and pour the invisible CO_2 gas into bottle B. Be careful not to pour out any of the liquid. The curved rim on the top of the bottle should hold the liquid back.
6 Light the taper again and test bottle B, then bottle A. Were you successful in pouring all the CO_2 from one bottle to the other?

Results

1 What colour is the CO_2 gas?
2 What is the test for CO_2?
3 Is CO_2 lighter or heavier than air? How do you know?
4 Baking soda is sodium hydrogen carbonate $NaHCO_3$ and vinegar is dilute acetic acid CH_3COOH. These react to produce sodium acetate $NaCH_3COO$, water and CO_2. Write a symbol equation for this reaction. Balance it if necessary.

Challenge

Is it possible to siphon CO_2 from bottle A to bottle B as if you are siphoning water? Put the tube just above the liquid in bottle A and suck briefly on the other end to get the gas flowing. Then quickly put the end of the tube into bottle B, as shown. Test to see if there is CO_2 in bottle B.



Uses of carbon dioxide

Carbon dioxide makes up a tiny part of the atmosphere—a bit less than 0.04%. Green plants use huge amounts of carbon dioxide in the process of photosynthesis. You breathe out carbon dioxide produced in your bodies during the process of respiration. Carbon dioxide is also produced by power stations that burn coal and by cars that burn petrol, diesel or gas. Because of the carbon cycle, the amount of carbon dioxide in the world stays about the same. However, in recent years the carbon cycle has not been able to keep up with the extra carbon dioxide released. Many scientists believe this excess carbon dioxide is causing global warming, due to the enhanced greenhouse effect.

Carbon dioxide is used in drinks to produce bubbles. It is dissolved in the drink at high pressure and comes out of solution as bubbles when the bottle or can is opened. It gives the drink its tangy taste. After drinking a fizzy drink, it is the carbon dioxide in a burp that burns the back of your nose.

Bubbles of carbon dioxide released from a soft drink

In cakes, self-raising flour is used to produce the many small bubbles of carbon dioxide gas that make the cake rise. In bread, yeast is used to produce carbon dioxide.

Solid carbon dioxide, or dry ice, is used as a refrigerant. It changes directly from a solid to a gas without going through the liquid phase. This is called *sublimation*. If you drop it into hot water a 'fog' is produced, which is sometimes used on stage or in television shows for an eerie effect.

Carbon dioxide has two important properties. Things will not burn in it, as you saw in Investigation 2 on the previous page. It is also much heavier than air so it sinks to the ground. This is why carbon dioxide is used in some fire-extinguishers, especially for electrical fires. It forms a gaseous blanket over the fire and stops air getting to it.

Using a carbon dioxide fire-extinguisher

Over to you

1 Copy and complete these sentences.
   - **a** Hydrogen is used in balloons because it is ______ than air.
   - **b** Hydrogen can be made by adding hydrochloric acid to ______.
   - **c** Plants use carbon dioxide gas for______.
   - **d** Humans breathe in ______ and breathe out ______.
   - **e** The gas that is sometimes used to put out fires is ______.
   - **f** The gas that goes 'pop' when a lighted taper is placed in it is ______.

2 Give three uses for each of the gases hydrogen and carbon dioxide.

3 Predict what would happen if you put a glowing splint into a bottle full of carbon dioxide.

4 You have a test tube containing a colourless, odourless gas. How could you test whether it is hydrogen or carbon dioxide?

5 Why does a bottle of soft drink go 'flat' if it is left open?

6 You are given three balloons inflated to the same size. One contains oxygen, one contains hydrogen and the third contains carbon dioxide. Without testing the gases, how could you work out which gas is in each balloon?

7 Another way of making carbon dioxide is to add hydrochloric acid to marble chips (calcium carbonate $CaCO_3$). Work out the products of this reaction and write a balanced equation.

4.2 Metal reactions

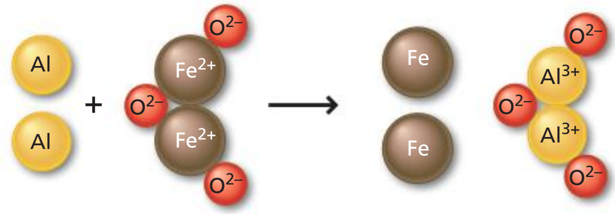
Imagine a scene from a movie in which revolutionaries attack an embassy and search the ambassador's office, looking for secret documents. They find a filing cabinet marked 'top secret' but as they open the top drawer it bursts into flames. The filing cabinet is destroyed by blinding heat, hot enough to melt steel.

Believe it or not, such a spectacular reaction can occur, but how? It is a simple reaction between aluminium powder and iron oxide (rust). It is called the *thermite reaction*. The reaction is very exothermic, which means it produces large amounts of heat and light. In fact, it can produce temperatures as high as 2200 °C. Since the melting point of iron is 1530 °C, the iron produced in the reaction is molten!

The thermite reaction is used to weld lengths of railway track together. A ceramic mould is placed around the gap between the tracks and the aluminium and iron oxide are placed in a large crucible above the gap. The reaction creates a crucible full of molten iron, which flows into the gap and welds the tracks together.

The thermite reaction is used to weld railway tracks.

The thermite reaction is an example of a **displacement reaction**. The aluminium is much more reactive than iron. It breaks up the iron oxide compound and captures the oxygen, as shown top right. As it does this, it frees the iron metal from the compound.



aluminium + iron oxide → iron + aluminium oxide

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

The more reactive metal *displaces* or pushes out the less reactive metal and takes its place. The reaction is a bit like what happens when an old lady carrying a handbag containing money is attacked by a robber. The robber is more powerful and the bag is displaced from the old lady to the robber.

old lady with money + robber → old lady + robber with money

The thermite reaction is too dangerous for you to do, but you can try Inquiry 1.

INQUIRY 1 *Silver crystals*

You will need: test tube and rack, silver nitrate solution, 15–20 cm copper wire, pencil

1. Three-quarters fill the test tube with silver nitrate solution. **Be very careful not to spill it as it stains hands, clothing and benches**.
2. Twist the copper wire around a pencil to make a spiral, with a long piece left over to make a hook. Put it in the test tube, hooking it over the lip of the test tube so you can lift it out later.
3. Leave the test tube in a dark cupboard overnight. In the morning observe what has happened.
   - What new substances have been formed?
   - Write a word equation for the reaction that has occurred, then wrote a balanced symbol equation.

   You could also try adding steel wool (iron), zinc or magnesium to copper sulfate.

INVESTIGATION

3 *Reactivity of metals*

Aim

To compare the reactivity of some metals by measuring the rate at which they produce hydrogen gas when they react with hydrochloric acid.

Risk assessment and planning

Read the investigation carefully before starting and do a risk assessment. Then design a suitable data table to record your results. One person in your group will need to be the timer and another will record the results. You must collect and record the data carefully or you will not be able to make a reliable conclusion from the experiment.

Apparatus

- 5 cm strips of aluminium, copper, iron, magnesium and zinc (all the same width)
- retort stand and clamp
- *dilute hydrochloric acid (2 M)*
- steel wool
- 250 mL conical flask
- two-holed stopper fitted with thistle funnel and delivery tube
- pneumatic trough or large ice-cream container
- stopwatch or clock with second hand
- two 50 mL measuring cylinders

Method

1 Use steel wool to clean each of the metal strips.

2 Set up the apparatus as shown. Clamp a measuring cylinder full of water upside down over the end of the delivery tube in the pneumatic trough. Put the first metal strip in the flask.

3 Measure out 50 mL of hydrochloric acid and add it to the thistle funnel. Start timing immediately.

4 Record the volume of hydrogen gas in the measuring cylinder every 30 seconds until gas is no longer produced, the cylinder is full or 10 minutes has passed, whichever comes first.

5 Repeat the procedure with the other metals, emptying the flask each time and rinsing it with water.

Results

1 Plot the results for all the metals on one set of axes, clearly labelling the line for each metal. Which is the independent variable and which is the dependent variable?

2 What patterns can you see in the graphs?

3 Write balanced equations for the reaction of each metal with hydrochloric acid.

4 Write a *general* word equation for the reaction of a metal with an acid.

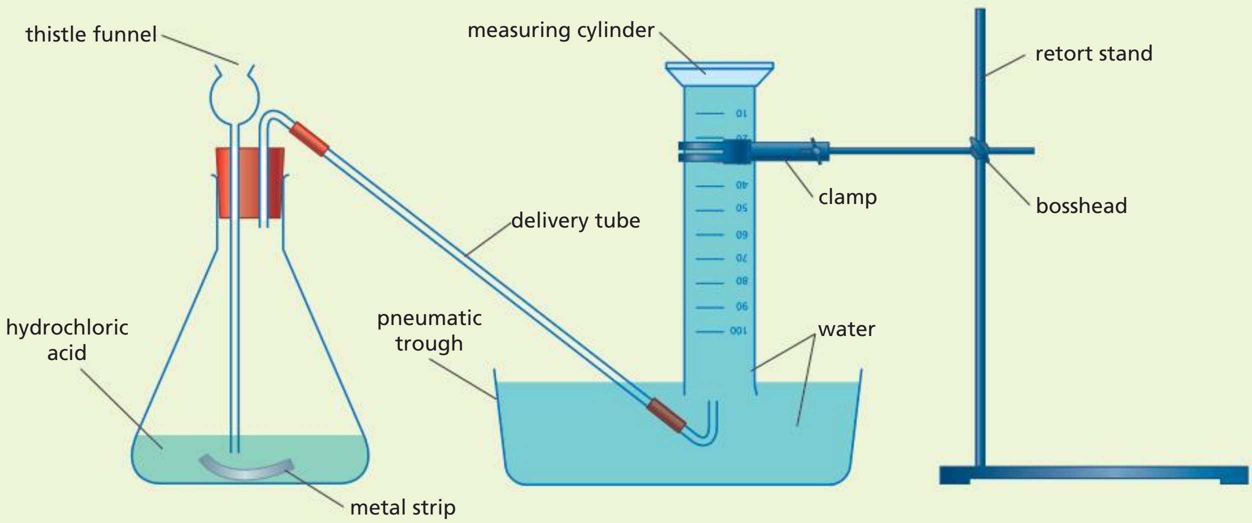
Discussion

1 Were there any variables in the experiment that were not properly controlled? How could this affect the results?

2 If you were repeat the experiment, how could you improve it?

Conclusion

From your experiment, list the metals you investigated from the most reactive to the least reactive.



The activity series

Chemists have arranged the metals in a list, from the most reactive to the least reactive. This is called the **activity series**. Do your results from Investigation 3 on the previous page agree with this?

potassium	K
sodium	Na
calcium	Ca
magnesium	Mg
titanium	Ti
aluminium	Al
zinc	Zn
iron	Fe
tin	Sn
lead	Pb
copper	Cu
silver	Ag
gold	Au

The activity series of metals

You can use the activity series to predict what will happen in reactions involving metals and metal solutions. The more reactive metal will always displace the less reactive metal. For example, in Inquiry 1 the copper displaced silver from a silver nitrate solution because copper is above silver in the activity series.

The activity series can be likened to a table that shows the positions of the teams in a sporting competition. A team near the top of the table will most likely beat a team near the bottom of the table.

Displacement reactions are used in industry. For example, titanium metal is extracted from titanium dioxide TiO_2 (rutile), which is separated from mineral sands. First the TiO_2 is converted to $TiCl_4$. When magnesium is added to $TiCl_4$, it displaces the titanium metal because it is more reactive than titanium. Titanium is used to make very strong alloys that are used in aeroplanes, nuclear reactors and replacement hip joints.

titanium chloride + magnesium → titanium + magnesium chloride

$$TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$$

Over to you

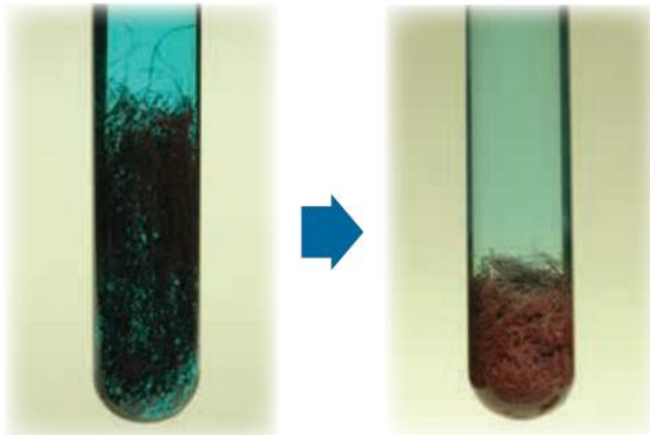
1 Arrange these six metals in order from most reactive to least reactive: aluminium, copper, gold, magnesium, silver, sodium.

2 Which metals are more reactive than lead but less reactive than zinc?

3 Pieces of iron are placed in four test tubes, each of which contains one of these solutions:
- silver nitrate
- sodium chloride
- magnesium chloride
- lead nitrate

In which test tubes will a reaction take place? Explain your answers.

4 When steel wool (which is mainly iron) is added to copper sulfate it becomes coated with an orange–red substance, and the solution turns green. Use what you have learnt in this section to explain what has happened. Write an equation for the reaction.



5 Which metals could be used to recover gold from a solution? Explain your answer.

6 Kimberley is trying to identify unknown metal X. When she puts it in zinc sulfate solution there is a displacement reaction and tiny bits of zinc fall to the bottom of the test tube. When she puts it in magnesium chloride, nothing happens.

a What is metal X? Give two suggestions.

b How could Kimberley find out which of these metals X is?

7 Saneel wants to put metals A, B, C and D in order of reactivity. To do this he adds them to solutions of compounds containing the four metals. His results are shown opposite. Put the four metals in order from most reactive to least reactive.

Solution of compound	Metal			
	A	B	C	D
A	—	✗	✓	✓
B	✓	—	✓	✓
C	✗	✗	—	✗
D	✗	✗	✓	—

4.3 Burning and rusting

Combustion

When things burn they combine with the oxygen in the air. The charcoal you burn in a barbecue is carbon. When it burns it combines with oxygen to form carbon dioxide. This process is called *combustion*.

$$\textbf{carbon} + \textbf{oxygen} \rightarrow \textbf{carbon dioxide} + \text{HEAT}$$
$$C + O_2 \rightarrow CO_2 + \text{HEAT}$$

You need a firelighter to start the charcoal burning, but once burning it produces enough heat to cook the meat. Many combustion reactions produce hot gases, which are usually seen as flames as they burn.

Substances that can burn are called *fuels*. Most fuels are compounds of carbon and hydrogen. When they burn they produce carbon dioxide and water vapour. For example, the natural gas used in kitchen stoves and Bunsen burners is methane (CH_4).

$$\textbf{methane} + \textbf{oxygen} \rightarrow \textbf{carbon dioxide} + \textbf{water} + \text{HEAT}$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{HEAT}$$

Car engines work by the combustion of petrol, diesel or LPG (liquid petroleum gas) in the cylinders. A mixture of air and fuel is drawn into each cylinder and ignited by a spark from the spark plug. The fuel reacts rapidly with oxygen in the air. The resulting explosion pushes the piston, which turns the drive shaft. The products of the reaction, carbon dioxide and water vapour, leave the engine through the exhaust pipe. Carbon monoxide (CO) is also formed because there is not enough oxygen in the cylinders to convert all the fuel to carbon *di*oxide (CO_2). This is called *incomplete combustion*. It also occurs when you use a yellow Bunsen burner flame and everything gets covered in soot (carbon).

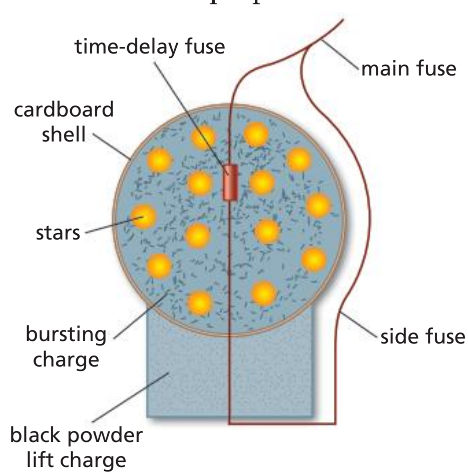
The main engines of the space shuttle use the combustion reaction between liquid hydrogen and liquid oxygen.

$$\textbf{hydrogen} + \textbf{oxygen} \rightarrow \textbf{water}$$
$$2H_2 + O_2 \rightarrow 2H_2O$$

Fireworks

The beautiful colours of fireworks are caused by an exploding shell launched high into the sky. The cardboard shell contains many little black balls called stars. These contain the chemicals that produce the different colours. For example, the white colours are due to the metals aluminium and magnesium burning at about 3000 °C. The gold colours are due to iron and charcoal burning at a lower temperature. The other colours are produced by adding small amounts of other metals. For example, barium produces a green colour, copper produces blue and strontium produces red. The stars are surrounded by a bursting charge—a powder containing a fuel and an *oxidiser*, which supplies the oxygen needed for combustion. At the bottom of the shell is a compartment that contains the black powder (gunpowder) lift charge.

To set off the fireworks, the shell is placed in a plastic cylinder and the main fuse is lit at the top. This burns and lights the side fuse that ignites the lift charge at the bottom. This propels the shell high into the sky, where the time-delay fuse ignites the bursting charge in the shell. The stars then ignite, sending colours across the sky as the various metals burn.



SCIENTISTS AT WORK

Matches

On the side of every matchbox you will find the element phosphorus. In 1669 a German alchemist named Hennig Brandt was trying to convert a common material into gold. He collected a large amount of human urine and evaporated it until he was left with a solid. When he heated this solid in a furnace it began to glow! A shining liquid dripped out, igniting spontaneously when it contacted air. It was not gold that he had discovered but white phosphorus. This reacts dramatically with oxygen in the air:

phosphorus + oxygen → phosphorus oxide + HEAT

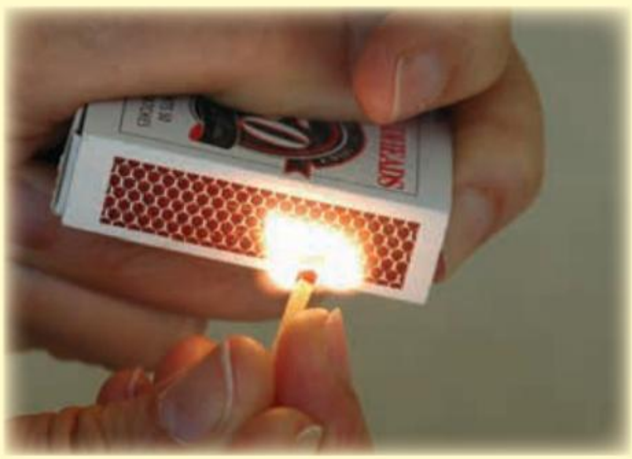
$$P_4 + 5O_2 \rightarrow P_4O_{10} + \text{HEAT}$$

After the discovery of white phosphorus there were reports of people painting their faces and hands with it so that they would glow in the dark. But it is doubtful if anyone tried this more than once since it produces painful burns. In the Sherlock Holmes story *The Hound of the Baskervilles*, a large dog is coated with phosphorus, making it appear like a ghost. Of course, the movie makers did not actually use phosphorus to make the dog glow.

Not long after white phosphorus was discovered, the British chemist Robert Boyle coated a piece of paper with phosphorus and a small stick of wood with sulfur. When he rubbed the stick across the phosphorus-coated paper, enough heat was produced to start a fire. This was the first match, but it was not practical because white phosphorus ignites spontaneously in air. Another early invention involved coating the end of a stick with a paste of sugar and potassium chlorate (an oxidiser), then dipping it into concentrated sulfuric acid. This was also impractical because sulfuric acid is so corrosive.

In 1827 John Walker, an English pharmacist, invented a match that could be struck on any rough surface. He mixed potassium chlorate with antimony sulfide and coated a splint of wood with it. When he struck it, the splint burst into fire. However, the reaction produced the gas sulfur dioxide (SO_2). These bad-smelling matches made a loud bang when lit and were called *lucifers* after Lucifer the Devil. Eventually a small amount of white phosphorus was added to the mixture on the tip of the match. This got rid of the loud bang but the matches were very unstable. They could ignite if exposed to sunlight or even if the box was shaken.

In 1844 another form of phosphorus, called red phosphorus, was discovered. It does not ignite spontaneously in air. In today's matches this red phosphorus is glued to the side of the box, where it is converted to white phosphorus when the match is struck. The white phosphorus ignites spontaneously and starts another chemical reaction with the sulfur and potassium chlorate on the match head.



INQUIRY 2 **Fire writing**

Teacher demonstration

You will need: saturated solution of sodium nitrate, small paintbrush, sheet of paper, pencil, wooden splint, matches, 2 retort stands

1. Dip the small paintbrush in the sodium nitrate solution and use it to write a message or draw a picture on the paper. Trace it several times. The letters or the parts of the picture must all link up.
2. Put a pencil mark at the start of the message or picture and leave the paper to dry.
3. Suspend the sheet of paper between the retort stands. Light the wooden splint, then blow it out so its end is glowing. Touch the glowing splint to the start of the message until the treated paper starts to glow and char. Then stand back and watch.
   - Try to explain how the fire writing worked. (*Hint:* sodium nitrate is an oxidiser. On heating it breaks into two simpler substances. This reaction is called **decomposition**.)

sodium nitrate → sodium nitrite + oxygen

$$2NaNO_3 \rightarrow 2NaNO_2 + O_2$$

Respiration

Respiration occurs in the cells in your body. It is a slow combustion reaction that releases energy from the food you eat. During respiration the glucose in digested food reacts with the oxygen you breathe in. The products of this reaction are carbon dioxide, water and energy.

glucose + oxygen → carbon dioxide + water + ENERGY

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

Oxidation and reduction

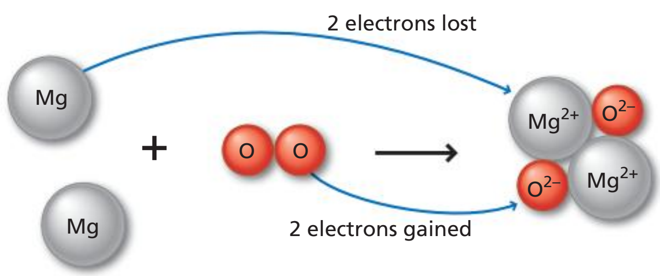
During combustion substances combine with oxygen in the air. This process is called **oxidation**. For example, magnesium burns in air with a brilliant white flame to produce a white powder of magnesium oxide.

magnesium + oxygen → magnesium oxide

$$2Mg + O_2 \rightarrow 2MgO$$

Burning magnesium

During this reaction each magnesium atom loses two electrons to form a magnesium ion (Mg^{2+}). So oxidation is a loss of electrons. At the same time, each oxygen atom in the oxygen molecules gains two electrons to form an oxide ion (O^{2-}). This gain of electrons is called **reduction**. So one reactant loses electrons and the other gains electrons.



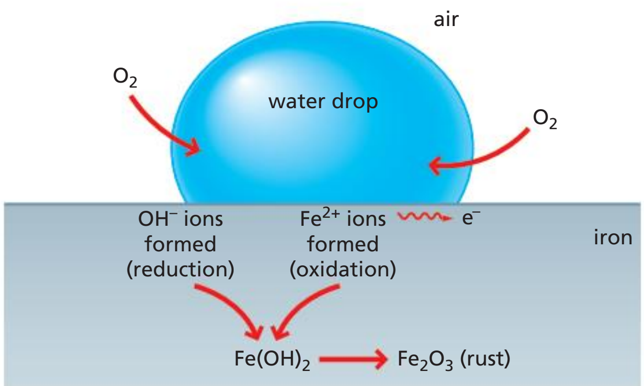
Oxidation and reduction always occur together, so the two words *red*uction and *ox*idation are combined to form the word *redox*. In **redox reactions** electrons are transferred from one reactant to the other.

Use this memory aid to help you remember what happens in redox reactions:

- **O**xidation **I**s **L**oss of electrons—**OIL**
- **R**eduction **I**s **G**ain of electrons—**RIG**

Rusting of iron

Corrosion is a redox reaction that occurs when a metal reacts with air and water. When iron corrodes the process is called *rusting*. Imagine a drop of water on a piece of iron. Near the centre of the drop the iron atoms lose electrons to become positive ions (Fe^{2+}). This is oxidation, which can be shown by an ionic equation, where e^- represents an electron.



The electrons released flow across the surface of the iron to the edges of the drop. Here there is a high concentration of dissolved oxygen, and the oxygen molecules gain electrons to form hydroxide ions (OH^-). This is reduction.

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

The iron ions and the hydroxide ions then combine to form iron hydroxide $Fe(OH)_2$, which then forms iron oxide Fe_2O_3, which is rust. The overall reaction for rusting is:

iron + oxygen → iron oxide

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

An old truck rusting

INVESTIGATION

4 Corrosion of iron

Aim

To investigate the corrosion of iron and how it can be prevented.

Risk assessment and planning

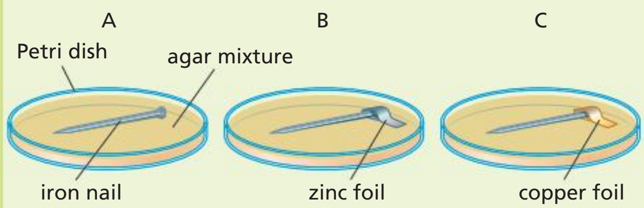
Read the investigation and do a risk assessment.

Apparatus

- 0.5 M potassium ferricyanide
- agar powder
- sodium chloride
- phenolphthalein
- 3 Petri dishes
- 250 mL beaker
- heating equipment
- 3 clean, bright nails
- strip of zinc foil
- strip of copper foil

Method

1. Dissolve about 3 g of agar and 1 g of sodium chloride in 100 mL of water by warming the mixture gently.
2. While the mixture is warm add 1 mL of potassium ferricyanide (to test for Fe^{2+} ions) and 10 drops of phenolphthalein (to test for OH^- ions).
3. Put one of the nails in dish A. Fold the strip of zinc tightly around the head of a second nail as shown and put it in dish B. Repeat this with the copper strip for dish C.



4. Cover the nails completely by pouring the agar solution over them. Do not move the dishes until the agar sets to a gel.
5. Leave the Petri dishes for one or two days. The water in the agar will cause rusting.

   Observe and record what happens.

Results

1. Draw a diagram for each Petri dish. You could take photographs. A blue colour indicates the presence of Fe^{2+} ions where oxidation has occurred, causing corrosion. Pink indicates the presence of OH^- ions where reduction has occurred.
2. Did the zinc strip stop the iron corroding? What about the copper strip?

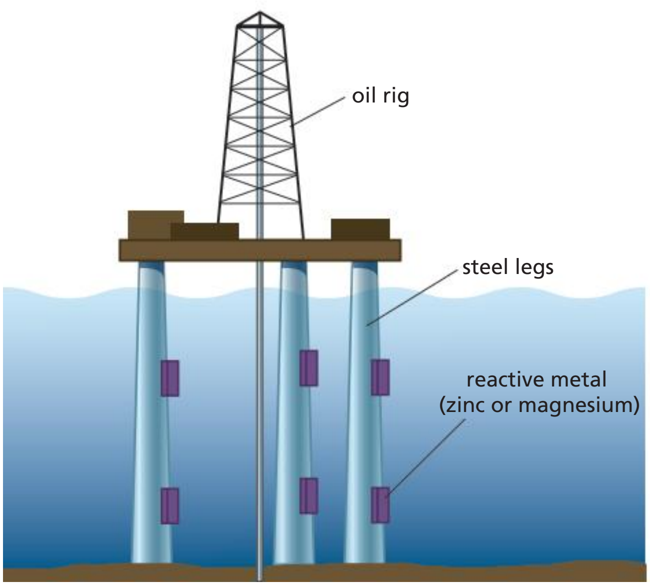
Slowing down corrosion

To slow down the rusting of iron and steel you need to keep air and water away from them. A simple way to do this is to paint the object, as is done with car bodies, ships' hulls, bridges and iron railings. A layer of oil will also protect iron (e.g. on a bicycle chain). The iron can also be coated with plastic. This is sometimes done with outdoor furniture.

You can also coat the iron with a layer of another metal. For example, tin cans are made of steel that has a thin coating of tin. Tin is less reactive than iron and corrodes very slowly. It stops air and water coming into contact with the iron and protects the iron from acids in the canned food.

Another way to protect iron from rusting is to coat it with a layer of zinc. This is called *galvanising*. Zinc is a more reactive metal than iron. So in the presence of air and water the zinc corrodes, leaving the iron unaffected. Many building materials are made from galvanised iron (see photograph top right).

The iron or steel does not need to be completely covered by zinc, as you found in Investigation 4. When you wrapped a piece of zinc around the iron nail, the zinc corroded but the iron did not. This is because zinc is more reactive than iron. This process is called *sacrificial protection* because the reactive metal sacrifices itself to save the iron. The hulls of ships and offshore oil and gas platforms are protected in this way.



The blocks of reactive metal on the legs of this oil platform prevent them from rusting. The reactive metal corrodes and has to be replaced regularly.

This roof is made from Colorbond® steel coated with a zinc–aluminium alloy and painted.

Over to you

1 Which two substances cause rusting?

2 List five different ways in which a metal can be prevented from corroding.

3 What is the process of galvanising? How does this prevent iron from rusting?

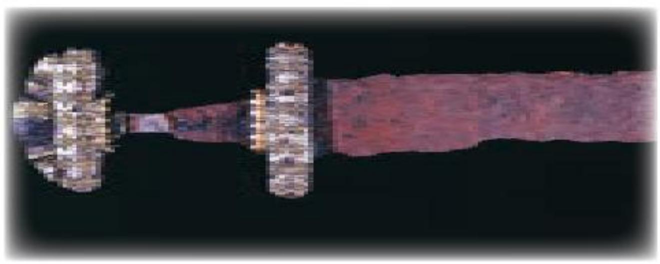
4 What is the fuel in the combustion reaction that takes place in every cell in your body?

5 Explain why reduction and oxidation always occur together. Give an example.

6 Suggest why the steel used to make food cans is coated with tin rather than zinc.

7 Spacecraft must carry a supply of liquid oxygen for the engines, as well as fuel. Why?

8 Look at this photograph of a Viking sword. Why is the gold and silver handle in good condition, yet the iron blade is badly corroded?



9 An engineer wants to protect an offshore oil platform from rusting. To do this she wants to attach blocks of another metal to the steel legs. She is considering three different metals—lead, magnesium and zinc. Which would be the best metal to use? Why?

10 Consider the thermite reaction (p. 76):

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

a Which metal loses electrons?

b Which metal gains electrons?

4.4 Batteries

INVESTIGATION

5 Making a battery

Aim

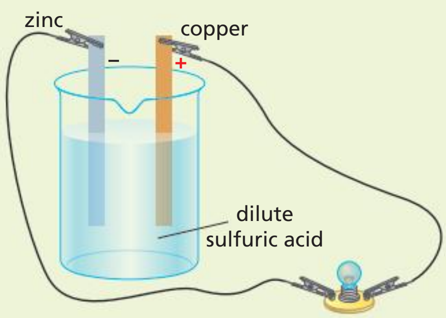
To use a chemical reaction to generate electricity.

Risk assessment and planning

What precautions will you need to take?

Apparatus

- *dilute sulfuric acid (2 M)*
- 2 connecting wires with crocodile clips
- ammonium dichromate
- 250 mL beaker
- 1.5 V torch bulb in holder
- zinc strip
- copper strip
- voltmeter
- spatula



Method

1. Connect the zinc strip and the copper strip to the torch bulb as shown.
2. Carefully pour dilute sulfuric acid into the beaker until it is a little over half full.
   - What happens at the zinc strip? At the copper strip?
3. What happens if you take one of the strips out of the acid?
4. Disconnect the bulb and replace it by a voltmeter. Make sure the zinc strip is connected to the negative terminal, and the copper strip to the positive terminal.
5. Place the strips back in the acid.
   - What is the reading on the voltmeter? Does it stay the same?
   - Predict what would happen if all the zinc reacted.
6. What effect does adding a spatula of ammonium dichromate have? Measure the voltage.

Conclusion

Write a suitable conclusion for this investigation.

Electricity from chemicals

What you made in Investigation 5 is called an **electrochemical cell**. It is a device that uses redox reactions to convert chemical energy into electrical energy. Most people call an electrochemical cell a battery, even though a battery is actually a number of cells connected in series and enclosed in a single container.

When zinc and copper are placed in dilute sulfuric acid, several reactions take place. The zinc and copper strips are called **electrodes** and the sulfuric acid is called the **electrolyte** (ee-LEK-tro-lite). The zinc is more reactive than copper so it loses electrons to form Zn^{2+} ions and electrons. This is oxidation.

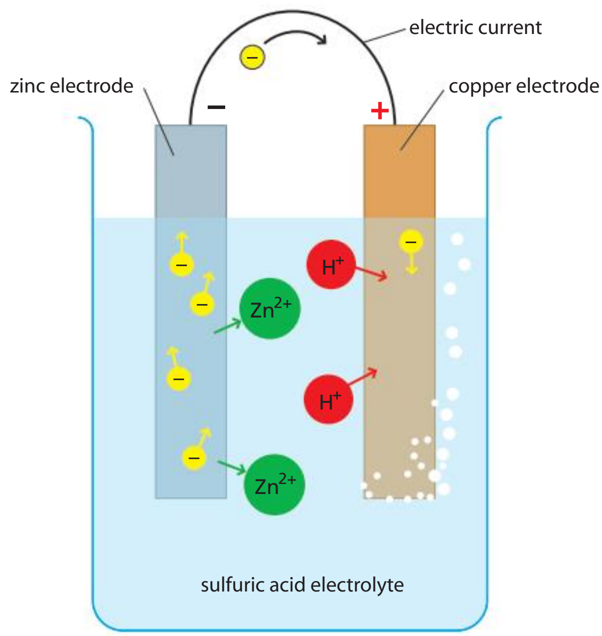
$$Zn \rightarrow Zn^{2} + 2e^{-}$$

The Zn^{2+} ions move into the electrolyte, leaving the electrons behind.

When the zinc strip is connected by a wire to the copper strip, electrons flow from the zinc through the wire to the copper. Here they react with hydrogen ions from the acid to form bubbles of hydrogen gas. This is reduction (gain of electrons).

$$2H^{+} + 2e^{-} \rightarrow H_2$$

The electrons produced at the zinc electrode are used up at the copper electrode. While the reactions continue there is a continuous flow of electrons through the wire, that is, an electric current. There is also a flow of ions through the electrolyte.

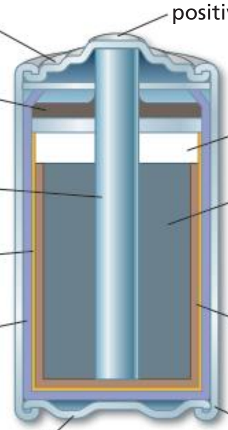


You may have noticed that the voltage produced by the cell dropped fairly rapidly. This is because the copper electrode becomes covered with bubbles of hydrogen gas, which block the H^+ ions from reacting with the electrons. The ammonium dichromate you added reacts with the hydrogen, clearing it away and allowing the reaction to continue, increasing the voltage again.

Dry cells

The D, C, AA and AAA size cells used in torches and various everyday appliances are called dry cells. This is because the liquid electrolyte has been replaced by a moist paste in a sealed container.

Inside the steel case is a zinc container. This is the negative electrode and it loses electrons (oxidation) to form Zn^{2+} ions, like the wet cell on the previous page. The positive electrode is a carbon rod surrounded by manganese dioxide and powdered carbon. The reduction reaction at this electrode is complicated, but each of the Mn^{4+} ions in the manganese dioxide gains one electron to become an Mn^{3+} ion (reduction). The moist electrolyte paste is slightly alkaline and allows the movement of ions.



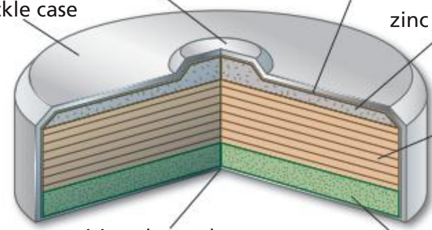
The zinc slowly dissolves. Eventually the chemicals inside the cell are used up and electrons are no longer produced. When this happens the cell is said to be 'flat'.

Alkali cells

Alkali cells are similar to dry cells. The main difference is that the electrolyte is a strong alkali called potassium hydroxide, which allows ions to flow through it more easily than the electrolyte in a dry cell. This is why alkali cells last five to eight times as long as dry cells. They are used in electric shavers, portable televisions, walkie-talkies, portable radios and electric toys.

Button cells

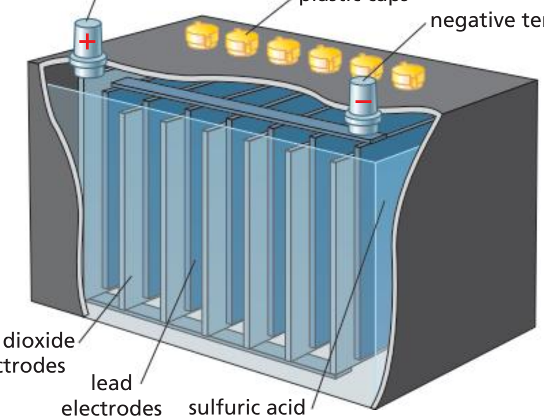
Small button cells are used in watches, calculators, cameras, hearing aids and hand-held electronic games. One type consists of an outer container of nickel or steel, with zinc powder and silver oxide separated by an electrolyte. The zinc is oxidised as usual and the silver ions in the silver oxide are reduced to silver atoms.



Rechargeable batteries

The problem with most cells and batteries is that you have to throw them away once they are 'flat'. However, with some cells it is possible to reverse the reactions that occur in them by passing electricity through them in the opposite direction. Rechargeable nickel–cadmium and lithium-ion batteries are widely used in mobile phones, portable tools and radio-controlled model cars. Most satellites also use them.

Another common rechargeable battery is the car battery. It has six cells connected together as shown. Each cell produces about 2 V—so the total voltage is 12 V. The electrodes are made of lead and lead dioxide (PbO_2), in a sulfuric acid electrolyte.



At the negative electrode the lead is oxidised to Pb^{2+} ions.

$$Pb \rightarrow Pb^{2+} + 2e^-$$

At the positive electrode the Pb^{4+} ions in the lead dioxide gain electrons to become Pb^{2+} ions. When the battery is producing electricity, the Pb^{2+} ions react with the sulfuric acid to form lead sulfate, which is insoluble. As the battery is used, this lead sulfate builds up on the electrodes and causes the battery to go flat. When the battery is recharged (whenever the engine of the car is running), the lead sulfate is changed back to lead and lead dioxide.

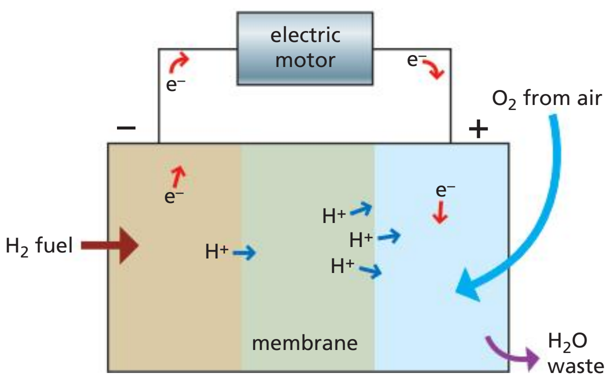
Fuel cells

Fuel cells are electrochemical cells that produce electricity continuously and do not need to be recharged. Hydrogen–oxygen fuel cells are used in the space shuttle and are now being used in cars and buses.

Each fuel cell consists of two electrodes separated by a membrane, which acts as the electrolyte. The membrane is a sheet of rubbery plastic coated with a platinum catalyst. At the negative electrode the catalyst splits hydrogen gas into H^+ ions and electrons.

$$2H_2 \rightarrow 4H^+ + 4e^-$$

The H^+ ions pass through the membrane, whereas the electrons leave the cell and form an electric current. When the H^+ ions and electrons meet at the positive electrode they combine with oxygen from the air to form water.



$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

As long as hydrogen and oxygen are fed into the cell it continues to produce electricity. The big advantage of the fuel cell is that the only waste produced is water.

Car manufacturers are using fuel cells in experimental cars with electric motors. Hydrogen is stored as a liquid in steel tanks. These cars will almost certainly be widely used in the future.

From 2004 to 2007 three experimental Mercedes-Benz buses were trialled in Perth. They ran on hydrogen produced at the Kwinana oil refinery. In the photograph you can see the exhaust of pure water vapour above the bus.

Over to you

1 Make a list of all the devices you can think of that use batteries.
2 What is the difference between a cell and a battery?
3 What are the three main parts of an electrochemical cell?
4 What happens inside all cells and batteries to cause an electric current to flow?
5 What has happened when a battery is flat?
6 **a** Why are car batteries so heavy?
b What is the electrolyte in a car battery?
7 Write an ionic equation for the reaction that occurs at the zinc electrolyte in a dry cell.
8 Write an ionic equation for the reaction that occurs in a car battery when lead ions (Pb^{2+}) react with sulfate ions (SO_4^{2-}) from the sulfuric acid.
9 Is the reaction that occurs at the negative electrode of a fuel cell oxidation or reduction? Explain.
10 Give two reasons why fuel cell cars would be better for the environment than petrol cars.
11 Explain how a car battery can be used to store electricity.

4.5 Electrochemistry

INVESTIGATION

6 Extracting copper

Aim

To extract copper from copper sulfate solution by passing electricity through it.

Risk assessment and planning

Read the investigation carefully. Why do you need to take special care in step 2?

Apparatus

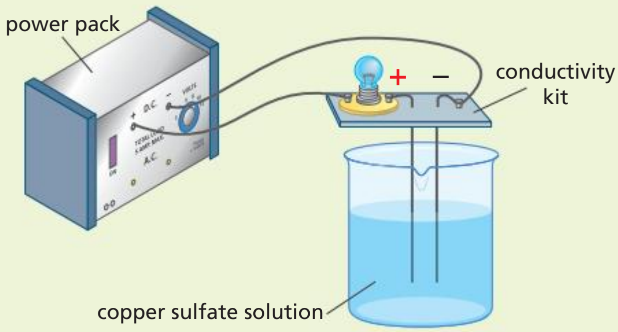
- Bunsen burner, tripod and gauze mat
- conductivity kit and connecting wires
- copper oxide
- *dilute sulfuric acid (1 M)*

- 50 mL beaker
- filter paper
- power pack
- 2 heatproof mats
- spatula
- glass stirring rod

Method

1 Add about 20 mL of dilute sulfuric acid to the beaker. Then add a pea-sized amount of copper oxide.

2 Carefully warm but do not boil the solution, using a small Bunsen flame. Stir until all the black copper oxide has reacted with the sulfuric acid to form blue copper sulfate. Turn off the burner.



3 Let the beaker cool, then carefully put it on a heatproof mat on the bench.

4 Connect up the conductivity kit to the power pack set on 6 V DC, as shown.

5 Put the electrodes into the solution and turn on the electricity for 2–3 minutes.

Record your observations. Which electrode has a coating of copper—the positive or the negative?

Results

Suggest why the copper was deposited on the *negative* electrode. Write an ionic equation for the reaction that occurred there. Why did the colour of the solution change?

Electrolysis

In Investigation 5 you saw how the chemicals in an electrochemical cell react to produce electricity. In Investigation 6 you saw the opposite—electricity causing chemical reactions. This process is called **electrolysis** (ee-lek-TROL-e-sis).

Copper oxide is an insoluble base. It reacts with sulfuric acid to form copper sulfate, which is soluble. In solution, copper sulfate breaks up into Cu^{2+} and SO_4^{2-} ions.

$$CuSO_4 \rightarrow Cu^{2+} + SO_4^{2-}$$

The water breaks up into H^+ and OH^- ions.

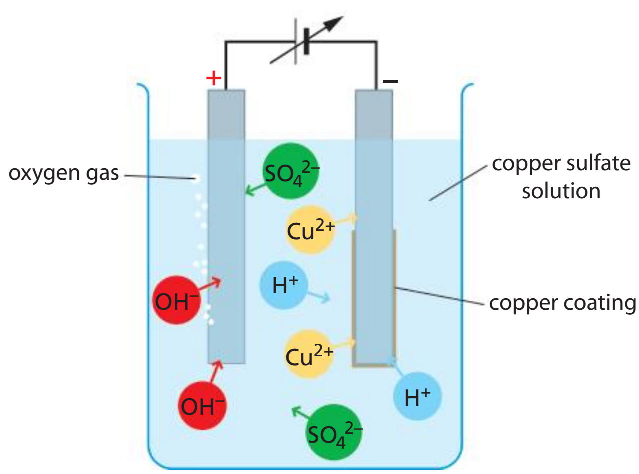
$$H_2O \rightarrow H^+ + OH^-$$

When the electricity is turned on, the positive ions (Cu^{2+} and H^+) are attracted to the negative electrode. Here the Cu^{2+} ions are reduced to copper metal.

The negative ions (OH^- and SO_4^{2-}) are attracted to the positive electrode. Here the OH^- ions are oxidised to form oxygen gas and water.

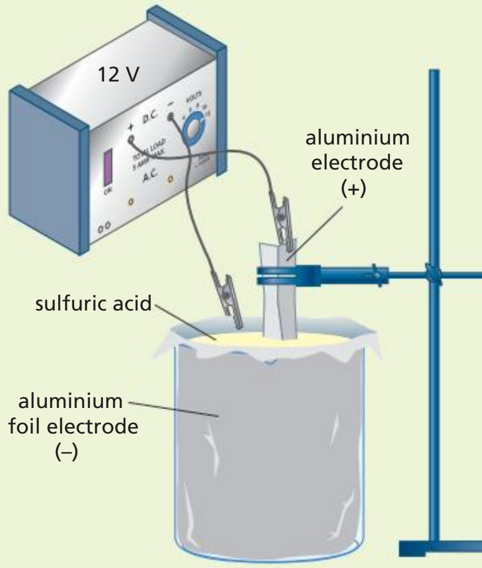
$$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$$

The H^+ and SO_4^{2-} ions remain in solution.



INVESTIGATION

7 Anodising aluminium



Aim

To use electrolysis to give a piece of aluminium a coloured coating.

Risk assessment and planning

There are several hazards in this investigation. What are they?

Apparatus

- *dilute sulfuric acid (2 M)*
- piece of aluminium
- aluminium foil
- detergent
- fabric dye solution
- two 250 mL beakers
- retort stand and clamp
- power pack and connecting wires
- heating equipment
- stainless steel pot scourer
- metal tongs

Method

1. Scrub the piece of aluminium using warm water, detergent and a stainless steel pot scourer. *Do not touch the aluminium with your fingers from now on. Use tongs.*
2. Line a beaker with aluminium foil, then three-quarters fill it with dilute sulfuric acid.
3. Set up the apparatus as shown.
4. Set the power pack on the lowest DC voltage and gradually increase it to 12 V. Leave for about 15 minutes.
5. Turn the power pack off and use the tongs to remove the aluminium. Wash it under the tap.
6. In a second beaker, heat a dye solution until it is almost boiling.
7. Put the aluminium in the dye solution and leave it there for 10 minutes or until the aluminium is coloured.
8. Rinse the aluminium and allow it to cool.
9. To seal the anodised surface, boil the aluminium in water for 10 minutes.

Discussion

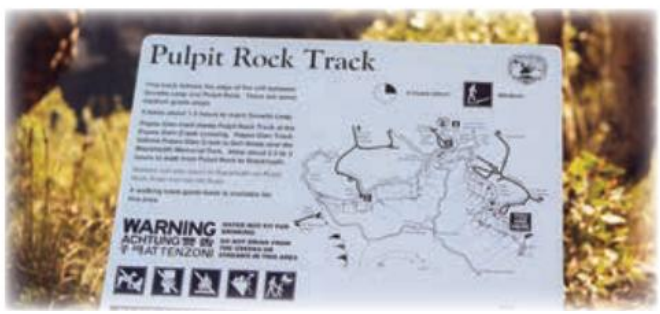
1. Why do you think it was necessary to clean the aluminium so carefully to start with?
2. Suggest why you could not touch the aluminium with your fingers after step 1.
3. Are you happy with the anodised aluminium you made? Could you improve your method? How?

Challenge

As a project you could make a useful object (e.g. an anodised aluminium key ring).

Anodising aluminium

Aluminium metal normally has a coating of aluminium oxide, which resists further corrosion. You can make the aluminium more resistant to corrosion by making this coating much thicker using electrolysis, as you did in Investigation 7. The oxygen produced at the positive electrode reacts with the aluminium to form aluminium oxide. This process is called *anodising*. You can also add a dye to colour the aluminium.



Anodised aluminium is used to make weather-resistant outdoor signs.

Electroplating

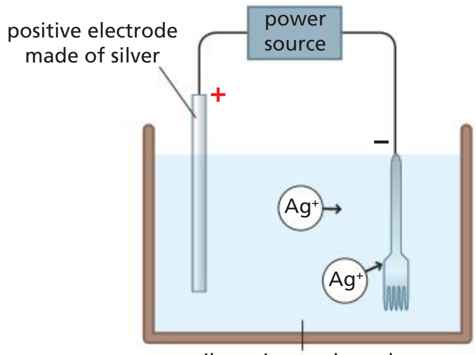
Putting a layer of metal on the surface of another metal using electrolysis is called **electroplating**. For example, to put a silver coating on a steel fork you use the set-up shown. The positive electrode is made of silver and the electrolyte is silver nitrate, which contains Ag^+ ions. Oxidation occurs at this electrode.

$$Ag \rightarrow Ag^+ + e^-$$

The Ag^+ ions are attracted to the negative electrode, where they are reduced.

$$Ag^+ + e^- \rightarrow Ag$$

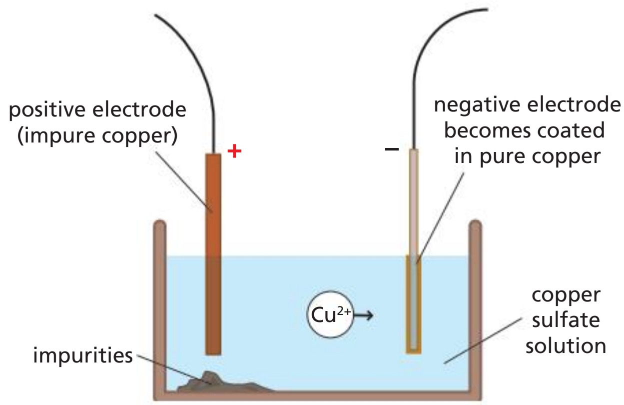
The overall result is that the silver electrode slowly dissolves and the fork is electroplated with silver.



Gold is expensive, so most jewellery is gold plated. For example, a bracelet can be made out of a cheaper metal and then electroplated with a thin layer of gold. However, this thin layer tends to wear off.

Refining copper

The copper made by smelting copper ore still contains about 3% impurities. Electrolysis is used to purify the copper. The impure copper is used as the positive electrode. The negative electrode is made from a piece of very pure copper. Both electrodes are placed in a solution of copper sulfate.



During electrolysis the positive electrode dissolves and the Cu^{2+} ions move through the electrolyte to the negative electrode. Here they are reduced to copper metal. As a result this electrode becomes coated in pure copper. The impurities fall to the bottom of the tank. They may contain small amounts of precious metals such as gold, silver and platinum.

Chemicals from sea water

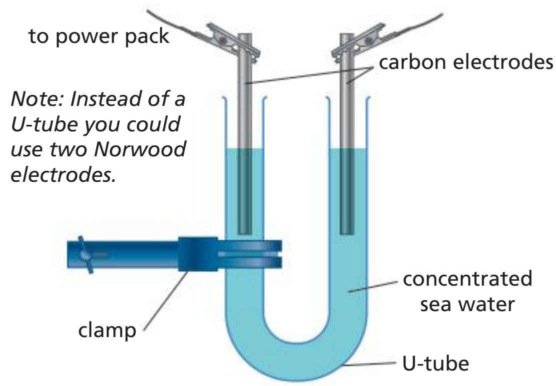
When sea water is run into large artificial lakes, the water evaporates in the sun, leaving salt (sodium chloride). This salt can be used to make many other useful chemicals. For example, a concentrated salt solution (or sea water) can be electrolysed to produce chlorine, a poisonous green–yellow gas.

INQUIRY 3 Chlorine from sea water

You will need: sea water, heating equipment, U-tube, 2 carbon electrodes, connecting wires, power pack, retort stand and clamp, phenolphthalein

1 Prepare concentrated sea water (brine) by boiling about 1 litre of sea water until there is only about 200 mL left. (Alternatively, dissolve 36 g of sodium chloride in 200 mL of water to make brine.)

2 Fill a U-tube with the concentrated sea water and place 2 carbon electrodes in the water as shown.



3 Turn on the power pack (6 V DC) for about 10 minutes.
- Describe what happens.
- At which electrode (positive or negative) does the chlorine gas form? Suggest *why* it forms at this electrode.
- How could you find out what the invisible gas formed at the other electrode is?

4 Add a few drops of phenolphthalein to test for OH^- ions in the U-tube.

Making chlorine

To explain what happened in Inquiry 3 we need to look at the ions in concentrated sea water. There are Na^+ and Cl^- ions, as well as H^+ and OH^- from the water. The Cl^- and OH^- ions are attracted to the positive electrode, where the Cl^- ions are oxidised to chlorine.

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

The Na^+ and H^+ ions are attracted to the negative electrode, where H^+ ions are reduced to hydrogen.

$$2H^+ + 2e^- \rightarrow H_2$$

The Na^+ and OH^- ions are left in solution, forming sodium hydroxide. This is why the phenolphthalein turned pink.

In industry a different method is used to make chlorine and sodium hydroxide. The positive electrodes are made of carbon, and the negative electrode is made of mercury, which is a liquid and a good conductor of electricity.

Chlorine forms at the positive electrodes, as in Inquiry 3. Instead of hydrogen, sodium is formed at the negative electrode.

$$Na^+ + e^- \rightarrow Na$$

This sodium dissolves in the liquid mercury and flows out of the cell into a tank of water. Here the sodium reacts with the water, forming sodium hydroxide and hydrogen gas.

sodium + water → sodium hydroxide + hydrogen

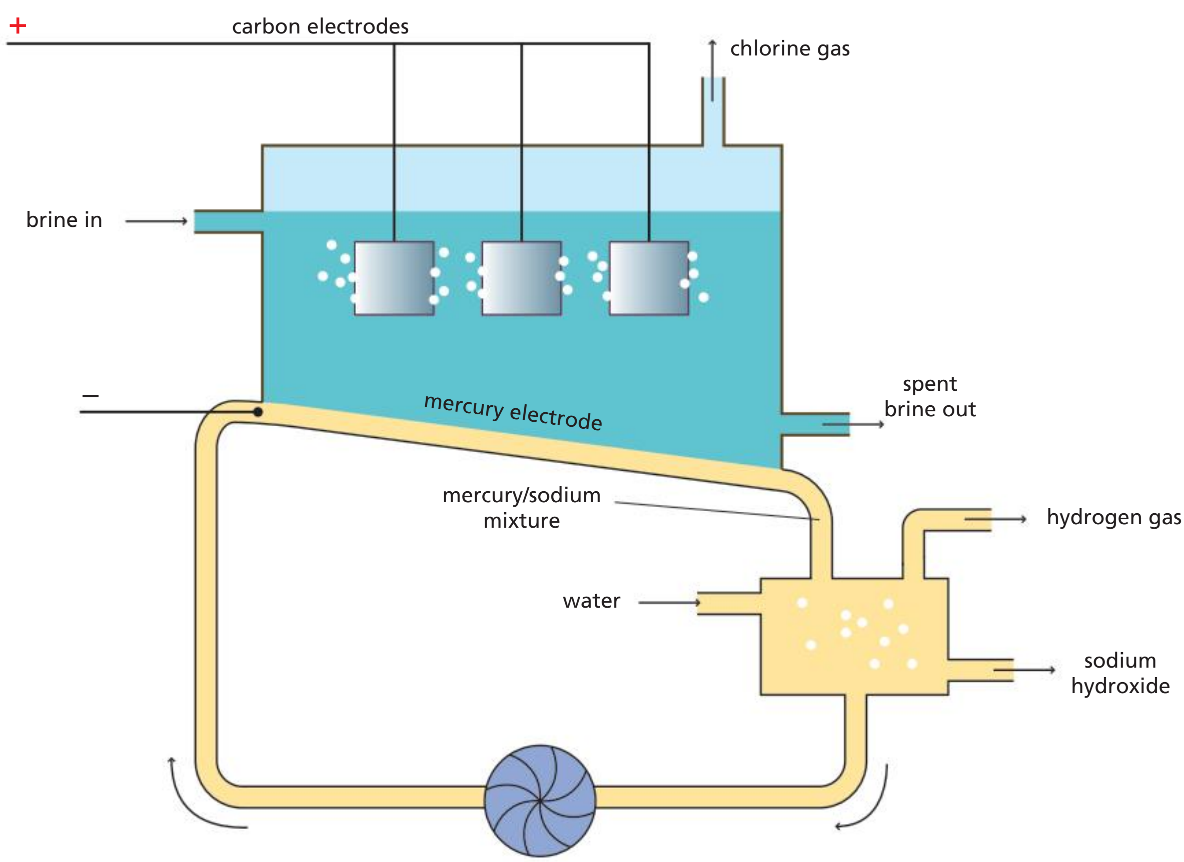
$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

The mercury that is left is then pumped back to the electrolysis cell and used again. As mercury is very poisonous it is not allowed into the environment.

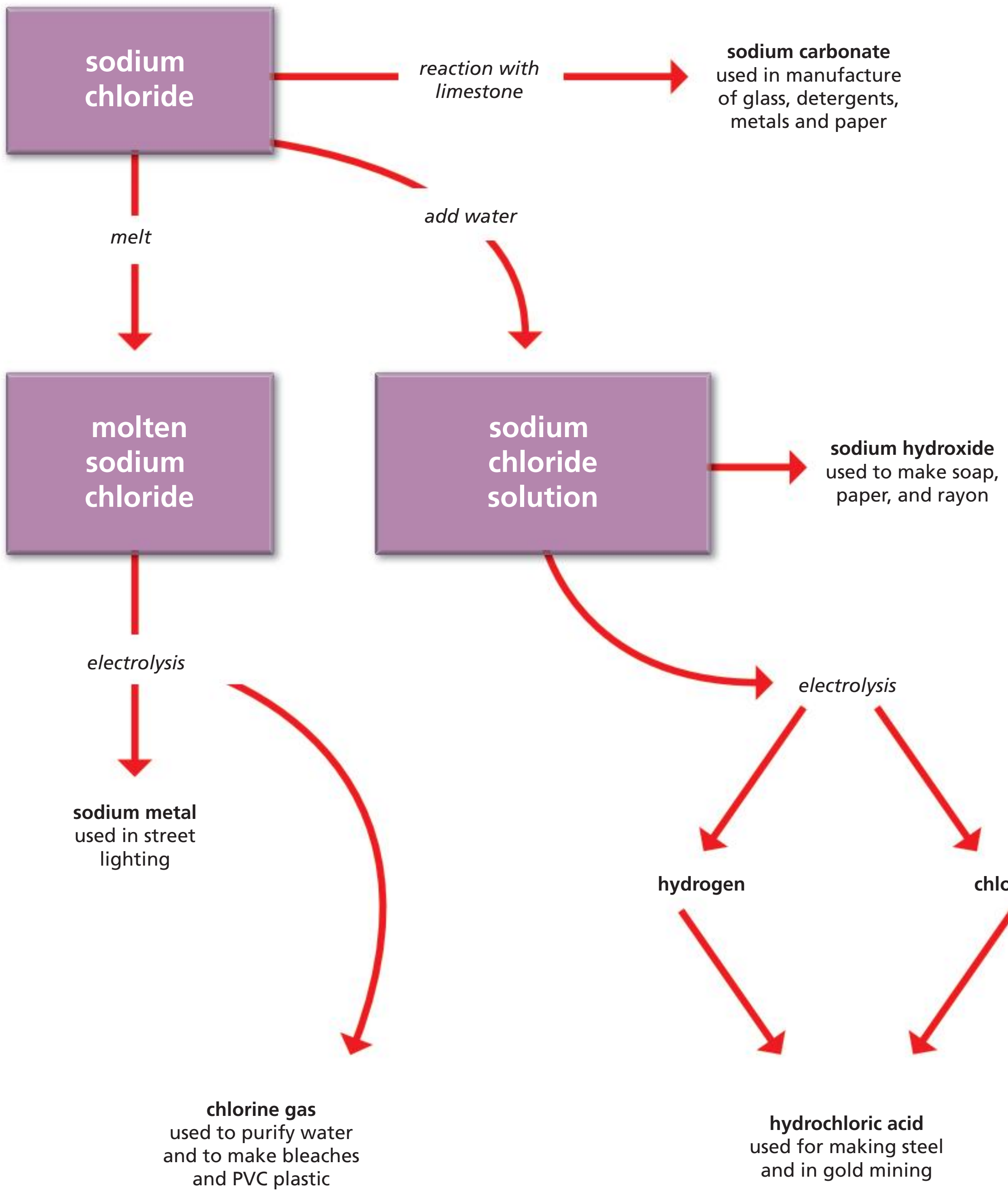
Sodium and chlorine can also be produced by the electrolysis of molten (melted) sodium chloride. As you can see in the flow diagram on the next page, sodium chloride can be used to make many different chemicals with many different uses.

PROBLEM SOLVING

Have you finished your research from page 72? If you have not chosen a substance, you could investigate one of the examples in this chapter, e.g. hydrogen (pp. 73–74), fireworks (p. 79), phosphorus (p. 80), copper (pp. 87, 89), chlorine (p. 90) or dioxin (p. 92).



How sodium chloride is used

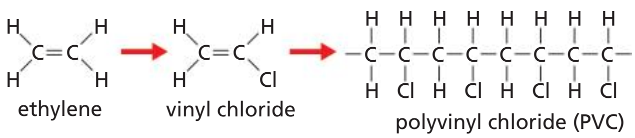


Over to you

1. How is electrolysis different from what happens in an electrochemical cell?
2. **a** What ions exist in a copper sulfate solution?
   b When electricity is passed through copper sulfate solution, what happens at the negative electrode? Write an equation for this reaction.
   c Is the reaction in part **b** oxidation or reduction?
3. **a** Dilute sulfuric acid is added to zinc oxide. Write a balanced equation for the reaction.
   b Predict what will happen when electricity is passed through the solution formed in part **a**. (*Hint:* See p. 87.)
4. Use the flow diagram above to answer the following.
   a What are some of the uses for chlorine and sodium hydroxide?
   b Which of the substances in the flow diagram are elements?
   c List the steps needed to make hydrochloric acid from sodium chloride.

Dioxin—should we be worried?

The poisonous gas chlorine produced by the electrolysis of sodium chloride can be reacted with hydrocarbons to make chlorinated hydrocarbons. For example, ethylene reacts with chlorine to make vinyl chloride, which can be polymerised to make *poly*vinyl chloride (PVC), as shown.



Many synthetic compounds have been made using chlorine. Two of these (2,4-D and 2,4,5-T) were found to be very effective weed killers. *Agent Orange*, used in the Vietnam War, was a mixture of these two chemicals. It got its name because it was shipped to Vietnam in drums marked with an orange band. It was sprayed from planes, causing the trees in the jungles to drop their leaves, making it easier to find the enemy.

In 1969 scientists observed birth defects in laboratory mice exposed to 2,4,5-T. Further tests, however, showed it was an impurity in the 2,4,5-T that was the problem. This was called *dioxin*, the most lethal synthetic compound ever tested on laboratory animals. It caused miscarriages, birth defects, disorders of the nervous and immune systems, and cancer. However, because experiments cannot be done on humans, we cannot be sure that dioxin will affect us in the same way.

Despite its toxicity in animals, there is no recorded case of dioxin killing a human. In 1976 there was an accident at a factory manufacturing pesticides and herbicides in Seveso, Italy. Dioxin was released into the air and people in the area developed a severe skin rash called chloracne. This is like normal acne but occurs all over the body and lasts longer. In the 'Agent Orange' trial, US$180 million was paid to 200 000 Vietnam veterans for diseases and birth defects they claimed were caused by the dioxin in Agent Orange. However, both parties signed an agreement saying that no connection had been proven between Agent Orange and disease.

The pesticides 2,4-D and 2,4,5-T have been banned but many other sources of dioxin have been identified. Dioxins are unintentional by-products of many industrial processes, including waste incineration, chemical manufacturing, pesticide production, chlorine bleaching of paper pulp and smelting. In fact, any process in which chlorine and carbon compounds are reacted together at high temperatures can produce small amounts of dioxin. Furthermore, dioxin is also produced by natural causes, such as bushfires and volcanoes.

Dioxin in the air eventually settles on the leaves of plants, which are then eaten by animals. In this way the poison is passed up the food chain, becoming more concentrated, until it reaches us. Dioxin is insoluble in water but readily soluble in fat, so it builds up in fatty tissue. It has been detected all over the world, even in penguins in Antarctica!

Most dioxin enters our bodies in our food, especially foods that contain fat, such as dairy products, meat, fish, eggs, breast milk and infant formula. As a result, people who eat large amounts of fatty foods *could* have an increased chance of getting cancer.

At this stage there is no clear indication that dioxins are causing increased disease in the general population. Some scientists suspect that dioxins *may* be responsible for a worldwide decrease in the proportion of boys born, but there is no proof. In the end it all depends on how much we value products such as PVC made from chlorine, and what level of risk we are prepared to live with.

Debate

Research dioxin and then have a debate on how serious a threat it is to our health. Use what you learnt about debating on pages 19–20. One side of the debate could argue that urgent steps need to be taken to reduce dioxins in the environment. The other side could argue that dioxin is in low enough levels not to be a threat.

THINKING SKILLS ?

1 Aluminium metal is extracted by the electrolysis of molten aluminium oxide (Al_2O_3).

  a What ions would be in this liquid?

  b Which ions would be attracted to the negative electrode? What do you predict would happen at this electrode?

  c What would happen at the other electrode?

2 Mia wants to electroplate a penknife with nickel using nickel sulfate solution.

  a Draw a diagram to show how she could do this.

  b What would the positive electrode be made of?

  c Write ionic equations for the reactions occurring at each electrode. (Nickel ions are Ni^{2+}.)

3 a Why is it that when a metal reacts with a non-metal, the reaction is always a redox reaction?

  b Which element is oxidised—the metal or the non-metal?

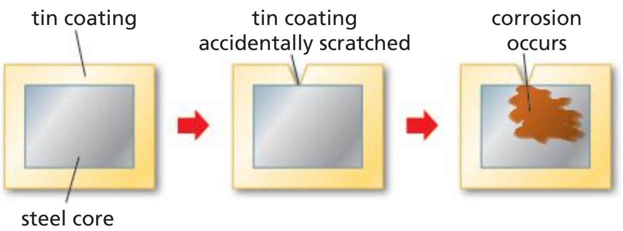
  c Which element is reduced?

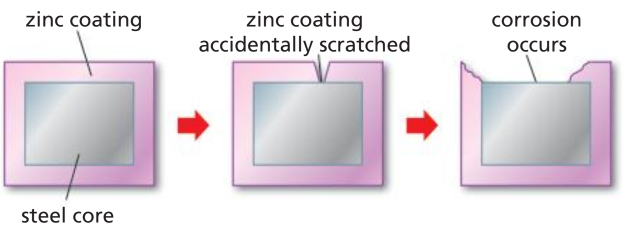
4 Use the diagrams below to answer these questions.

  a Does a coating of tin stop steel from corroding? Explain.

  b How does a coating of zinc stop steel from corroding?

  c If the coating is damaged, which corrodes more rapidly—the tin-coated steel or the zinc-coated steel? How can you explain this?





5 Bert left some lead sinkers in the bottom of his aluminium boat after his last fishing trip.

  a Write an inference as to why the boat leaked the next time he went fishing.

  b Design an experiment to test your inference.

6 The jewellery used in body piercing is surgical-grade stainless steel, platinum or gold. Explain why these metals are used rather than cheaper ones.

7 You are given samples of manganese and iron, as well as their soluble salts manganese chloride and iron chloride. How could you find out which metal is more reactive using only these four samples?

8 Why would you *not* try to prove that sodium is more reactive than magnesium by putting sodium into magnesium sulfate solution?

9 a Sea water contains gold. Where do you think this gold came from?

  b Suggest a way to extract this gold.

10 When making bread, yeast is added to the dough to make it rise. Why is it important to let the dough rise slowly in a warm place rather than putting it straight into a hot oven?

11 In hair removal by electrolysis, a small electric current is passed through your body using two electrodes. This produces sodium hydroxide, which destroys the roots of the hairs. Using what you have learnt about electrolysis, explain how the sodium hydroxide could be produced. (*Hint*: Your body tissues contain dissolved sodium chloride.)

12 Match these six types of reactions to the six examples below:

combustion	acid on metal
corrosion	neutralisation
precipitation	decomposition

  a $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$

  b $2H_2O \rightarrow 2H_2 + O_2$

  c $2Na + 2HCl \rightarrow 2NaCl + H_2$

  d $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

  e $2Mg + O_2 \rightarrow 2MgO$

  f $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

Knowing and Understanding

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

1 The ways in which the gases hydrogen and ______ dioxide are used depends on their ______ .

2 In the ______ series the ______ are arranged in order from the most reactive to the least reactive.

3 When a reactive metal is placed in a solution containing ______ of a less reactive metal, the less reactive metal is ______ from the solution.

4 Burning or ______ occurs when a substance reacts with the ______ in the air, releasing heat and light.

5 Reduction occurs when an atom or ion ______ electrons. ______ occurs when an atom or ion loses electrons. Reduction and oxidation always occur together in ______ reactions.

6 ______ is a redox reaction that occurs when a metal reacts with air and water. When iron corrodes the process is called ______.

7 An electrochemical ______ is a device that uses redox reactions to convert chemical energy into ______ energy. It consists of two ______ in an electrolyte.

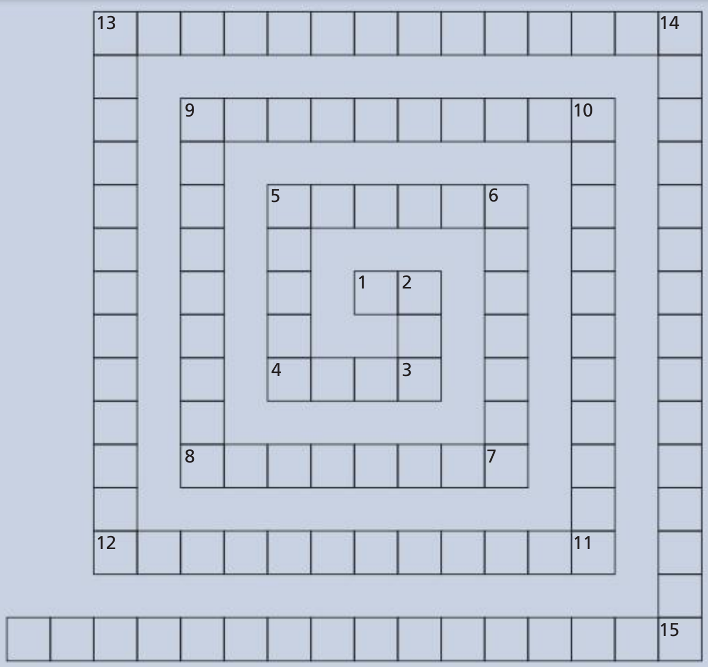
8 ______ is the process of passing an electric current through an ______ to produce chemical reactions at the electrodes.

activity
carbon
cell
combustion
corrosion
displaced
electrical
electrodes
electrolysis
electrolyte
gains
ions
metals
oxidation
oxygen
properties
redox
rusting

Self-management

Copy and complete this spiral crossword. Start in the centre and work your way out of the maze by putting in the answers to the clues. The last letter of each word is the first letter of the next word.

1 Carbon monoxide
2 Number of electrons lost by a hydrogen atom
3 The shells of these are made of calcium carbonate
4 An alloy of iron
5 A state of matter
6 Carbon ______
7 A tiny negatively charged particle
8 Oxygen and chlorine are examples of these
9 These contain dissolved carbon dioxide
10 Compound used in button cells
11 To use electricity to put a layer of metal on the surface of another metal
12 These are used to put out fires



13 Chemical extracted from sea water
14 To do with electricity and chemical reactions
15 Formed when lithium metal reacts with water

Checkpoint

1 When a sheet of iron is galvanised it is coated with:

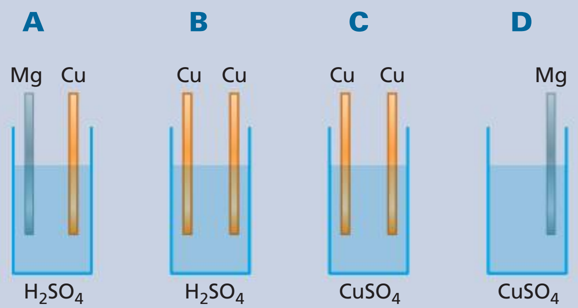
A aluminium. **C** tin.
B plastic. **D** zinc.

2 When zinc metal is added to copper sulfate solution, the zinc goes into solution and copper metal is formed. This is because zinc is more reactive than copper.

Which of the following substances would most rapidly produce copper when added to a copper sulfate solution?

A copper **C** oxygen
B magnesium **D** zinc

3 Which one of these diagrams correctly shows an electrochemical cell?



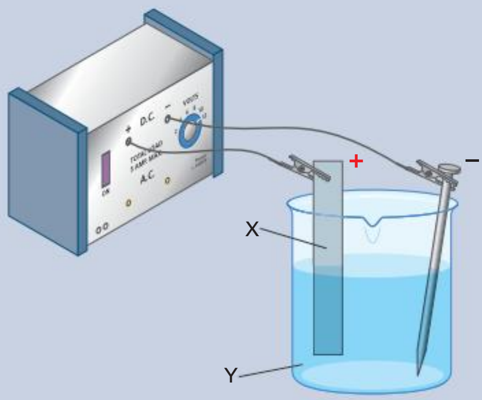
4 To electroplate the nail in the set-up below with a coating of lead:

A X should be copper and Y should be copper sulfate solution.

B X should be lead and Y should be copper sulfate solution.

C X should be lead and Y should be lead nitrate solution.

D X should be carbon and Y should be lead nitrate solution.



5 You have a sailing boat with an aluminium hull. You want to protect it from corrosion by bolting small pieces of metal at several places on the hull. Which one of the following metals should you use? Explain your answer.

A iron **C** magnesium
B lead **D** sodium

6 In an electrochemical cell an electrode of magnesium reacts with dilute sulfuric acid. Which one of the following ionic equations describes what happens at the magnesium electrode?

A $Mg + 2e^- \rightarrow Mg^{2+}$ **C** $Mg \rightarrow Mg^{2+} + Mg^{2-}$
B $Mg \rightarrow Mg^{2+} + 2e^-$ **D** $2H^+ + 2e^- \rightarrow H_2$

7 Jack has a silvery piece of metal but he is not sure whether it is silver or aluminium. Suggest a simple test he could do to find out.

8 **a** Describe what happens when you put a piece of magnesium in some dilute hydrochloric acid.

b How could you test the gas that was produced during the reaction?

c Write a balanced equation for the reaction.

9 When 1.0 g of manganese dioxide was added to 100 mL of hydrogen peroxide, the hydrogen peroxide decomposed into water and oxygen gas. The volume of oxygen given off was measured every minute.

Time (minutes)	Volume of oxygen (cm^3)
0	0
1	40
2	66
3	88
4	104
5	116
6	118
7	120
8	120

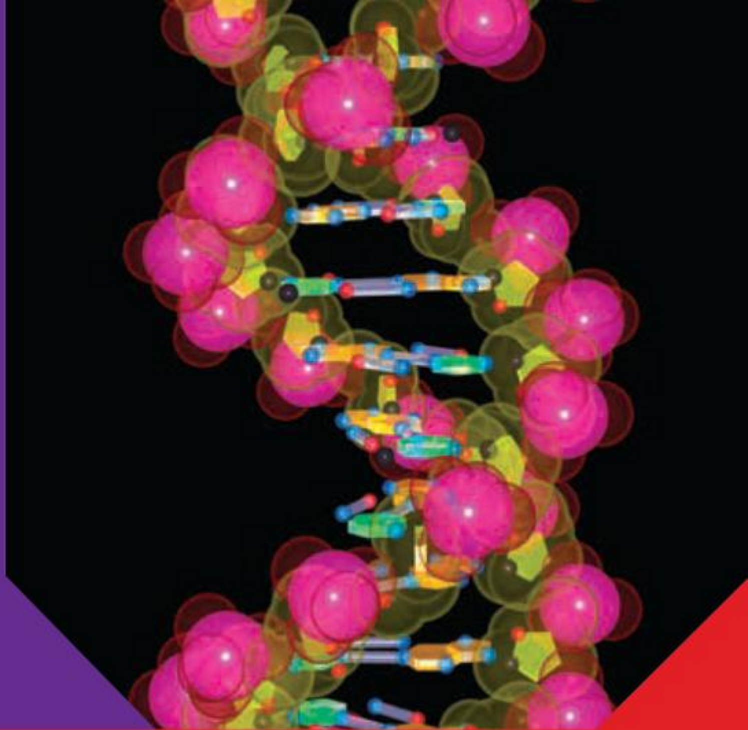
a Draw a labelled diagram of the apparatus that could be used to carry out this experiment.

b Display the results of the experiment in a graph.

c Write a conclusion for the experiment.

10 During rusting the iron is oxidised. Explain this statement using an ionic equation.

5



DNA and genetics

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

Science Understanding

- draw diagrams to show the difference between mitosis and meiosis
- use models and diagrams to represent the relationship between chromosomes, DNA and genes
- use Punnett squares to predict the results of dominant–recessive inheritance

Science as a Human Endeavour

- follow the historical development of the helix model for the structure of DNA
- research Professor Elizabeth Blackburn and other Australian Nobel Prize winners

Science Inquiry Skills

- write an argumentative essay about whether we should create the perfect child

LITERACY FOCUS

alleles
asexually
characteristics
chromosomes
clone
co-dominance
deoxyribonucleic acid (DNA)
dominant
genes
genetic variation
genetics
genotype
haemophilia
heredity
human genome
incomplete dominance
meiosis
mitosis
mutation
pedigree
phenotype
Punnett square
recessive
sex-linked inheritance

Focus for learning

Do you look like your mother, father, brother or sister or are you totally different? In some families it is very easy to see a resemblance between family members. In other families the connection is not always obvious.

You would expect some similarities between you and your family because half of the characteristics you possess came from your mother and the other half came from your father. The characteristics you have make you a unique person, unlike any other.

This chapter looks at how characteristics are passed on from one organism to the next. This is called **genetics** or *heredity*.

Some diseases can be inherited. These are called *genetic diseases*. Examples are Down syndrome (mental retardation and physical disability) and haemophilia (blood clotting disorder). The study of genetics is enabling scientists to correct many genetic diseases and make changes to the genetic make-up of organisms that were not possible in the past. Scientists have been able to make an identical copy or **clone** of some animals, such as sheep and horses. Could genetics be used to clone a human or allow parents to select the characteristics they want for their child? This chapter looks at the possibilities.

Cloned sheep

PROBLEM SOLVING

The perfect child

Write a two-page argumentative essay discussing the following statement: 'Parents should be allowed to select the characteristics they want for their children.'

There are many issues relating to this topic that you could discuss in your essay. For example, should parents be allowed to have children that are free from genetic disease, or produce a child to provide body cells for one that is ill? Should parents be allowed to choose the sex of their child or choose what they consider to be good characteristics for their baby, such as blond hair?

Each 'Problem solving' throughout this chapter will give you some issues to consider in your essay. You will also need to do more research. It may help to complete a SWAP table as you collect information and read through the chapter.

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 selecting characteristics.

3 Under the heading 'Weaknesses' write all the points that you can think of against selecting characteristics

4 Now explain what needs to happen to turn the arguments against selecting characteristics (weaknesses) into strengths. Write these in the ' Action' column.

5 Under the heading 'Possibilities', explain what the future holds.

5.1 Mitosis and meiosis

How does a single egg grow to produce all the cells that make up a baby, and how does this baby continue to produce new cells to grow into an adult? The answer is **mitosis** (my-TOE-sis). In this process one cell divides into two cells, each identical to the original cell. The dividing cell is called the *parent cell* and the two cells that are made are called *daughter cells*. In mitosis, the information in the nucleus must be copied exactly.

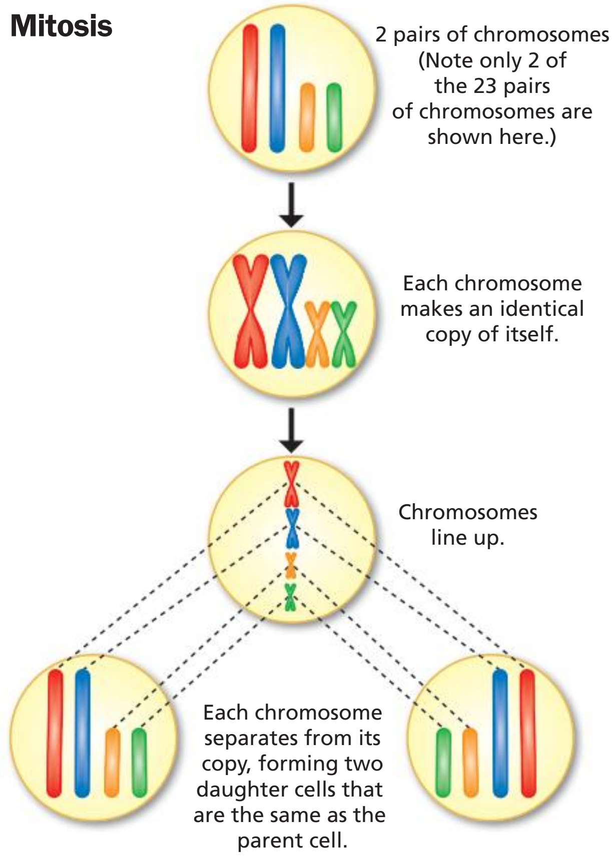
When a cell is about to divide in this way, the material in the nucleus forms thread-like bodies called **chromosomes**. The word mitosis comes from the Greek word *mitos* meaning thread, after the chromosomes. Apart from sex cells, every cell with a nucleus in your body has 46 chromosomes (23 pairs) that can only be seen when the cell is about to divide. During cell division, each chromosome makes a copy of itself. The individual chromosomes and their copies all line up in the centre of the cell. The chromosomes then separate from their copies and two cells form. It is important that identical cells are made as this process is used for growth and to replace damaged and worn-out cells in the body. Mitosis occurs in areas where growth is taking place. It does not happen in all cells all the time. Some cells are unable to carry out mitosis. For example, nerve cells are not able to replace themselves if they are damaged.

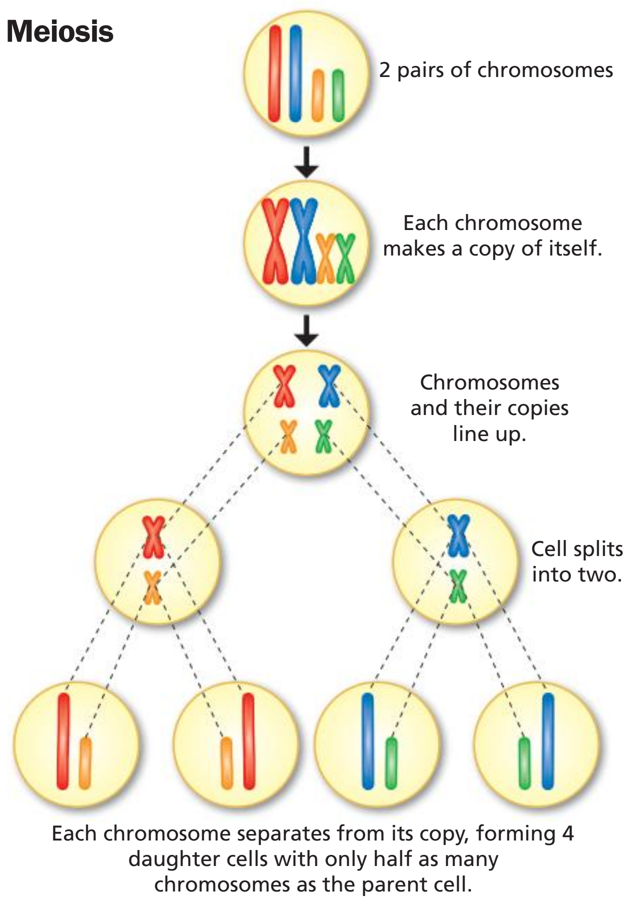
Meiosis

An egg cell and a sperm cell join to form a single cell with 46 chromosomes, and each body cell is made from this one cell. Egg and sperm cells must have only 23 chromosomes each, so that when they come together, the resulting cell (zygote) has 46.

Cells in the ovaries and the testes therefore do not carry out mitosis to produce egg and sperm cells. They carry out a process called **meiosis** (me-OH-sis). In this process the daughter cells produced have half as many chromosomes as the parent cell. Meiosis comes from the Greek word *meioun* (make smaller).

In meiosis, as in mitosis, the chromosomes make copies of themselves before they separate into two new daughter cells. Then another stage occurs in which the chromosomes in each daughter cell separate again. In meiosis, four daughter cells are produced, each with only half the number of chromosomes as the parent cell. So they have 23 chromosomes, not 46 chromosomes.





Boy or girl

It is possible to remove a cell from a growing embryo and use the cell to tell whether the embryo is a boy or a girl. Scientists do this by taking the 46 chromosomes in the cell and pairing them up. They then number each pair from 1 to 23. The 23rd pair is called the *sex chromosomes*. In women the chromosomes in this pair both look like an X, so XX is female. In men, one looks like an X and the other is different. Scientists call it the Y chromosome. So males are XY.

When a cell in an ovary makes egg cells, all the egg cells contain an X chromosome. In men, half of the sperm cells contain X chromosomes and half contain Y chromosomes. So when an egg carrying an X chromosome joins with a sperm carrying either an X or a Y chromosome, there is a 50% chance of the child being male (XY) and a 50% chance of the child being female (XX).

Genetic variation

You should now be able to explain why you share characteristics in common with your family and why you have characteristics that are unique to you.

To make sperm and egg cells meiosis occurs. There are no rules to determine which chromosomes end up in which sperm or egg cell. There are also no rules to determine which sperm cell eventually joins with which egg cell. These processes occur *randomly*, almost like a lucky dip, so not all your characteristics will be exactly the same as those of your parents. However, because you receive 23 chromosomes from your mother and 23 from your father, there will be characteristics you share with your parents. You will also share these characteristics with your brothers and sisters (siblings).

Human reproduction is an example of *sexual reproduction*, in which sex cells (sperm and egg cells) unite to produce offspring that are genetically different from the parents. So humans are not all the same, even in the same family. **Genetic variation** occurs between people and this variation is important. If a change occurs in the environment, then there is a chance that some individuals will not be affected by it because they are genetically different. This is explained further in Chapter 6.

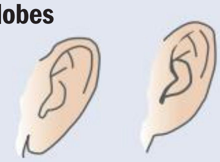
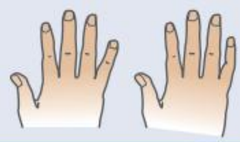
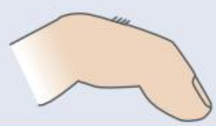
Some organisms reproduce *asexually*, without the joining of sex cells. In this case the offspring are identical to the parent and there is little or no variation between individuals.

INQUIRY 1 Inherited characteristics

Look at the table of inherited characteristics.

1 Which characteristics have you inherited? Check your family and see which characteristics they have.

2 Have you inherited more of your characteristics from your mother or your father? Explain.

Ear lobes 	Are your ear lobes attached or do they hang free, as pictured?
Darwin's point 	Do you have a bump on the inner rim of your ear?
Widow's peak 	Does your hair line form a V in the middle, as pictured?
Second toe 	Is your second toe longer or shorter than your big toe?
Folding hands 	Do you fold your hands with your left thumb on top of your right thumb or vice versa?
Little finger 	Does the tip of your little finger bend in towards your other fingers or away from them?
Mid-digital hair 	Do you have hair on the second knuckle of your fingers (or toes)?
Tongue rolling 	Can you roll your tongue, as pictured?

INQUIRY 2 Tasting PTC

You will need: untreated test paper, PTC paper

The ability to taste PTC (phenolthiocarbamide) is an inherited characteristic.

1 Taste a piece of untreated paper, then taste a piece of PTC paper.

2 If you can taste a difference between the two pieces of paper, you have inherited the ability to taste PTC.

INQUIRY 3 Mitosis and meiosis

You will need: pipe cleaners, butcher's paper, marker pens

1 Using the equipment provided, explain to a partner how the processes of mitosis and meiosis differ. Swap over and repeat the process.

2 If you feel confident, you could use an overhead transparency, pipe cleaners and overhead pens to show the class the difference between the processes.

Over to you

1 What are chromosomes?

2 Do all cells in the body carry out mitosis? Explain.

3 How many chromosomes do the cells produced by meiosis have? Is this the same for mitosis?

4 Why is there a 50% chance of having a boy or a girl?

5 What does the 23rd pair of chromosomes look like for girls? Is this the same for boys?

6 Would the chromosomes of identical twins be the same? What about the chromosomes of non-identical twins? Explain.

7 What is the difference between asexual and sexual reproduction?

8 What is genetic variation and why is it important?

9 Look at the following table:

Organism	Chromosomes
Fruit fly	8
Cat	38
Dog	78
Shrimp	254
Garden pea	14

a Copy the table and add humans to it.

b How do the organisms in the table differ from one another?

c How many *pairs* of chromosomes does each of these organisms have?

d Is it true to say that the most intelligent organisms have the greatest number of chromosomes?

e Is there a relationship between the size of the organism and the number of chromosomes it has in its cells?

10 Catherine brought her two baby twins, Hugo and Lily, to playgroup. One of the women there commented on how lovely the identical twins were. Another said they could not possibly be identical twins because they were a boy and a girl. Who is right?

PROBLEM SOLVING

Here is another issue you could discuss when deciding on the perfect child.

Some genetic diseases are caused by an individual having the incorrect number of chromosomes. For example, Down syndrome is called trisomy 21 because instead of two chromosomes making up the 21st pair, there are three. This means that each body cell has 47 chromosomes, instead of 46. A person with Down syndrome suffers from mental retardation and changed physical features.

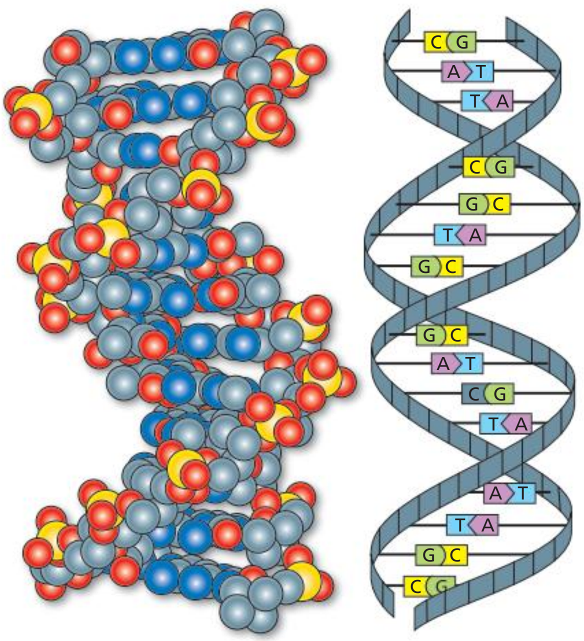
Could diseases like this be prevented if we could ensure that every child has the right number of chromosomes?

You could also investigate Patau syndrome, Edwards syndrome, Turner syndrome and Kleinfelter syndrome.

5.2 DNA and genes

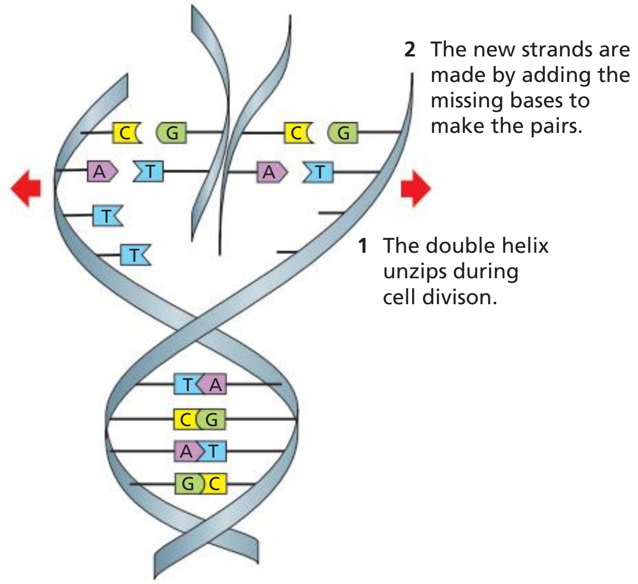
So far you have learnt that every individual grows from a single cell, and that when a cell is about to divide thread-like bodies called chromosomes appear in the nucleus. You have learnt that each cell in your body, other than egg and sperm cells, contains 23 pairs of chromosomes. Half of the chromosomes you receive come from your father and the other half from your mother. Let's expand this further.

Chromosomes are in fact long threads of **DNA** (**deoxyribonucleic acid**), a chemical that contains all the genetic information to make you, an individual. Each chromosome is made up of different units called *bases*. There are four bases: adenine (A), guanine (G), thymine (T) and cytosine (C). Adenine and thymine always join together, and guanine and cytosine always join together. So the DNA molecule looks like a twisted ladder of base pairs, called a double helix. The bases along the length of one strand of the DNA 'ladder' join to the bases on the other strand. The rungs of the ladder are formed by the base pairs.



Left: A model of what DNA looks like. It is made up of sugar (deoxyribose), phosphates and bases containing nitrogen. Right: The arrangement of bases forms a double helix.

During cell division the DNA is copied. The twisted ladder of the double helix 'unzips'. Since A and T always pair together and C and G always pair together, each strand can be copied by adding the



missing base to make the pair. In this way, identical copies of the DNA molecule can be made. These two DNA strands then separate and move into each new daughter cell. In this way each new cell contains identical DNA to the parent cell.

Genes

How the bases are arranged along a chromosome is very important. The different patterns of bases form **genes**, which are the code or blueprint for all the functions of every cell in the body. They are also the blueprint for the characteristics that make each organism different. Just as plans are drawn up to build a house, genes are the plans to build individual organisms.

Genes are the code to tell body cells how to make proteins. They also control how the proteins work in the body. For example, genes and the proteins they make determine how an organism develops from an individual cell to an adult, what nutrients are made in the body, the types of enzymes that are produced, as well as how a person looks and behaves.

You can see how complex each person is when you examine the *human genome*, or all the genetic information of an organism, in this case a human being. There are about three billion pairs of bases coding for 30 000 or more genes, which code for different proteins. There are also base sequences in the DNA that start and stop the making of proteins, and so-called 'junk' DNA that does not seem to code for anything at all. It is the sequencing of the bases along the DNA, and the position of genes, that provide human variation and give you a distinct set of characteristics, different from everybody else.

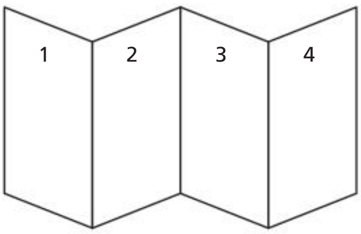
Making proteins

Three bases together form the code for one amino acid. From previous study you know that amino acids are the basic building blocks of proteins. There are 20 different types of amino acids in your body. The different combinations of these amino acids make different proteins. With four bases combining to make three-base codes there is the possibility of 4 × 4 × 4 = 64 different codes. This is far more than the number of amino acids needed. So, each amino acid has several different three-base codes to make it. Some of these codes are shown in the table below.

INQUIRY 4 Making and copying DNA

You will need: sheet of A4 paper, copy of the DNA molecule on the bottom right, coloured marker pens

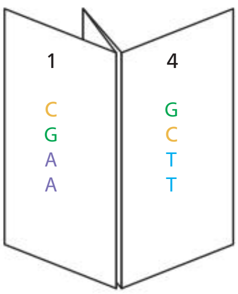
1 Fold a piece of A4 paper as pictured. Fold the panels behind panel 1 so that they are flat.



2 Write the following DNA sequence down the length of panel 1:

C G A A C G T T T G G G T C A G A A C G T A C G G A A G G G

3 Unfold panel 4 so that it lies next to panel 1. On panel 4 write the bases that link to those on panel 1.



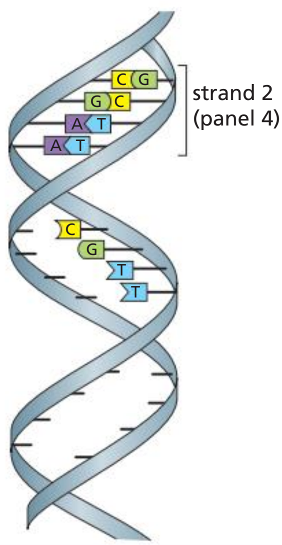
4 You have now made a double-stranded DNA molecule. Imagine this molecule is 'unzipping' to make a copy of itself. Open your paper so that panels 2 and 3 are visible. Panel 3 will be a copy of panel 1, and panel 2 will be a copy of panel 4 as the molecule unzips. Write the correct base sequences on these panels.

5 Use the table above right to list what amino acids the panel 1 sequence of bases will code for. Remember three base sequences together code for one amino acid.

6 Write which amino acid you think each three base sequence on panel 4 will code for. Check your answers in the table above.

DNA code	Amino acid	DNA code	Amino acid
GCT GCC GCA GCG	alanine	CCT CCC CCA CCG	proline
TTA TTG CTT CTA	leucine	CGA CGC AGA CGT	arginine
TCA AGT TCT	serine	GGG GGA GGC	glycine
AAT AAC	asparagine	TTT TTC	phenylalanine
TGT TGC	cysteine	AAA AAG	lysine
CAT	histidine	TGA	STOP
ACG	threonine	GAA	glutamic acid

7 Use the base sequences you wrote on panels 1 and 4 to draw a DNA molecule. You could use this picture of a DNA molecule as a template. You will need to have your own colours for each base and you may need to repeat the template a number of times.



SCIENTISTS AT WORK

The structure of DNA

The discovery of the structure of DNA is extremely controversial. There is a lot of debate over whether Rosalind Franklin should be given more recognition for her part in the discovery. Read the story and decide for yourself.

In 1938 Franklin went to Cambridge University, where she completed a three-year degree in chemistry. She went on to do her PhD. In 1947 she moved to Paris and began working on X-ray crystallography (taking X-rays of the structure of crystals). In 1951 she was asked to establish an X-ray crystallography unit at King's College in London. A student of the college, Raymond Gosling, had taken an X-ray picture of DNA and Franklin was asked to work in this area. Also heading a research team working on DNA was Maurice Wilkins, who had a PhD in physics. Wilkins thought that Franklin was his technical assistant, so things did not begin well.

Franklin used very fine X-ray beams to photograph DNA. Her X-rays showed that DNA was a helix shape. She also found that water easily stuck to the DNA. Franklin reasoned that the water would be attracted to the phosphates of the DNA, which must be positioned on the outside of the molecule. She inferred that the bases must be on the inside.

In November 1951 Franklin presented her findings at a seminar that was attended by James Watson, who had a PhD in zoology and a keen interest in genetics. He had been working with an X-ray crystallography team at Cavendish Laboratories in Cambridge, looking at proteins in cell nuclei. When he arrived back at Cambridge, Watson used information from Franklin's seminar, plus his own knowledge, to build the first model of DNA. He worked with his research student, Francis Crick. They presented their model to Franklin and Wilkins, who dismissed it because it was incorrect.

In May 1952 Franklin produced an excellent picture of DNA. However, she did not release her findings because she wanted to obtain more data. She also rejected the opportunity to work with James Watson. So Watson went to Wilkins to see if he could get the information from him. Without Franklin's permission, Wilkins showed Watson one of Franklin's X-rays of DNA, along with her calculations of its structure. With the information from Franklin's seminar, the photograph and their own research, Watson and Crick had all they needed to build the correct model of DNA.

Watson and Crick with their model of the DNA molecule

On 17 March 1953 Franklin produced a draft paper of her findings, ready for publication. Watson and Crick published their findings the next day. They did acknowledge that they had used the 'unpublished' work of Wilkins and Franklin in their findings. In 1962 Watson, Crick and Wilkins received the Nobel Prize in Physiology and Medicine for their work. Only Wilkins acknowledged Franklin in his Nobel lecture. In 1956 Franklin discovered that she had ovarian cancer. She died in 1958, only 37 years old.

Should Rosalind Franklin be given more recognition for her part in the discovery of the structure of DNA?

INVESTIGATION

1 Extracting DNA

Aim

To extract DNA from kiwifruit.

Risk assessment and planning

Read through the investigation. What possible hazards are there that you need to be aware of?

Apparatus

- *methylated spirits in a dropping bottle*
- ice
- ripe kiwifruit
- salt (sodium chloride)
- washing up liquid
- digital balance
- measuring cylinder
- stirring rod
- 250 mL beaker
- two 500 mL beakers
- chopping board and knife
- vegetable peeler
- Bunsen burner equipment
- thermometer
- inoculating loop

Method

1 Place the dropping bottle of methylated spirits in a 500 mL beaker of ice to cool it. (The methylated spirits must be ice-cold, not frozen, for this investigation.)

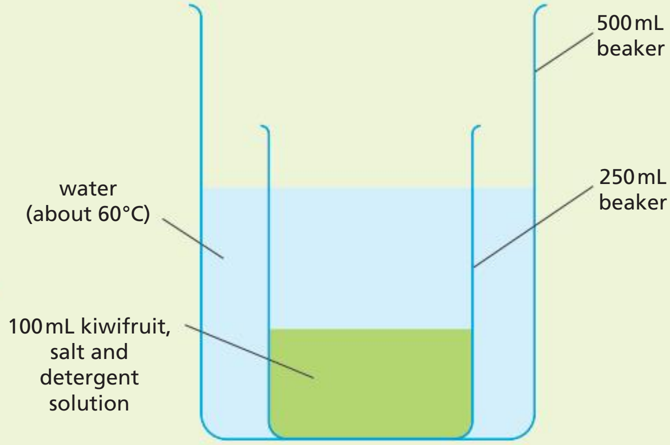
2 Measure 3 g of salt and 10 mL of detergent accurately.

3 Place 100 mL of water in a 250 mL beaker, add the salt and detergent and gently stir. Do not let the solution froth.

4 Peel and finely chop (do not crush) one kiwifruit. Add this to the salt and detergent solution. Stir gently. (The salt and detergent break down the cell membranes of the kiwifruit so that the contents of the cells are released.)

5 Heat 200 mL of water in a second 500 mL beaker until it reaches 60 °C. Remove the beaker carefully from the heat.

6 Place the kiwifruit, salt and detergent solution into the warm water from step 5 as pictured, for 15 minutes.



Then remove it. (During this time protease enzymes in the kiwifruit break down any proteins that are attached to the DNA. The beaker now has DNA, proteins and other cell components in it.)

7 Pour 50 mL of methylated spirits down the side of the small beaker so that it forms a purple layer on top of the green kiwifruit solution.

8 Let the solution stand. A white layer should form between the kiwifruit and the methylated spirits. (The methylated spirits separates the DNA from the rest of the kiwifruit solution. The DNA forms a solid layer between the solution and the methylated spirits.)

9 Using the inoculating loop, remove some of the white layer. This is the DNA of the kiwifruit. Look at it under a microscope. Your teacher may help you with this. Draw and describe what you see.

Discussion

1 How easy was it to separate DNA from the cells of the kiwifruit? Explain.

2 Why do you think it was important to finely chop, not crush, the kiwifruit?

3 How did you break up the cell membranes and why was this necessary?

4 When Rosalind Franklin was extracting DNA she tried oranges. This fruit does not have the same enzymes in it that the kiwifruit has. Why do you think she was unable to separate DNA from oranges?

5 Where would you expect to find DNA in the cells of the kiwifruit?

Over to you

1 What does DNA stand for?

2 Which four bases make up DNA? Describe how they pair up to make this molecule.

3 How does the cell make a copy of a DNA molecule? A picture might help you explain this.

4 What are genes and what do they do?

5 A scientist knew that one strand of DNA contained the following base sequences:

TTA TCT GGA CCG GCT GCG

- **a** What would be the base sequences on the other strand of DNA?
- **b** Write the sequence of amino acids that would be made.

6 Name the four people involved in the discovery of the structure of DNA.

7 James Watson and Francis Crick make no mention of Franklin in their Nobel lectures. Suggest a reason for this.

8 With three-base codes there are more codes than amino acids, what happens to the extra codes?

9 In the 1950s women were not treated in the same way as men. For example, there were men-only dining rooms at colleges and universities.

- **a** Do you think the type of environment that Franklin worked in may have contributed to her lack of recognition? Explain your answer.
- **b** Do you think that the view men had of women at the time contributed to Wilkins's treatment of Franklin when she first started to work with him?
- **c** Do you think the views of society at the time can explain why Franklin's part in the discovery of the structure of DNA was overlooked when the Nobel Prize was awarded?

10 Use the internet to find out more about winning a Nobel Prize. Find out who has won a Nobel Prize in the last 10 years and what for.

PROBLEM SOLVING

In your perfect child essay you need to discuss whether it is possible for parents to select the characteristics they want for their children. To do this it would be necessary to know how each of the three billion bases that make up the human genome are positioned on the DNA. It would also be necessary to know what proteins the 30 000 or so genes code for and how these proteins are expressed as characteristics. Is this possible?

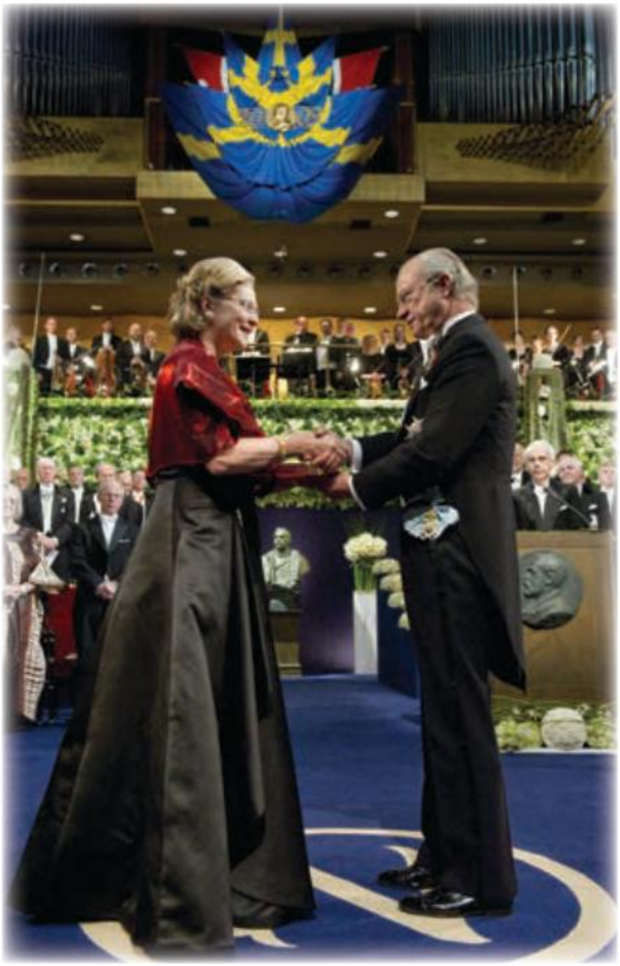
The Human Genome Project

All the genetic material contained in an organism is called its ***genome***. The Human Genome Project began in 1989. The goals of the project were to discover the sequence of bases on the human genome and to identify all the genes it contained. If scientists could do this they would have a blueprint for making a person. In April 2003 these goals were achieved. Scientists also sequenced the genomes of brewer's yeast, roundworm, fruit fly and mice in an effort to discover which genes are critical for life.

The work of this project has not ended. Scientists still want to discover more about how DNA and proteins interact with one another to create living things. They also want to use their knowledge of the genome to help treat diseases.

The Human Genome Project raises many issues. For example, could people be required to undergo gene sequencing (determining the order of the base pairs on their DNA) to gain employment or insurance? What would happen if they carried a defective gene? Could we select the genes that we want for our children? Can we replace defective genes? Would anything be wrong with this? More about this later!

Australia's Nobel Prize winners



This photo shows Professor Elizabeth Blackburn receiving a Nobel Prize in Physiology or Medicine from King Carl XVI Gustaf of Sweden on 10 December 2009 in Stockholm, Sweden. Professor Blackburn was born in Hobart, and is the first Australian woman to receive a Nobel Prize. She presently works at the University of California in San Francisco, and shared the prize with Carol Greider and Jack Szostak.

Professor Blackburn pioneered the study of telomeres, the caps that protect the ends of chromosomes in body cells. She also discovered the enzyme telomerase which makes telomere DNA and thus protects people's genes from wearing down with age. Eighty-five per cent of all cancers depend on telomerase for their growth. So scientists think it may be possible to treat most cancers by developing drugs that stop telomerase working.

The Nobel Prize awards were established in 1895 by the Swedish chemist and inventor of dynamite Alfred Bernhard Nobel. He had intended that dynamite be used for peaceful purposes and was dismayed it was being used in war. In 1888 a French newspaper, thinking it was Alfred and not his brother who had died, published his obituary under the heading 'The merchant of death is dead'. This inspired him to change his will so that his money would be used to create a series of prizes for discoveries that 'confer the greatest benefit on mankind' in physics, chemistry, physiology or medicine, peace and literature. Each Nobel Prize winner receives a gold medal and a sum of money. Professor Blackburn and her co-workers shared about $1.5 million.

Professor Blackburn is the eleventh Australian to receive a Nobel Prize. She has spoken out against closing career avenues to women because of the responsibilities of mothering young children. The other Australian prize winners in science are summarised in the table.

Scientists	Year	Prize	Details
Lawrence & William Bragg	1915	physics	X-ray crystallography
Howard Florey	1945	physiology & medicine	medicinal properties of penicillin
Sir Frank MacFarlane Burnet	1960	physiology & medicine	immunology
Sir John Carew Eccles	1963	physiology & medicine	nerve cells
Sir John Warcap Cornforth	1975	chemistry	molecular structure of cholesterol
Professor Peter Dohety	1996	physiology & medicine	immunology
Professor Barry Marshall & Dr Robin Warren	2005	physiology & medicine	discovery that *Helicobacter pylori* bacteria cause stomach ulcers

- Use the internet to research the Nobel Prize. How are the prizes awarded? Which famous scientists have won the prize?
- Choose an Australian Nobel Prize winner and use the internet to research the details of their work and their life. Share your findings with others in the class and discuss whose discovery you think 'confers the greatest benefit on mankind'.

5.3 Dominant or recessive?

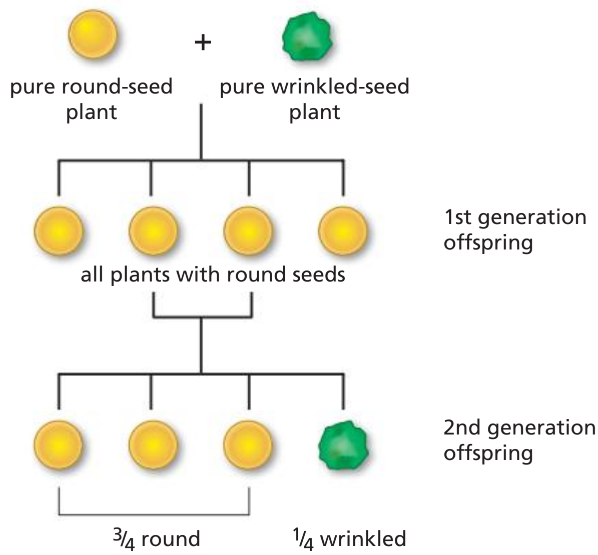
Before the 20th century people did not know about genes or DNA and could not explain how family characteristics were passed on from one generation to the next. However, some of our understanding of genetics today is based on the breeding experiments that were started by an Austrian monk, Gregor Mendel, in 1858.

Mendel carried out experiments with garden pea plants and kept very accurate records of his experiments. The pea plants that Mendel used reproduced by *self-pollination*. However, Mendel took the pollen from the flowers of one pea plant and pollinated the flowers of another pea plant with it. This is called *cross-pollination*. By doing this he was able to control the characteristics that the pea plants inherited.

Mendel found that some of the characteristics that were seen in the parent plants were passed on to their offspring. For example, pea plants could produce round or wrinkled seeds. In his first cross he pollinated pea plants that only produced round seeds (called pure round-seed plants) with plants that produced only wrinkled seeds (pure wrinkled-seed plants). All the offspring from this cross (the *first generation*) had round seeds.

When Mendel crossed two plants from the first generation that had round seeds, he found that around three-quarters of the offspring from the *second generation* had round seeds. The other quarter had wrinkled seeds (see diagram).

Mendel said that the wrinkled-seed characteristic had been 'hidden' in the first generation, so he called this a **recessive** characteristic. He used the word **dominant** to describe the characteristic that appeared most of the time, in this example, round seeds.



Mendel performed hundreds of crosses like this and studied many different pea characteristics, such as stem length, seed colour and flower position. His results were always the same. Each time he found that in the first generation only the dominant characteristic was shown, and in the second generation the recessive characteristic reappeared. This type of inheritance pattern is called *dominant and recessive inheritance* or *complete dominance*.

Mendel could not explain how the pea characteristics were passed on. He suggested that there must be 'units of inheritance' that were responsible for the pea characteristics. Mendel also realised that for any one characteristic there could be different versions. For example, the seeds could be round or wrinkled.

Today we know that the 'units of inheritance' that Mendel was referring to are called genes. Different versions of a gene are called **alleles** (al-LEALS). Round and wrinkled seeds are caused by different alleles, different versions of the gene that determines seed shape.

Genotype and phenotype

Mendel's crosses can be explained using genetics. The cells of pea plants contain chromosomes made up of DNA. Each strand of the DNA is made up of genes that code for the characteristics Mendel observed.

If each characteristic that an organism has is controlled by a pair of genes, then a pure round seed plant must have two genes for round seeds. Let's represent a gene for round seeds by the letter R. So the genes for pure round seed plants would be **RR**. Capital letters are used because this is a dominant characteristic. Representing the genes in this way is called showing the **genotype** (GEE-no-type). Pure wrinkled seed plants would have two genes for wrinkled seeds, and therefore the genotype **rr**. Lower-case letters indicate that wrinkled seed shape is a recessive (hidden) characteristic.

Plants from the first generation that have one parent with pure round seeds (RR) and one with wrinkled seeds (rr) would have the genotype **Rr**. This can be worked out using a Punnett square, which is explained in the Skill section on the next page. Since round seed shape is dominant over wrinkled shape, the plants with the Rr genotype would all have round seeds. The characteristic shown, in this case round seeds, is called the **phenotype** (FEE-no-type). If you now cross two round seed plants (Rr), the possible genotypes of the offspring are RR, Rr and rr. So the phenotypes could be round seeds (RR, Rr) or wrinkled seeds (rr).

Over to you

1 Explain the difference between:
   a dominant and recessive characteristics
   b a gene and an allele
   c genotype and phenotype
2 Long stems in peas are dominant to short stems. If a pure long-stem pea was crossed with a pure short-stem pea, what genotypes and phenotypes would the offspring have? If two of the offspring are crossed, what would the resulting genotypes and phenotypes be? Use a Punnett square (see next page) to help you.
3 Lily has red hair but neither of her parents do. One aunty (mother's sister) and her grandfather (mother's father) also have red hair. Using a Punnett square, show how Lily came to inherit red hair. Show all genotypes and phenotypes.

INQUIRY 5 *Dominant and recessive characteristics*

1 Look at the following table.

Dominant	Recessive	Dominant	Recessive
round face	long face	freckles	no freckles
wide eyes	narrow eyes	right-handed	left-handed
long nose	small nose	short-sight	normal sight
brown hair	blond hair	curly hair	straight hair
brown hair	red hair	thick lips	thin lips
baldness in men	thinning hair	low voice in men	high voice
thinning hair	baldness (women)	high voice (women)	low voice
long chin	normal chin	obese body	lean body

2 List the features you have from the table above, showing both possible genotypes and phenotypes. For example, if you have freckles you would write FF or Ff, and if you have no freckles, ff.
3 Now repeat this for the members of your family. Is there a pattern of dominant or recessive characteristics in your family? Punnett squares may help. Do your findings support Mendel's results?
4 Why is it that women are more likely to have high voices and less likely to go bald? Show all genotypes and phenotypes.

PROBLEM SOLVING

If parents selected the characteristics they wanted for their children, could unwanted characteristics caused by dominant or recessive genes be avoided? For example, cystic fibrosis causes breathing and digestive problems. It is passed on by a recessive gene. A person needs to inherit two recessive genes to get cystic fibrosis.

Beta-thalassaemia is also caused by a recessive gene which affects the production of normal haemoglobin, causing faulty red blood cells to be produced.

Dwarfism, anonychia (absence of fingernails and toenails) and some forms of Alzheimer's disease are all caused by inheriting a dominant gene.

SKILL

Punnett squares

A **Punnett square** is used in genetics to show the outcomes of different crosses. Each square in the table indicates the possible offspring that can be produced by the parents chosen.

Let's say that a pure yellow seed plant is cross-pollinated with a pure green seed plant. Yellow is the dominant characteristic in this case. To make a Punnett square for this example, follow these steps:

1 List the genotypes for each plant. Let's choose Y for the dominant characteristic.

pure yellow seed plant: YY

pure green seed plant: yy

2 Draw up a table with four boxes like this:

		Parent 2	
		y	y
Parent 1	Y		
	Y		

3 Now fill in the four boxes in the table:

		Parent 2	
		y	y
Parent 1	Y	Yy	Yy
	Y	Yy	Yy

4 State what the possible genotypes are from the table. Each square represents ¼ or 25% of the possible genotypes of the offspring. In this case, all four squares have the genotype Yy. So 100% will be Yy.

5 State what the phenotypes are for each square. All four squares have the same phenotype. So 100% will be yellow seeds.

In the above example the offspring that were produced all had yellow seeds. However, they did not have a pure genotype of YY. Instead they were Yy. An individual with a pure form of a genotype is referred to as *homozygous*, meaning the organism has two identical genes for the characteristic being studied. An individual with two different genes for the characteristic being studied is referred to as *heterozygous*.

Let's try another example. Imagine that two offspring with the genotype Yy (heterozygous individuals) are crossed.

1 The genotypes will be Yy for one parent and Yy for the other.

2

		Parent 2	
		Y	y
Parent 1	Y		
	y		

3

		Parent 2	
		Y	y
Parent 1	Y	YY	Yy
	y	Yy	yy

4 The first square in this cross represents ¼ of the possible genotypes or 25%. So 25% of the genotypes are YY. Two of the squares have the genotype Yy. If each square is ¼ of the possible genotypes, then two squares will be ½ of the genotypes, or 50%. So 50% of the genotypes are Yy. The final square, representing 25%, has the genotype yy. So 25% will have the genotype yy.

5 There are 25% YY and 50% Yy that will all have yellow seeds. So ¾ or 75% will have yellow seeds. The other ¼ or 25% will have green seeds.

Questions

1 a State the possible genotypes and phenotypes for the offspring when a brown-eyed homozygous male is crossed with a blue-eyed female. Assume that the gene for brown eyes is dominant over the gene for blue eyes.

b Would the outcome be the same if the male in the cross was heterozygous for brown eyes? Use a Punnett square to work this out.

2 State the possible genotypes and phenotypes for the offspring of a cross between two heterozygous coloured seed plants. Assume that coloured seed plants are dominant over white seed plants.

5.4 Other forms of inheritance

Incomplete and co-dominance

With dominant and recessive inheritance, one gene masks or hides the effects of another. However, genes do not always work in this way. If a black mouse is crossed with a white mouse, the offspring are grey. This is called **incomplete dominance**. The cross has resulted in a blending of the parents' characteristics. To show this, capital letters are used for each gene.

		White mouse	
		W	W
Black mouse	B	BW (grey)	BW
	B	BW	BW

If two of the grey mice are mated, then the following offspring are possible:

		Grey mouse	
		B	W
Grey mouse	B	BB	BW
	W	BW	WW

In this example, 25% of the offspring are black, 50% are grey and 25% are white.

Incomplete dominance is common in many organisms. For example, red-flowered snapdragons crossed with white-flowered snapdragons produce plants with pink flowers. Another example is seen in budgerigars. Yellow budgerigars crossed with blue budgerigars produce a green variety.

A cross between organisms can also produce offspring with characteristics that show both of the parents' characteristics. This is called **co-dominance**. Co-dominance can be seen in roan cattle. Red cattle have red hair, white cattle have white hair and roan cattle have both red and white hair.

Co-dominance can be seen in blood types. If a person gets a gene for **A** type blood from one parent and **o** type blood from the other parent, the person will have **A** type blood because the **o** is recessive. The same occurs for a person with a gene for **B** type blood and one for **o** type blood. The person will have **B** type blood. But if a person inherits a gene for **A** type blood and a gene for **B** type blood, their blood will have both **A** and **B** types of protein present on the surface of their blood cells.

INQUIRY 6 Incomplete and co-dominance

You will need: a copy of this activity, scissors, glue

A fly with horizontal black stripes on its abdomen (HH) was mated with a fly with vertical black stripes on its abdomen (VV). All the offspring produced had black abdomens.

1 What type of inheritance pattern does this cross show? Draw a Punnett square to show this cross, and give all genotypes and phenotypes.

2 Two of the black offspring were then crossed. What possible offspring would you expect to be produced from this cross? Draw a Punnett square to show your answers.

3 The following offspring were produced. Using your copy, cut out the flies and group like ones together. Show their genotypes and phenotypes.

4 Do the numbers of offspring produced fit the pattern of offspring you expected from such a cross?

5 A fly with horizontal black stripes on its abdomen (HH) was mated with a fly with vertical black stripes on its abdomen (VV). Instead of black flies, a mistake occurred and all the offspring had a combination of vertical and horizontal stripes on their abdomen. What type of inheritance would this be called? If two of these flies were then crossed, what would the expected outcomes of their offspring be? Show all working.

Sex-linked inheritance

Earlier you learnt that each cell in your body has 46 chromosomes, or 23 pairs of chromosomes. The chromosomes in one of these pairs are called the sex chromosomes. In females, the pair contains two X chromosomes. In males, it contains an X and a Y chromosome. Some characteristics can be passed on through genes found on the X or the Y chromosome. This is called **sex-linked inheritance**.

Some genes are found on the X chromosome. Females have two sets of these genes because they have two X chromosomes. Males only have one set of these genes because they have only one X chromosome. The Y chromosome carries a different set of genes. In normal circumstances, this is not a problem. However, let's imagine that there is a faulty gene on one of the X chromosomes. This faulty gene causes a disease. With two X chromosomes, females are less likely to develop the disease because they have a second X chromosome, which may carry a correctly functioning gene. This gene can mask the effect of the faulty one.

Males only have one X chromosome, so if they get an X chromosome with the faulty gene they will develop the disease. Diseases such as colour blindness, haemophilia and Duchenne muscular dystrophy are passed on in this way. They are sex-linked diseases which, because they are passed on via the X chromosome, are also referred to as X-linked diseases.

In the following example of colour blindness, XX is a normal female, XY is a normal male, X^cX^c is a female who is colourblind, X^cY is a male who is colourblind, and X^cX is a female who is a *carrier* of the disease. This means that she does not have the disease but carries the faulty gene on one of her X chromosomes. If a normal male and a carrier female have children, the possible outcomes will be:

		Normal male	
		X	**Y**
Carrier female	**X^c**	X^cX carrier female	X^cY colourblind male
	X	XX normal female	XY normal male

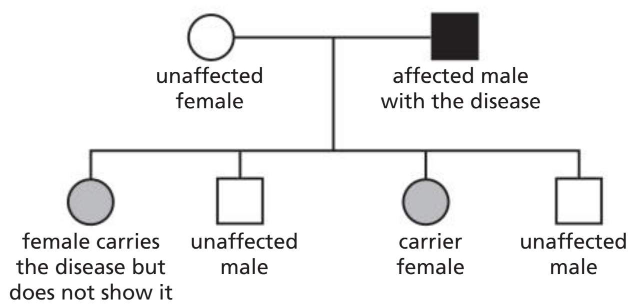
There is a 50–50 chance that one female will be a carrier and a 50–50 chance that one male will be colourblind. The other children will be normal. Let's look at another cross.

		Colourblind male	
		X^c	**Y**
Carrier female	**Xc**	X^cX^c colourblind female	X^cY colourblind male
	X	X^cX carrier female	XY normal male

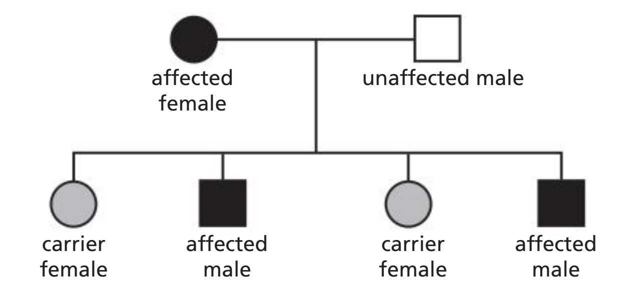
So, for a female to be colourblind, her father must have the disease. Her mother must also be either a carrier of the disease or have the disease herself.

Pedigrees

It is very time consuming to draw Punnett squares and work out genotypes from this. It is often easier to draw genetic **pedigrees** or family trees to show the information. In a family tree, the different individuals involved are represented by symbols, as shown below. Both pedigrees show the inheritance of haemophilia, a disease in which blood fails to clot.



In the above example, none of the children have the disease. Only the male parent has the disease.



In this example, the mother has the disease and the female offspring both carry it. Both males have the disease. The importance of pedigrees

The importance of pedigrees

Some genetic diseases appear to run in families and can be detected either before or at birth. Some examples are:

- cleft lip (split in the upper lip between the mouth and the nose)

- cleft palate (the roof of the mouth is not joined properly)
- spina bifida (incomplete development of the brain and spinal cord)
- congenital heart disease (heart defect occurring at birth)

Some genetic diseases develop with age, for example, diabetes and Alzheimer's disease.

Pedigrees can be drawn for people who have members of their family with these diseases, so that a person's risk of developing these genetic diseases or passing the condition on to their children can be assessed.

Over to you

1 A blue-feathered bird was crossed with a white-feathered bird and the offspring all had silver feathers.

a What are the genotypes of the two birds and the offspring?

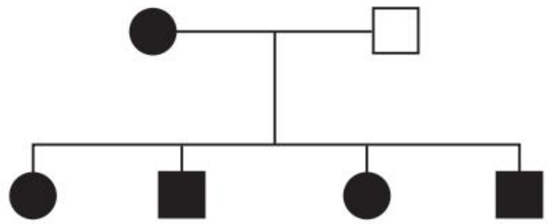
b If two silver birds were mated, predict the genotypes and phenotypes of the offspring.

c What type of inheritance is this?

2 If two orange-flowered trees are crossed, the offspring produced are 25% red-flowered, 50% orange-flowered and 25% yellow-flowered. What are the genotypes and phenotypes of the plants that the two orange-flowered trees came from?

3 A tabby cat (black and tan fur) is produced by a cross between a black cat and a tan cat.

a What type of inheritance is this?



b If a tabby cat and a tan cat are crossed, what will the genotypes and phenotypes of the offspring be?

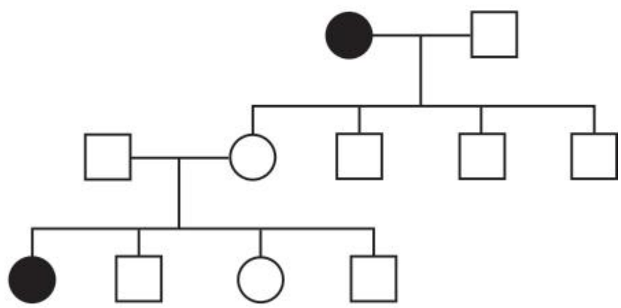
c What would the colour of the parents need to be to get all tabby offspring?

4 Huntington's chorea (mental deterioration and involuntary movements) is caused by a dominant gene (H). A person who is HH or Hh will have the disease. Not having the disease is recessive (hh).

a Show the genotypes for each individual in this pedigree.

b How do you know from the pedigree that this disease is caused by a dominant gene?

5 The following pedigree shows how cystic fibrosis is inherited in a family.



a What type of inheritance is shown in this diagram? How do you know?

b List the genotypes and phenotypes for each individual in the pedigree.

c Are there some individuals you are not sure of?

5.5 Genetic disease and cloning

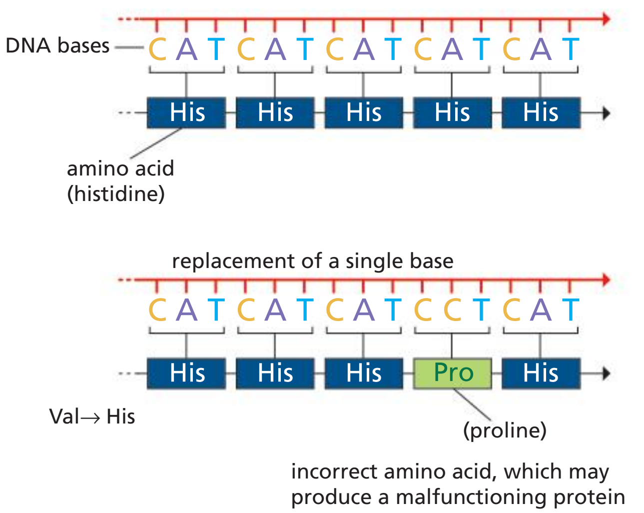
Genetic disease

You have already looked at some of the causes of genetic diseases, for example, dominant and recessive genes, an abnormal number of chromosomes or defective genes on the X chromosome. An example of such a disease is phenylketonuria (PKU), which occurs when a person is unable to produce phenylalanine, an essential amino acid occurring in proteins. This condition is caused by a defective gene.

There are, however, other causes of genetic disease. A permanent change in the DNA sequence that makes up a gene can cause disease if the gene no longer produces the same protein as it did before, or if the protein ceases to function as it should. This type of change in the DNA is called a **mutation**.

If mutations occur in egg and sperm cells, then the changes to the DNA (genes) can be passed on to any offspring. Mutations can be caused by environmental factors such as exposure to ultraviolet radiation from the sun. Chemicals, high temperature and viruses can also cause changes to DNA sequences.

Mutations can also occur through chance mistakes. For example, if the wrong base is copied when a chromosome duplicates, then an incorrect amino acid may be inserted into the protein sequence. A protein may also be shortened and thus fail to function as it should.



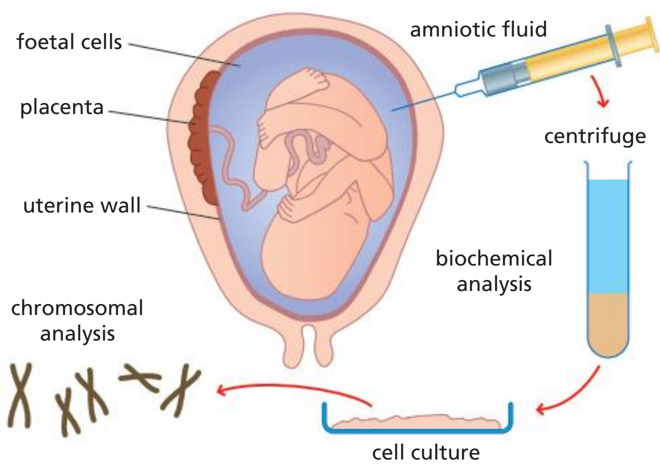
Top: A correct DNA code
Bottom:The same DNA code showing how one error in a base sequence can cause a mutation

Mutations in certain genes have been found to cause Alzheimer's disease or increase a person's chance of developing it. Mutations are more common in the eggs of older women. As you learnt previously, at birth a female has all the eggs she is going to need in her lifetime. So as a woman ages, her eggs age too. Older women therefore have a low pregnancy rate. This is because many of their eggs have genetic defects (they carry defective genes) or chromosomal abnormalities (the numbers of chromosomes are incorrect). So their embryos do not develop properly.

Genetic testing

Genetic testing is available to all pregnant women in Australia if they decide to have it. During the first eight weeks of pregnancy a doctor performs an ultrasound test. Sound waves are used to produce a picture on a computer screen of the baby developing in the uterus. The size of the baby can be measured to see how old it is.

An ultrasound performed at 12–15 weeks can show the heart, brain and spine. The skull and limbs can be measured to indicate how well the baby is developing. At this time a pregnant woman can also choose to have *amniocentesis* (AM-nee-oh-sen-TEE-sis). A very fine needle is inserted into the woman's abdomen and a small amount of amniotic fluid removed. The baby is surrounded by this fluid to protect it while it is in the uterus. Cells from the developing foetus found in the amniotic fluid are examined for chromosomal abnormalities (e.g. Down syndrome). Diseases such as spina bifida, thalassaemia, PKU and Tay-Sachs disease (a fatal disease causing the slow breakdown of nerve tissue)



Amniocentesis

can also be detected. Analysing the chromosomes can also indicate what the sex of the baby is.

Other tests include chorionic villus sampling, in which samples are taken from the placenta. A blood sample from the mother can also be used to assess whether the baby is at risk of developing a disease.

If an abnormality is found during any genetic testing, the parents face a difficult decision. They have to decide whether to proceed with the pregnancy or terminate it. Some religions oppose the termination of a pregnancy. There is also the question of what quality of life the child will have and whether the parents can pay for the treatment the child will need.

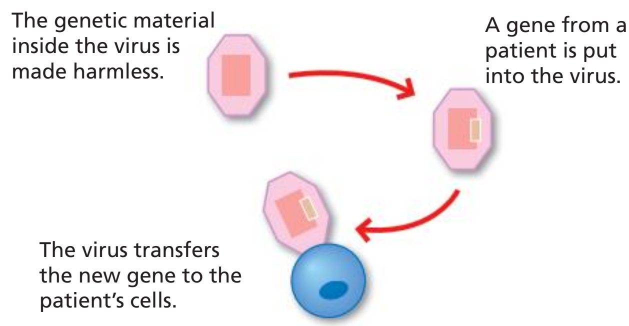
Pre-implantation genetic diagnosis

Parents who have an inherited disease in their family and face the risk of passing it on to their children can choose to undergo in-vitro fertilisation (IVF) and have the embryo tested for genetic disease. A number of eggs from the mother are fertilised with the father's sperm in vitro, which means 'in glass', such as a Petri dish or test tube. Each fertilised egg cell then starts to divide. After three days, each zygote has grown to eight cells. At this point one cell can be removed from each embryo using suction, without any harm, and tested for genetic disease. This is called pre-implantation genetic diagnosis (PGD). Using fluorescent probes, the chromosomes are checked to make sure they are normal. The DNA sequence that causes the disease can be selected, copied and analysed. Embryos that have been tested and are normal can then be inserted into the uterus of the mother in the hope that one or more will develop.

Gene therapy

Diseases such as cystic fibrosis, haemophilia and sickle cell anaemia (blood cells shaped like sickles, causing poor blood flow) have been linked to defective genes that produce faulty proteins. Gene therapy aims to produce healthy cells that function correctly by replacing or correcting the defective gene. This can be done by switching off genes that do not work properly, replacing a defective gene with one that is normal, or inserting genes that are missing.

Gene therapy can be performed in different ways. Genes can be inserted into cells that have been removed from a patient. These modified cells are



then transplanted back into the patient, as shown in the diagram. Viruses are sometimes used to 'carry' the gene or genes into the patient. The genetic material of the virus is disabled so that it no longer works. The new gene is then inserted into the viral DNA. When the virus is allowed to infect the patient, it transfers the new gene or genes into the cells it infects.

Gene therapy has many real-life applications. For example, people who suffer from type 1 diabetes cannot make insulin because the cells in the pancreas that make it have been destroyed. Insulin is an important protein that travels through the body in the blood and controls the level of blood sugar. Without insulin a person can experience very high or low levels of blood glucose, leading to fatigue, vomiting, coma and death. Diabetics must therefore inject themselves with insulin every day. However, gene technologists have been able to insert the insulin gene into liver cells and get these cells to produce insulin to correct the problem.

PROBLEM SOLVING

Here are some more issues for you to consider in your essay.

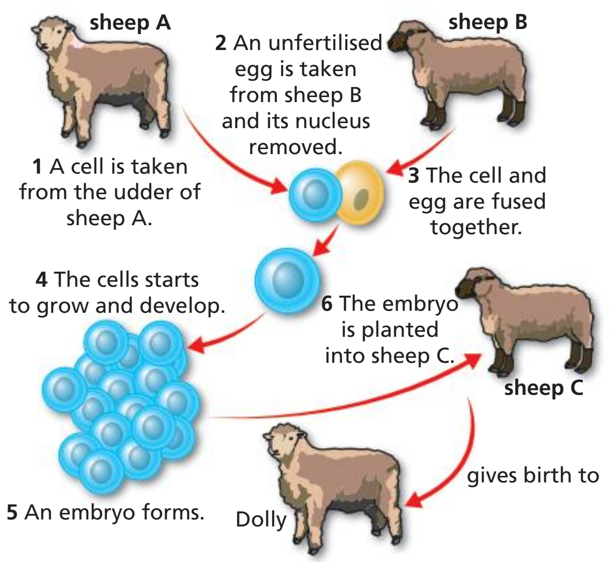
- If parents are able to select the characteristics of their children, at what stage of the child's development should they do this?
- Will parents have to undergo in-vitro fertilisation and subject the embryo to genetic testing and gene therapy to get the desired characteristics they want? Is this playing God?
- Do we have the right to choose what our children will be like?
- Should we eliminate all genetic diseases? Are we limiting the variation in a population if we allow parents to select their children's characteristics?

Science as a Human Endeavour

Cloning

In sexual reproduction, a sperm and egg meet to produce an offspring that is genetically different from its parents. In asexual reproduction, there is no meeting of a sperm and egg. The offspring is genetically identical to the parent. A **clone** is the term used to describe the asexual reproduction of an organism or a cell.

In 1997 Scottish scientists created history by cloning a lamb from an udder cell of a ewe—a female sheep (sheep A). The DNA from the udder cell was removed and fused with a cell from another ewe (sheep B), which had its nucleus removed. After fusion the new cell began to grow. After six days the embryo was implanted into another ewe (sheep C), who gave birth to a lamb called Dolly. However, Dolly was put down prematurely at 6 years old because she developed diseases of old age as her cells were as old as her mother's.



The procedure used to make Dolly

Since Dolly, mice, goats, cows, pigs and a horse have been cloned. It is only a matter of time before an attempt is made to clone a human. The *Prohibition of Human Cloning Act* was passed by the Australian government in 2002. This Act prevents cloning and the trade of embryos, eggs and sperm in Australia.

INQUIRY 7 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 cloning of humans should be allowed? Move to the corner that applies to you.

3 The 'strongly agree' and the 'strongly disagree' corners 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.

These are some of the issues you may need to discuss before completing this activity:

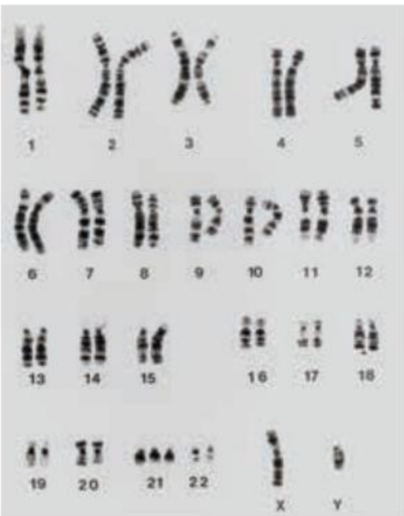
- What would be the benefits of cloning people?
- Who would you clone and why?
- Should people who suffer from a genetic disease be allowed to be cloned?
- Should people who have committed a crime be prevented from being cloned?
- Would cloning reduce variation among humans and how could this affect us?
- Would cloned individuals have the same rights as non-cloned people?
- Human cells can be cloned to replace organs. If a patient's cells are cloned and a new organ is grown, the patient's body is less likely to see the organ as foreign, so organ rejection is less likely. This is called therapeutic cloning. Should this type of cloning be allowed?
- Could making a clone have unintended consequences?
- How do you think religious groups view cloning?

THINKING SKILLS ?

1 Some genes appear on the Y chromosome only. Hairy ears are an example of an unwanted characteristic that is inherited in this way.

- **a** If a man with hairy ears marries a normal woman, show what the possible characteristics of the children could be. Use a Punnett square.
- **b** Draw a pedigree of your findings.
- **c** Is it possible for a woman to have hairy ears? Explain.

2 A cell from an embryo was extracted as the cell was undergoing mitosis. The chromosomes were put into pairs and numbered.



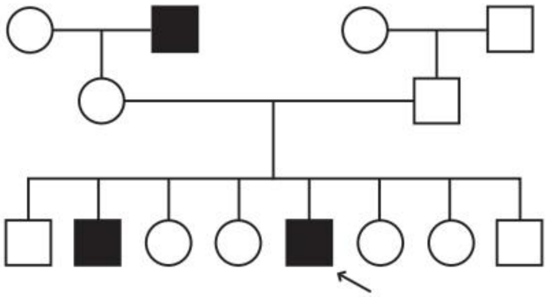
- **a** Is there anything wrong with this embryo?
- **b** What is this called?
- **c** What characteristics would this cause?
- **d** Is the embryo male or female?
- **e** What counselling would you give the parents?

3 A diabetic woman had gene therapy. Insulin-producing cells were injected into her liver. Would her children inherit these insulin-producing cells? Explain.

4 A defective gene is removed and a normal functioning gene is inserted into a newly fertilised egg cell. This cell is then allowed to develop and grow into an adult. If this person then had children, would they inherit the genetic change? Explain.

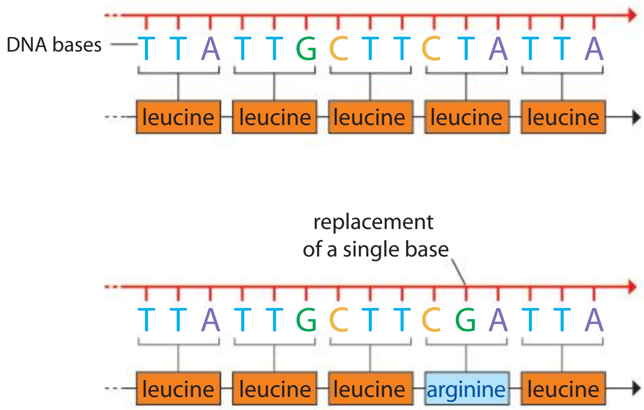
5 Are identical twins clones of one another? Explain.

6 The following pedigree shows how hairy eyeballs are passed on in Australian shepherds (dogs).



- **a** Which sex of the dogs is affected by hairy eyeballs?
- **b** What type of inheritance is shown in this pedigree? Give reasons for your answer.
- **c** Would you expect any females to have the disease? What would the genotypes of the parents have to be for this to occur?
- **d** Show the genotype of the individual indicated by the arrow on the pedigree.

7 Look at the following diagram.



Top: A correct DNA code
Bottom: The same DNA code showing how one error in a base sequence can cause a mutation

- **a** What do the letters in the first line represent?
- **b** What do these letters code for?
- **c** What has gone wrong?
- **d** How could this affect the individual with this sequence?

Knowing and Understanding

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

1 Repair, replacement and growth of cells occurs through the process of _______. This is different from _______, which is the process that occurs to make egg and sperm cells.

2 You inherit _______ chromosomes from your mother and the same number from your father. They pair together to make _______ chromosomes in each cell in your body (excluding sperm and egg cells).

3 Chromosomes are made up of _______. A segment of DNA that codes for a characteristic in the body is called a _______.

4 Different versions of a gene are called _______. For example, there are genes with different alleles that control eye colour.

5 There are different patterns of inheritance. If one gene is shown and the other gene is hidden, this is called _______ and _______ inheritance.

6 _______ occurs when both characteristics of the parents are seen in the offspring. A blending of characteristics is called _______.

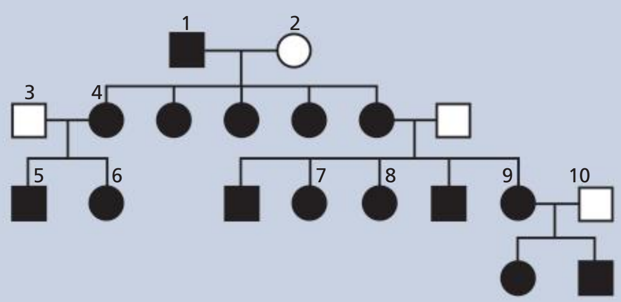
7 Inherited characteristics can be shown using a _______, which is a family tree.

alleles
co-dominance
DNA
dominant
gene
incomplete dominance
meiosis
mitosis
pedigree
recessive
46
23

Self-management

Some questions are made up of a number of different parts. When you complete these questions you need to read the introductory material provided carefully, then work through each part of the question point by point. Here are some examples of questions like this that will help you review the chapter.

1 The following diagram shows how polydactyly is inherited in a family. Polydactyly is having more fingers and toes than normal.



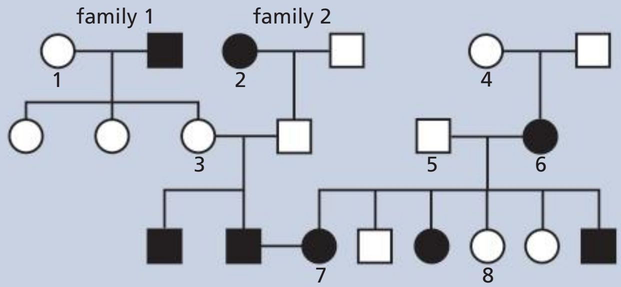
a What type of diagram is this? Which symbols represent males and females?

b How many males and females have the disease?

c Explain the following patterns of inheritance: dominant and recessive, co-dominance, incomplete dominance, sex-linked. Which one explains how polydactyly is inherited? Give reasons for your answer.

d What are the possible genotypes and phenotypes of the numbered individuals?

2 Write your own set of questions for this diagram, which shows the inheritance of albinism. This is the loss of pigment (colour in cells) in the eyes, hair or skin.



Checkpoint

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

1 Match the following words to their meanings: zygote, alleles, heterozygous, chromosome.

a thread-like bodies seen in the nucleus of a cell when the cell is about to divide

b different versions of a gene

c the cell produced by the joining of a sperm and an egg

d a type of organism that contains two different versions of a particular gene

2 Which of the following are true and which are false?

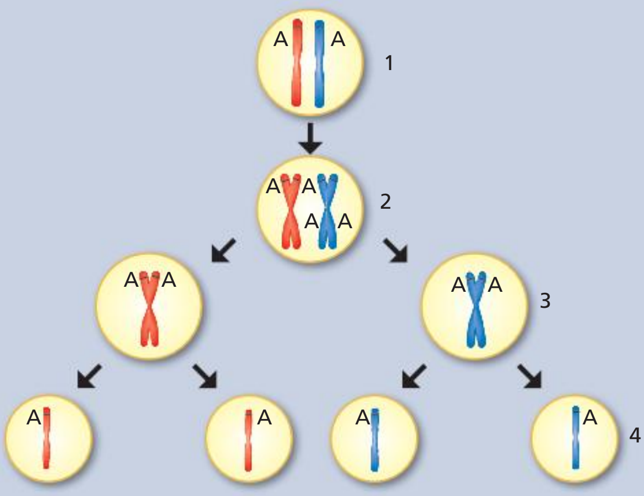
a Chromosomes are made up of DNA.

b Co-dominance occurs when the offspring show a blend of the characteristics of the parents.

c In X-linked inheritance, the male will always show the disease if he inherits a faulty X chromosome.

d The term 'genome' is used to describe all the genetic material an organism has.

3 Study the following diagram carefully.



a If circle 1 represents a body cell, then what do the objects inside the circle represent?

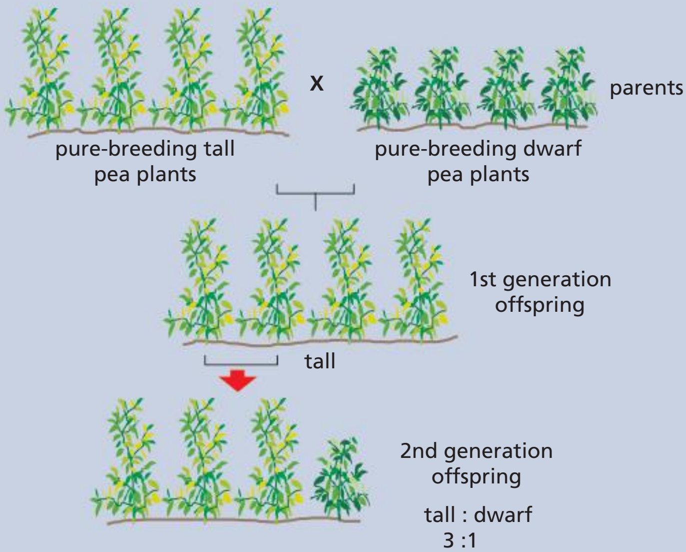
b What does the letter A represent?

c What process does the diagram show?

d Where would this process take part in the body of a female?

e How many chromosomes would be found in cell 1? How many chromosomes would be found in cell 4?

4 Look at the following crosses between pea plants.



a What is meant by 'pure-breeding tall pea plants'? What is another name for 'pure'?

b What would the genotypes and phenotypes of the parents and offspring be from each cross?

c What type of inheritance is this? How do you know?

d Who was the first person to identify this type of inheritance pattern?

5 Look at the following diagram.

a What does this diagram represent?

b What do the letters A, T, G and C stand for?

c Bases are normally arranged along a strand of DNA in sets of three, as shown. Why do you think this is?

d What are the sets of three letters called, and what do they code for?

6

Evolution

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

Science Understanding

- outline the processes involved in natural selection, including variation in organisms and selection by the environment
- evaluate and interpret evidence for evolution, including the fossil record, comparative anatomy and DNA comparisons

Science as a Human Endeavour

- use the theory of evolution to illustrate that scientific theories are tentative and may need to be changed in the light of new evidence
- discuss how societal and religious values have had an impact on the development of the theory of evolution
- use the Mungo Man discovery to discuss the arrival of the ancestors of Aboriginal people in Australia
- consider arguments for and against applications of genetic engineering

LITERACY FOCUS

Archaeopteryx
biodiversity
comparative anatomy
creationism
Diprotodon
evolution
evolutionary tree
evolutionist
extinction
gene pool
gene technology
genetically modified (GM) food
Gondwana
malaria
Mungo Man
natural selection
Pangaea
sickle-cell anaemia
species
Velociraptor

Focus for learning

In your study in science you have probably learnt how scientific ideas have changed over time. For example, look at the structure of the atom. The plum pudding model of the atom made up of positive and negative charges was replaced by Ernest Rutherford's model of the atom. In his model, positive charges are located in the nucleus and negative charges move around it.

Another example can be seen in the observations of Nicolaus Copernicus. His controversial view that the sun, not the Earth, was the centre of the solar system changed scientific thinking. In Chapter 5 you also saw how Mendel's ideas have been modified in the light of new findings today.

So even though scientific theories and models drive the investigations of scientists and allow them to predict future outcomes, they are *never final.* Scientific theories can be *speculative* (risky) and *tentative* (open to change). Theories are developed from many careful observations and tested hypotheses; but, as naturalist Charles Darwin once wrote, 'I have … endeavoured … to give up any hypothesis … as soon as the facts are shown to be opposed to it'. Science is therefore subject to change.

In this chapter you will study the theory of **evolution**, which tries to explain how all life on Earth came to exist. It is a theory based on evidence that is tentative and limited (incomplete).

For many biologists and naturalists evolution is seen as a process in which all life on Earth passes through different stages. Each stage is slightly different and more complex than the stage before. It is often referred to as the gradual unfolding of life. The word evolution is used to describe this process because it comes from the Latin word *évolútus*, meaning unrolled. It is a process of gradual change that has occurred over millions of years and is still going on today.

Many ideas have been put forward to explain how all life on Earth came to exist. For example:

- creationism—God created all life on Earth
- spontaneous generation, in which living things appear from non-living things
- evolution of organisms from pre-existing life (e.g. single-celled organisms give rise to multicelled organisms, jellyfish to fishes, fishes to amphibians, etc.)
- genetic variation and the environment cause change in organisms.

PROBLEM SOLVING

Which idea?

Your problem in this chapter is to research some of the ideas that explain how all life on Earth came to exist. You must examine at least two different ideas and explain the good and bad points of each. You must then explain how *you* think life on Earth came to exist. Is there one idea or several ideas that can be used, or is there still not enough evidence to decide?

Put forward your ideas in a two minute class presentation. Be prepared for questions from the class and support each point you make with evidence.

SCIENTISTS AT WORK

The history of a theory

Before the 1700s very few people believed in scientific theories to explain creation. The majority of people believed that God created heaven and Earth. God also created all living things on Earth separately from each other. God created humans, and all other living things were inferior to humans. Many people believed that the Earth and all life on it were fixed and permanent. As a result of creation, all organisms appeared on Earth at the same time and the Earth itself was about 6000 years old.

Georges-Louis Leclerc, Comte de Buffon (1707–1788) questioned this way of thinking. He believed that life on Earth was not fixed. He also questioned the age of the Earth. He wondered about the similarities between humans and apes, and how the environment affected organisms.

Carolus Linnaeus lived at the same time as Buffon. He was very interested in natural theology, a school of thought that believed that since God created the world, it was possible to understand God by studying his creation. Linnaeus began studying plants and producing a natural classification system. He grouped organisms on the basis of similar characteristics and soon realised that life on Earth was not fixed. Like Buffon, he suggested that plants might be altered by their environment.

French biologist Jean-Baptiste de Lamarck (1744–1829) was an expert in invertebrate classification. He proposed that the environment causes the needs of organisms to change, which then alters their behaviour. This, in turn, causes organisms to use or disuse organs. If they use an organ it gets larger. If they stop using it the organ shrinks or disappears. The characteristics that organisms develop in this way (acquired traits) can then be inherited by the offspring.

Using Lamarck's theory, the long necks of giraffes can be explained by saying that these animals once had short necks, but a change in their food supply meant that they had to stretch up to reach their food high in the trees. The giraffes had to use their necks so they grew longer. The long necks were then inherited by their offspring. So, over time all giraffes developed long necks.

Lamarck also believed that organisms on Earth developed from inferior beings until they reached perfection or became human. **Species** did not become extinct, they just changed their form.

Erasmus Darwin (1731–1802) believed that all life on Earth developed from a single common ancestor. He suggested that competition between organisms for resources meant that the strongest organisms survived and that this caused changes in groups of organisms. His ideas probably influenced his grandson, Charles Darwin.

Charles Darwin

Charles Darwin was born on 12 February 1809 in Shrewsbury, England. He studied medicine but did not like to see surgery performed so he went to Cambridge University to become a clergyman. When he finished his study, Darwin took a job as an unpaid naturalist on the ship HMS *Beagle* from 1831 to 1836. The crew of the *Beagle* had to survey the coast of South America and parts of the Pacific. Darwin's job was to record the plants and animals he found on the voyage. He collected many different specimens and recorded many observations.

During his voyage Darwin read the *Principles of Geology* by Charles Lyell, who proposed that the Earth in the past was shaped by wind, rain, earthquakes and volcanoes, and that these forces continued to shape the Earth. Darwin started to look for evidence of this and question what life was like in the past compared to what he saw on his travels.

Charles Darwin

While on the *Beagle* Darwin went to the Galapagos Islands. At each island he visited he noticed that the tortoises and finches were slightly different from the ones on the other islands. Darwin inferred that the finches lived in a different environment on each island and that is why they were different.

On his travels Darwin also collected fossils of organisms that no longer existed. He inferred that the organisms must have developed slowly over millions of years from common ancestors.

Darwin also observed slight differences or variations between organisms of the same species. He reasoned that there must be a struggle for existence. He had read the work of Thomas Malthus, who argued that human populations were able to reproduce in greater numbers than their food supply could support. However, these numbers were controlled by disease, famine and war. Darwin inferred that some variations helped organisms survive and reproduce. Favourable characteristics would be passed on and over time the group of organisms would gradually change. This theory is known as **natural selection** and can be summarised in five points:

1. There is variation between organisms.
2. The numbers of natural populations remain fairly constant even though they reproduce in far greater numbers.
3. There is a struggle for survival.
4. Some variations help organisms survive. Organisms with less favourable characteristics die out.
5. The variations with survival value are passed on to the following generations, so over millions of years species become better adapted to their environment.

If we use the giraffe example again, Darwin would say that there is variation among giraffes, some having longer necks than others. The shorter-necked giraffes would die out when food in the lower branches of trees ran out. The longer-necked ones could reach food higher up and would have had a greater chance of surviving and passing on long necks to their offspring. So over time the giraffe population would all come to have long necks.

Darwin developed his theory of natural selection after returning to London from his voyage on the

Beagle. However, he did not publish his work for 20 years. The changes in organisms he was theorising about took place over millions of years, much longer than a lifetime, so he could not test his theory, only collect evidence to support it.

In 1858 Darwin read a paper by Alfred Russel Wallace (1823–1913), which outlined a theory very similar to his own. Like Darwin, Wallace had observed the natural world on expeditions to South America and Indonesia. After seeking advice from his friend Charles Lyell about what he should do, Darwin presented his findings at the same time as Wallace presented his on 1 July 1858. The following year Darwin produced a condensed version of his theory in a book called *On the Origin of Species by Means of Natural Selection*.

Darwin's ideas were very controversial. With his theory of natural selection he was able to propose a process to explain *how* evolution occurred. He claimed that humans, like all other organisms, developed because of evolution. This went against the teachings of the Church, which stated that humans were created by God. So, as with the many scientists before him, Darwin's ideas were rigorously debated. However, he had gathered such a lot of evidence to support his ideas that it was very hard for the others to criticise them.

Today debate still occurs over the theory of evolution. Creationists believe that God created the universe and all life on Earth. They say that nobody observed the origin of the universe or a single living thing, so how do we know? Other people believe that God created all life but that evolution can be used to explain the changes in living things since that time. The study of genetics has shown how and why variation between organisms occurs.

INQUIRY 1 Black and white

Peppered moths exist in Britain in two forms—a peppered form with black spots on white wings and a pure black variety. These moths live on lichen-covered trees that are peppered in colour. In the industrial areas of Britain the numbers of pure black moths have increased. The trees in these areas have smoke-stained trunks.

You will need: two sheets of poster paper (one black and one white), 20 black-coloured counters (the same colour as the poster paper), 20 white-coloured counters, stopwatch

1. In pairs, suggest why you think the numbers of black moths are increasing. Record your inference.
2. Place all the counters on the white poster paper.
3. You now have 10 seconds to pick up as many counters as possible, one at a time. Your partner can be timekeeper. How many counters of each colour did you collect?
4. Repeat step 3, but this time place all the counters on the black poster paper.
5. Swap with your partner and allow them to collect the counters. You are now timekeeper.
   - Which counters did you collect the most of on each coloured background?
   - Did the coloured background make a difference to the colour of the counters collected? Explain.
   - If the white counters represent the peppered moths and the black counters represent the black moths, which moths would survive better on each coloured background?
   - Explain whether your inference in step 1 was correct.
   - How would the following people explain the increasing numbers of black moths in Britain?

     a creationists **b** Lamarck **c** Charles Darwin

Peppered and black varieties of moths

INQUIRY 2 Evolution rap

Write your own rap song explaining the different theories of evolution. Here's an example.

Evo-LU-tion, Evo-LU-tion,
if you wanna survive, it's the solution.
Lamarck didn't get it, yeh he got it wrong,
The world had to wait, till Darwin came along.

Yeh, Darwin's the man, yeh, Darwin's the boss.
He figured it out, on Galapagos.
If the dinosaurs knew it, there'd be no surprise.
They'd have missed that rock, when it fell from the skies.

Evo-LU-tion, Evo-LU-tion,
if you wanna survive, it's the solution.
Your problem here, is to write a rap song,
so all in the class can rap along!

Over to you

1. Draw a timeline showing the different theories people had to explain how life on Earth came to exist.
2. Who put forward the following ideas?
   - **a** If an organism uses an organ it becomes larger.
   - **b** There are similarities between humans and apes.
   - **c** Organisms can be classified on the basis of their similarities.
3. Neither Charles Darwin nor Lamarck could explain how characteristics came to appear in a population of organisms in the first place. How would you explain this to Darwin and Lamarck now?
4. Giant tortoises live on the Galapagos Islands. How would Charles Darwin, Lamarck and creationists explain how these tortoises came to be so large?

PROBLEM SOLVING

What can you use from this section to help you with your problem? Research creationism, Lamarckism and Darwinism on the internet.

6.1 Variation

You already know that genetic variation exists between people. In other words, we are not all the same. Genetic variation occurs because each person receives 23 chromosomes from their mother and 23 from their father. Which chromosomes and genes a person receives occurs randomly.

You know that there can be different forms of genes called *alleles*. For example, scientists now know that one of the genes for eye colour is located on chromosome 15 and comes in two different forms—brown and blue. The difference between the brown and blue alleles is caused by a slight difference in the base sequence of the eye colour gene. This produces a different amino acid and a different characteristic. If an individual inherits a blue allele from one parent and a brown allele from the other, they will have brown eyes because blue is recessive. The protein produced by the allele for blue eyes is not faulty and still works correctly. It is just masked by the effect of the allele for brown eyes.

Whether a person has blue eyes or brown eyes does not seem to affect how well they see or how well they survive. Inheriting different forms of the gene for eye colour, therefore, does not affect the individual.

Sometimes, however, a change in a gene sequence can affect individuals and their chances of survival. A slight difference in a gene sequence can produce a faulty protein or one that does not work as it should. As you saw in Chapter 5, if a mutation occurs in a gene sequence it may mean that the blueprint for the cell to make a protein is altered so that the protein produced is faulty or fails to function at all. Some genetic diseases are caused by changes like this.

For example, thalassaemia is an inherited blood disorder that can be fatal in infants if not treated early. A mutation in the gene for globin causes this disease. Globin is a colourless protein that makes up the oxygen-carrying compound haemoglobin found in red blood cells. Sufferers of thalassaemia have defective red blood cells and cannot carry enough oxygen around their body.

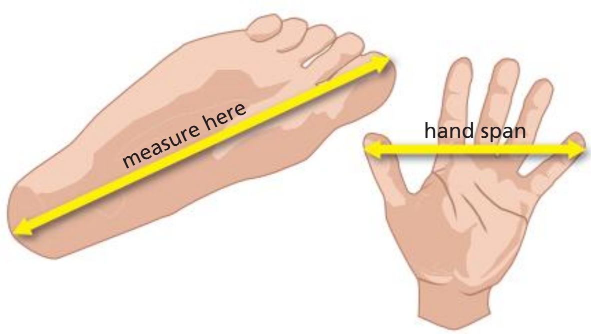
Whether a mutation affects how well an organism survives often depends on the environment in which the organism lives. This is seen with *sickle-cell anaemia*, a disease that is also caused by a mutation in the globin genes. The mutation leads to a change in just one amino acid, causing red blood cells to be crescent- or sickle-shaped. This affects their oxygen-carrying capacity, and sickle cells can block capillaries. This causes the death of the tissue around the blockage, resulting in severe pain. Any organ can be affected. For example, if a blockage occurs in the brain, a sufferer may die of a stroke. Kidney failure, leg ulcers and deformity of the hip and shoulder joints also occur. Mortality from this disease is very high in the first two years of life.

In most cases, sickle-cell anaemia makes it difficult for a person to survive. However, in parts of Africa and India a high number of people live with the disease and survive. So sickle-cell anaemia somehow helps these people. Inquiry 5 explores this further.

INQUIRY 3 Variation in a group

You will need: tape measure, ruler

1 Draw up a data table to record the following:
   - a height of all individuals in the class
   - b length of each foot from the back of the heel to the tip of the longest toe for each person in the class
   - c the hand span of each hand for each person in the class. (This is measured from the tip of the little finger across the outstretched palm to the tip of the thumb.)



2 Carry out each of the measurements listed above. Once you have collected your data, draw a graph for each set of measurements.

3 Describe the variation in the class for each characteristic you graphed.

4 Do these variations affect the survival chances of people in the class? Explain your answer.

5 Explain what you think causes the variations you have measured.

INQUIRY 4

Variation between groups

You will need: skeleton of a dog and a cat and/or a copy of the skeletons of the dog (below) and cat (next page).

In this activity you will look at observable differences in the external characteristics of organisms.

1 Look at the skulls of a dog, a coyote and a wolf. Describe the similarities and differences between them.

Domestic dog

Coyote

Grey wolf

2 Which of these organisms are the most closely related? Why?

3 If there were no labels on the photographs, could you distinguish the domestic dog from the other organisms? Explain your answer.

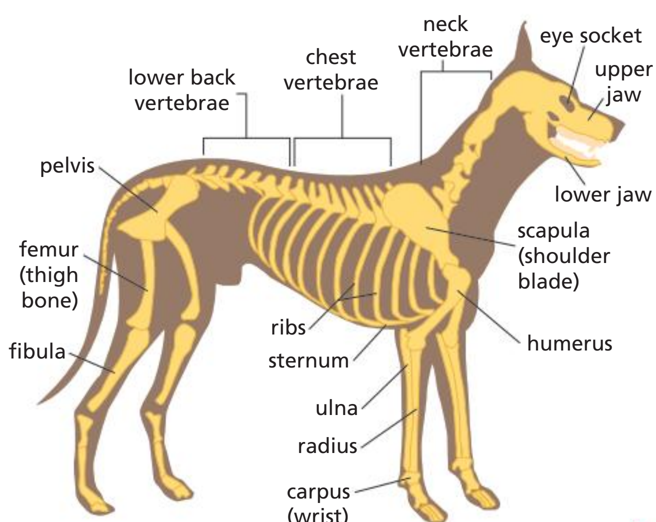
4 Look at the two skulls pictured top right. What are the similarities and differences between these?

5 How do these skulls differ from the skulls of the dog, coyote and wolf?

6 Would you group all the organisms whose skulls you have studied together in one group? Explain your reasoning.

7 If you are now told that the two skulls above belong to a tiger and a cat, does this alter your answer to question 6? Which skull belongs to the tiger and which one belongs to the cat? Explain your reasoning.

8 Look at the labelled skeleton of a dog below. Use this to label a copy of the skeleton of a cat on the next page.



INQUIRY 4 continued

Domestic cats

9 What are the similarities and differences between a dog and a cat? Why do you think they are classified as different organisms, or different *species*?

10 How do you think these variations between cats and dogs came about?

Over to you

1 How does variation in humans occur?

2 Give an example of how a slight change in a DNA base sequence can result in a different phenotype being expressed.

3 Give an example of a variation that:

 a does not affect an organism's chance of survival in a positive or negative way

 b increases an organism's chance of survival

 c decreases an organism's chance of survival

4 Why do you think variation between organisms of the same group or species is important?

5 Give an example of variation between different species other than the one presented here.

6 How would Charles Darwin, Lamarck and creationists explain variation in organisms?

INQUIRY 5 Sickle-cell trait

You will need: an atlas

One form of malaria, called malignant malaria, is a very severe and fatal form of the disease. It is caused by a *Plasmodium* parasite that lives in human red blood cells for parts of its life. Look at the two maps and answer the questions below.

1 Using an atlas, list the regions of Africa where the incidence of sickle-cell anaemia is 7.5% or more of the population.

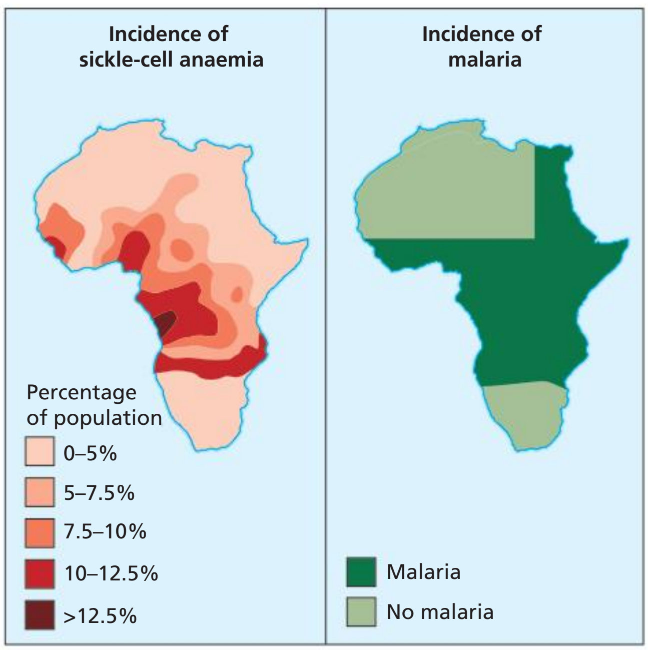
2 Are the same regions affected by malaria and sickle-cell anaemia? Explain.

3 Sickle-cell anaemia is inherited as a recessive characteristic. If the genotype for sickle-cell anaemia is ss, people without the disease would have the genotype SS, and heterozygous individuals would have the genotype Ss. These people are said to have sickle-cell trait but they show a normal phenotype. It is only at very low levels of oxygen in the air that their red blood cells change and become sickle-shaped.

 a Using a Punnett square, show all the possible genotypes and phenotypes for a union between a normal individual and a person with sickle-cell anaemia.

 b Using a Punnett square, show all the possible genotypes and phenotypes for a union between two people with sickle-cell trait.

4 People with sickle-cell trait have extra protection against the malaria parasite. People with sickle-cell anaemia do not seem to have the same protection. So sickle-cell trait is an advantage in Africa. Would people with this trait have the same advantage if they lived in Australia? Explain.



6.2 Natural selection

You have seen how important variation is between individuals. A change in a gene can affect the amino acid that is produced and therefore the characteristic displayed. A slight change like this can increase or decrease an individual's chances of surviving, depending on the environment in which it lives. But how does this happen?

In most groups of organisms more offspring are produced than actually survive to maturity and reproduce. For example, in some plants, hundreds of thousands of seeds are produced but 99% of them die before they can germinate. They may be eaten by animals or land in an area with poor conditions for growth. Of the seeds that do germinate, only a few grow to become adult plants. Again they may be eaten or scratched from the soil by animals, or grow in an area where sunlight and water are limited.

Another example is seen in rock lobsters. Each female can release about 300 000 eggs, which hatch and develop out at sea. Only about 30 of these eggs survive and return to the reef to continue growing, and only a handful of these survive to reproduce. Which ones survive?

Within any group of organisms, some individuals will have characteristics that give them an increased chance of surviving in the environment in which they live. These organisms are said to be better adapted to their environment.

Imagine a group of plants growing on the edge of a swamp. These plants are regularly submerged by water during periods of high rainfall. In years of drought, the plants that survive and reproduce are those that can tolerate the dry conditions.

Organisms that are better adapted to their environment have an increased chance of surviving to become adults and reproduce. They then pass the favourable characteristics on to their offspring, who will be better able to survive and pass the characteristics on to their offspring, and so on. Over time the group of organisms becomes better adapted to their environment, with the favourable characteristics dominating the group. Organisms with unfavourable characteristics are more likely to die before reproducing.

An example of this can be seen with kangaroos. Their body structure is very well suited to living in the hot Australian environment. Kangaroos have large ears with a network of small blood vessels just below the surface. The blood vessels and the large surface area of the ears help radiate heat from the kangaroo's body. The long legs of the kangaroo help it keep its body up away from the hot earth. Its tail aids in hopping so that less energy is used. Over time all kangaroos have come to possess these characteristics because they give such individuals a greater chance of surviving.

Biologists say that the hot Australian environment in this example has chosen, or *selected*, the best characteristics for survival. This process is referred to as natural selection. It is also called *survival of the fittest*. This does not mean that the people who can run the fastest or lift the most weights will survive. The fittest in this case are those organisms that have the best adaptations to their environment.

Think of the dinosaurs. They were bigger and stronger than many of the small mammals they lived with. Yet when a change occurred in their environment, the smaller mammals had characteristics that helped them live in the new conditions. The dinosaurs had characteristics that were not favoured by the environment and they died out or became extinct.

The theory of natural selection also states that present-day organisms have developed from past organisms (ancestors) and it is possible that many organisms share the same ancestors. This has produced a slow unfolding or unrolling of life, each change building on past changes.

We can now explain why some rock lobsters survive and some do not. The rock lobsters with the characteristics best suited to life on the reef will survive, reproduce and pass their characteristics on to their offspring. Those that have unfavourable characteristics will die out. Over time the population of rock lobsters will become more adapted to the environment in which they live.

INQUIRY 6 Geological time scale

The history of the Earth shows that all life, and the structure and climate of the planet, is constantly changing. The **geological time scale** below summarises some of these changes. It represents the record of organisms found as fossils. Each portion of time on this table is called a *period* and some periods are divided into smaller divisions called *epochs*. Read the table and answer the questions at the bottom of the next page.

Era	Period	Epoch (time)	Climate and seas	Life and geography
CAINOZOIC	**Quaternary**	Holocene (present–10 000 years ago)	Warm, melting ice, sea levels rising	• Humans are the major group of animals and many organisms die out. • Natural vegetation removed, replaced by crops and grazing plants, introduced plants in many areas.
		Pleistocene (10 000–2 million years ago)	Most recent ice age, alternating cold and warm periods	• Woolly mammoths, woolly rhinoceroses, giant marsupials and giant flightless birds present. • Many mammals die out. • Humans grow in numbers. • Conifers replace many of the grassland and woodland plants. 
	Tertiary	Pliocene (2–5 million years ago)	Ice caps spreading, cooler than Miocene	• Many organisms die out. • Hoofed mammals present in large numbers. • The first ancestors of humans appear. • Many grassland environments.
		Miocene (5–25 million years ago)	The Earth cools further	• Monotremes, marsupials, sabre-toothed cats, monkeys and apes present. • Grasslands spread.
		Oligocene (25–38 million years ago)	Ice caps form, the climate cools, sea levels fall	• The first ruminants (e.g. cows). • Grasslands and woodlands replace many forests. • Grasses present.
		Eocene (38–55 million years ago)	Warm climate, seas flood the land.	• Bats, lemurs, elephants, pigs, horses, deer, rhinoceroses, cats, dogs, bears, rabbits, moles, penguins, flightless birds present. • Palms present. 
		Palaeocene (55–65 million years ago)	Sea levels fall	• Early primates (apes and monkeys), rodents, gliding mammals. • Flowering plants in large numbers.
MESOZOIC	**Cretaceous** (65–145 million years ago)		Warm and wet climate to start with but then cools	• Snakes and insects, such as moths and butterflies, present. • Many organisms die out, such as dinosaurs and ammonites. • Flowering plants appear.
	Jurassic (145–210 million years ago)		Warm climate continues, becoming wetter	• Dinosaurs still the major group of animals. • *Archaeopteryx*, the first bird, appears. • Ants, wasps, bees, caddis flies, earwigs and flies in large numbers. • Pine trees, cypresses and redwoods present.
	Triassic (210–245 million years ago)		Warm temperatures, drier climate, sea levels very low	• Dinosaurs and reptiles the major groups of animals. • Frogs, tortoises, turtles, crocodiles, shrimps and lobsters present. • The first mammals appear and ammonites almost disappear. • Forests of cycads, gingkos and conifers.

INQUIRY 6 *continued*

Era	Period	Epoch (time)	Climate and seas	Life and geography
PALAEOZOIC	**Permian**	(245–290 million years ago)	Ice age and falling seas at the beginning of the period	• Aquatic reptiles exist. • Huge period of extinction (50% of animal groups lost, including some amphibians, ammonites and trilobites). • Ferns and forests spread, conifers appear.
	Carboniferous	(290–360 million years ago)	Tropical conditions in many parts, increase in oxygen levels, two ice ages	• The first reptiles appear. • Some sea lilies, corals, trilobites and molluscs die out. • Amphibians in large numbers. • Grasshoppers, cockroaches, termites, silverfish, beetles and giant dragonflies present. • Coal develops from decaying forests, giant club mosses, horsetails and tree ferns. 
	Devonian	(360–410 million years ago)	Climate warming further, droughts and torrential rain.	• First amphibians on land. • Some corals and brachiopods die out. • Sharks, rays, lobe-finned and ray-finned fish, ammonites, mites, spiders and wingless insects present. • Forests and large trees present, club mosses and horsetails present.
	Silurian	(410–440 million years ago)	Ice age at the beginning of the period, then climate becomes warmer	• Increase in echinoderms, brachiopods, trilobites, corals and nautiloids. • First jawed fish, other fish in large numbers. • Sea scorpions, scorpions and millipedes present.
	Ordovician	(440–510 million years ago)	Warm, melting ice and rising seas; ice age at the end of the period	• Increase in the numbers of sea lilies, brachiopods, molluscs. • Corals, nautiloids and jawless fish present. • Land plants appear.
	Cambrian	(510–570 million years ago)	Oxygen levels in the atmosphere increase; ice age at the end of the period	• Sponges, starfish, sea urchins, sea lilies, shelled animals, trilobites, brachiopods, molluscs and primitive fish appear. • Algae such as seaweed present.
PRE-CAMBRIAN		(570–4600 million years ago)	Very warm and starts cooling; ice ages 2.3 billion years ago, 1 billion years ago and 600 million years ago	• Flatworms, segmented worms, jellyfish and echinoderms appear. • Multicelled organisms appear. • Photosynthetic organisms appear but no plants. • Single-celled organisms appear.

1 Highlight any words in the table you do not know and find their meaning.
2 Has the Earth always had the same climate? Explain.
3 In which periods did groups of organisms (both plants and animals) become extinct (die out)?
4 Can you infer from the information in the table why these organisms became extinct?
5 Are there any patterns of organisms living in a particular climate?
6 Insects and mammals pollinate flowering plants. In which order did these groups appear?
7 Is there evidence in the table that present-day organisms came from past organisms?

Changing Australia

The continents of the world were once joined together in a large landmass called *Pangaea*, which then split into two landmasses called *Gondwana* and *Laurasia*. Australia, together with Africa, South America, India and Antarctica, formed Gondwana. About 40 million years ago Australia broke away from the other continents and began moving to its present position.

Australia's position on the Earth has changed and this has affected its climate. For example, Australia was attached to Antarctica for millions of years and was much further south than it is today. It is estimated that the temperatures ranged between –6 °C and 3 °C. So, organisms living in Australia at this time would have experienced a very cold climate.

Australia has experienced glacial (ice ages) and interglacial periods, making the climate colder and warmer, and affecting sea levels. When the sea level was low, Tasmania was joined to mainland Australia by a land bridge and there were also land bridges from Australia to the neighbouring countries in the north.

Organisms living in Australia during these times would have either survived the changes or become extinct. Scientists have found bones, impressions or traces of now-extinct animals and plants at many different places in Australia. These fossils are allowing scientists to piece together, almost like a jigsaw puzzle, a history of life on our continent.

Pollen and spores found at fossil sites show that there were many ferns, ginkgos, cycads, araucaria (primitive conifers) and flowering plants in ancient Australia. Today ferns, one type of ginkgo, modern araucaria trees (e.g. hoop pine, bunya pine and Norfolk Island pine) and flowering plants still exist.

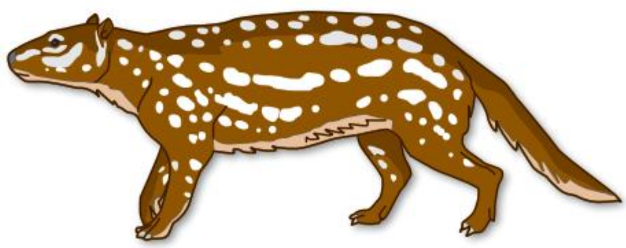
Many different animals that lived in Australia are now extinct. Three examples are given on the right.

Diprotodon

Diprotodon was a large hippopotamus-sized animal and the largest recorded marsupial—about 3 m long and 2 m high. It lived on leaves, shrubs and grasses and wandered around woodlands and grasslands. It lived during the Pleistocene epoch.

Tingamurra

Tingamurra was a small ground-dwelling mammal that lived on insects and fruit. It was about 20 cm long. It is believed that *Tingamurra* was the only land-based *placental* mammal in Australia at this time. (Dogs, cats and humans are also placental mammals.) *Tingamurra* lived during the Eocene epoch.



Steropodon

Steropodon was an egg-laying mammal like the platypus and echidna today. It lived in creeks and billabongs and was about 35 cm long. *Steropodon* lived during the early Cretaceous period at the time of the dinosaurs.

Extinctions

Changes in the environment, like the ones you have just read about, are natural. However, by far the greatest changes that organisms face today are caused by humans (e.g. pollution, clearing of forests, overfishing and introduced organisms). Those organisms that cannot survive these changes die out. The **extinction** of the Pyrenean ibex is evidence of this in the 21st century.

Pyrenean ibex

The Pyrenean ibex once lived in rocky mountain habitats in the French Pyrenees and Spain. In 1993 there were only 10 individuals left. Diseases from livestock, competing with other species for food, changes in climate and being hunted by humans are some of the reasons why these animals have not survived.

In 1999, the last known ibex nicknamed Celia was caught and a sample of tissue taken from her ear for future cloning. An electronic tracer was attached to Celia and she was released. However, she was found dead on 6 January 2000. Her skull had been crushed by a falling tree.

You can see from this example that both biotic and abiotic factors in the environment affect the survival chances of organisms. Biotic factors, such as competition for food, diseases and predation, and abiotic factors, such as changing climate, affected the survival chances of the ibex.

INQUIRY 7 Internet research

Use the internet to find out about extinct organisms in Australia and the world. You could look up the following: thylacine, *Ekaltadeta*, *Dromornis*, *Muttaburrasaurus*, *Austrosaurus*.

Choose one organism from your research and answer the following questions.

1. What environment did the organism live in?
2. What changes occurred to the environment to cause the animal's extinction?
3. Were these changes abiotic or biotic?
4. Could the extinction of this organism have been avoided?

INQUIRY 8 Survival of the fittest

Design your own game to show how natural selection occurs. For example, you could design a board game like Monopoly in which each player has 10 counters that they must get around the board twice. The counters represent the organisms in the population. Instead of landing on chance, going to jail or passing 'go', you could have the abiotic and biotic factors that affect organisms in their environment spread around the board. For example, it could be possible to land on a square where the organisms develop a disease or their food supply dies out, or they could find a mate or avoid a predator. The person who finishes the game with the most surviving counters wins. You could call your game 'Survival of the fittest'.

Over to you

1. Describe in your own words what natural selection means.
2. Do organisms always become better adapted to their environment? Explain.
3. When did reptiles, amphibians, mammals and humans first appear?
4. Does the information presented in this section evidence supporting the theory of evolution or creationism? Explain your answer.

6.3 Evidence for evolution

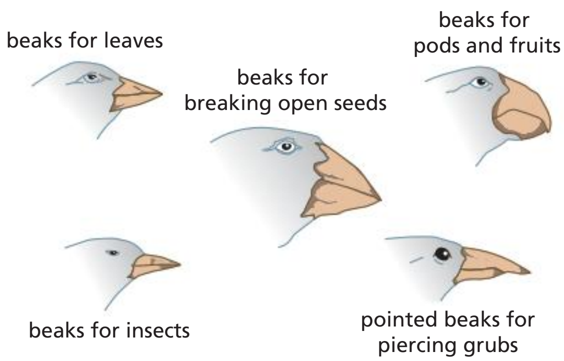
Erasmus Darwin was one of the first naturalists to suggest that there was one common ancestor or one group of organisms from which all others developed. But he could not explain how one group of organisms could develop into others.

Evidence from the Galapagos

The Galapagos Islands are a remote group of islands in the Pacific, west of Ecuador. Charles Darwin visited the Galapagos Islands on his voyage in the *Beagle*. He noticed that all the finches from all the islands had common features, but that each island had its own distinct group.

Darwin inferred that to start with there must have been one population of finches with variations between individuals. As the Galapagos Islands formed, the population of finches must have become separated. Each island environment favoured the characteristics of some finches more than others. For example, finches with beaks that could smash open seeds survived on the islands where hard seeds were common. Finches with fine beaks to feed on insects survived on the islands where insects were common. The finches with the most favourable characteristics on each island survived and over time more and more finches inherited these characteristics.

Darwin inferred that, as isolation increased, interbreeding between finches of different islands ceased. The finches on each island became different species—groups of organisms that could interbreed successfully to produce fertile offspring. In other words, if the isolated group was reunited with the finches it was originally separated from, fertile offspring could not be produced.



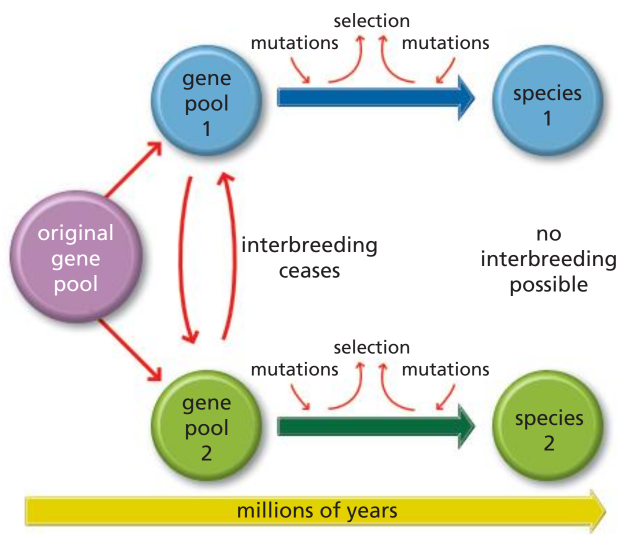
The different beaks of finches

Gene pools and mutations

With your knowledge of genetics you should be able to expand Darwin's explanation of the different finch species on the Galapagos Islands. The original finch population contained a wide variety of genes, which produced the phenotypes or observed variations in the finches. All these different genes together formed the **gene pool**—all the different genes in a group.

When the finches became separated, the original gene pool became spread across the islands. So each island had only some of the genotypes and phenotypes of the original finch population. During the early separation there may still have been interbreeding, mixing up the gene pools on each island. Also, mutations would have added new genes to each island's gene pool. Any finches that could not survive in their new environment would have died, causing the loss of genes from the gene pool on that island.

Once interbreeding ceased, the environment would have favoured some genotypes and not others. These genes would have been passed on from one generation to the next. Genes for unfavourable characteristics on a particular island, such as blunt beaks that did not help the finches find food, would have been lost from the island gene pool when those finches died. Mutations and natural selection would have continued to affect the gene pool on each island until eventually the finches had such different gene pools that they became different species. In this way the finches evolved from one species into many different species.



How gene pools change

Fossil evidence

On page 120 you were told that the theory of evolution is based on evidence that is limited. This can be seen in the fossil record. Putting together the fossil record of all life on Earth is like trying to piece together a jigsaw puzzle with many of the pieces missing. You can put some pieces in place but there are huge gaps. You have some idea what the picture is but until you find all the pieces you cannot be completely sure you are right. However, the fossil record does provide some important information.

A fossil can form if the dead body of an animal or plant is quickly covered by sediment, for example, at the bottom of a stream or lake. The soft parts of the organism decay, leaving the harder parts behind. These make an imprint in the rock that forms as the sedimentary layers build up on top of the organism. The rock containing the fossil may be exposed or brought to the surface by the action of folding and faulting, or by weathering and erosion.

Since sedimentary rock like this is formed with one layer sitting on top of another, it is possible to infer that the oldest rocks are those at the bottom of the rock layers. So any fossils found in these layers will be older than those found in the layers at the top. The dating of rocks has confirmed this.

What palaeontologists (scientists who study fossils in rocks) have discovered is that, in general, very simple organisms are found in the older rock layers and more complex organisms are found in the younger layers. From this, they have inferred the order in which organisms appeared on Earth.

The evidence in the rocks appears to show that all life on Earth today developed from common ancestors or common groups of organisms in the past. Palaeontologists can trace the development of organisms and observe the structural changes in species from ancient rocks to younger ones. For example, it is possible to trace the development of elephants through the ages.

The ancestor of present-day elephants, called *Moeritherium*, lived on Earth 60 million years ago. It was similar to a pygmy hippopotamus with no trunk. The skull and teeth of *Moeritherium* were similar in structure to present-day elephants with small tusks that grew from incisor teeth rather than from canines.

After *Moeritherium*, the variety of organisms in the elephant group increased. There were over 350 different species. One of these evolved into *Primelephas*, an animal that lived 5–7 million years ago. *Primelephas* had a set of tusks on both its upper and lower jaw.

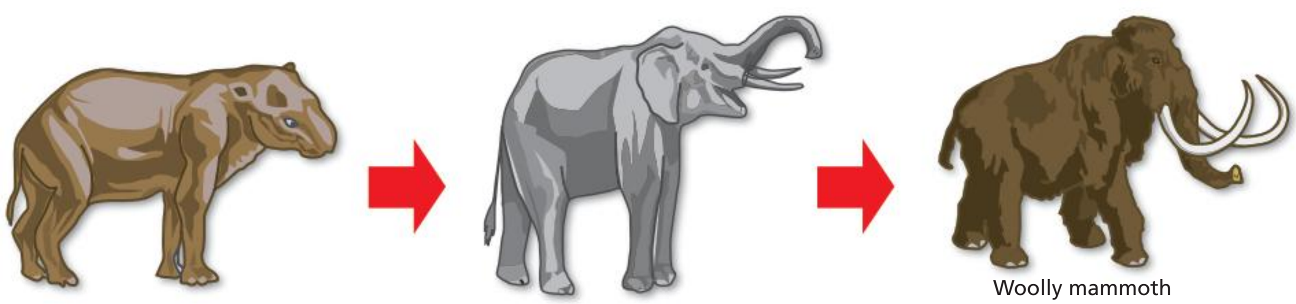
Elephant evolution then split into two distinct groups of organisms. One group gave rise to our present-day African elephants and the other group gave rise to Asian elephants and mammoths. Mammoths lived on Earth from 2 million to 8000 years ago.

Comparative anatomy

It is not only the fossil record that helps scientists infer the elephant's history. A comparison of the structure of ancient elephants with present-day elephants has also provided valuable information. This is called *comparative anatomy*, when the arrangement and order of bones, and the shapes and sizes of organisms, are compared to one another. Scientists infer that the closest living relative of the elephant alive today is the sea cow, or dugong. They have inferred this by observing its structure. Inquiries 9 and 10 will give you more of an understanding of how comparative anatomy works.

Embryo comparisons

Not only have scientists compared the structure of living organisms with past organisms to show the links between them, they have also looked at the embryonic development of organisms. The embryos of organisms classified in different groups show remarkable similarities. You will see examples of this in Inquiry 11.



Moeritherium (60 mya) *Primelephas* (5–7 mya) Woolly mammoth (less 2 mya–8000 years ago)

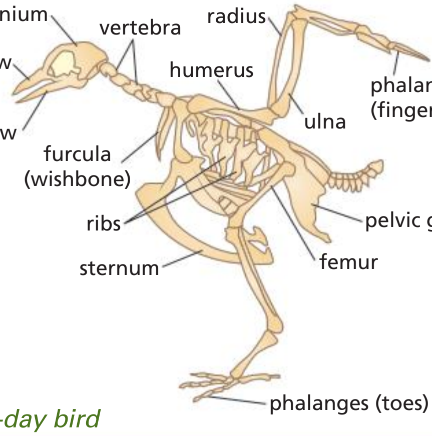
INQUIRY 9 Archaeopteryx

The fossil record provides a history of many different organisms on Earth. However, there are missing links. For example, scientists infer that birds, mammals and reptiles share a common ancestor. It was not until 1861 that a fossil called *Archaeopteryx* (ar-kee-OP-ter-ix), meaning 'ancient wing', was found in Germany. It was 150 million years old. Scientists infer that *Archaeopteryx* is a transitional organism part way between reptiles (including dinosaurs) and birds. They infer that it closely resembles the 'raptor' dinosaurs, such as *Velociraptor,* which appear in the movie *Jurassic Park*.

1 Look at the following three diagrams. What are the similarities and differences between:
   a a velociraptor skeleton and *Archaeopteryx*?
   b *Archaeopteryx* and the skeleton of present-day birds?
2 Would you agree that *Archaeopteryx* is the transitional fossil that explains the link between dinosaurs and birds?
3 Why do you think the fossil record is incomplete?

Reconstructed Velociraptor skeleton

Archaeopteryx fossil

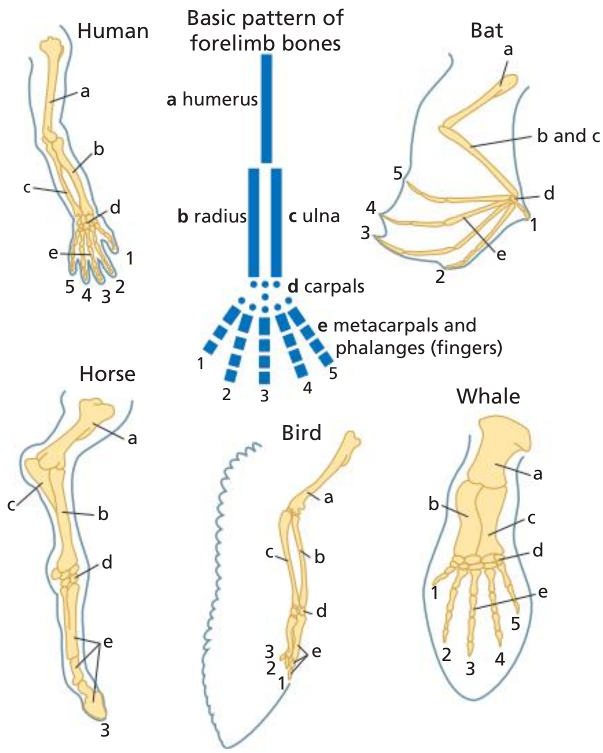


Present-day bird

INQUIRY 10 Comparing forelimbs

The following diagram shows the forelimbs of five different animals.

1 What are the similarities and differences between these five skeletons?
2 Do you think these organisms share a common ancestor? Explain your answer.
3 How would Charles Darwin, Lamarck and a creationist explain these similarities and differences?

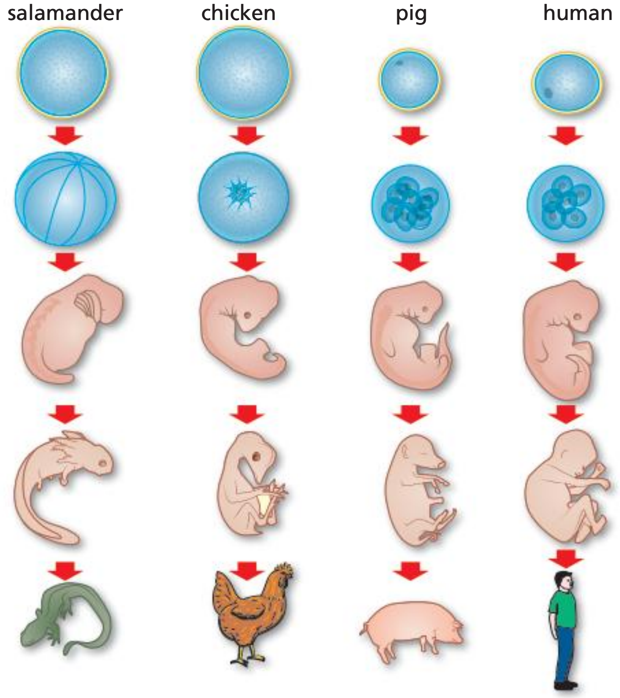


INQUIRY 11 *Embryo comparison*

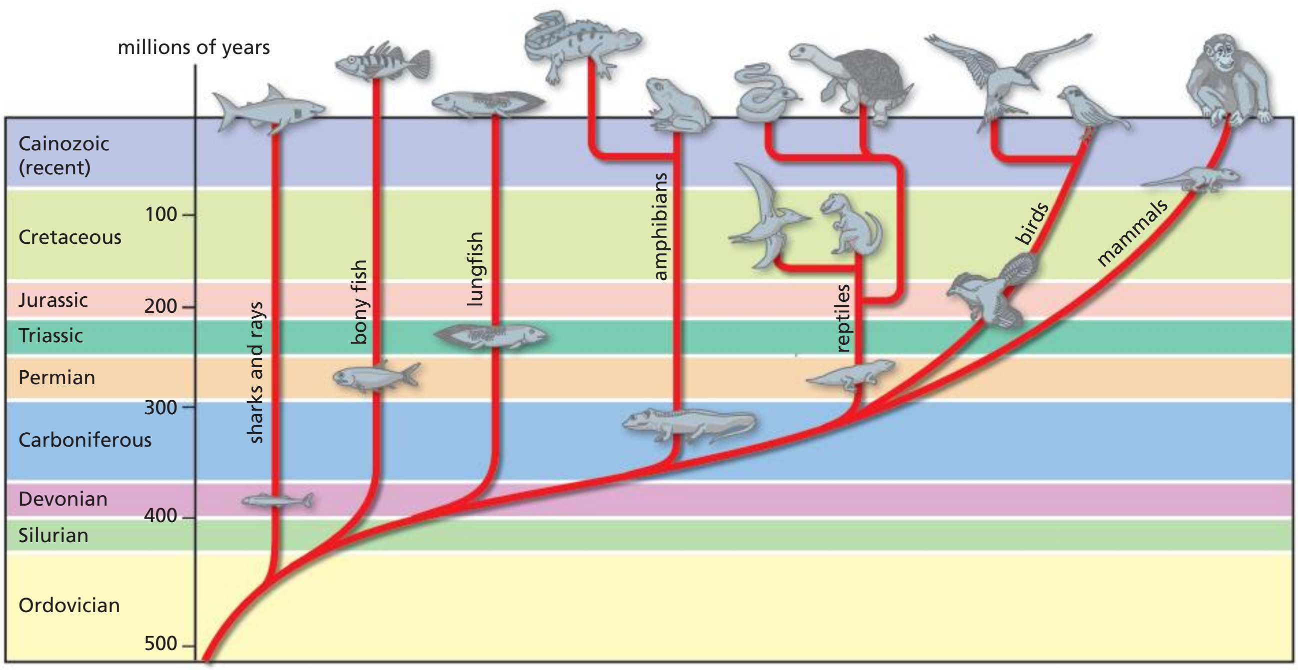
The embryos of different organisms provide further evidence to support the theory that present-day organisms evolved from organisms in the past.

The diagram on the right shows different stages in the development of a bird (chicken), amphibian (salamander), and mammals (human and pig) from fertilised egg to adult.

1 What are the similarities and differences between the embryos of:
  a birds and amphibians?
  b birds and mammals?
  c amphibians and mammals?
  d two mammals?
2 Which organisms do you think are the most closely related? Explain your answer.
3 How would evolutionists explain the embryonic development of these organisms?
4 Examine the evolutionary tree below, which shows when organisms appeared on Earth (according to the fossil record) and how scientists infer these organisms are related. All organisms below the top line are extinct.
  a When did the ancestors of amphibians, birds and mammals first appear on Earth?
  b Which organisms are the most closely related: amphibians and birds, or birds and mammals? Explain.



5 Does the embryonic development of the four organisms you studied above support the evolutionary tree? Explain.
6 If you had a diagram showing the embryonic development of a lizard (reptile), predict which organism it would most closely resemble. Explain your prediction.

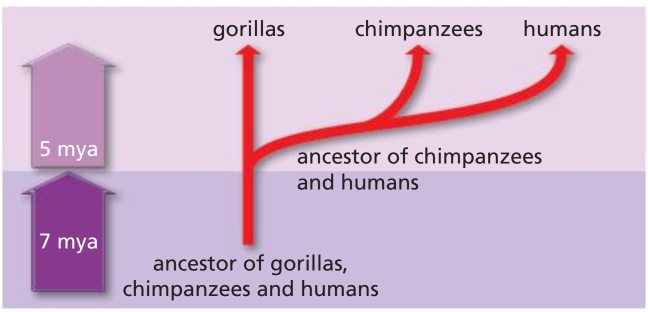


Evolutionary tree showing the inferred ancestors of present-day organisms

DNA comparisons

Today it is possible to use DNA and protein sequencing to compare evolutionary relationships. Scientists can extract the DNA from cells and compare the genetic information of two organisms. In protein sequencing scientists determine the identity and order of the amino acids present in a protein, for example, haemoglobin. They can do this for two different organisms and look for differences.

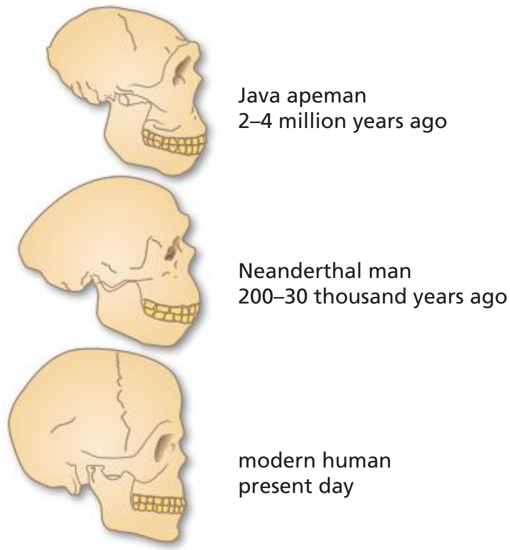
Tracking mutation rates in DNA has also provided evolutionary information. Substitutions that occur in DNA can be examined. This is when one base in a sequence is replaced by another. Mutations can also occur when whole sections of DNA are deleted or added. This usually occurs in the parts of DNA that do not code for genes—'junk' DNA. From mutation rates scientists have inferred that the last common ancestor of chimpanzees, humans and gorillas lived about 7 million years ago. The last common ancestor of humans and chimpanzees lived about 5 million years ago. So we are more closely related to chimpanzees than to gorillas. In fact, we share about 99% of our DNA with chimpanzees.



Mapping the human genome and the genomes of other organisms is providing more evidence for evolutionary links between organisms. For example, about 60% of the genes of humans and fruit flies are the same. With this information scientists could cure diseases in humans. For example, when the human gene that causes Parkinson's disease is inserted into a fruit fly, the fly develops the disease. Fruit flies could therefore be used to test treatments for Parkinson's disease in humans. Another example occurs with chimpanzees. These animals do not get AIDS. A comparison of the genes of humans and chimpanzees may explain why chimpanzees do not develop this disease and help scientists find a cure.

Over to you

1. What does the word 'species' mean? How did the Galapagos Island finches become different species?
2. Using the words genes, phenotypes and gene pool, explain how a new species can arise from a population of organisms.
3. The following diagrams show three stages in the evolution of humans (as indicated by these fossil skulls).



   a. How would palaeontologists know how old these skulls are?
   b. How could comparative anatomy help in identifying the ancestors of humans?
   c. How could you explain the similarities and differences in the human skulls using the theory of natural selection?
   d. How would genetics explain the changes in the human skulls from millions of years ago to today?
4. Explain how you think humans and chimpanzees became different species.
5. What could cause the development of species today?
6. How will mapping the genome of different species help in our understanding of evolution and contribute to solving human disease?

PROBLEM SOLVING

What evidence have you collected in this section? What can you use to help you with your problem? Which idea do you think best explains how life on Earth came to exist?

Science as a Human Endeavour

Mungo Man

Archaeologists excavate the remains of Mungo Man.

In 1967 geologist Jim Bowler was studying an ancient inland lake in south-western NSW when he found some burnt human bones buried in the sand. These bones proved to be the cremated remains of a young woman, now known as Mungo Lady. In 1974 Bowler found the tip of a skull in the same area. Excavation by archaeologists revealed the skeleton of an old man, now known as Mungo Man. The way his hands were interlocked over his pelvis suggested that this was a ceremonial burial.

Scientists have dated the remains of Mungo Man and Mungo Lady and estimates vary between 40000 and 60000 years. This is much older than other remains found in Australia, dated at about 20000 years. So Bowler's discovery showed that the ancestors of modern Aboriginal people were in Australia at least 40000 years ago! It is thought these people arrived in Australia between 60000 and 120000 years ago. The sea level was much lower then, and mainland Australia was joined to Papua New Guinea and Tasmania. The people probably arrived in the north of Australia by boat from Indonesia, then spread throughout the continent.

It is inferred Mungo Man's people lived along the shore of an inland lake, where there was plenty of food. However, by 40000 years ago Australia had entered an ice age and the climate had become much drier. The lake dried up and dust covered Mungo Man's burial site. At the same time there were huge animals in Australia, called megafauna. For example, there was a giant kangaroo and a marsupial lion. This megafauna disappeared from Australia between 50000 and 20000 years ago. Some researchers say this was because of climate change. Others say it was due to excessive burning and hunting by Aboriginal people, or it may have been due to both.

All the human remains found in Australia are of modern-day *Homo sapiens*. Those from Lake Mungo are said to be gracile, which means they have delicate faces and foreheads, like modern-day Aboriginal people. However the younger remains are robust, with big bones and projecting faces. Alan Thorne from the Australian National Museum in Canberra infers the gracile people came from China and the robust people came from Indonesia. His team claims to have extracted DNA from Mungo Man, and that it doesn't match the DNA of any other humans. This challenges the widely accepted theory that all humans originally came from Africa.

Over the years large numbers of Aboriginal skeletons were collected and sent to universities and museums throughout the world. The Aboriginal people consider this a great injustice. Following the discoveries at Lake Mungo, the Aboriginal people in the region protested about their dead ancestors being disturbed. As a result a law was eventually passed making it illegal to remove or interfere with any object of archaeological significance before approval is given by the local Aboriginal people.

Over to you

1. Why is the finding of Mungo Man so significant?
2. How long have *non*-Aboriginal people been in Australia?
3. What do you think caused the extinction of the megafauna in Australia? Justify your answer.
4. Try to suggest why there are two distinct types of ancient people found in Australia.
5. Do you agree with the law protecting Aboriginal heritage? Explain your answer.

DNA and evolution

When you talk about ethics you are inquiring into the moral values of human behaviour and asking whether it is right or wrong to do something. The answer can depend on the religious beliefs, customs, traditions and manners that you have been taught. Something that may seem wrong to you may not seem that way to others.

Scientists come up with some wonderful ideas and inventions (technology) but it is important to discuss the implications and issues arising from them. The following questions can be used to help you do this.

a Will it cause harm to other people or other living things?
b Will it affect the resources on Earth or the way they are distributed?
c Will it discriminate against certain groups in society?
d Will it affect religious beliefs or other customs?
e Is it against the law, or will laws need to be changed?
f Will it affect the privacy and rights of others?
g What are its advantages and disadvantages?
h What are the future possibilities?

Read through the article below and answer these questions.

1 What is the human genome?
2 How many nucleotides (molecular letters) form the genome?
3 How many genes (words) are needed to make a person?
4 Why is the number of genes needed to make a person 'less momentous than previously assumed'?
5 Which organism is mentioned that has more genes than humans?
6 What are the 'rewards and benefits' of the human genome project?
7 Why could the finding that humans have less genes than some organisms be controversial?
8 Work through Questions a–h above using this article.

Genome genius bears fruit: ten years ago researchers decoded the book of life

In February 2001, two teams writing in two journals published separate reports laying out nothing less than the genetic blueprint of humanity.

News that the two groups had each ordered key molecular letters in nature's instruction manual for building a person, the human genome, was hailed worldwide as momentous. Yet their self-described working drafts of the sequence of the genome's three billion letters, nucleotides, revealed that *Homo sapiens* was genetically less momentous than previously assumed.

Until the groups led by Francis Collins, head of the publicly sponsored International Human Genome Sequencing Consortium, and Craig Venter, the ambitious founder of the private Celera Corporation, reported their results in *Nature* and *Science*, respectively, scientists assumed it took anywhere from 50 000 to 140 000 genes—the 'words' formed by the nucleotide letters—to make a person. After all, surely the planet's most complex species had the most complex genome of all. The real tally? About 20 500 genes.

Worse, an international consortium reported in this week's *Science* that the near-microscopic freshwater crustacean *Daphnia pulex*, the water flea, has the most genes ever sequenced, about 31 000 of them. Aside from that kick to human vanity, sequencing the human genome has led to a bounty of discoveries. As Collins writes in this week's *Science*, 'What a difference a decade makes.'

University of Melbourne geneticist Bob Williamson agrees. 'The rewards and benefits of the human genome project have been astronomical,' he says, pointing to new knowledge of the operation of genes, genetic mutations driving disease and even the evolution of species, including our own. That's because not only are researchers exploiting the genome data, they're using what Venter calls 'the new generations of sequencing technology'. It's both faster and cheaper that the multi-year, multibillion-dollar effort behind the 2001 results . . .

***The Australian* 5 February 2011**

6.4 What will happen in the future?

The word biotechnology can be split into 'bio', meaning life, and 'technology', which deals with the development of useful products. Biotechnology therefore means using living things to create useful products.

Biotechnology has been used for hundreds of years to produce food items. For example, bacteria and yeast are used to make bread, cheese, wine and beer. Selective breeding is one way that humans can change plants and animals for their own use. For example, dog breeders may deliberately select the characteristics they want in a dog by allowing a dog with the characteristics they want to breed with it. As you learnt in Chapter 5, Gregor Mendel deliberately selected the characteristics he wanted in pea plants.

Selective breeding like this has changed species. Horse breeders have selectively bred the animals with the characteristics they want to produce fast and sleek racehorses, or strong and large horses such as Clydesdales to pull heavy loads. In this way humans have made some characteristics more important than others and altered the natural evolution of these organisms.

Gene technology

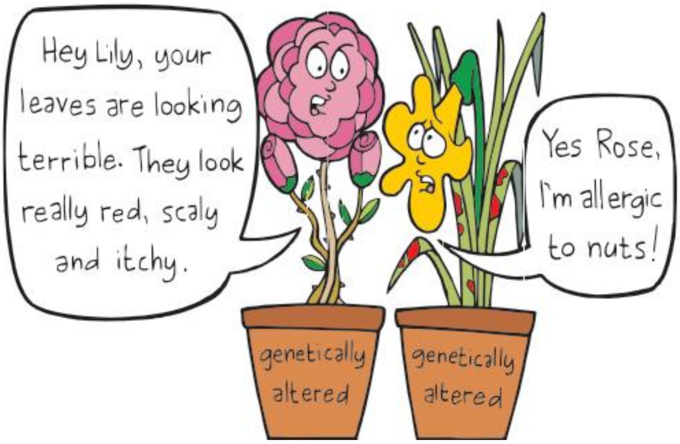
Today, however, we do not need to breed organisms to select desired traits. Using **gene technology** we can transfer genes from one individual to the next, removing a gene from a plant or animal and inserting a different one in its place. For example, it is possible to insert a gene into corn to make it resistant to pests so that less pesticide is needed to grow the corn. An organism that has had the sequence of its genes rearranged is called a *genetically modified organism* (GMO).

Gene technology could produce foods that have a greater protein or carbohydrate content, or produce fruit and vegetables that stay fresher longer, or produce foods that do not cause allergies. Imagine producing tomatoes that are able to survive packaging and handling so that waste is reduced. Foods could also be engineered to have a higher vitamin C content and be healthier for us. Much of Australia's farmland is contaminated by salt. Gene technology could develop crops that are salt-resistant.

There are, however, some concerns about gene technology. Switching genes from different species may take generations to show undesirable side effects. Also, if viruses are used to transfer genes into organisms, could new viruses be formed and thus new diseases?

People are concerned about how safe genetically modified foods are to eat because they contain new genetic material (DNA). Food Standards Australia New Zealand (FSANZ) has issued strict standards and labelling for the introduction of genetically modified foods in Australia. At present, only genetically modified potato, corn, soy beans, canola and cotton oils have been approved for food in Australia.

People are worried about allergic reactions to genetically modified foods. Suppose a person is allergic to a protein in one food, for example peanuts. If peanut genes produce the same proteins when placed into other foods such as soy, could the soy then have the same allergic properties as the nuts?



There are also concerns about genetically modified organisms escaping. For example, what happens if seeds from pest-resistant genetically modified crops spread and wild populations become established? If cross-breeding between these wild populations and weeds occurs, the weeds could develop the pest resistance of the modified crops.

There are also concerns that the pest-resistant crops might kill other insects as well as the ones they are designed to resist. What this will do to natural populations is untested and so the effects are unknown. The Skill section on page 141 will examine some of the benefits and problems associated with gene technology. The table on the next page lists some of the issues.

Positive arguments for gene technology in agriculture	Negative arguments for gene technology in agriculture
1 Improved food storage and handling. Improved preservation of food. Improved taste and textures for consumers.	1 Eating genetically modified foods may have unintended consequences and be a higher risk than we think.
2 Improved nutritional value. New products are able to be developed.	2 Instead of genetically altering our food, people should be encouraged to eat a wide variety of foods, especially fresh foods.
3 Improved quality of product: more wool, more meat with less fat.	3 Animals are given extra copies of growth hormone genes, producing more meat. Is this humane?
4 Improved resistance to disease, drought, salt, heavy metals and temperature.	4 Genetically modified organisms could invade natural environments (e.g. genetically modified eucalypt plantations contaminating native eucalypts through cross-pollination).
5 Special products could be developed (e.g. using bananas to deliver the measles vaccine).	5 Foods altered for medicinal purposes could enter the general food supply and be sold as normal foods.
6 Improved pest resistance so that less pesticide is used in the environment (e.g. pest-resistant cotton requires 50% less pesticide than normal cotton).	6 Pests may develop resistance to the genetically modified crops, as they do with present pesticides. The pest-resistant plants could affect beneficial insects that are not pests.
7 Plants can be made herbicide-resistant so that weeds can be sprayed without killing the crop.	7 Genes for herbicide resistance could be passed on to weeds by cross-pollination, giving these weeds a greater survival chance.
8 Genetic modification of pest organisms to make them sterile.	8 Eliminating an organism from the food web will affect natural ecosystems.

Loss of biodiversity

If you listed all the organisms you rely on in a day the list might include cows for milk, plants for vegetables and pigs for meat. There might also be plants that provide us with cotton and linen for clothes, and wood for building houses. There is a rich variety of life on Earth that you rely on. **Biodiversity** is the term used to describe this variety of life on Earth.

A wide variety of different organisms on Earth, and differences between organisms within a species, is very important. This is because genetic variation is the basis of natural selection. Some characteristics may increase an organism's chance of survival and ensure the survival of its species. If we select the characteristics we think are important and allow only the organisms with these characteristics to grow and reproduce, are we reducing biodiversity? Will humans come to rely on only a small variety of organisms to survive? Will humans give GMOs an increased chance of surviving through gene technology and affect the natural evolution of organisms? Or will the opposite occur? For example, will we create new organisms by switching genes around and create a whole variety of new species?

Since the evolution of organisms takes millions of years we will not be able to see what the effects of our actions are. It will be up to our descendants to answer some of the questions raised above.

Over to you

1. Rank the positive arguments in the table above from the statement you think is the most important to the least important. Do the same for the negative arguments. Explain whether you think the positive arguments outweigh the negative ones for the use of gene technology.
2. Scientists have discovered a gene that tells plants when to flower. Altering the activity of this gene affects flowering times. What are the advantages and disadvantages of this for nurseries, florists and farmers?
3. As a class, collect genetically altered food products from the supermarket. You could make a display of these food products in the library and explain to the school community what genetically modified food is.
4. Carry out a survey of the students and teachers in your school to find out if they would eat genetically modified food. The Skill section on page 16 will help you with your survey.

PROBLEM SOLVING

Have you developed your own explanation of how all life on Earth came to exist? Are you ready for your presentation? Do you have evidence to support what you are saying in case you are challenged?

SKILL

Detecting bias in articles

When you read articles in newspapers, magazines, journals or on the internet, the author of the article may be trying to 'sell their point of view' or convince the reader of their argument, rather than giving the facts. These steps will help you to detect such bias in your reading.

1 Look at the name of the author and their background. For example, you may find articles against nuclear power written by people who are part of the Greenpeace organisation with its aim to expose global environmental problems and to nurture life in all its diversity. So you would not expect these articles to promote the benefits of nuclear technology. You may also find articles against Darwin's theory of evolution written by religious groups.

2 Try to work out why the person is writing the article. Are they presenting both the positive and negative sides of the argument? Or are they presenting one side of the argument only?

3 What type of language are they using? Do they use *coercive* (forceful and compelling) language that plays on people's emotions? If they are presenting the positive side of the argument, do they use words that are positive? For example, this technology is *exciting*, *important*, *vital*, *necessary*. Or do they use negative words? For example, these findings increase *fears*, or should be looked at with *scepticism*.

Read the article on this page and decide what argument the author is presenting and whether it is biased. List any coercive words used.

Modified cows produce 'human' milk

Scientists in China have reportedly created genetically modified cattle that can produce 'human' milk.

The researchers, writing in the *Public Library of Science ONE* journal, said they have successfully created cows that produce lysozyme—a human protein—by implanting genetically modified embryos into surrogate cows. Lysozyme is found in human breast milk and helps boost babies' immunities. 'The milk tastes stronger than normal milk,' said Professor Ning Li, lead research author and director of the State Key Laboratories for AgroBiotechnology at the China Agricultural University. 'We aim to commercialise some research in this area in coming three years. For the "human-like milk", 10 years or maybe more time will be required to finally pour this enhanced milk into the consumer's cup.'

Li added that milk from a genetically modified cow would have a 'much higher nutritional content'. However, the research was drawing both supporters and detractors, with those opposed to genetically modified food sounding words of caution. 'We have major concerns about this research to genetically modify cows with human genes', Helen Wallace, director of biotechnology monitoring group GeneWatch UK, said. 'There is a question about whether milk from these cows is going to be safe

for humans and it is really hard to tell that unless you do large clinical trials like you would a drug, so there will be uncertainty about whether it could be harmful to some people.'

Professor Keith Campbell, a University of Nottingham biologist, disagreed. 'Genetically modified animals and plants are not going to be harmful unless you deliberately put in a gene that is going to be poisonous. Why would anyone do that in a food? Genetically modified food, if done correctly, can provide huge benefit for consumers in terms of producing better products.'

Daily Telegraph **4 April 2011**

THINKING SKILLS ?

1 Read the following passage: 'Snakes ... have adopted the habit of crawling on the ground and hiding in the grass, so that their body, as a result of continually repeated efforts at elongation for the purpose of passing through narrow spaces, had acquired a considerable length, quite out of proportion to its size. Now, legs would have been quite useless to these animals and consequently unused ... The disuse of these parts ... resulted in the complete disappearance of these same parts.'

- **a** In the author's opinion, what caused elongated bodies in snakes?
- **b** How did their body change because of this?
- **c** One of the evolutionists mentioned in 'Scientists at Work' wrote this passage. Who was it? Give reasons for your answer.
- **d** How would creationists explain the crawling habits of snakes?

2 An early theory to explain all life on Earth was that organisms existing today have been exactly the same since life on Earth began. Explain whether each piece of evidence below supports this theory.

- **a** Plants and animals alive today are generally not found as fossils.
- **b** No fossilised remains of mammals have been found from 300 million years ago.
- **c** Fossils have been found which appear to be intermediate between different species of organisms. For example, *Archaeopteryx* has characteristics of both birds and reptiles.
- **d** Many organisms not alive today have been found in the fossil record.
- **e** Organisms such as lungfish have changed little over 150 million years.

3 Which of the these two sentences is more correct? Explain your answer.

'Birds and mammals evolved from reptiles' *or* 'The ancestors of reptiles gave rise to organisms with bird-like characteristics and others with mammal-like characteristics'.

4 Natural selection is a theory. Does this mean that it is absolutely true? Explain.

5 A *genus* is a group of organisms that contains different species that are very closely related. Humans (*Homo sapiens*) are in the genus *Homo*. We are the only species—*sapiens*—in this group. Chimpanzees are in the genus *Pan*. Their species name is *troglodytes*. DNA analysis has shown that humans share 99% of their DNA with chimpanzees. In the light of this, do you think chimpanzees should be classified as *Homo troglodytes* and be placed in the same genus as humans? What do you think religious groups would say? Explain.

6 Humans and mice have 80% of their DNA in common. Humans and cabbages share 20%.

- **a** Why do you think humans and cabbages have DNA in common?
- **b** Why would mice and humans have so much DNA in common?
- **c** How could evolutionists use this information? What do you think creationists would say about it?

7 Explain whether you agree or disagree with this statement: 'It would be better to use sustainable farming techniques and eat a wide variety of fresh foods than to use gene technology'. (Sustainable means being able to continue into the future without harming the environment.)

8 Scientists have discovered a gene that produces limes (a citrus plant) with few or no seeds. It may be possible to insert this gene into other citrus plants to produce seedless fruit.

- **a** How could seedless limes be produced using selective breeding techniques without using gene technology?
- **b** Using what you learnt in Chapter 5, how can genes be transferred from one plant to another?
- **c** Would you buy the seedless citrus fruit knowing it is genetically modified? Explain?

9 What religious arguments could be put forward against the use of gene technology?

10 Is it better to eat genetically modified foods that are pest-resistant than to feed our children food that has been treated with chemicals? Explain your answer.

Knowing and Understanding

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

1 _______ is a word that means _______ in Latin and describes the slow unfolding of life.

2 Mutations that cause a disease such as thalassaemia _______ a person's chances of survival.

3 _______ is a process in which the environment *selects* the best characteristics for survival. It is also called *survival of the fittest*.

4 Biologists use the word _______ to mean a group of organisms that can interbreed successfully to produce fertile offspring.

5 For a new species to form, a group of organisms must be _______ from other groups so that interbreeding cannot take place. This takes millions of years.

6 Charles Darwin observed variations in organisms and realised that there must be a struggle for _______ between organisms in natural populations. Those organisms better _______ to their environment survive and reproduce.

7 Evidence to support the theory of natural selection includes _______, comparative anatomy, a comparison of embryos from different species and _______ evidence.

8 _______ may alter the natural evolution of organisms.

- adapted
- decrease
- DNA
- evolution
- fossils
- gene technology
- isolated
- natural selection
- species
- survival
- unrolled

Self-management

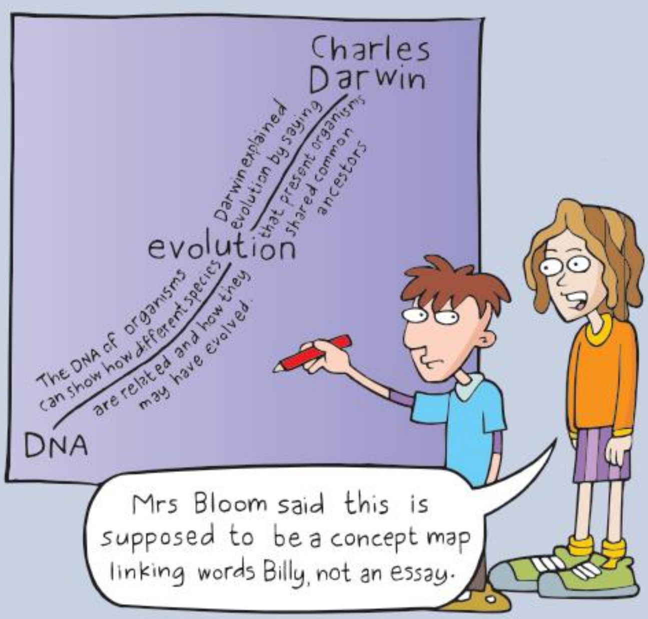
Finding the links

1 Get into groups of three. To summarise this chapter, draw up a concept map to show how the words in the chapter link together. The central word for your map will be *evolution*. Add the following words to your map: genetic variation, gene technology, genetically modified foods, natural selection, Charles Darwin, adaptations, species, fossils, embryos, comparative anatomy.

2 Draw a line between words that link together and explain why you have chosen to link the words on the line.

3 Swap your concept map with another group. Add any links that you have missed.

4 A good skill is to be able to link the work you have done in one chapter with work you have done in another. You should be able to link evolution with genetics. Using a different coloured pen, add the following words to your concept map and link the words as before: genes, genotype, phenotype, DNA, mutations, gene pool, human genome.



Checkpoint

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

1 Which of the following statements are true and which are false?

a Evolution is a process in which all life on Earth becomes less complex.

b Genetic variation within groups of organisms is needed for evolution to occur.

c Mutations always produce variations that decrease an organism's chance of survival.

d Two organisms are considered to be of the same species if they can interbreed and produce fertile offspring.

e Organisms that are better adapted to their environment survive and reproduce.

For questions 2–5 choose the *best* response.

2 Natural selection means:

A changes in different species of organisms.

B the fittest person wins the race.

C the organisms with the characteristics most suited to the environment survive.

D there are a lot of variations between organisms in a group.

3 Scientists infer that some organisms have become extinct because:

A other organisms replaced them.

B the environment changed.

C they were too big to survive.

D they were not adapted to the environment.

4 Which of the following statements about the formation of new species is correct according to Darwin?

A New species form when a group of organisms becomes separated so that interbreeding cannot take place.

B The environment causes some organisms to change to a new species without isolation.

C New species arise automatically but this takes millions of years.

D New species cannot just appear. All life on Earth was fixed at creation.

5 A gene pool is:

A the pool of genes that makes up an individual organism.

B all the different genes in a group of organisms.

C a group of organisms sharing resources.

D all the phenotypes of a group of organisms.

6 Give an example of one natural and one unnatural change in the environment that has caused the extinction of organisms.

7 An early theory of evolution states that the environment causes the needs of organisms to change, and this then changes their behaviour. This, in turn, causes organisms to use or disuse organs. Used organs increase in size. Disused organs shrink or disappear. The organs that are needed by these organisms to survive are then inherited by the offspring.

a Which of the scientists you have studied proposed this theory?

b Would Charles Darwin have agreed with any part of this theory? If so, which parts of the theory would he have agreed with?

c Why is evolution considered to be a theory?

8 How can the following be used to support the theory of natural selection?

a the fossil record

b embryo comparisons

c DNA comparisons

9 Scientists have been able to genetically modify plants to produce new ones, such as blue carnations. What is one positive argument and one negative argument for these new organisms?

10 Scientists have used genes from a common soil bacterium to modify corn plants so that they produce a natural insecticide. The caterpillars die when they eat the corn and farmers do not have to spend millions of dollars spraying insecticide.

Milkweed plants grow as weeds in corn crops and are food for caterpillars of the monarch butterfly. The monarch caterpillars do not eat the corn but they do eat any corn pollen that falls on the milkweed plants. Pollen from the genetically modified corn contains insecticide. The monarch butterfly is important in natural ecosystems. Do you think genetically modified corn should be grown? Explain.

7

Forces and motion

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

Science Understanding

- give examples to illustrate the law of conservation of energy
- use friction to explain why no system can be 100% efficient
- collect and record data on distance, time, speed and acceleration
- use Newton's three laws to analyse the motion of objects

Science as a Human Endeavour

- consider issues relating to youth and drink driving

Science Inquiry Skills

- use the formula v = d/t or F = ma to calculate the third variable when you know the other two variables

LITERACY FOCUS

acceleration
action and reaction
air resistance
anti-lock braking system (ABS)
average speed
blood alcohol concentration
conservation of energy
deceleration
Doppler shift
friction
gradient
inertia
kinetic energy
Newton's laws of motion
reaction distance
reaction time
ticker-timer
velocity
weight
whiplash

Focus for learning

You may be very excited at the thought of driving a car. In a few years you will be able to get a licence and have the freedom to drive around by yourself. Cars are one of the most amazing inventions of our time and have revolutionised travel. They are also one of the most dangerous machines you will ever use.

When you are in a car there are many different forces acting and these forces, combined with speed, can be deadly. People are injured or killed on Australian roads every day. So you have a huge responsibility to yourself and others to drive safely.

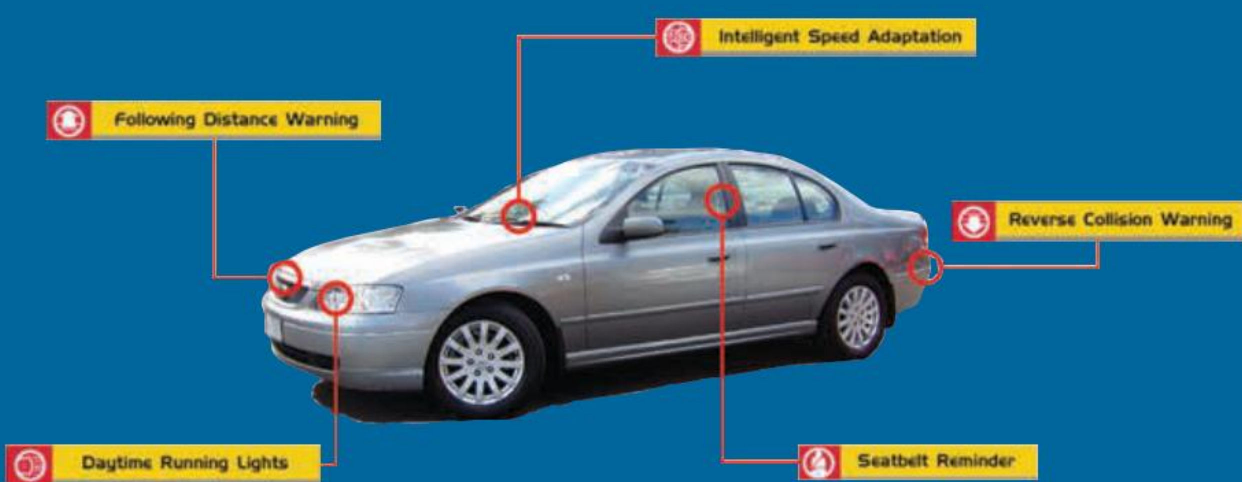
Car manufacturers spend a lot of time and money designing cars to be as safe as possible. In fact, it is the design and use of safety features such as seat belts that have reduced the Australian road toll. In 1970, 3798 people died on our roads. In 1973 the government made it compulsory to wear seat belts. As new cars were introduced with seat belts the road toll began to decrease, and has continued to do so even though the number of cars on Australian roads has increased over time. The road toll in 2009 was 1507.

PROBLEM SOLVING

SafeCar

The Ford Motor Company, the Monash University Accident Research Centre (MUARC) and the Transport Accident Commission (TAC) have designed a TAC SafeCar that decreases the risk of having an accident. Your chapter task is to find out more about TAC SafeCar and then design your own TAC SafeCar. Five SafeCar features are shown in the diagram below. You need to add six new features of your own. You must draw a diagram of your car and write a brief discussion explaining why you think each safety feature is necessary. Try to use Newton's three laws in your discussion.

On this TAC website you can check the safety ratings of cars



7.1 Forces

A force is a push or a pull. Forces can bend or stretch an object, changing its shape. Forces can move an object, bring it to a stop or change the direction in which it is moving. Look at the cartoon below. In part A the man is pushing against the car, so he is exerting a force on the car. His hands do not sink into the car as he pushes, so there must be a force acting in the opposite direction. This is an example of *Newton's third law of motion*, which is often referred to as **action and reaction**.

As the man exerts a force on the car, the car exerts a force back that is *equal* but *opposite* in direction. The force of *gravity* is also acting on both the man and the car, holding them on the Earth's surface. They are not sinking into the ground, so the downwards force from gravity must be balanced by the upwards force from the road. There is no movement, so all the opposing forces are *balanced* (or in equilibrium).

Gravity is an important force because it holds everything on Earth. Objects fall to Earth, and the moon is kept in orbit around the Earth because of gravity. Tides occur because of the effect of the moon's gravity on Earth. The pull of gravity on objects gives them *weight*. This is different from mass, which is the amount of matter an object contains. Weight is a force and is measured in newtons (N). Mass is measured in kilograms (kg).

In part B of the cartoon, there is movement. The opposing forces on the car are no longer equal. They are *unbalanced*. For the men to move the car they must overcome the force of *friction*. The force exerted by the two men is stronger than the friction, so the car moves. Gravity still acts on both the men and the car. Once the car is moving there will still be friction between the tyres and the road opposing the movement.

In part C, the car gets away down the slope and the force of gravity takes over. The men have lost control of the car.

Friction occurs whenever one object moves on, through or across another. It is a force that acts in the opposite direction to the movement. Friction between the tyres of a car and the road causes the tyres to slowly wear and lose their tread. Friction also causes the tyres to become hot as they roll along. Similarly, an engine becomes hot because of the friction between the moving parts inside it. Engine oil helps lubricate these parts and reduces the friction.

Friction can occur between objects as they move through water. For example, friction occurs between the hull of a boat and the water. Boats are streamlined and have smooth surfaces to help them cut through the water.

Friction can also occur when objects such as a car move through air. The air molecules hit the car as it moves along. So the air resists the movement. This is called *air resistance*. As the air flows over the moving car, drag occurs in a backwards direction. A racing car has a very smooth bonnet and streamlined shape to reduce air resistance and enable the car to reach high speeds. Air rushing past the car at high speed can also create lift, so racing cars have spoilers, often on the rear of the vehicle, forcing it downwards to increase traction (grip) and improve handling.

Action and reaction forces can be represented on a diagram. In the diagram below the force pulling to the right is 7 N greater than the one pulling to the left. This difference is called the *net force* and there will be movement in the direction of the net force. In this example the block will move to the right.

Forces and cars

How can forces be applied to driving a car? If a car collides with a tree, it exerts a force on the tree, and the tree exerts a force on the car (action and reaction forces are equal and opposite). Let's say you are driving and the car in front of you stops suddenly. You hit it with a force of 1500 N, and the other car exerts a force of 1500 N on your car. Both cars will experience the effects of these forces. The more force you hit the other car with, the greater the damage will be to both cars.

In normal conditions, friction between the tyres and the road stops a car from skidding (losing grip and sliding). However, when you brake to avoid a collision, the brakes may lock, stopping the wheels from turning, which in turn lose their grip on the road so that the car starts to skid. Many cars have anti-lock braking systems to maintain traction during braking and allow the car to stop as quickly as possible without locking the wheels.

Energy conversions can be seen in the cartoon on page 147. As the men push the car and move it, the chemical energy from the food they ate is converted to kinetic energy as the car moves. The men also get hot. This heat energy produced during respiration is a by-product (unwanted waste).

When the car starts moving down the hill, potential energy is converted to kinetic energy. At the top of the hill the car has stored potential energy because of its height. As it moves downhill the potential energy is converted to kinetic energy.

A car has kinetic energy as it moves along. In a collision with another car, some of this energy will be transferred to the other car and the people in it. Modern cars are built with crumple zones at the front and rear to absorb as much of this energy as possible and to protect the passengers from harm.

INQUIRY 1 Grim statistics

1 Draw a graph showing the total numbers of people killed on Australian roads since 1984.

2 Draw a graph of one of the groups (columns) in the table. What does this graph show you? Make inferences to explain your observations.

3 Suggest reasons for the shape of the graph.

Australian road fatalities, 1984–2009

Year	Drivers	Passengers	Pedestrians	Motor cyclists	Cyclists	Other	Total
1984	1036	756	541	390	90	9	2822
1986	1134	730	537	405	78	4	2888
1988	1144	776	548	323	87	9	2887
1990	935	634	420	262	80	0	2331
1992	815	570	350	197	41	1	1974
1994	809	501	367	190	59	2	1928
1996	869	499	351	193	57	1	1970
1998	741	468	318	181	44	3	1755
2000	852	450	287	191	31	6	1817
2002	785	422	249	224	34	1	1715
2004	761	361	220	195	43	3	1583
2006	759	336	229	239	39	0	1602
2008	694	303	193	245	27	2	1464
2009	718	331	201	225	31	1	1507

4 Look at the following table. Are males or females more likely to be involved in fatal crashes? Explain.

	Drivers	Passengers	Pedestrians	Motor bike riders	Cyclists	Total
Males						
2008	516	171	134	227	25	1073
2009	530	180	143	213	26	1092
Females						
2008	178	131	59	18	2	388
2009	188	147	57	12	5	410

5 Can you think of any television advertisements designed to reduce the road toll? Describe one and explain what it is aimed to do.

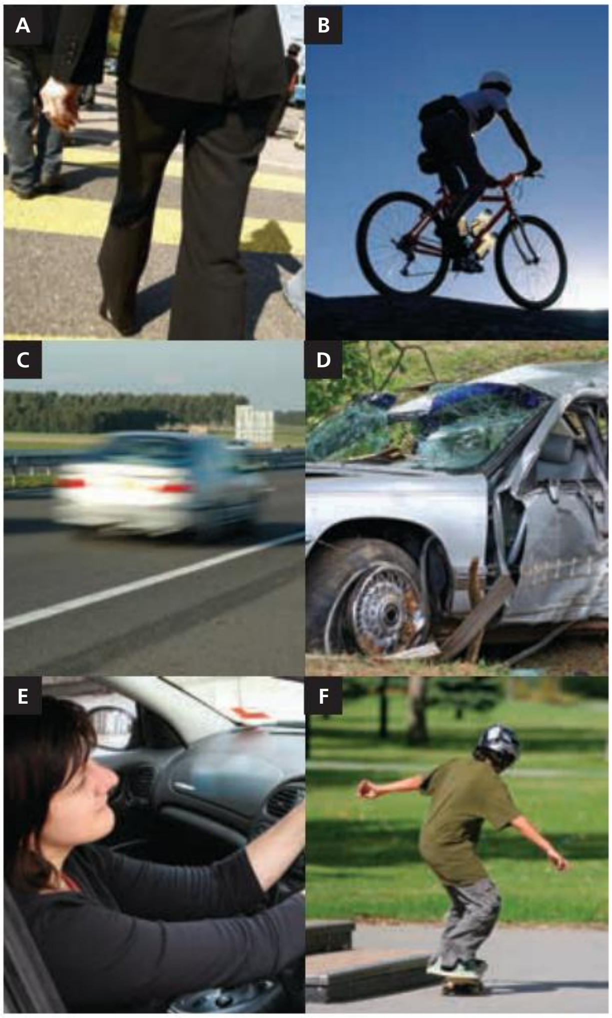
INQUIRY 2 *Recognising forces*

Look at these everyday situations.

1 Describe the main forces acting on the objects pictured.

2 Which forces act together in pairs? Identify the action and reaction forces.

3 Are the forces balanced or unbalanced (i.e. is there a net force)? If so, in which direction?



INQUIRY 3 *Friction at work*

Design a way to demonstrate one of the following.

1 Friction is needed to walk along a path.

2 Sliding friction is greater than rolling friction.

3 Friction is needed for a pen to write on a surface.

INQUIRY 4 *Crumple zones*

You will need: 1 kg mass, 2 white tiles, cardboard box, sticky tape, pillow, 3 hard-boiled eggs, safety glasses

Your teacher will demonstrate step 1 with all students at a safe distance and wearing safety glasses.

1 Place a white tile on the floor beside a laboratory bench. Drop a 1 kg mass onto the tile from the bench. What happens to the tile?

2 Tape an empty cardboard box shut and sit it on top of another white tile in the same position as before. Drop the 1 kg mass again. What happens to the tile this time?

3 Repeat step 2 using a pillow instead of a cardboard box. What happens?

- Was the cardboard box or the pillow more effective in preventing the tile from being broken?
- How does the box act like the crumple zones at the front and rear of a vehicle?
- Draw a diagram for steps 1–3 showing the different forces acting. Label the action and reaction forces and show the net force.

4 Now repeat steps 1–3, dropping an egg instead of a 1 kg mass.

- If the egg was a person, would they have survived each impact? Why or why not?
- If the box and pillow acted like the crumple zones in a vehicle, does this safety feature always save lives? What other factors need to be considered?

Over to you

1 Draw an example of a stationary object, labelling the forces involved. Draw arrows on your diagram to show how the forces are balanced.

2 Give an example of how different forces act together.

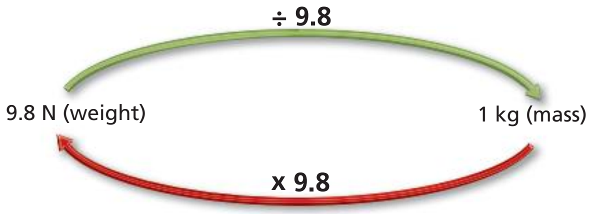
3 Give an example of how different forces affect the motion of objects.

4 A car is moving in a straight line at a constant speed. What forces are acting on the moving car?

SKILL

Unit conversions

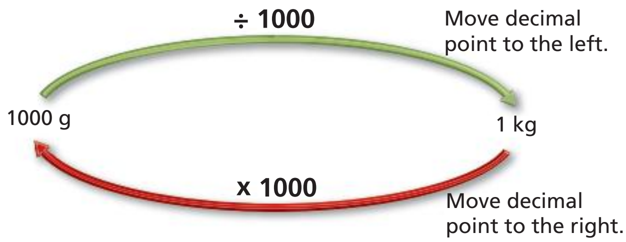
During this chapter you may need to make unit conversions to be able to complete a question. For example, force is measured in newtons and a 1 kg mass has a weight of 9.8 N, so how do you convert kilograms to newtons? The following diagram will help you.



Let's imagine your mass is 60 kg and you want to convert this to your weight in newtons. Multiply the number of kilograms by 9.8 to get the answer (60 × 9.8 = 588 N). To convert 588 N back to kilograms, you divide by 9.8 (588/9.8 = 60 kg).

Grams to kilograms

This time you want to change 53 g to kilograms. Look at the following diagram.

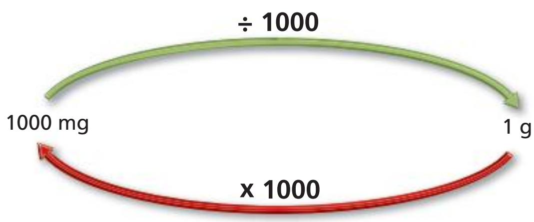


As there are 1000 g in 1 kg, you need to divide 53 by 1000. So the answer is 0.053 kg. You may have also noticed that you moved the decimal point three places to the left to get your answer.

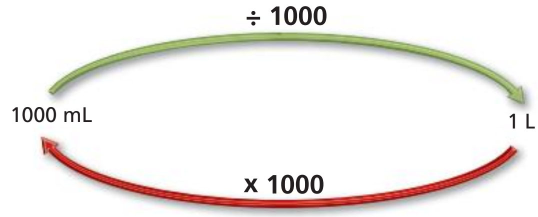
$$00053.0 \rightarrow 0.053$$

To convert 78 kg to grams, multiply 78 by 1000, or move the decimal point three places to the right. So the answer is 78 000 g. The following diagrams may help you to answer the questions on the right.

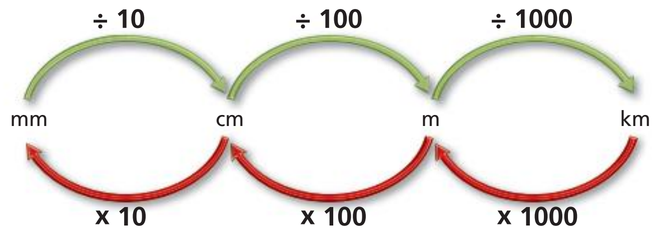
Milligrams to grams



Millilitres to litres



Millimetres to kilometres



Questions

1 Convert:
- **a** 4 kg to grams
- **b** 10 g to milligrams
- **c** 500 g to kilograms
- **d** 30 mg to grams
- **e** 1 kg to milligrams

2 Convert:
- **a** 7.8 mL to litres
- **b** 4.2 L to millilitres
- **c** 49 mL to litres
- **d** 9456 mL to litres

3 Convert:
- **a** 6.8 km to centimetres
- **b** 3.9 m to millimetres
- **c** 900 mm to centimetres
- **d** 82 cm to metres
- **e** 9 km to millimetres

4 Draw a diagram like the ones on this page to show how to change seconds to minutes and minutes to hours. Use this diagram to answer the following. Convert:
- **a** 20 minutes to seconds
- **b** 3 hours to seconds
- **c** 35 seconds to hours
- **d** 53 minutes to hours

7.2 Speed

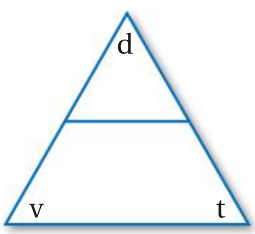
It is the school swimming carnival and you have entered the 100 m freestyle event. The swimming champion from last year is in the same race and you want to beat her. Who is going to win? The winner will be the person who covers the 100 m *distance* in the fastest possible *time*, or the person who has the fastest **speed**. The units used to measure speed in the race are metres per second. In some circumstances (e.g. car races) kilometres per hour are used.

$$\textbf{average speed} = \frac{\textbf{distance travelled}}{\textbf{time taken}} \quad \text{or} \quad \mathbf{v} = \frac{\mathbf{d}}{\mathbf{t}}$$

Distance is measured in metres (m), time in seconds (s) and speed in metres per second (m/s).

While swimming the race your speed may vary. You may start very quickly and then slow down. So the term 'average speed' is used rather than 'speed'. The symbol v represents average speed. This symbol stands for **velocity**, which is speed in a particular direction.

When you know two of three variables (speed, distance or time) you can change the equation around to calculate the third variable. For example:



$$v = \frac{d}{t}$$

$$d = vt$$

$$t = \frac{d}{v}$$

Using a formula

1 Miranda travelled 60 km from Pakenham to Melbourne. It took her an hour to make the journey. What was her average speed?

$v = \frac{d}{t}$ $\quad v = \frac{60}{1}$ $\quad$ Answer: 60 km/h

To give the answer in metres per second, you would need to do the following:

$$\frac{60 \times 1000}{1 \times 60 \times 60}$$

60 × 1000 ← convert km to m

1 × 60 × 60 ← convert seconds to minutes and then to hours

Answer: 16.7 m/s

2 Ayrton took 2 hours to travel from his home town to his uncle's farm at an average speed of 90 km/h. How far did he travel?

$d = vt$ $\quad d = 90 \times 2$ $\quad$ Answer: 180 km

Convert this answer to m/s yourself.

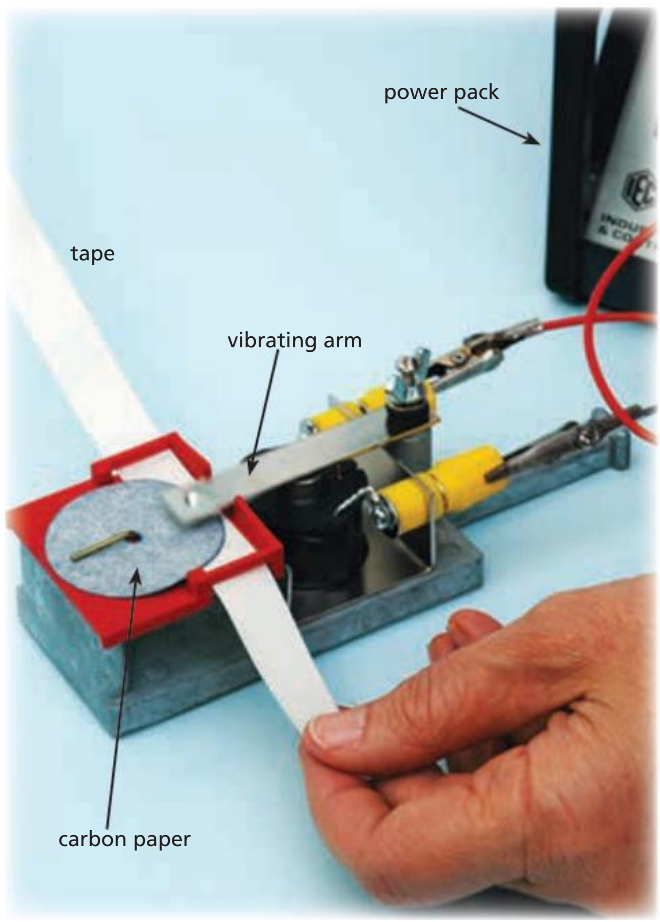
3 Rikea travelled 250 km at an average speed of 85 km. How long did it take her to make this journey?

$t = \frac{d}{v}$ $\quad t = \frac{250}{85}$ $\quad$ Answer: 2.9 h

Convert this answer to seconds yourself.

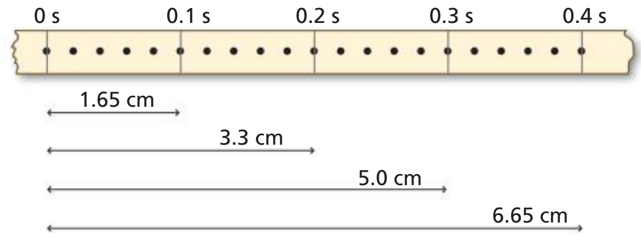
Measuring speed with a ticker-timer

Ticker-timers are used to measure speed. A ticker-timer has a vibrating arm that hits a piece of carbon paper, leaving purple marks on the tape underneath as it is pulled through. The arm hits the paper and makes a dot on it 50 times per second. So the dots are spaced 1/50 of a second apart. Thus, five dots represent 0.1 seconds (5/50 = 0.1).

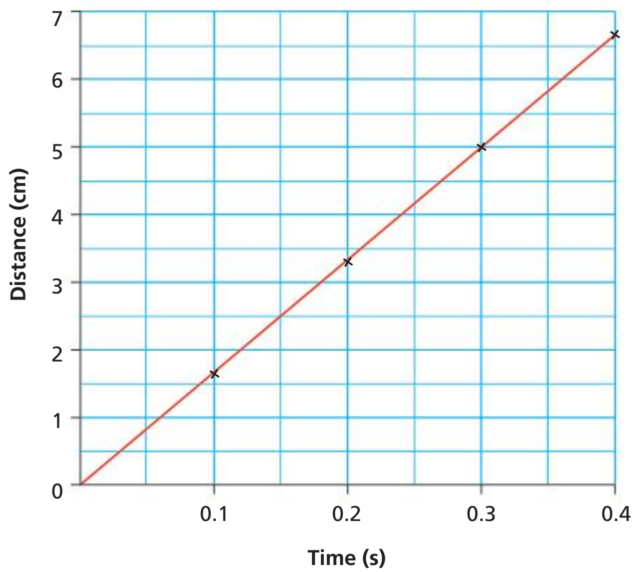


A ticker-timer

Let's imagine that Riff pulled the tape through the timer. His tape is shown here:



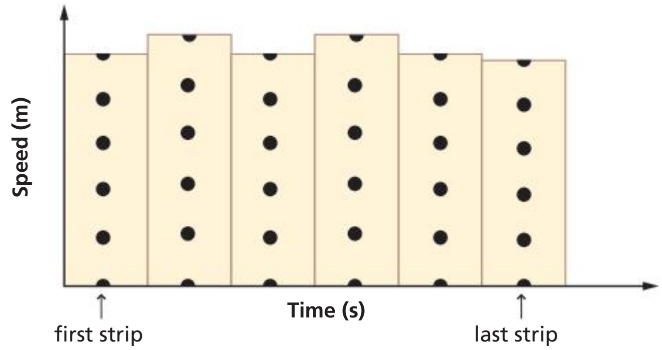
He then measured the distance travelled after 0.1 second, 0.2 second, 0.3 second and so on and used this data to draw a graph with time in seconds on the x-axis and distance in centimetres on the y-axis. The gradient (slope) of this graph gives the speed. As a similar distance is travelled for each 0.1 second time interval, the gradient (speed) is fairly constant.

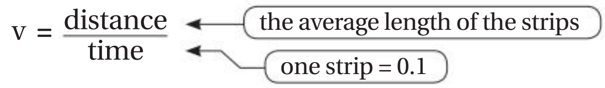


$$\text{gradient} = \frac{y}{x} = \frac{\text{rise}}{\text{run}}$$

$$= \frac{6.65\,\text{cm}}{0.4\,\text{s}} = 16.6\ \text{cm/s}$$

Another way to use the data is to cut the tape into 0.1 s intervals and stick the strips in their correct order on a graph. Here is an example. It has time on the x-axis and speed (distance in 0.1 second) on the y-axis.





For example, if the average length of the strips is 1.7 cm, and each length represents 0.1 second, then:

$$v = \frac{1.7\,\text{cm}}{0.1\,\text{s}} = 17\ \text{cm/s}$$

You will practise using the ticker-timer and drawing these graphs in Inquiry 5. Complete this activity before reading on.

Ticker-tape observations

What did you notice when you pulled the tape through the ticker-timer quickly in Inquiry 5? You probably saw that the dots were spaced far apart like this:

When you pulled the tape through the ticker-timer quickly a lot more tape went through the timer before the vibrating arm had a chance to hit the carbon and mark the tape.

When you pulled the tape through slowly, the dots were much closer together, like this:

This is because very little tape went through the ticker-timer before the vibrating arm hit the tape again.

INQUIRY 5 *Using a ticker-timer*

You will need: ticker-timer, ticker-tape, scissors, ruler

1 Your teacher will show you how to set up a ticker-timer and pull ticker-tape through it.

2 Practise pulling the tape through at a constant speed.

3 Switch off the timer once you have obtained a tape at a constant speed for ten 0.1 s intervals (50 dots).

4 Use the tape to draw a:

a distance–time graph b speed–time graph

5 Predict what you think the distance between the dots on the ticker-tape will look like if the tape is pulled through the ticker-timer very quickly. What will the tape look like if this is done very slowly? What will each graph look like?

6 Test your predictions. You will need at least ten 0.1 s intervals on the tape.

7 For each tape draw a:

a distance–time graph b speed–time graph

8 Were your predictions correct? Explain your findings.

9 What does the gradient on a distance–time graph represent? Draw what you think the gradient would look like for:

a constant speed

b increasing speed

c decreasing speed

10 What does the gradient on a speed–time graph represent? Draw what you think the gradient would look like for:

a increasing speed

b decreasing speed

c constant speed

You can check whether your answers are correct in Section 7.4.

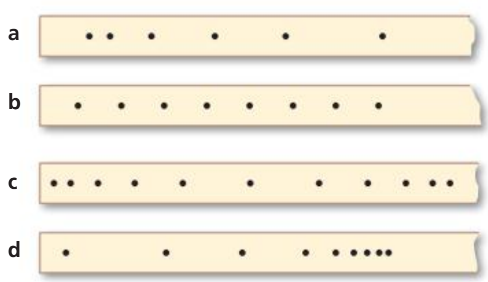
Instead of using a ticker-timer you may be able to do this activity using a motion detector connected to a datalogger.

Over to you

1 Jesse is planning her holiday. She has to travel 980 km to reach her first destination. To complete the driving time in 11 hours (without considering break times) what will her average driving speed need to be? Convert this to m/s.

2 Austin travelled 570 km to get to Melbourne. How long did it take him to make the journey if his average speed was 95 km/h? Convert this to m/s.

3 What do the following ticker-tapes indicate?



SCIENTISTS AT WORK

James Scully

James Scully studied mathematics, physics, politics and history at Year 12. He completed a combined Bachelor of Arts and Science degree, then honours and masters in Applied Mathematics. He then got a job at the Accident and Research Centre at Monash University, managing the centre's database of crashed cars.

James and a colleague developed a computer spreadsheet that relates the stopping distance of a braking vehicle to its speed and the reaction time of the driver. The spreadsheet shows that a small increase in speed can greatly increase the stopping distance of the vehicle. It also shows the speed at which an obstacle is hit if the car leaves the road or misses a corner. Even modern vehicles with excellent safety features are unable to protect their occupants adequately at impact speeds greater than 30–50 km/h. This is why you often hear reports of people being killed after their vehicle left the road and struck a tree or pole. James hopes that this research can reduce the number of people killed or injured in road accidents by communicating more effectively to drivers (and young drivers in particular) the consequences of speeding.

James has studied various accident 'black spots' around Victoria to see whether road works have improved these sites. He compared the number of crashes at these sites before and after the road works were completed. He also analysed data on the types of vehicles (large and small cars, 4WD etc) involved in serious accidents. From this he was able to work out which vehicles offer the best protection to occupants when a crash occurs. This work is heavily promoted in the media and through websites such as www.howsafeisyourcar.com.au.

James and his colleagues recently evaluated the effectiveness of Electronic Stability Control, a system that senses when a car is out of control and adjusts the power and braking force of each of the car's wheels to keep it on the road. They found that cars with Electronic Stability Control were less likely to be involved in serious single-vehicle accidents.

Another area of research James is involved with is studying high-risk intersections where digital red-light speed cameras have been installed (see photo). These cameras detect vehicles disobeying red light signals and vehicles travelling too quickly through the intersection. From their work they have been able to recommend where red light speed cameras should be placed to encourage drivers to slow down through intersections. They also worked with an engineer on ways of making the intersection safer.

Questions

1 What does the slogan 'Every K over is a killer' mean?

2 What are 'black spots' on our roads?

3 How has James used the mathematics he studied at university in his job?

4 Do you think red light speed cameras reduce the number of accidents? Justify your answer.

5 Would you like to do the sort of work that James Scully does? Explain.

7.3 Speed and stopping distance

INVESTIGATION

1 Braking bicycles

Aim

To investigate the relationship between speed and stopping distance for a bicycle.

Risk assessment and planning

Copy the table below to record your data.

Speed	Time taken (s)	Braking distance (m)	Speed (m/s)
Slow			
Medium			
Fast			

Apparatus

- bicycle and helmet
- stopwatch
- tape measure
- chalk

Method

1 On a flat bitumen surface, measure 20 m with a tape measure. At the 0 m mark write 'start'. At the 20 m mark write 'stop'. Make sure you have plenty of bitumen before the start line and after the stop line.

2 One student rides a bicycle over the 20 m distance.

3 A student at the start line will yell 'start' when the front wheel of the bicycle passes them so that a student with a stopwatch (the timer) can start timing. A student at the stop line will yell 'stop' when the front wheel of the bicycle passes them so that the timer can stop timing. When the bicycle rider hears 'stop' they must apply the brakes and stop.

4 The bicycle rider will need to practise riding the 20 m at a slow, medium and fast speed, then braking safely. Calculate the speed over 20 m in m/s.

5 Once the bicycle has stopped, measure the distance from the stop line to the front tyre. Record your results.

Discussion

1 What variables were controlled in this experiment?

2 What variables were not controlled and how could they have affected the results?

Conclusion

How does speed affect stopping distance?

'Every K over is a killer.' 'Wipe off five to save lives.' These messages appear on many Road Traffic Authority advertisements on television. Using road accident data, scientists at the University of Adelaide assessed the risk of being killed or injured in a car crash at different speeds. They found that every 5 km/h over 60 km/h doubled a person's risk of being involved in a crash. For example, travelling at 65 km/h doubled a person's chance of being killed or injured compared with travelling at 60 km/h. At 70 km/h the risk was four times as great. Travelling at under 60 km/h reduced the risk in the same way. Investigation 1 looked at speed and stopping distance. It can be used to explain these statistics.

One variable used in Investigation 1 was the time it took the bicycle rider to apply the brakes. For the rider to stop the bicycle, they had to react when they heard 'stop' and apply the brakes. This is their *reaction time*. During this time the bicycle continued at the same speed. The distance it travelled in this time is the *reaction distance*. Once the brakes were applied the bicycle still took some distance to stop. This is the *braking distance*. So:

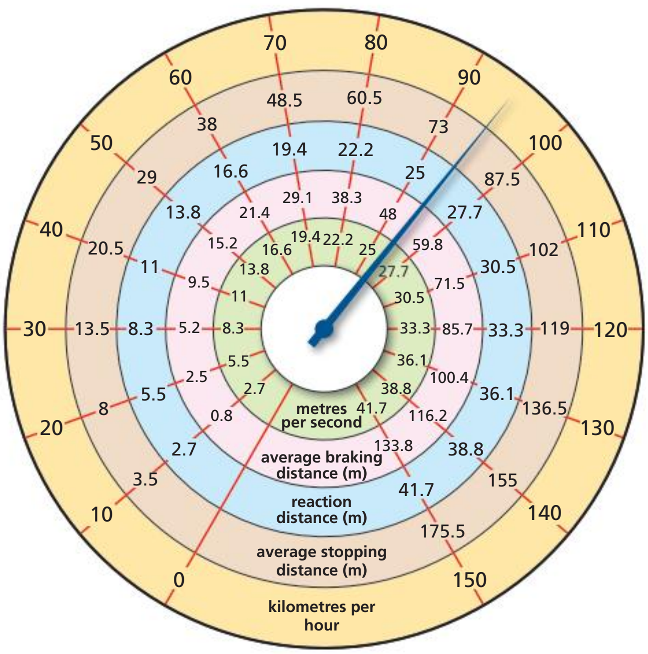
$$\text{stopping distance} = \text{reaction distance} + \text{braking distance}$$

This formula can be used to explain many dangerous situations on the road. Let's imagine that Henry is driving along a road and a koala walks out onto it. Henry sees the koala but the car moves some distance (reaction distance) before he applies the brakes. Once the brakes are applied, the car travels the braking distance. The reaction distance and the braking distance together determine whether Henry hits the koala.

Speed and stopping distance

If you think of Henry and the koala, Henry can reduce his reaction distance by reacting quickly. A younger driver is likely to react to the danger more quickly than an older driver. It is also true that a driver with distractions in the car, such as listening to music, talking on a mobile phone or children screaming in the back seat is likely to have a longer reaction time.

The speedometer below shows how different speeds affect stopping distance. Let's imagine that two cars are driving along a freeway. Car A in the left-hand lane is travelling at 60 km/h. Car B in the right-hand lane is travelling at 70 km/h. They are both level with each other when another car pulls out from the side of the road and swerves across both lanes. The two drivers react together with the same reaction time, which on average is 1 second. The average stopping distance of car A is 38 m (see chart below). The average stopping distance of car B is 48.5 m. So there is a difference of 10.5 m. This could mean that car A misses the swerving car and car B hits it.

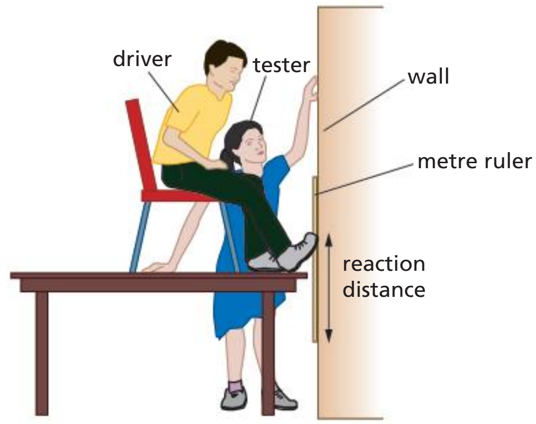


In suburban streets many states have reduced the speed limit from 60 km/h to 50 km/h to lower the risk of car accidents and pedestrian deaths. You may not think that 10 km/h is going to make that much difference, but at a speed of 50 km/h the average stopping distance is 29 m compared with 38 m at 60 km/h. This 9 m difference could save a pedestrian's life.

INQUIRY 6 Driving distractions

You will need: metre ruler, chair, table, whistle, tambourine, maracas, cymbals

1. Get into groups of four.
2. Set up the apparatus as pictured.



3. One group member holds a ruler just above the toe of another.
4. The person holding the ruler then drops it without warning. The person being tested must stop the ruler from falling by pressing their toe against the wall without lifting their heel off the table. Repeat this three times and calculate an average reaction distance.
5. Carry out steps 3 and 4 again while the other group members make loud music next to the 'driver'.
6. Measure the reaction distance for the other group members.
   - Did noise affect reaction distance?
   - What variables could have affected the outcome of this activity? Did you control these?
7. Design an experiment to see if talking on a mobile phone while driving affects reaction distance. (You do not need a mobile phone. Holding a conversation with the 'driver' will do.)

When you learn to drive a car, remember that as little as 5 km/h over the speed limit can have very dangerous consequences for you, other drivers and pedestrians. The greater the speed the more force on impact, and the more chance there is of serious damage. You can also look at this in terms of energy transfer. The faster you are going, the more kinetic energy you have, and the more energy that is transferred to any object or person that you hit.

INQUIRY 7 Crash data

1 Look at the following tables, which show the percentage of fatal crashes by crash type, time of day/week, and speed limit for two different years.

Table 1 Period	Crash type		
	Pedestrian	Single vehicle	Multiple vehicle
2005	15.2	40.4	44.4
2009	14.2	37.4	48.4

Table 2 Period	Time of day		Time of week	
	Day	Night	Week-day	Week-end
2005	55.0	44.5	58.3	41.7
2009	58.0	42.0	61.8	38.2

Table 3 Period	Speed limit (km/h)		
	Up to 60	61-90	91+
2005	21.5	22.2	56.2
2009	20.5	22.0	57.5

2 Are crashes more likely to involve pedestrians, single vehicles or multiple vehicles? Suggest inferences to explain your observations.

3 Are crashes more likely to appear in the daytime or at night, during the week or at the weekend? What reasons can you suggest to explain these figures?

4 Predict which day of the week you think crashes are most likely to occur. Give reasons for your answer. How could you test your prediction?

5 From the table, is it true to say 'speed kills'? Why or why not?

6 Explain whether your reading in this chapter supports the data presented in Table 3.

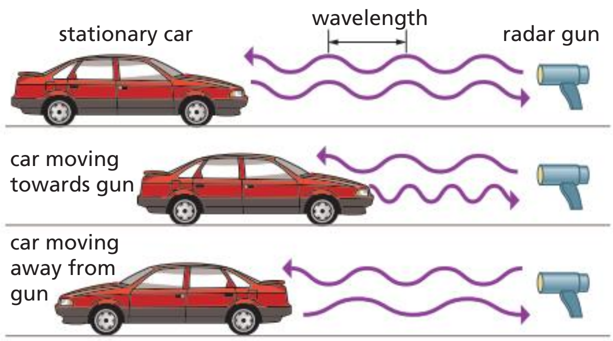
7 Do you think advertising campaigns telling people to slow down have been effective in reducing fatal car crashes since 2005? Give reasons for your answer.

PROBLEM SOLVING

What safety features could you put in your SafeCar to warn drivers when they are speeding and about dangers on the road ahead?

INQUIRY 8 Speed radar gun

Speed radar guns emit radio waves, which are reflected from a car and returned to the gun. Radio waves travel at a set wavelength. If a car is stationary, the radio waves reflected from the car have the same wavelength as the outgoing waves. If a car is moving towards the gun, the radio waves bunch together over the shortened distance so the reflected radio waves have a shorter wavelength. If a car is moving away from the gun, the radio waves lengthen over the increased distance so the reflected radio waves have a longer wavelength. This difference in wavelength is called the *Doppler shift*. It is used to determine the speed of the car.



Laser radar guns use laser light instead of radio waves to measure the speed of the car. Small bursts of infra-red laser light are emitted from the gun and reflected from the car. The gun counts how long (in nanoseconds) it takes the light to be reflected. The speed of the car is calculated from this.

Ask your teacher to contact your local police station for a demonstration of how a radar gun works.

Over to you

1 How does travelling at 5 km/h over the speed limit affect a driver's chances of being injured or killed in a crash?

2 Describe the steps that must occur before a driver can stop when a dangerous situation occurs. Use the words: reaction distance, braking distance and stopping distance.

3 Explain how the slope of the road is likely to affect braking distance.

4 Explain how friction is likely to affect braking distance. How will the braking distance of a car with new tyres on a flat dry road be different from that of a car with worn tyres? What about on a flat wet road?

7.4 Acceleration

To overtake another vehicle on the road, you may need to speed up. The rate at which speed increases is called **acceleration**. To know whether an object's speed is increasing, you need to know the object's initial speed and its final speed over the time you are measuring.

For example, two boys want to know which of their go-carts can accelerate the most. They organise for a friend to measure their speed 5 seconds after they start a race. Go-cart 1 reaches a speed of 5 m/s, whereas go-cart 2 reaches a speed of 6 m/s. What was the acceleration of each go-cart?

$$\textbf{average acceleration} = \frac{\textbf{change in speed}}{\textbf{time taken}}$$

$$= \frac{\textbf{final speed} - \textbf{initial speed}}{\textbf{time taken}}$$

For go-cart 1, $a = \frac{5 - 0}{5} = 1$ m/s/s

For go-cart 2, $a = \frac{6 - 0}{5} = 1.2$ m/s/s

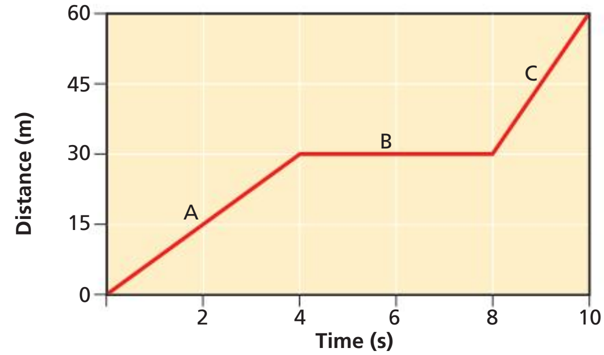
So go-cart 2 accelerated faster than go-cart 1. The unit used to measure acceleration is m/s/s or m/s^2. This is because it tells you how much the speed (in metres per second) changes each second.

Acceleration using a ticker-timer

In Inquiry 5 you were asked to predict what the ticker-tape would look like if you pulled it through the timer quickly and slowly. You then had to draw a distance–time graph and a speed–time graph.

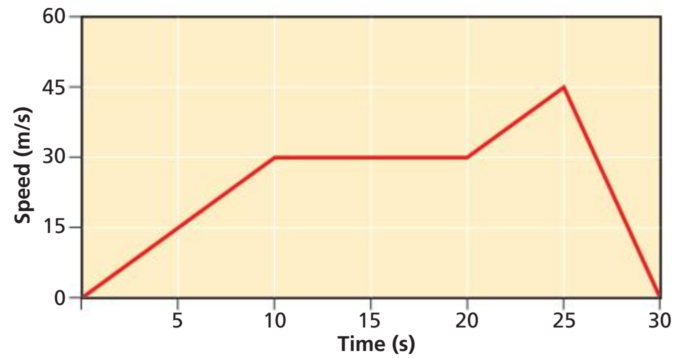
You may have realised that the gradient of a distance–time graph means something very different from the gradient of a speed–time graph. The gradient of a distance–time graph represents speed but the gradient of a speed–time graph represents acceleration. For a speed–time graph the distance travelled is the area underneath the graph.

Look at the distance–time graph top right. To work out the speed at various points you need to look at the gradient of the graph. The gradient at point A shows that the object is travelling at a constant speed. At point B there is no movement, and at point C the speed of the object is greater than at point A.



In the first 4 seconds the object moved 30 m. So the speed during this time was 30/4 or 7.5 m/s. Between 4 seconds and 8 seconds the object's distance remained at 30 m, so there was no motion. In the last 2 seconds the object moved 30 m, so the speed was 30/2 or 15 m/s, much faster than in the first 4 seconds.

The gradient in the speed–time graph below shows that an object is accelerating, then travelling steadily then accelerating again. The gradient then shows *negative acceleration*. In other words, the object's speed is decreasing. This is called *deceleration*.



To work out the acceleration using the graph above you again need to look at the gradient. In the first 10 seconds the object's speed increases from 0 m/s to 30 m/s.

So its acceleration is: $\frac{30 - 0}{10} = 3$ m/s^2

In the time interval between 10 and 20 seconds there is no acceleration. From 20 to 25 seconds the object's speed changes from 30 m/s to 45 m/s.

So its acceleration is: $\frac{45 - 30}{5} = 3$ m/s^2

In the last 5 seconds, deceleration (negative acceleration) is indicated by the minus sign:

$$\frac{0 - 45}{5} = -9 \text{ m/s}^2$$

INVESTIGATION

2 Speed and acceleration

Aim

To investigate velocity and acceleration.

Risk assessment and planning

Copy the tables below to record your data.

Table 1

Student	10 m	20 m	30 m	40 m	50 m
1					
2					
3					
4					
5					
6					

Table 2

Student		0–10 m	10–20 m	20–30 m	30–40 m	40–50 m
1	velocity					
	acceleration					
2	velocity					
	acceleration					
3	velocity					
	acceleration					
2	velocity					

Apparatus

- 5 stopwatches
- chalk marker
- tape measure
- coloured pens
- 5 coloured plastic cones

If your school has dataloggers available, you could also use these for this investigation.

Method

1 Using a tape measure and chalk marker, draw a line 50 m long on the oval.

2 Place a coloured plastic cone every 10 m along the line, starting at the 0 mark.

3 Give five students a stopwatch and have each student stand at a 10 m mark.

4 Line up six students on the 0 mark. Each student must run the 50 m, one at a time.

5 The students on each marker begin timing when each runner starts to run and stop timing when the runner reaches their mark.

6 Record all times in Table 1.

7 Using the formula v = d/t, calculate each runner's average speed over each interval they ran. Suppose a runner took 4 seconds to run 10 m, and 5.8 seconds to run 20 m. Their average velocity between 0 and 10 m would be 10/4 = 2.5 m/s.

Their average velocity between 10 and 20 m would be:

$$\frac{10}{5.8 - 4} = 5.6 \text{ m/s}$$

Place all your calculations in Table 2.

8 Using the formula:

$$\text{acceleration} = \frac{\text{final speed} - \text{initial speed}}{\text{time taken}}$$

calculate each runner's average acceleration during each 10 m interval. For example, using the above times, a runner's acceleration from 0 to 10 m would be:

$$\frac{2.5 - 0}{4 - 0} = 0.6 \text{ m/s}^2$$

From 10 to 20 m:

$$a = \frac{5.6 - 2.5}{5.8 - 4} = 1.7 \text{ m/s}^2$$

Place your calculations in Table 2.

9 Draw graphs of velocity (y -axis) versus time (x -axis) for each runner on one graph, using a different coloured pen for each runner.

10 Draw a graph of acceleration (y -axis) versus time (x -axis) for each runner on one set of axes. Use a different coloured pen for each runner.

Conclusion

1 How does the speed of each runner change over the 50 m distance covered?

2 How does the acceleration of each runner change over the 50 m distance covered?

3 Are there any differences between the students that you sampled? Would this be an accurate assessment of all students? Explain your answer.

Force, mass and acceleration

Imagine a truck and a car travelling along a highway together at the same speed. For the car to overtake the truck, more engine force will be needed to accelerate the car. If the same force is applied to both the car and the truck, the car will accelerate faster than the truck. This is because the truck has more mass than the car. The relationship between force (F), mass (m) and acceleration (a) is expressed in *Newton's second law of motion*, which states that:

$$\mathbf{F = ma}$$

This can also be written as $\mathbf{a = \frac{F}{m}}$ or $\mathbf{m = \frac{F}{a}}$

Force is measured in newtons, mass in kilograms and acceleration in metres per second squared. Here are some examples.

1 A car with a mass of 1000 kg accelerates at 26 m/s^2. What force is acting on the vehicle?

$F = ma$, so $F = 1000\ kg \times 26\ m/s^2 = 26\,000\ N$

2 An object is pushed by a force of 350 N and accelerates at 15 m/s^2. What is the object's mass?

$$m = \frac{F}{a} = \frac{350\ N}{15\ m/s^2} = \frac{350\ kg\ m/s^2}{15\ m/s^2} = 23.3\ kg$$

3 A block weighing 150 g is pushed along the ground with a force of 6 N. What is the acceleration of the block? (You will need to convert grams to kilograms, so 150 g is 0.15 kg.)

$$a = \frac{F}{m} = \frac{6\ N}{0.15\ kg} = 40\ m/s^2$$

4 A car accelerates from 0 to 72 km/h in 10 seconds and has a mass of 1000 kg. What is the force acting on the car? First you need to convert km/h into m/s:

$$72\ km/h = \frac{72 \times 1000\ (km\ to\ m)}{60 \times 60\ (h\ to\ s)} = 20\ m/s$$

So the acceleration of the car is:

$$a = \frac{20 - 0\ m/s}{10\ s} = 2\ m/s^2$$

$F = ma$, so $F = 1000\ kg \times 2\ m/s^2 = 2000\ N$

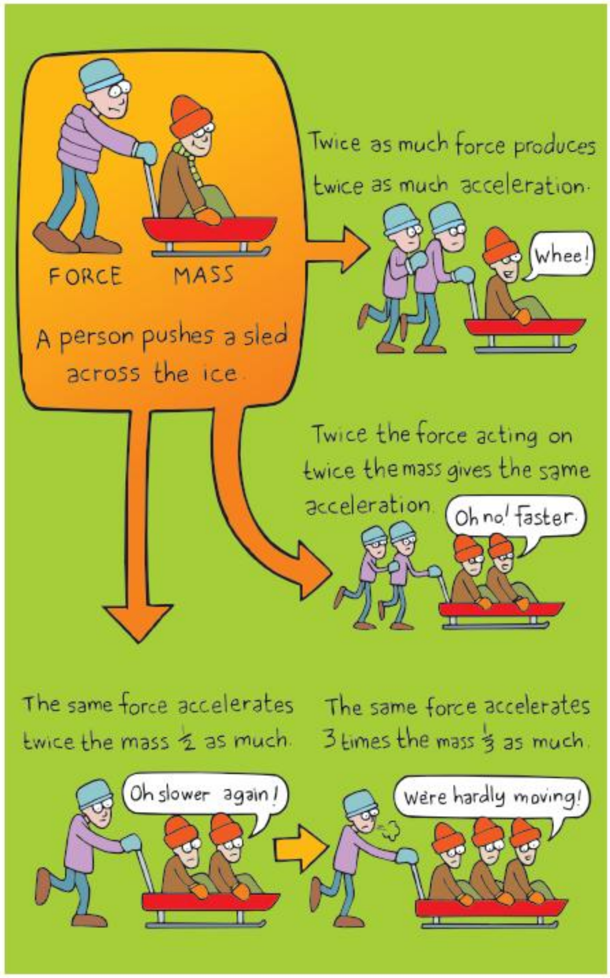
Handy tip

- To convert km/h to m/s, divide by 3.6
- To convert m/s to km/h, multiply by 3.6

INQUIRY

9 *True or false?*

The relationship between force, mass and acceleration is shown in these diagrams.



Demonstrate whether these statements are true or false using the equations on the left and your own figures. You could even design an experiment to demonstrate your calculations. For example: twice as much force produces twice as much acceleration for the same mass.

Let force = 80 N, mass = 20 kg

$$a = \frac{F}{m}$$

So acceleration $= \frac{80\ N}{20\ kg} = 4\ m/s^2$

For twice the force $a = \frac{160\ N}{20\ kg} = 8\ m/s^2$

So the statement is true.

INVESTIGATION

3 Mass and acceleration

Aim

To investigate the motion of a trolley on a ramp.

Risk assessment and planning

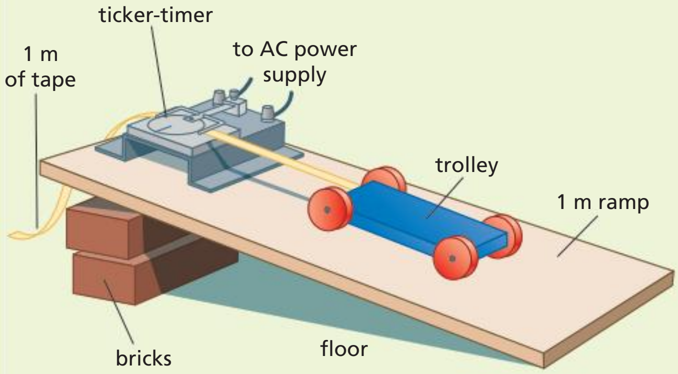
Read this investigation and outline any safety precautions you need to be aware of.

Apparatus

- ticker-timer and tape (or datalogger)
- masking tape
- (dynamics) trolley
- protractor
- plank (1 m long)
- two bricks
- clamp
- electronic balance
- assorted weights: 100 g, 500 g, 1 kg

Method

1 Set up the ramp, bricks and ticker-timer on the floor as pictured. (Make sure that the ticker-timer is firmly clamped so that it cannot slide down the ramp.)



2 Measure the angle between the ramp and the bench with a protractor and record this in your notebook.

3 Measure the mass of the trolley and record this in your notebook.

4 Thread the ticker-tape through the timer and stick the end of the tape firmly to the back of the trolley using masking tape.

5 Position the trolley at the highest point on the ramp.

6 Switch on the timer and release the trolley so it rolls down the ramp and pulls the ticker-tape through the timer behind it.

7 Use the tape to make a speed–time graph as you did in Inquiry 5. (Remember the gradient of this graph gives acceleration.)

8 Predict what you think increasing the mass of the trolley will do to its acceleration. Write your prediction in your notebook.

9 Test your prediction by taping a 100 g mass to the trolley and repeating steps 4–7.

10 Repeat for the other masses.

Discussion

1 Is there a difference in the gradients of the graphs you have produced?

2 Was your prediction correct? How did increasing the mass of the trolley affect its acceleration?

3 Which variables were controlled in this experiment?

4 Did you control all the variables in this experiment? Explain.

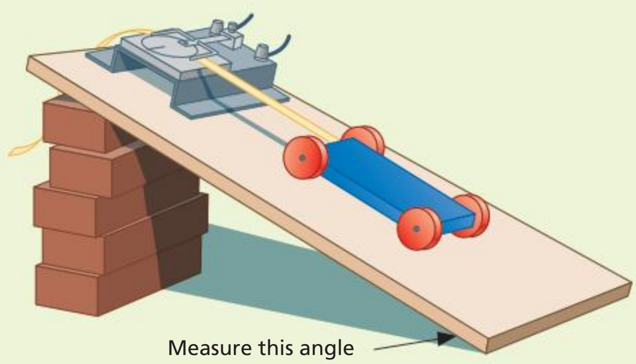
Conclusion

Write a conclusion describing what you found out.

Further investigation

Design and carry out your own investigation to test one of the following hypotheses.

A The greater the slope, the greater the acceleration of the object on it.



B The greater the slope, the further the object will go when it rolls off the slope.

C The greater the mass of the trolley, the further it will roll at the bottom of the slope.

Force, mass, acceleration and the car

In Section 7.3 you learnt that as little as 5 km/h over the speed limit can increase your chances of being killed or injured in a car crash. The faster you are travelling, the greater the force on impact.

Let's imagine that a car hits a pedestrian. Some of the kinetic energy of the car travelling at speed is transferred to the pedestrian. On impact the pedestrian's speed is the same as the car's speed. This means that the pedestrian is accelerated by the car. Imagine that the pedestrian has a mass of 50 kg and an acceleration of 320 m/s^2. Using the formula F = ma, the force on impact is 16 000 N. This force is enough to kill the pedestrian.

When a car hits a tree, the faster the car is travelling the more force it hits the tree with. Action and reaction forces mean that the car and the occupants of the car are also going to experience the same force. Air bags, bumper bars and crumple zones are designed to lessen the impact that this force has on the occupants of the car.

The faster you are going, the more kinetic energy you have and the more force you hit with. This is because the energy a body has as a result of its motion is equal to half of its mass multiplied by the square of its speed. The formula is: **KE = ½ mv^2**.

Over to you

1 Two dragsters are timed for the first 10 seconds of a race. Dragster 1 reaches a speed of 110 km/h. Dragster 2 reaches a speed of 90 km/h. What is the acceleration of each dragsters (in m/s^2)?

2 Amalie is testing how long it takes two cars to reach 100 km/h from a standing start. Car 1 takes 8.8 seconds and car 2 takes 9.6 seconds. Which car has the greater acceleration? (Your answer will need to be in m/s^2.)

3 If you run at an average speed of 6 m/s, how far can you run in 2 minutes?

4 An object accelerates at 75 m/s^2 with a force of 500 N. What is the object's mass?

5 Gaige records the force acting on an object as 550 kg. He measures the acceleration as 90 m/s^2. What is the mass of the object? (*Hint*: You will need to convert kilograms to newtons.)

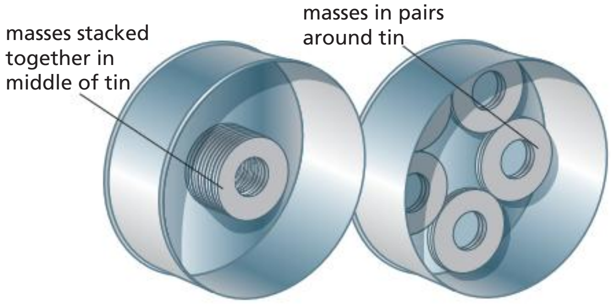
6 If you have a mass of 900 kg and a velocity of 100 km/h, how much kinetic energy do you have? Remember that energy is measured in joules. (You will need to convert km/h to m/s.)

INQUIRY 10 *Rolling biscuit tins*

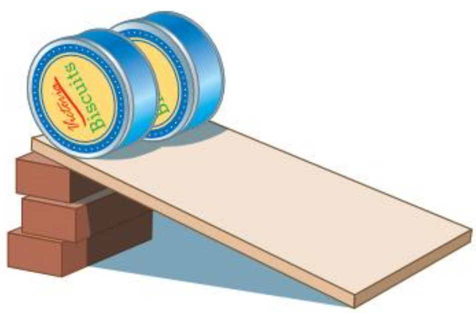
You will need: 2 biscuit tins, twenty 50 g masses, masking tape, wooden plank and bricks

You have seen that the mass of an object affects its acceleration, but does the *position* of the mass affect the object's acceleration? See the diagram below. What do you think? Make a prediction and write it in your notebook.

1 Stick the ten 50 g masses inside each tin, as pictured, using the masking tape.



2 Put the lids on. Then roll the tins down a ramp, hill or slope to see which tin reaches the bottom first.



3 Was your prediction correct? Write an inference to explain your observation.

4 Use your findings to predict what you think will happen when a tin filled with a solid (e.g. soil) and a tin filled with a liquid (e.g. water) are both rolled down a ramp together. Which tin will reach the bottom first? Test your predictions.

PROBLEM SOLVING

Can your SafeCar detect the mass of the person and the forces acting in a crash and adjust the inflation rate of an airbag or tension of a seatbelt? Could you have side airbags and, if so, how will these activate? How will the bumper bar be designed?

7.5 Collisions

Inertia

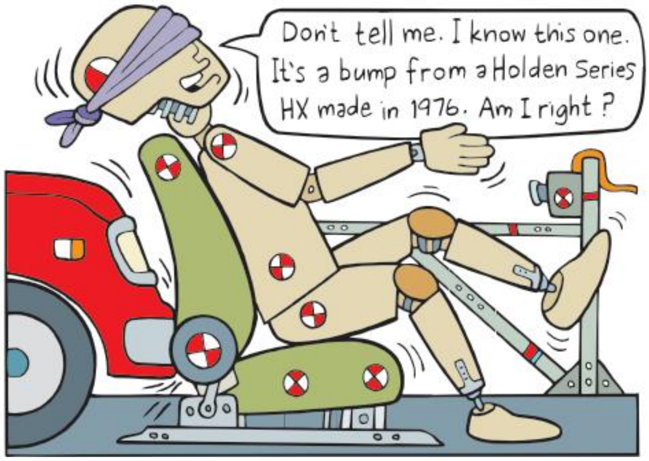
Newton's first law of motion states that an object will either remain at rest or continue to move in a straight line unless acted on by a net unbalanced force. This resistance that objects have to start moving or to change their movement is called **inertia**. In other words, if a stationary object has a lot of inertia it does not want to budge! This can be seen in the famous magician's tablecloth example. A magician places a vase of water and flowers in the middle of a table and, hey presto, pulls the tablecloth out from under the vase without tipping it over. This is because the vase, water and flowers are at rest and want to remain at rest. They stay in the same spot if the tablecloth is pulled out fast enough from under them.

Inertia is very important in everyday situations that occur on the road. Imagine you are standing in the aisle of a bus that is moving and then suddenly stops. Newton's first law can explain what happens in this situation. You are moving at the same speed as the bus when it comes to a sudden stop. You will continue to move forwards at the same speed and it will seem as though you are thrown forwards. Hopefully the bus is not moving very quickly and you will be able to stop yourself from being flung too far down the aisle.

Seatbelts are used to counteract inertia. When you are sitting in a car and it is moving, you are travelling at the same speed as the car. Your seatbelt stops you from continuing to move forward if the driver stops the car suddenly. People still die on Australian roads because they are not wearing a seatbelt. If a car stops suddenly and the occupants of the car are not strapped in, they can be flung forwards onto the dashboard or steering column. They may even travel through the windscreen and end up on the road. If they are in the back seat they can be flung onto the seats in front. Wearing a seatbelt reduces your risk of serious injury in a car accident by 50%. Wearing a seatbelt in the front seat has been shown to reduce the risk of fatal injury by 45%.

Modern cars are designed to counteract inertia. Collapsible steering columns and airbags minimise the risk of injury when occupants in the car are thrown forwards. In fact, airbags have reduced head injuries by 50%. Padding on instrument panels and recessed knobs and fittings prevent piercing injuries from frontal impact.

Inertia can also explain what happens to passengers in a rear-end collision. Imagine you are sitting in a car at the traffic lights when it is hit in the rear by another car. The force of the car from behind will push your car forwards. However, because stationary objects want to remain at rest, your body will resist the forwards motion and therefore seem to move backwards on impact. Your seat and headrest should cushion the impact. Without a headrest your head would be thrown back and you could suffer *whiplash*, which could damage your spine and neck.



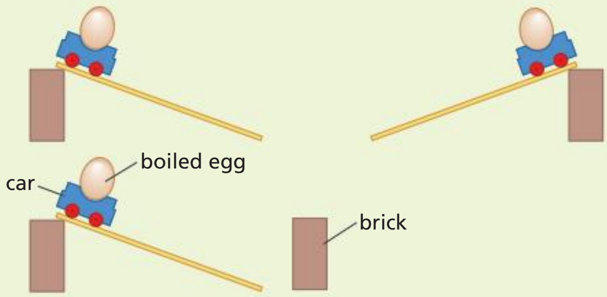
The mass of an object affects its inertia. The greater the mass, the more inertia an object has. For example, a truck has a greater inertia than a car. This means that if the truck is stationary, it will be harder to get moving, and if it is moving, it will be harder to stop.

INVESTIGATION

4 *Humpty Dumpty*

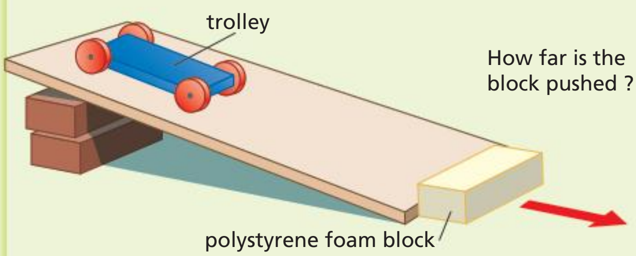
1 Design your own investigation to demonstrate what happens to the passengers of cars involved in the following situations:

- **a** two moving cars collide head-on
- **b** a moving car hits a stationary car
- **c** a moving car hits a tree

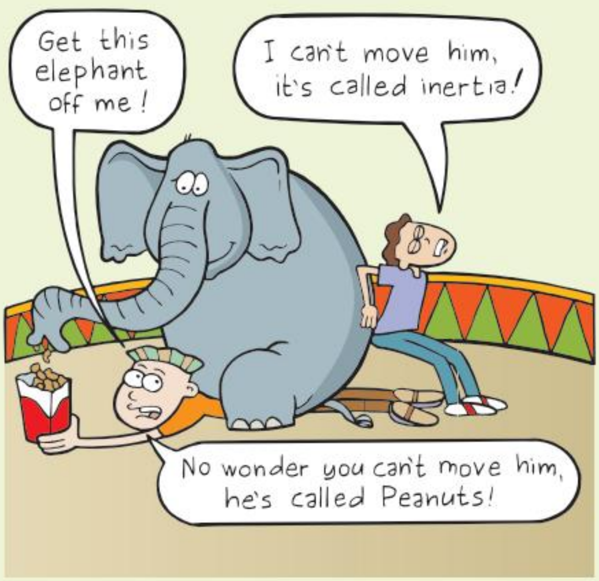


Do your results support what you have learnt in this section?

2 Design your own investigation to demonstrate how speed affects the forces that occur on impact.



Do your results in this investigation support what you have learnt in this chapter?

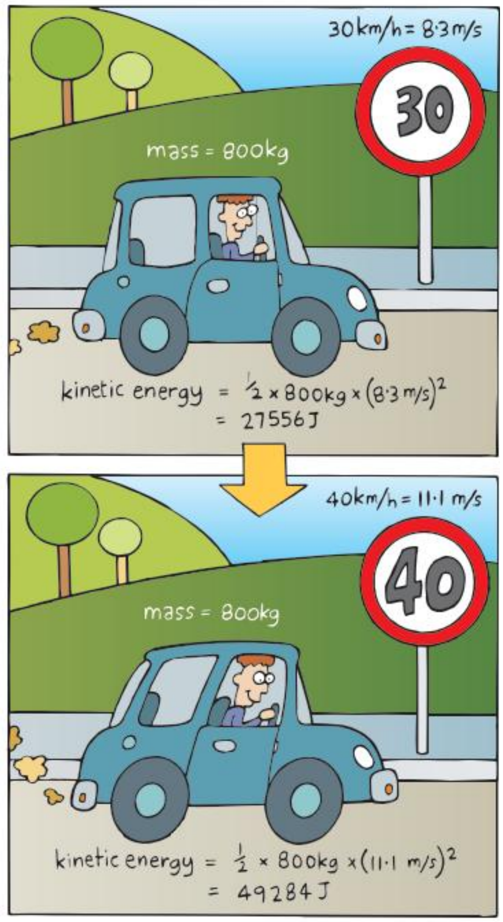


Kinetic energy

A moving car has a large amount of kinetic energy. To calculate the amount of energy it has you can use this equation:

$$\textbf{kinetic energy} = \frac{1}{2} \times \textbf{mass} \times (\textbf{velocity})^2$$

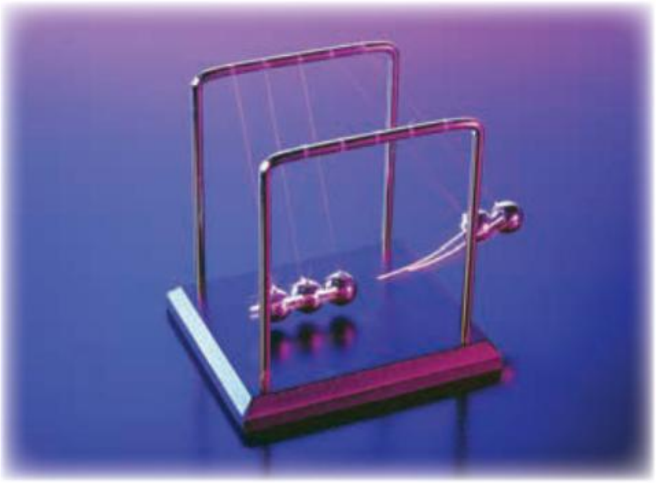
If the mass is in kilograms and the velocity is in metres per second, then the kinetic energy will be in joules. Notice that the amount of kinetic energy depends on the *square* of the velocity. So a small change in velocity means a large change in energy. For example, a car travelling at 40 km/h has almost twice as much kinetic energy as the same car travelling at 30 km/h. This is why there is a much greater risk of injury to pedestrians at speeds greater than 30 km/h.



Conservation of energy

As a car speeds up its kinetic energy increases very quickly. However, if the car collides with a tree and comes to a stop, what has happened to all the energy the car had?

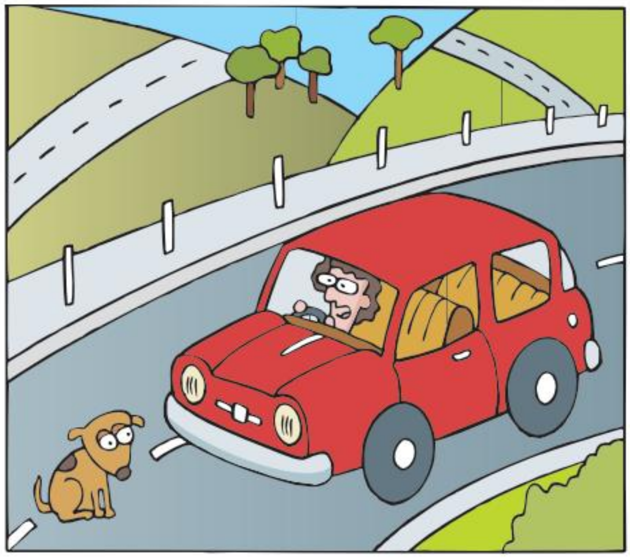
To understand this we can use Newton's cradle, shown in the photo. If you pull out the first ball and let it go, it hits the second ball in the line and comes to a dead stop. But the ball on the other end of the line jumps out the same distance you pulled the first ball out. It then falls back and the whole process is repeated. The balls go on clicking back and forth for a long time, before they eventually stop. If you pull out *two* balls to start with, then two balls jump out the other end, as shown. To see an animation of this search for 'Newton's cradle animation' on the internet.



What has happened is that the kinetic energy of the first ball has been transferred along the line of balls. The last ball in the line jumps out with the same amount of kinetic enerегy as the first ball had. Scientists have found that energy cannot just disappear. It can be converted from one form to another, but it cannot be created, destroyed or lost. This is the law of **conservation of energy**.

Let's apply the law of conservation of energy to a car involved in a collision. As the engine runs, the stored chemical energy in the petrol is converted into heat energy and then into kinetic energy. As the car moves there is friction caused by the car's moving parts and by wind resistance. As a result of this friction some of the kinetic energy is converted to heat energy of the air. Suppose a tyre blows. The brakes lock, the tyres smoke and some of the car's kinetic energy is converted to heat energy. Then crash! The car collides with a tree. The front of the car collapses and the engine is pushed backwards. Pieces of the tree fly off and glass flies everywhere. The car's kinetic energy is transferred to the moving engine, pieces of the tree and flying glass. The passengers are thrown forward but are restrained by their seatbelts. Loose objects in the car fly forward.

During the crash the kinetic energy of the moving car is transferred to other parts of the car and the tree, and converted to other forms of energy—sound and heat. There was no energy created, and no energy destroyed or lost. Energy was conserved.



The amount of kinetic energy before the crash equals the amount of energy transferred to other objects or converted to other forms of energy during the crash.

Efficiency

Whenever friction occurs, kinetic energy is converted to heat energy. This heat energy is then of no use. This is why no machine can be 100% efficient. If a machine has moving parts, there will always be friction. This is why the balls in Newton's cradle eventually stop, because friction produces sound and heat as the balls collide.

Scientists have found that *in all energy conversions and transfers, some energy is always converted to heat*. For example, when petrol is burnt in a car engine, only about 20% of the stored chemical energy is converted into kinetic energy. The other 80% is converted to heat and sound energy.

Energy can be used over and over again, but a bit is converted to heat energy every time it is used. This is why computers and mobile phones become warm when you use them. In fact, all energy ends up as heat eventually. This heat energy goes into the Earth's atmosphere and is eventually radiated into space.

To harness the energy around us we have to change its form, or move it from one place to another. Whenever we do this some energy is converted to heat. So you can never make a machine that is 100% efficient. To keep things going, you have to keep putting energy in.

Over to you

1 Unaisi puts a thin piece of cardboard on top of an open bottle. She then sits a coin on top of the card so that it is in line with the bottle opening. She flicks the card and the coin falls in the bottle. Try this for yourself and explain what Unaisi was demonstrating.

2 Explain how seatbelts counteract the problem of inertia in cars. Give two examples.

3 Explain why the following safety features are needed in cars:

- a head restraints
- b airbags
- c padded dashboards
- d recessed knobs and fittings
- e load covers or nets in the back of station wagons

4 Why is it harder to stop a loaded truck than the same truck without a load?

5 To charge a battery you have to supply electrical energy. But you never get as much energy out as you put in. Why is this?

6 State the law of conservation of energy. Illustrate your answer by listing the energy changes that occur when a fireworks rocket rises in the sky and emits coloured balls of light before the remaining pieces fall to the ground.

7 The cartoon on the right shows a design for a *perpetual motion machine*. Explain in energy terms why this machine will not work.

PROBLEM SOLVING

What other features will your SafeCar have? Here are some things for you to consider.

- What type of seats will your SafeCar have and how will they reduce whiplash in rear-end collisions? Will your car have a safety cage around its inner compartment?
- What type of braking system will your SafeCar have? Find out the difference between disc brakes and drum brakes. Which are safer and why? Investigate anti-lock braking systems (ABS) and traction control systems.
- What will the interior fittings, controls and surfaces be like? Will there be a collapsible steering column? If so, how will this work? What sort of padding on the inside door panels will your SafeCar have? What shape will the dashboard be, and how will you protect a person's knees from hitting hard parts of the car under and in front of the dashboard?
- What features will your SafeCar have to help you reverse? For example, will it be able to 'see' any obstacles behind it and warn the driver of an impending collision?

Youth and drink driving

Car accidents are one of the leading causes of death for Australians up to the age of 44. Injuries from car accidents are most common in the 15–24 age group. Three in every 10 fatal car accidents is caused by alcohol, and in the Northern Territory this is as high as two out of three. Alcohol-related car accidents cost the community about $767 million each year.

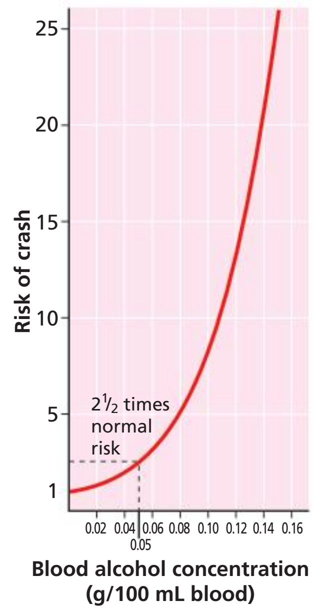
These statistics are of increasing concern when youth drinking is examined. The National Heart Foundation reported that although young people aged 20–24 drank less frequently than older people, they consumed far more alcohol when they did drink. It also reported that 38% of 16 year olds and 40% of 17 year olds had five or more drinks when they last consumed alcohol. Unfortunately young people are trying alcohol at the same time that they are learning to drive.

The measure of alcohol in the bloodstream is called the *blood alcohol concentration* (BAC). It is measured in grams/100 mL of blood. A BAC of 0.02% means that you have 0.02 g of alcohol in each 100 mL of blood in your body. The BAC of a person drinking can depend on many factors—how many drinks they have had and over what time, the strength of the alcohol, the size and build of the person, whether they have eaten and whether they are male or female. Women are affected by alcohol more quickly than men are.

The liver gets rid of alcohol at a rate of one standard drink per hour, or 10 g of alcohol per hour. Some common servings of standard drinks are shown top right.

Most men will reach a BAC of 0.05% after drinking three standard drinks in an hour. For women this is two drinks per hour. At this BAC a person may still feel all right to drive but they are not. Drinking and driving is deadly because of the effect alcohol has on the body. In small amounts, alcohol makes a person feels less inhibited and confident, but their reaction time becomes slower. They also take risks and do things they would not normally do. In large amounts, alcohol can affect decision-making, cause blurred vision, slurred speech, poor movement, a loss of concentration and coordination, and blackouts. The more alcohol

you consume, the greater your chance of having a car accident, as shown in the graph.



In most states a person cannot drive a car with a BAC of 0.05% or above. Learner and probationary drivers must have a BAC of zero. Random breath testing, tougher penalties for drink drivers, compulsory testing of crash victims and television advertising campaigns have lowered the levels of drink driving.

1. What is the legal BAC of drivers, learners and probationary licence holders in your state?
2. Suggest possible reasons why young people between the ages of 15 and 24 years are more likely to be killed or injured in a car accident.
3. Use the internet to research some of the effects of alcohol on the body and on driving ability. Try www.science.org.au/nova and search for ‘alcohol and cars’. You could also look up a government health department or contact your state alcohol and drug information service.
4. Road fatalities related to alcohol and the costs of alcohol-related car accidents are preventable. Debate whether the BAC for all drivers across Australia should be zero.

THINKING SKILLS ?

1 Speed cyclists use streamlined helmets and bicycles and wear special suits to reach very fast speeds. Why are these innovations necessary?

2 What force keeps your feet from slipping off the pedals when you ride a bicycle?

3 If a driver is driving sensibly, what keeps the car on the road?

4 What happens to a car if the driving force is:

a equal to the friction forces?

b greater than the friction forces?

c less than the friction forces?

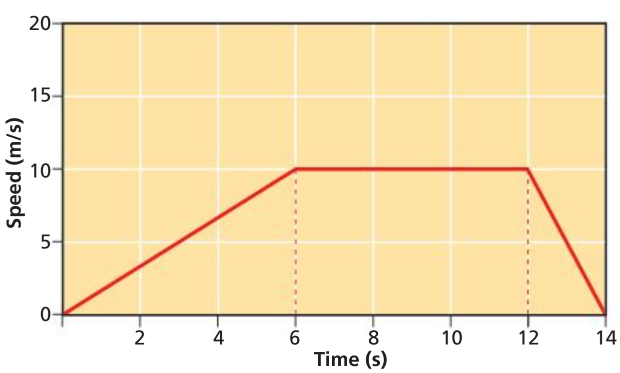
5 **a** If a police car is travelling at 60 km/h and the car in front (car A) is moving away from it at 20 km/h, what is the speed of car A?

b If car B is in front of the police car and the distance between the two cars remains the same, what is the speed of car B?

6 In a cross-country race a runner covers 50 m in 10 seconds. She then stops for 15 seconds and reads her compass before covering another 100 m in 20 seconds. Draw a distance–time graph of the runner's motion.

7 A cyclist in a race accelerates from 0 to 11 m/s in 7 seconds. He then has a constant speed for the next 10 seconds. As he approaches a bend it takes him 5 seconds to slow down from 11 m/s to 3 m/s. Draw a speed–time graph of his journey.

8 The area under a speed–time graph equals the distance travelled. If the area of a square is length × width, and the area of a triangle is ½ base × height, what is the distance covered for the following speed–time graph?

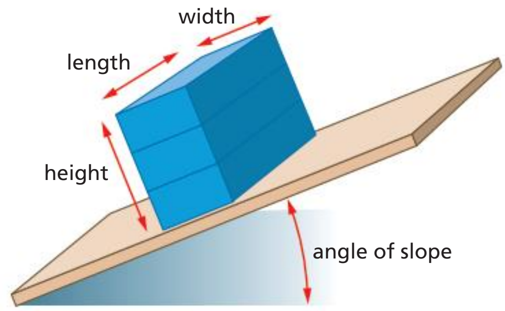


9 What is the acceleration of an airbag if it can be inflated in 1/10 of a second and hits the passenger with a speed of 320 km/h? Is it true to say that an airbag is like a pillow? Explain.

10 Karen took her two dogs Ciara and Zai to a dog racing track to see which dog was faster. The track was oval in shape. She put the dogs in two lanes next to one another and started them at the same place on the track. She timed the dogs as they ran around the track and to her surprise they both finished at exactly the same time, so she said they had equal speed.

Gordon said that the test was unfair because Zai's lane was on the outside of Ciara's. Gordon concluded that Zai had the greater speed. Who is right? Explain using the formula $v = d/t$ and your own figures.

11 Design an activity to investigate whether four-wheel drive vehicles are less stable on the road than normal vehicles. The following diagram will give you some clues on how to investigate this.



12 Investigate the tread of the tyres on the cars in the teachers' car park. Are there any cars that have unsafe tyres? Write a report to the car owner explaining why they should get new tyres and give the report to them.

Knowing and Understanding

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

1 Newton's third law of motion is referred to as action and _______. An example of this law is that for a person sitting in a chair, the chair will exert a force back on the person which is _______ and _______ in direction to the person's weight.

2 Average speed is calculated by measuring the _______ travelled in a certain period of _______. The symbol used for speed is v, which means ______.

3 The stopping distance of a person driving a car is made up of the reaction distance and the _______ distance.

4 To know whether an object's speed is increasing, the _______ speed and the final speed of the object after a certain time need to be measured. The rate at which an object's speed increases is called _______.

5 The formula F = ma stands for force equals _______ multiplied by acceleration. This is also known as Newton's _______ law of motion.

6 Newton's first law of motion states that an object will either remain at rest or continue to move in a straight line unless acted on by a net unbalanced force. This property is also referred to as _______.

7 The _______ of a speed–time graph represents acceleration. This is different from a distance–time graph, where the gradient represents _____

acceleration
braking
distance
equal
gradient
inertia
initial
mass
opposite
reaction
second
speed
time
velocity

Self-management

You will need: a model car

1 Get into groups of three and collect a model car from your teacher.

2 As a group describe what the gradient of graph 1 is showing you about a car's motion.

3 Now use the model car to demonstrate this motion to your group.

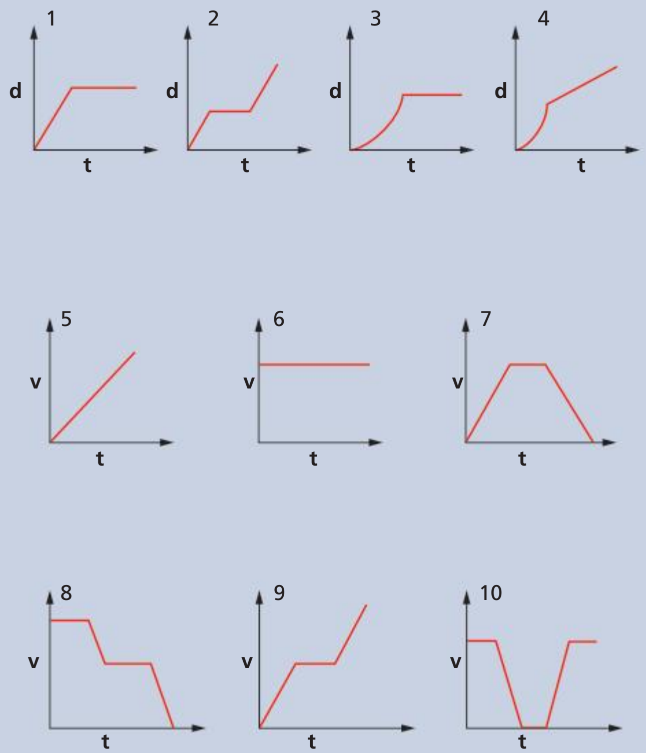
4 Work through each of the 10 graphs in the same way.

5 Your teacher will then ask your group to demonstrate the motion represented by one of the graphs to the rest of the class.

6 The other groups must try to identify which graph you have been demonstrating.

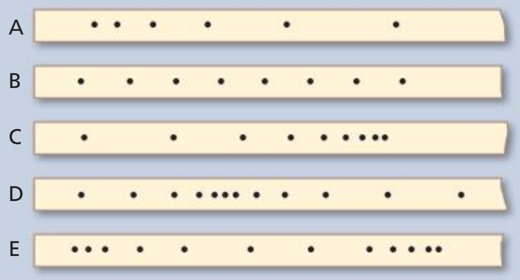
7 The winning group is the one that correctly identifies the most graphs.

8 If time permits you could demonstrate a graph your group has drawn and see if other groups in the class can draw the graph you are demonstrating.



Checkpoint

The following multiple-choice questions refer to the ticker-tapes below.



1 Ticker-tape B shows an object:

A travelling at a constant speed.
B not moving.
C accelerating.
D decelerating.

2 Ticker-tape C shows an object:

A stopping, then moving again.
B travelling at constant speed then stopping.
C accelerating.
D decelerating.

3 Ticker-tape E shows an object:

A slowing down and speeding up.
B speeding up and then slowing down.
C travelling at a constant speed.
D decelerating.

4 A ticker-tape that shows an object decelerating then accelerating is:

A ticker-tape A.
B ticker-tape B.
C ticker-tape D.
D ticker-tape E.

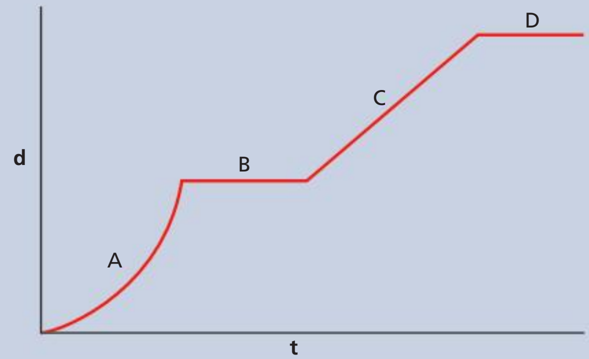
5 A car travels 150 km in 1.5 hours. What is the average speed of the car?

6 A car travels 180 km in 120 minutes. What is the average speed of the car?

7 A car travels at an average speed of 89 km/h and the journey takes 8 hours. What distance did the car cover?

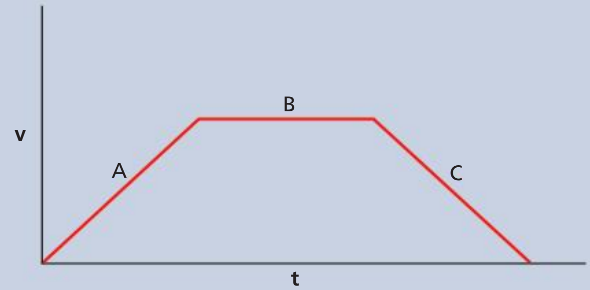
8 A bicycle rider increases his speed from 7 m/s to 10 m/s in 5 seconds. What is the rider's acceleration?

9 Points B and D on the graph below show:



A travelling at a constant speed.
B acceleration.
C no motion.
D the distance covered.

10 Point B on the graph below shows:



A travelling at a constant speed.
B acceleration.
C no motion.
D deceleration.

11 A 1500 kg car accelerates down a hill at 11 m/s2. What is the force acting on the car?

12 List Newton's three laws of motion and give an example of each.

13 A Volkswagen crashed into another vehicle causing about $500 damage to the Volkswagen. A woman in the Volkswagen died because her heart was punctured by the uncovered knob of her radio. The year was 1969. What forces were acting on the woman in the crash? How did these forces contribute to her death?

14 You are sitting at an intersection when another car fails to stop and runs into the back of your car. What happens to your head if you do not have a headrest?

8

Alternative energy sources

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

Science Understanding

- distinguish between renewable (e.g. solar) and non-renewable (e.g. coal) energy sources

Science as a Human Endeavour

- investigate the energy needed to manufacture various shopping bags
- research the arguments for and against, then make a decision on whether to build a tidal power station

Science Inquiry Skills

- compare energy use in Australia and other countries
- conduct a survey to find out the energy sources used by people in their homes
- design an energy-efficient house

LITERACY FOCUS

air pollution
appliances
biomass
carbon monoxide
conduction
convection
energy consumption
energy-efficient
fossil fuels
geothermal energy
hybrid electric car
hydro-electricity
insulation
kilojoules
landfill
methane
radiation
renewable energy
sewage
turbine

Focus for learning

How do you use energy? You might answer: when you are running, working hard or driving a car. Over half of the energy produced in Australia is used in households. This is mainly in the form of electricity and petroleum products. Australians are using more and more energy, which is an increasing problem.

Most of our energy needs are supplied by fossil fuels, such as coal, oil and gas. However, the combustion of these fuels contributes to global warming and climate change by increasing greenhouse gases such as carbon dioxide in the atmosphere. Scientists have predicted that the consequences of continuing to produce these gases will be an increase in sea level, changes to rainfall and a greater number of severe weather patterns such as cyclones. We must therefore reduce our use and reliance on fossil fuels.

Fossil fuels are **non-renewable** resources, which means that one day they will run out. Australians need to find energy sources that are **renewable**, or in continuous supply, such as solar energy. We also need to use as little energy as possible in our daily lives.

This chapter looks at some of the ways you can reduce the use of energy produced from fossil fuels. It examines renewable energy and looks at some energy-efficient initiatives.

PROBLEM SOLVING

Energy-efficient house design

Your chapter problem is to design an energy-efficient house showing the following things:

1 the materials the house is made of
2 the floor plan or design of the house
3 the orientation of the house relative to the sun
4 insulation, blind and awning materials
5 placement of vegetation around the house
6 types of appliances that could be used.

You will need to submit a draft floor plan and a rough outline of your ideas to your teacher. Use the internet to carry out some research. Use a search engine and enter key terms such as *energy-efficient house design*, *energy efficiency*, or look for an energy information centre in your state or a sustainable energy authority. You could also:

- contact the Australian Greenhouse Office or the Australian Building Codes Board to find out about regulations for energy-efficient housing
- visit homemaker centres to research home appliances
- use the internet or *Yellow Pages* to find companies that specialise in insulation and building materials
- visit plant nurseries to find out which trees are deciduous (lose their leaves in winter) or evergreen to help with your garden design.

The rest of the chapter will help you with your task.

An energy-efficient house with a wind generator, solar panels and solar water heater

8.1 The energy situation

There are over 20 million people in Australia, all using energy. Some people use more than others because of the lifestyle that they lead. Let's review what you should already know about energy.

Energy review

Energy can make things move and make things happen. It can produce heat, light and sound. It can cause things to burn or change form. You cannot hold it in your hands or show somebody what energy is, but you can notice its effects.

Energy is the ability to do work and work is done when energy changes from one form to another. For example, the *chemical energy* stored in your breakfast cereal is converted to *heat energy* that keeps your body warm and *kinetic energy* as you move around during the day.

You are able to do 'work' because of the energy changes that occur in your body when food is used in respiration.

Another example can be seen with a television set. *Electrical energy* in the form of an electric current is converted to *light energy* and *sound energy*. It is also converted to heat energy as an unwanted by-product of these changes.

These examples show that energy can be *converted* easily from one form to another. Energy can also be *transferred* between objects. Think of a pan on a stove. As the hotplate warms up, heat is transferred through the metal of the pan into whatever is inside it. Metals are good *conductors* because they allow this heat transfer to take place. The plastic pan handle does not allow the transfer of heat energy so you are able to hold the handle without burning your hands. The plastic is an example of an *insulator*.

When energy is converted from one form to another or transferred between objects it is never lost. The amount you start with is always the same as the amount you end up with. Energy cannot be created or destroyed. This is the *law of conservation of energy*.

To measure the amount of energy an object has, scientists use a unit called the joule (J). One thousand joules is a kilojoule (kJ). Large amounts of energy can be measured in megajoules MJ (10^6 joules or one million joules), gigajoules GJ (10^9 joules or one thousand million joules) and pentajoules PJ (10^{15} joules).

Energy use in Australia

The Australian Bureau of Statistics reports that over 99% of Australian households have a bath/shower and toilet, kitchen with cooking facilities and a refrigerator. Over 97% of households have a telephone. Virtually every household has a television, with almost 56% of households having more than one, and over 82% have a DVD player. Ninety-five per cent of households have a washing machine, and 51% have a clothes dryer. Add to this the households that have a microwave oven (79%), a separate freezer (40%), a computer (36%), an air conditioner (34%) and a dishwasher (30%) and you can see why Australia's consumption of energy is increasing every year.

In fact, household energy consumption increased from 18 GJ per person per year in 1980 to over 20 GJ this century, and this is only part of the total energy used in Australia. It does not include the energy needed to manufacture materials or goods, or the energy used in transport. The table below shows how our energy consumption compares with other countries, including some in Asia.

Country	Energy
Canada	40.8
United States	38.3
Sweden	33.9
France	31.6
United Kingdom	30.6
Australia	20.9
Japan	16.5
New Zealand	15.3
China	10.8
India	6.0

Residential energy consumption (GJ per prson per year)

INQUIRY 1 What energy do you use?

1 Keep a diary of all the times you use energy during a 24-hour period. For example, you might write:
  a alarm clock wakes me
  b hot water used in the shower
  c clean clothes and towels used
  d toaster used to make toast.

2 Once you have completed your list, write next to each example what energy source you used. For example, alarm clock wakes me (*electricity*), hot water used in the shower *(gas hot water system)*, clean clothes *(electricity for washing machine, solar energy to dry clothes)*.

3 Group the activities in your list under the following headings and allocate points for each:
  - essential—shower/bath, eating (1 point)
  - maintenance—washing clothes, dishes (2 points)
  - school or work (2 points)
  - transport (3 points)
  - appliances (3 points)
  - entertainment (5 points)
  - waste—left a heater, light or radio on when not using it (10 points)

  For example: alarm clock wakes me *(appliances 3 points)*, hot water used in shower *(essential 1)*, clean clothes *(maintenance 2)*.

4 Add up the total number of points you used in a day.

5 Go through the list and look at how many points you could save. For example, did you use a heater when you could have put on a jumper?

6 How many points did you save? Deduct the points you could save from your total number of points.

7 Make a list of suggestions of how you and your family could save energy.

INQUIRY 2 Energy and plastic bags

Presently Australians use, on average, 1 plastic bag per person every 2 days, or 3.9 billion plastic bags per year. To manufacture this number of bags, 20 000 tonnes of plastic are used. Plastic bags are lightweight, hygienic and strong. They can also be reused for garbage and nappy bags. However, most are not biodegradable and fill up the land used for garbage dumps (landfill). Their production also produces greenhouse gases. It takes 0.48 MJ to produce one bag, and the energy used to produce 8.7 bags could fuel a car for 1 km. But are the alternatives any better? Look at the table opposite.

Bag	Expected life (shopping trips)	Number of bags used per person per year	Annual greenhouse gas emissions (kg CO_2)	Annual energy use (MJ)
HDPE supermarket bag	1	143	1.7	58
LDPE department store bag	1	29	1.3	43
Calico (cotton)	52	9	2.5	160
Woven HDPE	104	1.65	0.6	19
Paper	1	172	3.9	24

HDPE: high density polyethylene, LDPE: low density polyethylene

1 Which type of bag can be used for the most shopping trips? How many of these bags can be used per year?

2 Which type of bag requires the least amount of energy to produce per year? Which type of bag produces the least amount of greenhouse gas?

3 Are paper bags a good alternative to plastic bags? Explain your answer.

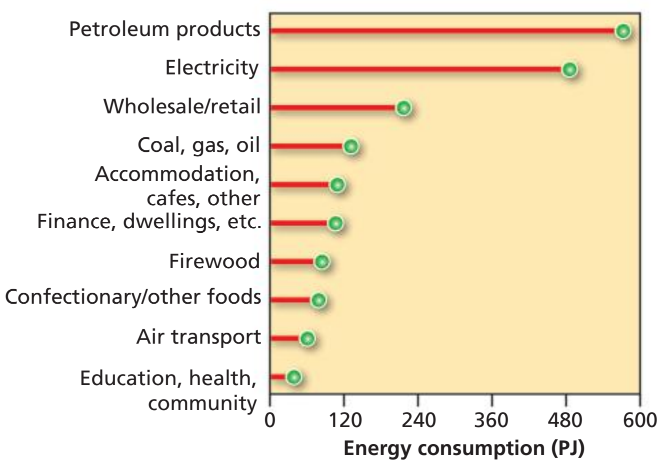
4 Explain how you can reduce the amount of energy you use.

SKILL

Interpreting statistics

Statistics is the term used to describe numerical figures or data collected on a particular subject. Statistics can be collected by many different organisations. For example, the Australian Bureau of Statistics collects information to see how society in Australia is changing. This information can be used by governments when planning and budgeting to provide the necessary goods and services. A magazine company may collect statistics on who their readers are so that they publish the right information and maintain their sales.

When presented with statistics, it is important to look at who has collected the data and why they collected it. Make sure you understand any new terms presented and analyse what the statistics are saying. For example, look at the following graph.



Direct and indirect household energy consumption

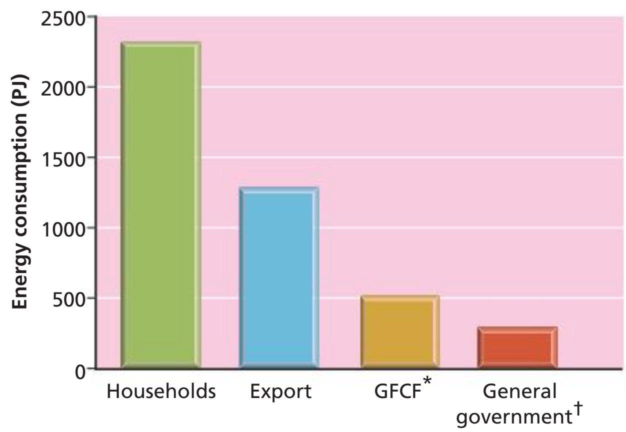
Direct energy use means using the energy source directly, for example, using gas for cooking. Indirect energy use means using a product that needed energy to make it (e.g. a plastic bag).

One way to interpret statistics like this is to make them into percentages. To do this, work out what the energy use was for each product type, for example about 580 PJ was used for petroleum products, 480 PJ for electricity etc., giving a total of about 2300 PJ. Then use this figure to convert each product type to a percentage. For example, for petroleum products, 580/2300 multiplied by 100/1 gives 25%. So the use of petroleum products contributed 25% to the total consumption of household energy, and electricity contributed 21%.

You also need to think about *why* the statistics are like this. You would expect the use of petroleum products to be greatest because of the number of cars used by each household. In fact, only North America and Italy have more cars per household than Australia. We also rely on electricity and use many electrical appliances, so it is not surprising that electricity is second on the list.

Questions

1 Look at the following graph.



Energy used for combustion in Australia

** Gross fixed capital formation (e.g. energy in buildings, road, rail and pipeline infrastructure)*

† General government (e.g. education, health and community services)

a In your own words, what do the following mean: *GFCF* and *General government*?

b In which sector is the most energy used for combustion?

c Are the figures what you would expect? Explain.

d Change the figures to percentages, then convert the column graph to a pie chart.

2 Look at the first table on the next page and answer these questions.

a Convert the figures presented to percentages. Draw a graph to display the information in the table, using the percentages you have worked out.

b What type of travel do you think would be included in *other*?

c How do the numbers of people using public transport, bicycles and walking compare to those using cars?

d Are the figures what you would expect? Explain.

SKILL continued

Number of persons travelling on various types of transport to work/study in Australia per year

Type of transport	Number (thousands)
Train	623.6
Bus	359.7
Tram/light rail	50.1
Ferry/boat	15.7
Taxi	9.1
Car/truck/van as driver	6539.8
Car/truck/van as passenger	457.9
Motorbike or motor scooter	66.0
Bicycle	98.4
Walk	378.7
Other	24.2
Total	**8623.2**

3 Look at the table below.

Principal fuel types per residence in Australia

Fuel type	Room heating (thousands)	Water heating (thousands)	Cooking (thousands)
Electricity	1997.3	4253.8	4181.1
Gas	2349.6	2526.7	2887.0
Wood	1118.3	73.9	51.4
Solar	0.8	344.7	–
Oil	156.3	2.2	0.9
Coal/coke	2.7	–	–
Other	44.5	12.4	14.8
Don't know	7.5	36.9	–
None	1458.1	–	–
Total	7135.1	7250.6	7135.2

a Convert the figures presented to percentages.

b Draw separate graphs for the fuel types used in room heating, water heating and cooking, using your percentages.

c How can you explain these statistics?

Too much energy

As you have learnt, a lot of our energy is used in households. In Inquiry 1 you probably listed many appliances that were used throughout the day. You also use many different products that require energy to be manufactured, for example plastic bags. In the Skill section you may have noticed that the majority of people travelling to work or study are single drivers with very few passengers, and that the number of people using public transport, walking or riding a bicycle is low in comparison. Add to this the amount of electricity used in room and water heating, as well as cooking, and you can see why Australia's energy consumption is high. We cannot go on using large amounts of energy and non-renewable resources such as coal, oil and gas. The next section examines this in detail.

Over to you

1 Draw a graph of the data in the text on page 173 showing the conveniences and appliances used in Australian households (e.g. 99% of Australian households have a shower/bath, toilet, kitchen and refrigerator, 97% have a telephone).

2 Draw a graph to show how Australian residential energy use compares with that in other countries.

3 How has Australian household energy consumption increased since 1980? What reasons can you think of to explain these figures?

4 Explain what the statistics in the table below tell you.

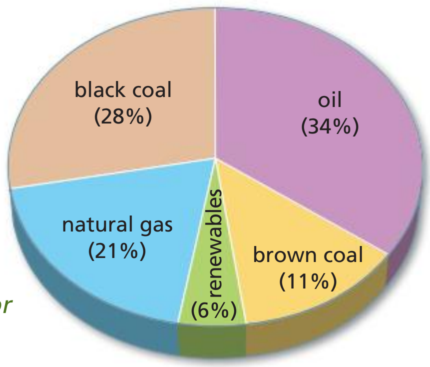
Energy consumption by different parts of the Australian community, 2006–2007

Sector	Percentage
Agriculture	1.6
Mining	7.9
Manufacturing	23.7
Electricity generation	29.4
Construction	0.4
Transport	23.5
Commercial and services	4.4
Residential	7.7
Other	1.4

Source: Australian Bureau of Agricultural and Resource Economics, 2009

8.2 The fuels we use now

Australians rely mainly on black and brown coal, oil and natural gas for energy. These are non-renewable and will eventually become so rare that it will be uneconomical to extract them from the Earth. These fuels have been made by decaying plant and animal materials deep underground. They have taken more than 65 million years to be produced, which is why they are called **fossil fuels**. Obviously they cannot be easily replaced. As shown in the pie chart below, Australians use only a small amount of renewable energy, such as solar energy. Because this is a renewable resource it will not run out like fossil fuels.



Australia's major energy sources

Australia has the world's sixth largest reserves of black coal and the second largest reserves of brown coal. At present 78% of our electricity is generated from coal. Our reserves of coal are large, so electricity can be produced and supplied cheaply to consumers. It is predicted that coal will continue to supply most of our energy for many years to come because of this.

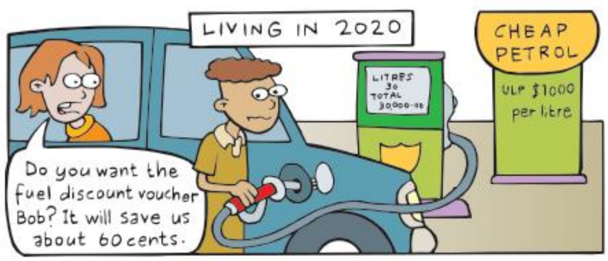
Australia has large reserves of natural gas and it is predicted that Australians will increase their use of this resource. Australia also has the largest reserves of uranium in the world, but uranium is not used in Australia for energy production. All the uranium mined in Australia is exported. The table below shows Australia's energy reserves for each resource, our yearly consumption of these resources and their life expectancy.

It is predicted that Australia will run out of oil within the next 14 years unless more oil is found. Of the energy used for transport, most of it comes from petroleum products made from crude oil.

At present Australia's production of oil is not enough to meet the demand, so Australia imports about 30% of its oil to meet this shortfall. However, these imports will increase as our own reserves decrease. It is estimated that by 2020 Australia's oil shortfall will cost about $40 billion.

You may have noticed how petrol prices change. If world oil prices increase, then the price of petrol also increases. If prices fall, our petrol prices also fall. However, as oil becomes more and more scarce in the future, oil prices and therefore petrol prices will increase to a point where it may be too expensive for some Australians.

Australia and the Asia–Pacific region share about 4% of world oil reserves, and Australia itself has only about 0.3%. In comparison, the Middle East has 65% of world oil reserves. The table on the next page shows the countries with the largest oil reserves.



Resource	Amount of resource available for economic use (PJ)	Consumption per year (PJ)	Predicted life of resource (years)
Brown coal	518 000	642	807
Black coal	1 092 000	1533 (+ 6943 exported)	129
Uranium	651 280	(4474 exported)	146
Natural gas	111 097	966 (+ 827 exported)	62
Liquefied petroleum gas	5943	48 (+ 73 exported)	49
Crude oil	15 533	529 (+ 594 exported)	14
Hydroelectric	–	52	–
Biomass	–	204	–
Other renewables	–	23	–
Total		**3997 (+ 12 911 exported)**	

Source: Australian Bureau of Agricultural and Resource Economics, 2009

Rank	Country	Oil reserve (billion barrels)
1	Saudi Arabia	264.5
2	Venezuela	211.2
3	Iran	137.0
4	Iraq	115.0
5	Kuwait	101.5
6	United Arab Emirates	97.8
7	Russia	77.4
8	Libya	46.4
9	Kazakhstan	39.8
10	Nigeria	37.2

Not ranked: Australia, 4.1; United States, 30.9; world total, 1383.2
Source: BP Statistical Review of World Energy, 2011

Why not continue to use fossil fuels?

Australia does have a large supply of coal and gas that could last for many years to come. So why not continue to use these?

About 73% of our greenhouse gas emissions are caused by the combustion of fossil fuels. Also, Australia has one of the highest rates of electricity consumption and transport use in the world. Half of Australia's energy-related greenhouse gas emissions come from producing electricity from coal. This is because three units of coal must be burnt to get one unit of electricity. This means there is a large loss of energy, and that substantial amounts of greenhouse gases are produced. A further quarter of energy-related greenhouse gas emissions are caused by industrial and domestic use of motor vehicles.

If we are to stop the changes that are occurring on our planet from the burning of fossil fuels, then we must make substantial reductions in the amounts of greenhouse gases we produce.

In Melbourne, radio and television broadcasts give smog warnings and advise the elderly or sick to remain at home. Pollution from burning fossil fuels is starting to make an impact on our way of life. We cannot continue to rely on fossil fuels for our energy supplies. This is why the Australian government is trying to promote the use of renewable energy. For example, one initiative is that by the year 2020 electricity retailers must increase to 20% the amount of electricity they are obtaining from renewable energy sources such as solar and wind energy.

Australians will have to increase their use of renewable energy resources to generate electricity in the next 20 years. This will enable us to reduce greenhouse gas emissions and use less fossil fuel.

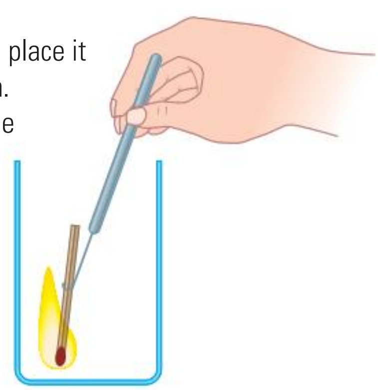
INQUIRY 3 *Dirty combustion*

When you light a match, the match (fuel) burns in air. This is an example of combustion.

You will need: old inoculating loop, 4 vials, watch glass, dropping bottles of methylene blue (tests for carbon dioxide), phenol red solution (tests for acid), cobalt chloride paper (tests for water), matches

1 Wind the wire of the inoculating loop around the match.

2 Light the match and place it in the vial as shown. What happens to the match and why?



3 Place 5 drops of methylene blue in the bottom of a clean vial and repeat steps 1 and 2. What happens to the colour of the methylene blue? How can you explain this?

4 Repeat steps 1 and 2 using a clean vial. When the match has finished burning, place a small piece of cobalt chloride paper up against the inside of the vial. What happens and why?

5 Place 5 drops of phenol red solution in the bottom of a clean vial and carry out steps 1 and 2 again. What happens to the colour of the phenol red solution? How can you explain this?

6 Finally, hold a burning match underneath the bottom of a watch glass. Be careful not to burn your fingers. What happens to the bottom of the watch glass as the match burns? Explain your observations.

- Summarise what this activity tells you about the combustion of fossil fuels.

INVESTIGATION

1 Burning fuels

Aim

To investigate what gases are produced from the burning of different fuels.

Risk assessment and planning

Read through the investigation and answer these questions.

1 What safety precautions will be necessary?
2 How should the fuels you use be disposed of at the end of the investigation?
3 Discuss why a fume cupboard should be used for this investigation.

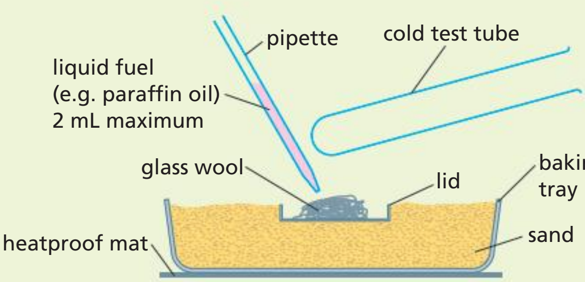
Apparatus

- baking tray
- glass wool
- gauze mat
- metal lid
- beaker
- tripod
- 5 mL pipette
- sand
- cobalt chloride paper
- test tube holder
- thermometer
- liquid fuel burner with removable cap
- draught shield (large metal can)
- stopwatch
- heatproof mat
- *methylated spirits*
- *kerosene*
- *ethanol*
- *paraffin oil*
- firelighter
- 5 clean, dry test tubes
- long matches
- safety glasses
- balance

Method

Part A

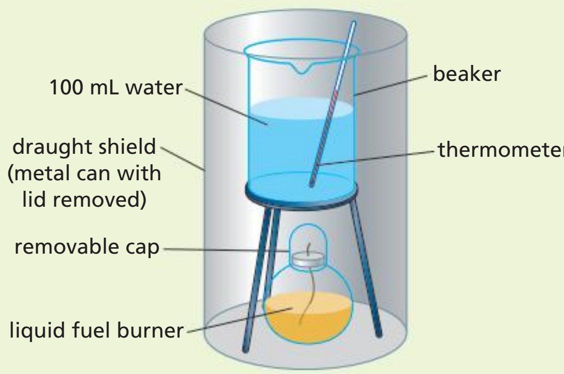
1 Fill the baking tray with sand and push the metal lid into the centre of the sand so that the sides of the lid are buried but the sand does not get into the lid. Place some glass wool in the centre of the lid.



2 Using a pipette, place 2 mL of ethanol onto the glass wool.
3 Light the ethanol on the glass wool.
4 Using a test tube holder, hold a clean and dry test tube in the burning ethanol.
5 Once the ethanol has finished burning, examine the test tube. Is it clean or dirty? Use the cobalt chloride paper to test for any water.
   Record your observations.
6 Repeat steps 2–5 for the other fuels. If you have solid fuels, such as a firelighter, remove the glass wool from the tin lid and place the solid fuel in the lid.
7 List the fuels you have tested from the cleanest to the dirtiest.

Part B

1 Fill the burner with ethanol. Use the balance to find the mass of the full burner.
2 Set up the apparatus as pictured.



3 Measure the temperature of the water. Light the burner and start timing.
4 After 10 minutes, cap the burner and again measure the temperature of the water. Record the temperature rise (final temperature–initial temperature).
5 Find the mass of the burner again and record how much fuel was used (initial mass of burner–final mass of burner).
6 Work out how much energy was released by the ethanol in 10 minutes. Use the formula:

$$\text{energy (joules)} = \text{temperature rise (°C)} \times \text{mass of fuel used (g)} \times 4.2$$

(4.2 joules of energy will cause a temperature rise of 1°C in 1 g of fuel.)

INVESTIGATION

1 continued

Results

1 Which fuel caused the greatest temperature rise?
2 Which fuel released the most energy?
3 Which was the most energy efficient? (To work this out you will need to divide the figure you calculated for the energy released by the mass of the fuel. Your answer will be in joules/gram.)
4 Which fuel in Part A was the cleanest?

Discussion

Was your experiment a fair test? Explain. If not, which variables did you fail to control?

Conclusion

Report your findings to the class. Include a list of criteria that make a good fuel.

Air pollution

Kerosene and paraffin oil are separated from crude oil using fractional distillation. Ethanol is made by the fermentation of plants, such as sugar cane. It is a type of alcohol. Methylated spirits contains ethanol but it is also mixed with methanol. All of these fuels contain hydrogen and carbon, so they are called hydrocarbons. With plenty of oxygen present, these fuels burn to produce carbon dioxide and water.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

methane + oxygen → carbon dioxide + water

If there is not enough oxygen available, then carbon monoxide can also be formed.

$$3CH_4 + 5O_2 \rightarrow CO_2 + 2CO + 6H_2O$$

methane + oxygen → carbon dioxide + carbon monoxide + water

Carbon monoxide is a very harmful gas. It can limit the oxygen-carrying capacity of red blood cells in the body, and if inhaled in large amounts can cause death.

You may have noticed black soot or carbon on the outside of the test tube in Investigation 1. This is because carbon can also be formed.

$$4CH_4 + 6O_2 \rightarrow CO_2 + 2CO + C + 8H_2O$$

methane + oxygen → carbon dioxide + carbon monoxide + carbon + water

Carbon is a pollutant in our atmosphere. It forms fine particles suspended in the air, which give a hazy appearance to the air.

Fuels such as coal and oil also contain sulfur, which combines with the oxygen in the air to form sulfur dioxide. It is one of the gases that cause acid rain.

INQUIRY

4 Energy poem

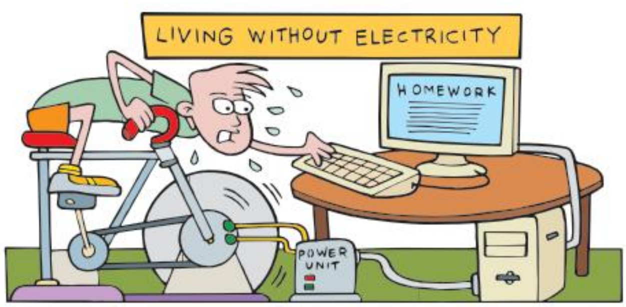
Write your own poem, like the one below, about what you have learnt so far about our energy situation. Read it to the class when you have finished.

We're driving there and racing here.
In our rat race there is no fear,
that pretty soon the oil will be gone.
Then pray tell what will we run on?

We switch on lights when nobody's home,
and people spend hours on the telephone.
We drive in our cars and the radios blare,
but who stops to care about our air?

Mum's drying clothes, Dad's on the tools,
but all these things are using gigajoules.
He's got his boom box, and her the TV,
but what will they do with no electricity?

The sun's always shining with lots of energy,
it's clean and safe, and more than we need.
So let's stop using coal and oil for power,
and switch to the sun when we want a shower!



Over to you

1 Why are oil, coal and gas called fossil fuels?

2 Why are fossil fuels non-renewable?

3 What resources does Australia have a large supply of? How do we use these resources?

4 What is combustion?

5 What substances are produced during the combustion of fossil fuels?

6 Why is most electricity in Australia generated from coal?

7 For how many years will our supplies of black coal, brown coal, oil and natural gas last?

8 If we have such a large supply of coal that can be used to generate electricity for many years to come, why do we need to find alternatives?

9 What prediction is made in this section about the resources we will be using for energy in the future?

10 What do you predict will happen as our supply of oil runs out?

11 If you were a member of parliament, what recommendations would you make about public transport facilities, the numbers of people travelling in motor vehicles, incentives for renewable energy development and greenhouse gas reductions?

12 Look at the table below.

a Which country or region uses the most energy per person?

b How does our energy supply compare with the rest of the world?

c How does Australia's energy use *per person* compare with the world average? How can you explain these figures?

d Which two regions or countries listed use the least amount of energy per person? How do you account for this?

e What proportion of the world's carbon dioxide from fuel combustion is produced in the United States? In Australia?

f Which countries are below the world average in the use of electricity per person?

g How much electricity does Australia supply per person compared to the rest of the world? How can you explain these figures?

h Is it true to say that Australians are the highest users of energy in the world?

PROBLEM SOLVING

What can you use from this section to help you with your chapter problem? Investigate how to reduce your use of electricity and gas in the home, and design a house that is less reliant on fossil fuels.

Country	Energy supply (PJ)	Energy supply per person (GJ)	CO_2 produced from fuel combustion (Mt)	CO_2 produced per person (t)	Electricity supplied per person (GJ)
World	517 865	77.4	29381	4.4	10.0
OECD*	161 778	135.9	12630	10.6	30.5
Middle East	67 198	337.7	1492	7.5	12.2
Former USSR	70 799	248.4	2426	8.5	16.8
Non-OECD Europe	2680	50.6	269	5.1	12.2
Asia	52 879	24.2	3023	1.4	2.6
Latin America	30 480	66.0	1068	2.3	7.0
Africa	48 609	49.4	890	0.9	2.1
Canada	17 056	511.7	551	16.5	61.4
United States	71 429	234.6	5596	18.4	49.1
China	83 443	62.6	6550	4.9	8.9
Indonesia	14 528	63.6	385	1.7	2.1
Australia	12 650	253.3	398	18.5	40.2

Source: International Energy Agency 2010

*Organisation for Economic Co-operation and Development member countries

8.3 Energy of the future

There are many possible alternatives that Australians can use for energy.

INQUIRY 5 Renewable energy

Copy the table below into your notebook and complete it as you read this section. You can use examples from the text or your own internet research in the final column.

Energy source	How it works	Benefits from using it	Problems with using it	Examples
Hydro-electricity				
Wind				
Solar cells				
Solar (thermal)				
Biomass				
Geothermal				
Waves and tides				

Hydro-electricity

Hydro-electricity means using water to make electricity. An energy change occurs when water falls from a waterfall into a stream or lake below. The water at the top of the waterfall has potential energy and as the water falls the potential energy is converted into kinetic energy. The height from which the water falls determines how much energy can be generated.

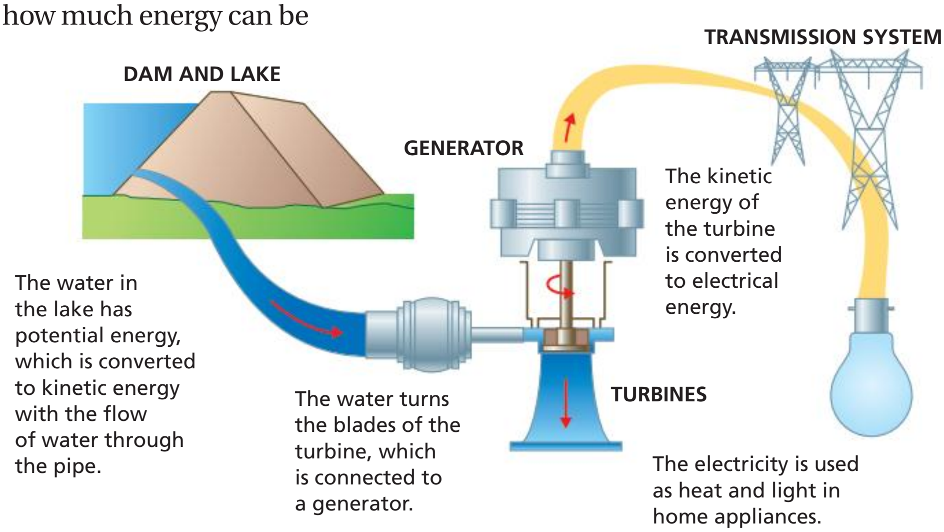
The Snowy Mountains Hydro-electric Scheme is one example in Australia of hydro-electricity. It is made up of 16 major dams, seven power stations, one pumping station, 145 underground tunnels and 80 aqueducts that channel water into the scheme. Five per cent of the energy requirements of New South Wales are provided by the electricity it generates.

Hydro-electricity is a renewable energy source because it relies on the cycling of water through the atmosphere, rivers and lakes. It does not produce wastes and is environmentally friendly. For example, the Snowy Mountains Hydro-electric Scheme saves 5.5 million tonnes of carbon dioxide each year from being pumped into our atmosphere. This is how much carbon dioxide would be released using coal to generate the equivalent amount of electricity. Water from the hydro-electric scheme is reused for irrigation of farming land in the Murray–Darling Basin.

Once a hydro-electric power station is set up, the operating and maintenance costs are low, so electricity can be produced quite easily and cheaply (about 3 cents/kWh). Add the information for hydro-electricity into your table in Inquiry 5.

To generate hydro-electricity a dam is built across a river, forming a reservoir behind it. From the reservoir the water flows through a pipe and into a turbine. The blades in the turbine spin as the water passes through it. The kinetic energy of the water is transferred to the turbine as the blades turn.

Each turbine is attached by a shaft to a generator, which is made up of a large magnet inside wire coils. As the shaft turns, the magnet spins, producing an electric current in the wire. Kinetic energy at the turbines is converted to electrical energy in the generator. The electricity then travels along transmission lines to be used at home or work.



How a hydro-electric power station works

Wind energy

Windmills are common in rural Australia. Farmers throughout the world have used the power of the wind for centuries to pump water. In the Netherlands, windmills are used to pump water to prevent many areas of the country from being reclaimed by the sea.

Wind farms

Australia's first wind farm was built in 1992 at Ten Mile Lagoon in Western Australia. It supplies about 2 MW of power to the Esperance region. Since then wind farms have been built all around Australia. The biggest ones are in South Australia and Western Australia.

The biggest wind farm is at Hallett, 220 km north of Adelaide. It has 142 turbines and generates 298 MW of clean, green, renewable energy when the turbines are at full power. This is enough electricity to supply 170 000 homes. The third biggest wind farm is Waubra near Ballarat in Victoria. It has towers 80 m high with blades 40 m long. By using wind power instead of burning coal to produce electricity this wind farm can reduce carbon emissions by 650 000 tonnes per year. Other large wind farms are at Capital near Queanbeyan in New South Wales, Woolnorth in north-west Tasmania and Walkaway near Geraldton in Western Australia.

A wind turbine works like a water turbine. It spins when the wind blows. The shaft leading from the wind turbine passes through a transmission box before turning a generator. The transmission box increases the turning speed of the shaft leading to the generator so that electricity can be generated.

Not everywhere in Australia is suited to wind power because a minimum wind speed of 15 km/h is needed. Victoria, Tasmania, South Australia and Western Australia are well suited for wind energy because they get a higher than average amount of wind. Winds that are too strong are also a problem, so if the wind reaches over 72 km/h the turbines shut down. There may also be days when there is not enough wind to power the turbines. Alternative energy sources are needed at these times.

Many more wind farms are under construction or in planning. You could research these on the internet for Inquiry 5.

Challicum Hills wind farm in Victoria has 35 wind turbines.

Solar energy

Solar energy is used to dry clothes and to make food. Many people have solar hot water systems, and initiatives are in place to encourage people to design and position their homes to use the sun's energy. Solar energy is renewable and it does not damage the environment or pollute the atmosphere.

Solar cells can be used to capture the sun's energy. When sunlight hits a solar cell, electrons move to the front surface, making it negative. The back of the cell becomes positive. If a wire is used to connect the two parts, an electric current flows between them. Light energy from the sun is converted to electrical energy by the solar cells, but this energy conversion is very inefficient. In 2009 a team of Australian and US researchers, led by Professor Martin Green from the University of New South Wales, set a world record for a solar cell array that was 43% efficient. Solar cells are expensive. It also costs about five times more to produce electricity from solar cells than from coal.

Each year about 5.6×10^{18} MJ of solar radiation hits the Earth. This is more energy than we need, but solar energy has to be collected over a large surface area and stored for times when there is no sun. It is therefore difficult to use solar energy for transport.

The World Solar Challenge is held in Australia every two years. This competition requires entrants to build and then race a solar-powered car 3000 km from Darwin to Adelaide. The solar cells cannot stick out from the sides of the car or cover more than 6 square metres. Batteries enable solar energy to be stored for use when it is cloudy. The winning car in 2009 completed the race in less than a day and a half, at an average speed of over 100 km/h.

Experimental power stations have been set up in the United States, Europe and Japan using solar cells arranged on large panels that can be angled to collect sunlight. These power stations produce 150–500 kW of power.

Solar thermal power plants are in operation in the Mojave Desert in California. They do not use solar cells. Instead, huge rows of curved solar mirrors are positioned so that the sunlight is focused onto a pipe full of water, which runs above the mirrors at their focal point. The pipe gets so hot that the water inside it boils and produces steam. This steam can then be used to power turbines and make electricity. Electricity from this solar power station is used by 350 000 homes.

The Australian National University in Canberra has demonstrated that it is possible to use solar thermal energy to produce electricity. Using a huge, steerable solar collector that tracks the sun, they have contributed 80 kW of power to Canberra's electricity supply.

The 'Big Dish' solar collector in Canberra

For Inquiry 5 you could research Australia's existing solar power systems at Liddell power station in the Hunter Valley in New South Wales, at Broken Hill in New South Wales, or at the University of Queensland. You could also investigate proposed projects such as the one near Mildura in Victoria.

INQUIRY 6 World solar challenge

Use the internet to find out more about the World Solar Challenge. What are the rules the competitors must follow when building their cars? What are some of the winning designs? How has solar car design changed since the first race in 1988?

Biomass

The organic matter that makes up living organisms is called **biomass**. The energy stored in this organic matter is called biomass energy.

When wood is burnt in a fire, biomass energy is used. The sugar industry uses biomass energy. For example, at Rocky Point Sugar Mill in Beenleigh, Queensland, the remains of the sugar cane (called bagasse) are burnt to produce enough electricity to power 20 000 homes. When the cane season is over, garden and tree clippings are used as fuel.

As biomass decays, methane is produced. This is an odourless, colourless, greenhouse gas, which has a warming effect 21 times greater than carbon dioxide. Landfill sites for our waste disposal contain biomass, so they produce methane. It is possible to use this methane to generate electricity and reduce greenhouse gas emissions by 4 tonnes of carbon dioxide for every megawatt-hour (MWh) of electricity made (1 MWh = 3.6 GJ).

In large cities around Australia, landfill generators produce electricity. The gas is extracted through wells that are drilled into the landfill site. Gas blowers are used to compress the gas so that it is at the right pressure to run the generators. Water vapour is removed before the methane is passed into the gas engine generators that produce electricity. Finally, a transformer is used to increase the voltage of the electricity produced before it passes to the distribution system for use.

Using biomass energy to generate electricity can reduce odours and diseases caused from decaying waste. Also, less garbage is sent to landfill sites, so less land is used for garbage disposal.

Geothermal

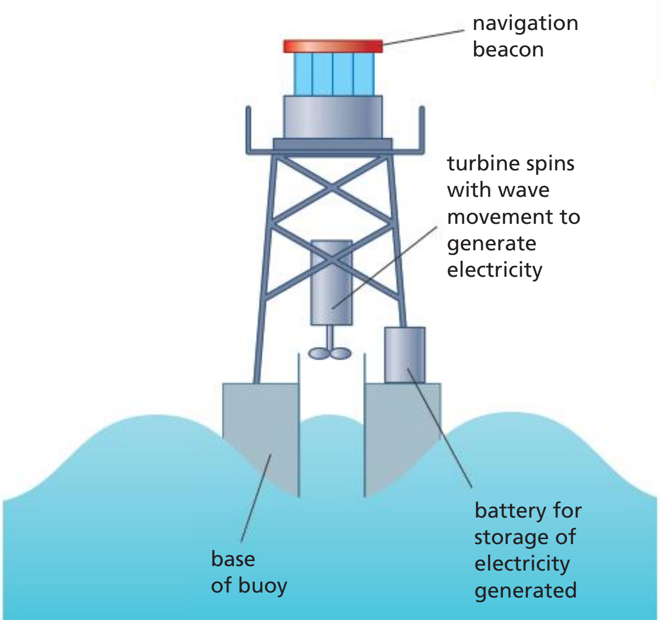
In New Zealand and Iceland, **geothermal energy** is used. This means using the heat of the Earth for power. In these places hot molten rocks lie very close to the surface, so by drilling a short distance down into the Earth, temperatures over 250 °C can be reached. Once holes are drilled down to the hot rocks, steam rises up through the holes and is used to power turbines, which spin generators. In some places water is pumped down into the Earth. It filters through the hot rocks, is collected and brought back to the surface, where it forms steam that turns turbines and generators.

The leftover warm water from this geothermal power station is enjoyed by swimmers in the Blue Lagoon in Iceland.

Once a geothermal power station is built the energy is almost free, and there is little impact on the environment. For Inquiry 5 you could research the Hot Dry Rock geothermal electricity project in the Cooper Basin, South Australia. It is estimated that this project could generate all the electricity Australia needs for 800 years!

Ocean waves and tides

Energy can be harnessed from waves and from tides. Waves are produced indirectly from the sun's energy. The sun's unequal heating of the Earth produces wind. When the wind blows over the sea it produces waves. The kinetic energy from waves can be converted to electrical energy. This is not a new concept. Buoys in the ocean that are navigation beacons for ships operate using wave energy. In the centre of the buoy is a pipe, which acts like a piston. As the buoy goes up and down in the waves, the water moves up and down in the pipe, drawing air in and pushing it out. This movement of air can spin a turbine and a generator. This produces electricity that can be stored in a battery and used to power the beacon light.



A wave-power navigation beacon

A wave power station works in a similar way. The rising waves can cause water in a chamber to move up and down, which in turn causes air in the top of the chamber to move and spin a turbine to generate electricity. The advantage of producing electricity in this way is that it can be made cheaply, but the waves must be strong all the time. Otherwise plenty of electricity is generated when there are a lot of waves and no electricity when the sea is calm.

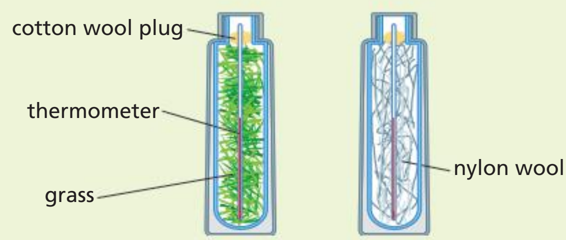
Electricity can also be generated from tides, which never stop. The largest onshore tidal power station in the world is in northern France, on the Rance estuary. It produces enough electricity to power 240 000 homes. An onshore tidal power station is constructed by building a barrage or dam across a bay or estuary, which is where a river affected by the tides meets the ocean. When the tide goes in and out, water flows through tunnels in the barrage, causing turbines to spin and generate electricity. Gates in the barrage let ships through.

Onshore tidal power is free and tides are very predictable, but electricity is only available when the tide is moving in and out. Also there are not a lot of places that are suitable for tidal power. The barrage also alters water flow in the estuary or bay. A solution could be to build offshore tidal power stations, which would not affect the environment as much.

INVESTIGATION

2 Biomass energy

Design your own activity to show how energy is produced from biomass. For example, you could set up two thermos flasks as shown below and measure the temperature in each. You will need to measure the temperature before you start, as well as during your test. Explain any energy conversions that take place.



Over to you

1 What is the difference between generating energy using:
   a solar cells and solar thermal energy?
   b waves and tides?
   c biomass energy and geothermal energy?
2 List the pros and cons for each of the renewable energy sources described in this section.
3 Why are there so few sites around the world where tidal power stations can be set up?
4 Rank the renewable energy sources in this section according to which would be best for Australia. Give reasons for your rankings.

Science as a Human Endeavour

Tidal power project

There are only about 20 suitable sites around the world where onshore tidal power stations are possible, because a large difference between high and low tide is needed. A site exists near Derby in the West Kimberley region of Western Australia, which has the second largest tidal movement in the world (a difference of 12 metres). Tidal Energy Australia has proposed establishing Australia's first tidal power project at this site to generate 48 MW of electricity. However, natural gas is preferred by the state government. Some of the arguments for and against tidal power in the Kimberley region are presented here.

1. Sort the arguments that are jumbled up in the table into 'For' and 'Against' tidal power in Western Australia.
2. Research this issue further on the internet. Then write a report to the government recommending whether or not the Derby tidal project should go ahead.

1 Tidal power would provide electricity for Derby as well as Broome, Fitzroy Crossing and remote Aboriginal communities.	**8** Three separate gas-powered stations at Broome, Derby and Fitzroy will be established, creating jobs in the local community.
2 Tidal power will increase local jobs and tourism because it will attract world attention.	**9** Remote Aboriginal communities will not be linked to the proposed gas power system.
3 Tidal power is clean, does not harm the environment, and reduces greenhouse gas emissions.	**10** The tidal power station will affect mangroves and fish stocks, and the reduction in greenhouse gases is minimal.
4 At present local towns burn diesel to run generators for electricity. This produces large amounts of greenhouse gases. The use of natural gas will halve present emissions.	**11** To start the $360 million tidal power project, $80 million in funding from the government will be needed. The gas power stations will cost $100 million, with $80 million being provided by investors.
5 Gas power stations will produce a more reliable electricity supply at a lower cost to consumers than tidal power.	**12** Electricity produced using natural gas will eventually increase in price as gas reserves become scarce in the future.
6 Taxpayers in populated areas of Western Australia subsidise the electricity supply to remote areas by $11 million each year. With tidal power there would be no need for subsidies.	**13** The mangroves in the area of the proposed tidal power project will be covered with water, producing methane and other undesirable side-effects.
7 Gas will be carried by trucks to the gas power stations, increasing traffic on local roads.	**14** Continuous power will be generated from the tides and electricity is easy to produce.

The proposed Derby tidal power station would be similar to this one at the mouth of La Rance River in France. It generates electricity as the tides flow in and out through the turbines under the barrage.

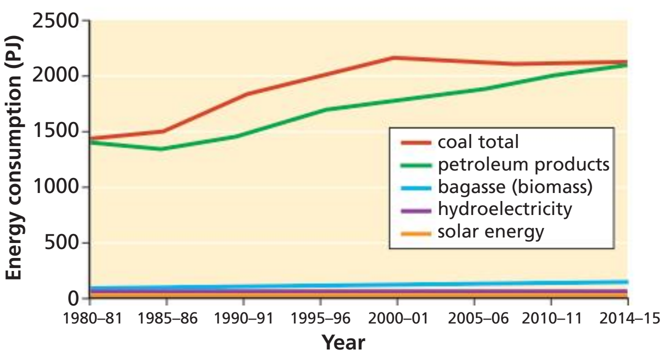
8.4 Saving energy

One type of renewable energy resource will not suit all places. For example, solar energy may not be as effective in parts of Europe as it is in the tropics. Also, electricity produced from many renewable energy sources is intermittent. For example, with wind energy there could be a little, a lot or none. So electricity needs to be obtained from a variety of renewable sources and stored to cater for peak periods when the demand for electricity is high.

It may be years before renewable resources provide the majority of Australia's energy needs. The table below shows how much renewable energy was used to generate electricity in 2008.

State	Renewable energy generated (GWh)	Share of renewables in total electricity (%)
New South Wales	4488	6
Victoria	1102	2
Queensland	1716	3
South Australia	1690	13
Western Australia	828	4
Tasmania	6480	80
Northern Territory	1	0
Australia	**16305**	**8**

The graph below shows our present and predicted use of different fuels to the year 2015.



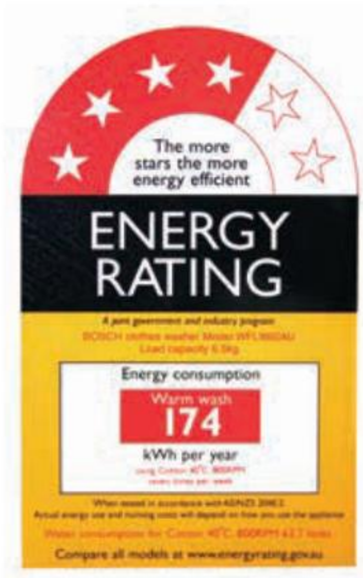
Energy consumption in Australia by fuel

As you can see from the graph, renewable energy is not predicted to make a huge impact on Australian society for many years to come.

There are ways that you can save energy, and therefore money, and reduce greenhouse gas emissions. Even though electricity is clean and pollution free where you use it, it has to be generated.

Since Australia generates most of its electricity in coal-fired power stations, a lot of pollution occurs where electricity is produced. In fact, 52% of Australia's greenhouse gas emissions come from producing electricity for use in our homes. For example, 28% of the emissions come from the use of hot water systems, 15% from space heaters and coolers, and 5% from cooking. Here are some things you can do to reduce these figures.

- Make sure dishwashers, clothes washers and dryers have a full load before using them. If you have a small number of things to wash, do them by hand. Use an airer or clothes line in the carport or garage for drying clothes on rainy days rather than using a clothes dryer.
- Front-loading washing machines use less water and electricity than top-loading machines. Suggest your parents buy a front-loading washing machine next time.
- Use the star rating system when purchasing household appliances. The more stars there are, the more energy-efficient the appliance. This means that the energy conversions that take place in the appliance occur with less energy wasted (e.g. as heat).



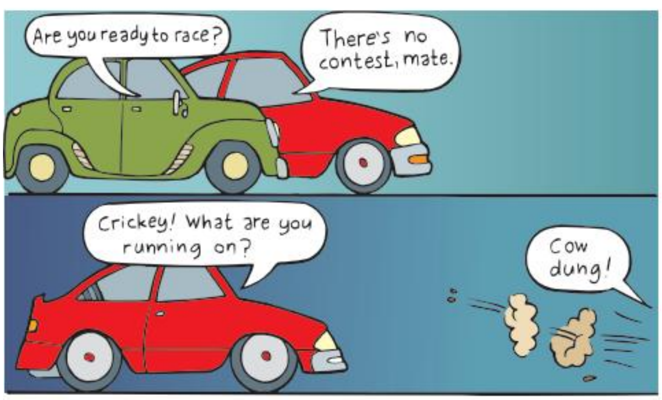
- Install a solar hot water system to use free energy from the sun, with a natural gas booster for cloudy days.
- Natural gas is more environmentally friendly than electricity because it produces less greenhouse gases to obtain and use it. Gas heaters are better to use than electric heaters. If you do use electricity to heat your home, buy a reverse cycle air conditioner that heats and cools. It is more energy-efficient than other electrical heaters. Gas is also a better source of energy for cooking, even though almost 60% of Australian households have electric cooktops and ovens.

- Change to Green Power, an initiative that began in 1997. People pay more for Green Power so that their electricity supplier can produce or buy the electricity from a renewable source, such as wind, solar, biomass or hydroelectricity. For example, AGL Victoria uses wind farms in Victoria and South Australia, the Wilpena Pound solar generator in South Australia and the Melbourne Water sewage treatment plant biogas generator for its green energy. Just over 800 000 households people across Australia have joined Green Power. However, this is a very small number when you consider there are over 20 million people in Australia.
- Turn off any appliances you are not using. Make sure lights are not left on when there is no-one in the room or in the house. Turn off lights in the classroom during break times and when school is over. Have a 'last person out turns off all the lights' policy.
- Recycle. It requires less energy to recycle products than to make new ones from scratch. For example, 20 recycled cans can be made using the energy to make just one new can. Use recycling bins at home and at school. Make sure plastic bottles, aluminium cans, paper and newspapers are not thrown out with the garbage.

Alternative fuels

It is predicted that by 2020, 38% of Australia's energy consumption will be used for transport. Scientists in Australia are therefore investigating new vehicle technology to save energy (see 'Scientists at Work' on the next page).

Energy can be saved by using alternative fuels. Ethanol is one example which can be made from sugar cane. It can be blended with petrol and used in a normal engine or used in its pure state in a modified engine. There is no excess carbon dioxide produced from using this fuel because the amount of carbon dioxide released when the ethanol is burnt is the same as that taken in by the sugar cane during photosynthesis.



Methanol is another alternative fuel and it can be made from natural gas, coal or biomass. Indy cars run on methanol and it is very clean burning. If methanol were made from biomass, then there would be no excess carbon dioxide produced. However, methanol is a highly flammable fuel.

Oils produced by plants such as canola, soya beans and sunflowers can also be made into fuel for diesel engines. So biomass energy has a lot of possibilities.

The decomposition of water using electrolysis produces hydrogen. It is a gas that can be used for transport and to generate electricity. When it is burnt, hydrogen combines with oxygen in the air to produce water again. Therefore the cycle is renewable.

Hydrogen can be used in a modified combustion engine. Mercedes-Benz and BMW have both produced cars with modified engines that burn hydrogen. Scientists in Russia have also experimented with aircraft fuelled with hydrogen. It could be the fuel of the future as long as it is produced using electricity made from renewable energy sources. For example, electricity that is generated from solar energy could be used to decompose water.

INQUIRY 7 Research

Choose one of the following activities to complete.

1. Investigate which cars have the best fuel economy. Present your findings as a consumer report and make a recommendation to the class about which cars should be purchased.
2. Find out what incentives and rebates are being offered for purchasing solar water heaters, and make recommendations to the class about which appliance they should buy.
3. Choose an electrical appliance to investigate, such as a dishwasher, refrigerator, clothes dryer, washing machine or heater. Find out which brand is the most energy-efficient, and make recommendations to the class about which appliance they should buy.
4. Advertise how to save energy at school by designing posters or making a presentation at assembly. Write some energy-saving tips for the school newsletter.

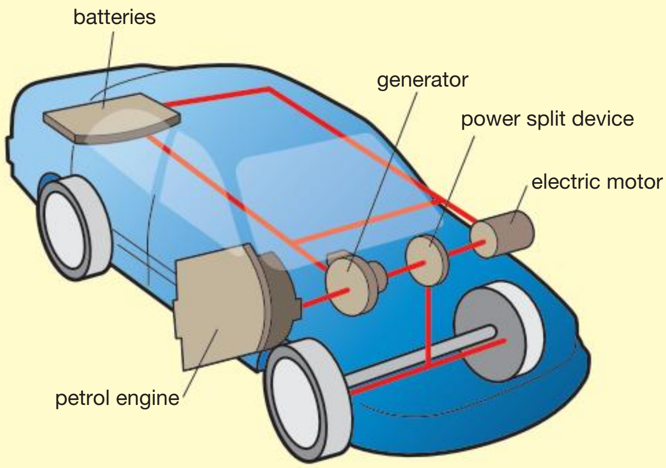
SCIENTISTS AT WORK

Hybrid electric cars

With the high cost of petrol and concerns for the environment, more and more people are buying hybrid electric cars. These are less costly to run and more efficient than normal petrol cars. They have an electric motor, which is used in conjunction with a small petrol engine. This means they can go twice as far on a litre of petrol and they produce only half as much carbon dioxide pollution.

When a hybrid car is cruising with charged batteries, the petrol engine is turned off and the electric motor is used. As the battery loses charge, the petrol engine powers the car while the generator recharges the battery. The electric motor also converts kinetic energy into electric energy during braking or when the car is slowing down. This electrical energy is stored in the batteries. Both engines are turned off when the car is stopped at traffic lights.

At present the most popular hybrids are the Toyota Prius and the Honda Civic, but more and more hybrids are becoming available. They are still relatively expensive to buy, but will become cheaper as more people buy them. The first Toyota Camry hybrids were built in Melbourne in 2010.



CSIRO and SP AusNet are currently road testing a plug-in hybrid. It is similar to a normal hybrid but uses larger batteries, which can be recharged by connecting to a standard household power point. Because of the larger batteries the plug-in hybrid can drive faster and further than a normal hybrid.

Before long hybrid cars will be replaced by fully electric cars. Before this becomes possible, new battery technology will be necessary. However, several car manufacturers are planning to release electric cars over the next few years. Eventually these electric cars will use fuel cells and hydrogen. And we may even have solar-powered cars.

INQUIRY 8 *Energy saving*

1 Use your electricity meter to see how much energy you use in a normal week (e.g. from 9 am Saturday to 9 am the following Saturday). Do not carry out any energy saving. Write down the reading on the electricity meter before starting. At the end of the week read the electricity meter again. Subtract the two figures to find how much energy you used in a week.

2 Now do this exercise again but only use electricity if it is absolutely essential. For example, wash the dishes instead of using the dishwasher, switch off any appliances that have illuminated displays when you are not using them (e.g. microwave). Heat, cool or light only the rooms that you are in. Avoid using the clothes dryer. How much energy did you save in a week? Did trying to save energy make a difference? Would you want to do this every week?

Over to you

1 What do the stars on appliances indicate?

2 What is Green Power? Where does your energy provider get its Green Power?

3 Compare and contrast the alternative fuels that can be used for transport.

4 Which state uses the most renewable energy to generate its electricity? Find out what type of renewable energy this state uses and why it uses so much.

5 Why is renewable energy not predicted to make a huge impact on Australian society for quite some time? (You may need to refer back to section 8.3.)

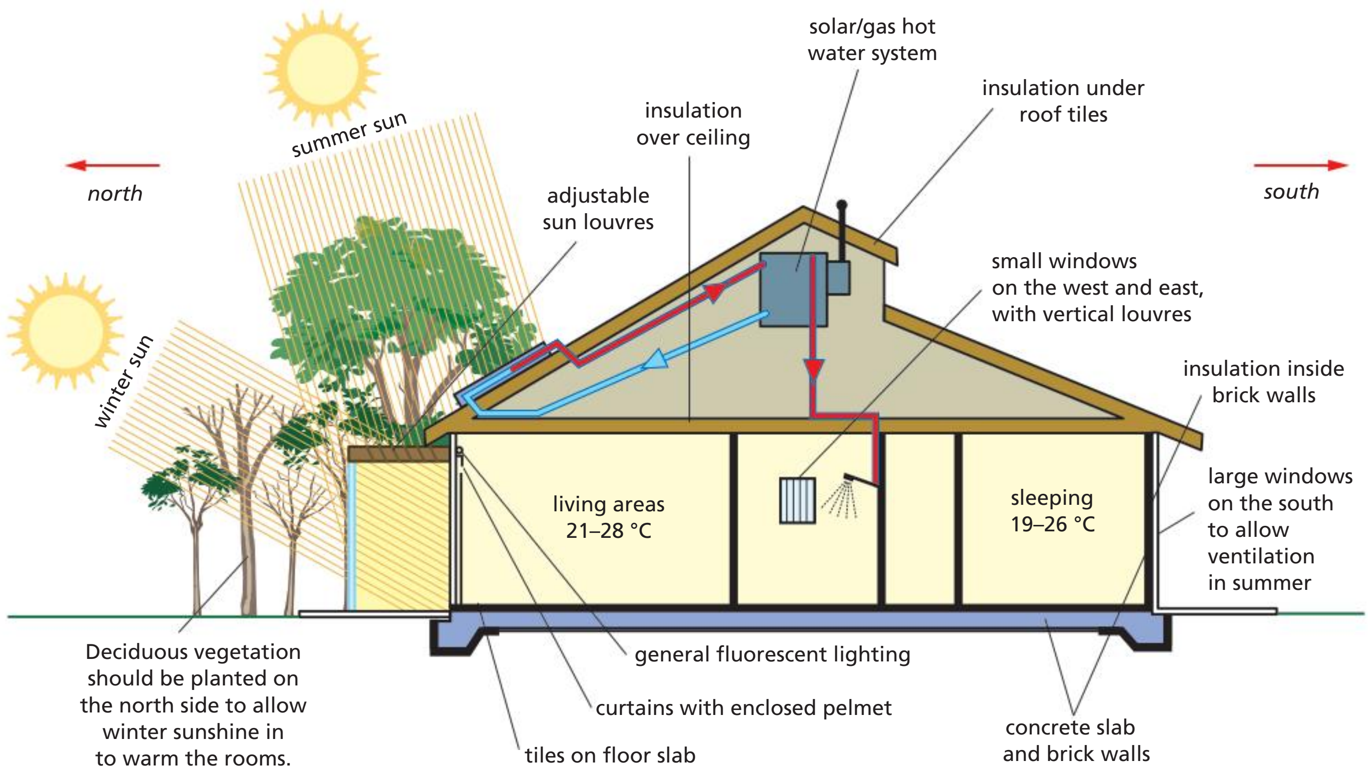
6 Use the internet to find out the latest developments in hybrid and electric cars.

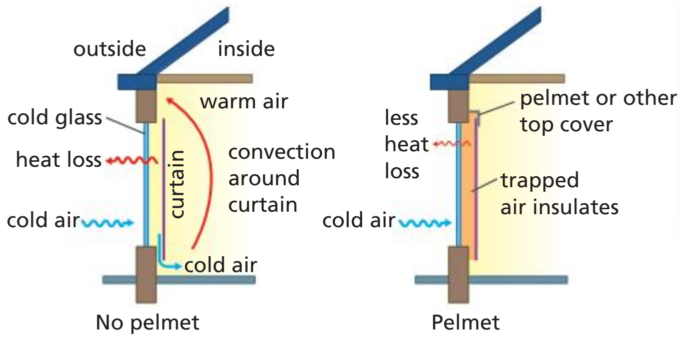
8.5 Energy-efficient houses

Changes are being made to the building code in many states in Australia so that new houses are more energy-efficient. In New South Wales, the Australian Capital Territory and Victoria regulations regarding more energy efficiency must be followed. Some regulations award 'stars' to homes that meet energy-efficiency standards, and new homes must have a certain star rating to be acceptable. When people sell their homes in the Australian Capital Territory the energy rating of their home must be advertised to potential buyers. In Victoria, a five-star rating scheme is used. Find out more about this by researching on the internet. You could also check the internet for the latest building codes in your state.

To design an energy-efficient house you need to remember that heat energy can move in three different ways. The first is by *conduction*, in which heat energy is transferred directly from one object to another. Heat will be lost or gained by conducton through the walls, ceiling, roof, windows and floor of a house. Thus the building materials used are very important. For example, homes that are built with concrete floors, brick walls and tiled roofs have more stable temperatures than weatherboard homes. Ceiling insulation in a brick veneer house can save 25% of heating costs and an extra 14% with wall insulation. Curtains and blinds can prevent heat being lost from windows in winter. Closing curtains and installing blinds and shutters on the outside of windows can stop heat from the summer sun entering the house.

Convection is the second way that heat energy can move. Imagine a wood fire in a room on a cold winter's evening. The heat from the wood fire passes to the air and the hot air rises. Cold air in the room then moves in to take its place. This circular movement of gases is convection. Gaps around windows and doors cause draughts in a room because of convection. Weather stripping around windows and doors can be used to stop this. Insulating windows with curtains and blinds that have a pelmet or top cover is also necessary. This can save about 6% on heating costs. Without a pelmet, convection can occur. Warm air can flow behind the curtain and heat is then lost through the window. Cold air next to the window can sink to the floor. With a pelmet, air is trapped behind the curtain and heat loss through the window is reduced (see the diagram on the next page).





The effects of pelmeted and unpelmeted curtains

Hot air that rises to the ceiling is transferred through it by conduction. Ceiling insulation will save on heating costs and it has been estimated that it will prevent 40 tonnes of greenhouse gases being released into the atmosphere over the lifetime of a house.

In conduction and convection, heat energy is passed through matter by the movement of particles. However, energy from the sun cannot reach the Earth by the movement of particles because there are no particles in space. Instead, heat rays travel in straight lines to Earth as radiation.

Effective house designs block radiation from the sun in summer and allow sun to enter the house in winter. Living areas should be placed on the north side of the house with adjustable louvres, blinds or shutters on the windows. Plants that lose their leaves in winter (deciduous) should be planted on this side too. These will shade the house in summer, reducing cooling costs. In winter, they will allow sunshine to enter and warm the house, reducing heating costs.

When installing lights, compact fluorescent light bulbs should be used. These last eight times longer than normal light bulbs and use only one-fifth of the energy. By 2008, 58% of households in Australia had installed these light bulbs in at least one room, and 22% had them in every room. Using these light bulbs can save a lot of energy. Solar water heaters and gas appliances are also recommended.

PROBLEM SOLVING

You should now be able to complete your problem using the information you have covered in this chapter. You can find more information by using the internet and searching under *energy-efficient house design*. You could also contact your state energy centre for information.

INVESTIGATION

3 House designs

Design your own experiment to test one of the following hypotheses.

1 Insulation in the ceiling, roof and walls of a house can affect how quickly a house heats up or cools down.
2 The thickness of insulation can affect the inside temperature of a house.
3 Reflective insulation underneath a roof can affect the temperature of a house.
4 Verandas around a house keep it cooler in summer.
5 Shading the north side of a house from hot sun will keep it cooler.
6 Curtains at the windows will keep a house warmer in winter and cooler in summer.
7 Houses with a tin roof heat up more quickly than houses with a tile roof, regardless of whether there is insulation in the roof.
8 A wooden house will heat up and cool down more quickly than a brick house.
9 Large windows on the south side of a house will allow ventilation and make the house cooler.

What equipment are you going to use and how are you going to test your hypothesis? You will need to record the temperature inside your model house before, during and after the experiment. Each test will need a control. For example, if you are testing hypothesis 1, you will need a model house with no insulation as a control.

Over to you

1 Imagine you are going to buy a new house. Would the energy-efficiency rating of the house influence whether you bought the house or not? Explain your answer.
2 Do you think it should be mandatory that new house designs meet energy-efficient building codes? Should it be mandatory that the energy-efficiency rating of a house be advertised to prospective buyers? Explain your answers.
3 If technology that reduces our use of fossil fuels is available, such as hybrid cars, then why are so few Australians changing to them? Do you think they will? If so when?

THINKING SKILLS ?

1 Hydro-electric schemes produce energy that is renewable with no pollution and no waste products. Is it true to say that they do not affect the environment? Explain.

2 When do you think there would be the highest demand for electricity in households during the day and during the year in your state? Give reasons for your answer. Would solar energy be able to provide for these peak periods or would a combination of renewable resources be needed? Explain your answer.

3 Explain how wind energy is a form of solar energy. Use diagrams to help with your explanation.

4 It has been predicted that in the future Australia will become a solar-powered 'hydrogen' society, and that desert areas could be used for intensive solar collection. Because of the amount of solar energy that Australia receives it could be as rich as some of the oil-exporting countries.

- **a** What do you think is meant by a solar-powered 'hydrogen' society?
- **b** How could the deserts be used for solar collection?
- **c** How could Australia become as rich as oil-exporting countries today?

5 Explain why you think a car that has clean oil and air filters, and is serviced regularly, uses less fuel.

6 Explain why you think keeping the tyres on a vehicle properly inflated saves fuel.

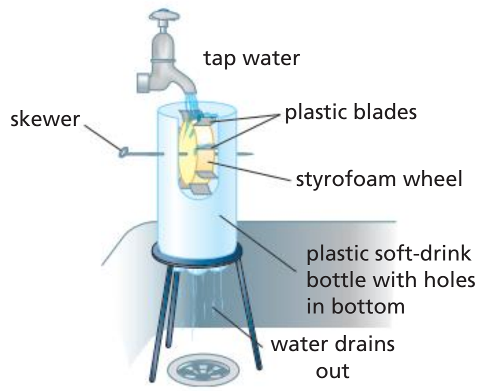
7 Interview an older person who may have lived without electricity when they were younger. Find out what this was like. You could also try to spend a day living without electricity and write about your experience.

8 Use the internet to find out what gas hydrates are. How could they help solve energy problems in the future?

9 Find out what resources are extracted from oil, for example, diesel fuel and naphtha. What products are made from these resources? (You could use the internet.) What products will you have to give up when oil is no longer available or too expensive for products to be made from it? Write a story about living without oil.

10 It has been said that solar energy does not cause damage to the environment. Is this correct? What materials are needed to make solar cells and how are they produced? How many solar cells are needed to produce large amounts of electricity for towns and cities? How much land do they take up? How large are solar dishes and solar towers?

11 Build a model of a water turbine.



12 Look at the information in this table.

Homes with:	NSW (%)	Vic. (%)	Qld. (%)	SA (%)	WA (%)	Tas. (%)	NT (%)	Aust. (%)
Winter sun in living areas	56.3	63.6	47.6	53.6	49.5	77.3	31.0	56.1
Roof insulation	46.3	70.4	30.8	69.7	56.9	62.3	44.0	53.2
Wall insulation	11.4	22.5	8.6	19.4	4.4	17.1	7.2	14.0
No insulation	52.4	28.7	67.0	29.2	42.7	35.9	55.2	45.5

- **a** What differences are there between the states?
- **b** How can you account for these differences?
- **c** Is it possible to have the same energy-efficient house design for all areas of Australia? Give reasons for your answer.

Knowing and Understanding

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

1 Most of our energy needs are supplied by ________ such as coal, oil and gas. The ________ of these fuels may contribute to global warming and climate change by releasing unwanted gases such as ________ into the atmosphere.

2 Australians are one of the highest users of energy per person in the world, and our energy ________ is increasing each year.

3 Three-quarters of Australia's ________ is made from coal.

4 By 2020 it is predicted that we will need to import most of our ________.

5 Most ________ gas emissions in Australia are produced from the combustion of fossil fuels. We need to change to ________ energy sources.

6 Some renewable energy sources presently used in Australia are biomass energy from the burning of ________, the use of ________ from landfill sites, ________ energy and ________ from falling water.

7 As Australians we need to be more energy- ________ in the way that we live.

bagasse
carbon dioxide
combustion
consumption
efficient
electricity
fossil fuels
greenhouse
hydroelectricity
methane
oil
renewable
wind

Self-management

Read the following article and answer the questions.

1 What other energy resources does Australia have besides coal? Which of these are renewable and which are non-renewable?

2 Why is coal-fired electricity seen to be a 'backbone energy source' in Australia?

3 Why do you think Australia produces such large amounts of greenhouse gases?

4 How can the author say Australia has 'the largest solar resources of any nation on Earth'?

5 What is hot rock energy?

6 Explain in your own words what you think the author means by a 'national energy super-highway'.

Solving Australia's energy dilemma

When it comes to energy, Australia is spoiled for choice, having the largest solar resources of any nation on Earth, along with hundreds of years' worth of coal, natural gas and hot rock energy (at present rates of consumption) as well as wave, wind and tidal resources.

The opportunity in the future is to blend these many different energy sources so as to reduce our reliance on any single source, to lower our greenhouse emissions and to develop an energy pattern that is more sustainable in the long run to underpin future growth in the economy and population.

Coal-fired electricity may still be a backbone energy source in the coming decades, but the polluting power stations of the early 21st century will gradually be replaced by ones that emit little or no greenhouse gas and that combine coal with solar and other energy forms. Hot rocks and solar power from the deserts could easily supply a quarter to a half of national energy needs by the 2030s, if developed.

To ensure that all forms of energy have the opportunity to contribute to national development, governments should focus on constructing a national energy super-highway using buried low-loss DC transmission lines, which will enable all sources of energy to compete on an equal footing, avoid 'picking winners' and will position Australia to supply electrical energy direct to the cities of Asia.

Julian Cribb, author and science writer, 2010

Checkpoint

1 Look at the following table.

Period	Total residential energy consumption (PJ)	Residential Energy consumption per capita (GJ)	Proportion of total energy consumption (%)
1973–74	231	16.9	8.8
1993–94	349	19.6	8.4
2007–08	426	20.1	7.4

Residential energy consumption in Australia

a What do GJ and PJ mean?

b What is meant by residential energy consumption?

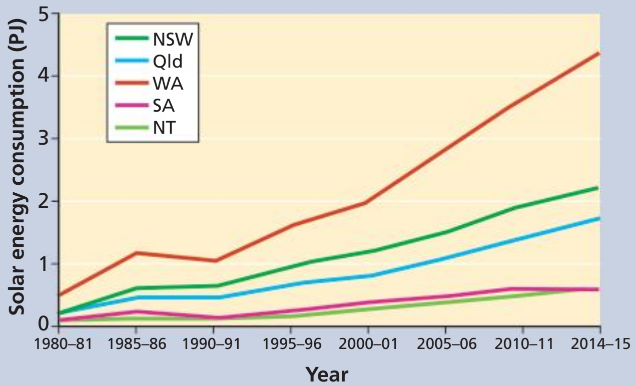
c What is happening to the amount of energy consumed per capita (per person) in Australia? How can you explain this?

d How does the amount of energy consumed per capita in Australia compare with other countries in the world?

e Suggest why residential energy consumption as a proportion of total energy consumption has *decreased*.

f How do Australian households use most of their energy?

2 Look at the following graph.



Solar energy consumption by state

a How much solar energy was used in 2005–06 for each state?

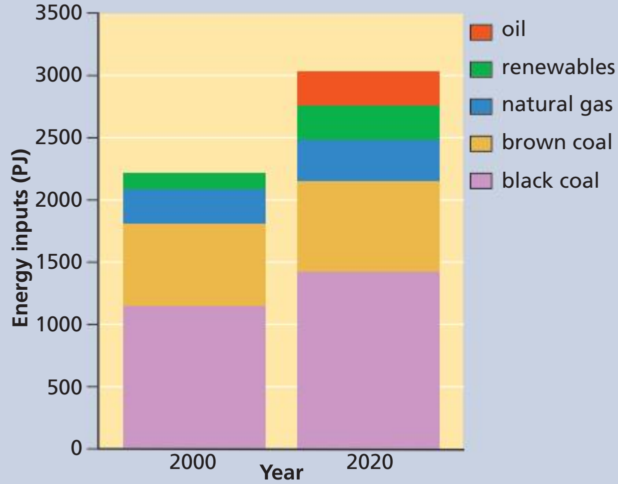
b Use the graph to predict what will happen to the amount of solar energy used in each state in the next 10 years.

c Suggest why the use of solar energy is predicted to increase?

d How can Australian households use solar energy *now* to reduce the use of fossil fuels?

e Why do you think Victoria and Tasmania are not included on this graph?

3 Look at the following graph.



Energy inputs into electricity generation

a What percentages did black coal and brown coal make up of the energy inputs into electrical generation in 2000? How is this predicted to change in 2020?

b Why will most of Australia continue to use coal until 2020 for electricity production?

c What percentage does natural gas make up of the energy inputs into electrical generation in 2000? What is predicted for 2020?

d Why will the use of natural gas increase in the future?

e What percentage did renewable energy make up of the energy inputs into electrical generation in 2000? What is predicted for 2020?

f Why are renewable energy resources not predicted to make a significant rise in the next 20 years?

g What is predicted to happen to oil between 2000 and 2020? Explain this prediction.

4 List five ways in which you can save energy in your home.

5 List one possible alternative transport fuel to replace oil, and explain its advantages.

9

Earth systems

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

Science Understanding

- research interacting Earth systems and how human activities can affect them
- accurately describe the role of the carbon and nitrogen cycles in Earth systems
- understand the importance of the greenhouse effect to life on Earth
- discuss the importance of the ozone layer in protecting us from ultraviolet light

Science as a Human Endeavour

- explore the social, political and economic aspects of using ethanol as a fuel

Science Inquiry Skills

- evaluate claims that human activity is contributing to global warming

LITERACY FOCUS

aerobic respiration
anaerobic respiration
atmosphere
biosphere
carnivore
chlorofluorocarbon (CFC)
decomposition
denitrifying bacteria
ecosystem
El Niño
greenhouse effect
herbivore
hydrosphere
La Niña
magnetosphere
nitrates
nitrogen-fixing bacteria
ozone layer
root nodules
trophic levels

Focus for learning

Over the next 100 years it is predicted that the Earth's average temperature will rise between 1.4°C and 5.8°C. You may not think this is much of an increase. However, imagine summer in Melbourne with maximum temperatures currently above 40°C, climbing to 46°C instead. There would be no snow on the mountains during winter, and tropical waters in Queensland could become like a warm bath. If temperatures were to increase by 5.8°C as predicted, this would be the fastest rise in temperature in the past 10 000 years of our planet's history.

Scientists have recorded an increase in global temperatures over the last century. In fact, the 20th century was the warmest century in the last 1000 years. In certain places around the Earth, ice on land (sheet ice) and ice in the sea (sea ice) is melting. It is predicted that if the world's sheet ice melts the sea level could rise 68 metres.

In Antarctica, ice covers an area of 14.2 million square kilometres, nearly twice the size of Australia. This is 90.6% of the world's ice and it is melting slowly. Ice is also melting in the Arctic, Greenland, the Himalayan Mountains, Mount Fuji in Japan and in the Andes in North America. Are these changes just part of the natural cycle of warming and cooling of the Earth, or is human activity speeding up these natural processes? This chapter will look at the natural cycles on Earth and how human activity is affecting them.

PROBLEM SOLVING

Natural cycles

Your problem in this chapter is to describe the cycles that exist in a natural ecosystem and to explain how human activities are affecting these natural cycles. For example, you could investigate natural cycles in mangroves (page 198) and explain how human activities such as water pollution, foreshore development and fishing have affected them. You could look at a coral reef (p. 212) or at a local ecosystem. It is up to you.

You will need to read the chapter to find out about natural cycles and then do some research of your own. You could present your findings to the class as a PowerPoint presentation.

9.1 Matter cycles

Food chains and webs

The place where an organism lives is called its *habitat*. The term **environment** refers to all the different factors that can affect an organism in its habitat. *Biotic* or living factors are such things as organisms of its own kind with which it might mate or form social groups, or organisms of different kinds that it may rely on for food or be hunted by. *Abiotic* or non-living factors are such things as rainfall, water availability and humidity.

The term *ecosystem* is used to describe the interactions that a group of organisms may have with each other and with their environment. Organisms live where they do because they have characteristics that help them survive there. These characteristics are called *adaptations*. Organisms can survive in an environment because of how they act (behavioural adaptation), how they are built (structural adaptation) or how their body works (functional adaptation).

The feeding relationships that exist between organisms can be shown in a *food chain*. This links together the organisms that are eaten with those they are eaten by. For example:

green plant → insect → magpie → feral cat

A food chain is a very simple way to describe feeding relationships in ecosystems. *Food webs* show the complex feeding relationships that exist. For example the food web below is for a mangrove ecosystem.

Photosynthesis and respiration

The basis of all food chains and webs on Earth is photosynthesis. Green plants or *producer* organisms carry out photosynthesis by capturing light energy from the sun and converting it to chemical energy in the form of food. Green plants rearrange the carbon, hydrogen and oxygen atoms from carbon dioxide and water to make sugar (glucose):

carbon dioxide + water → glucose + oxygen

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

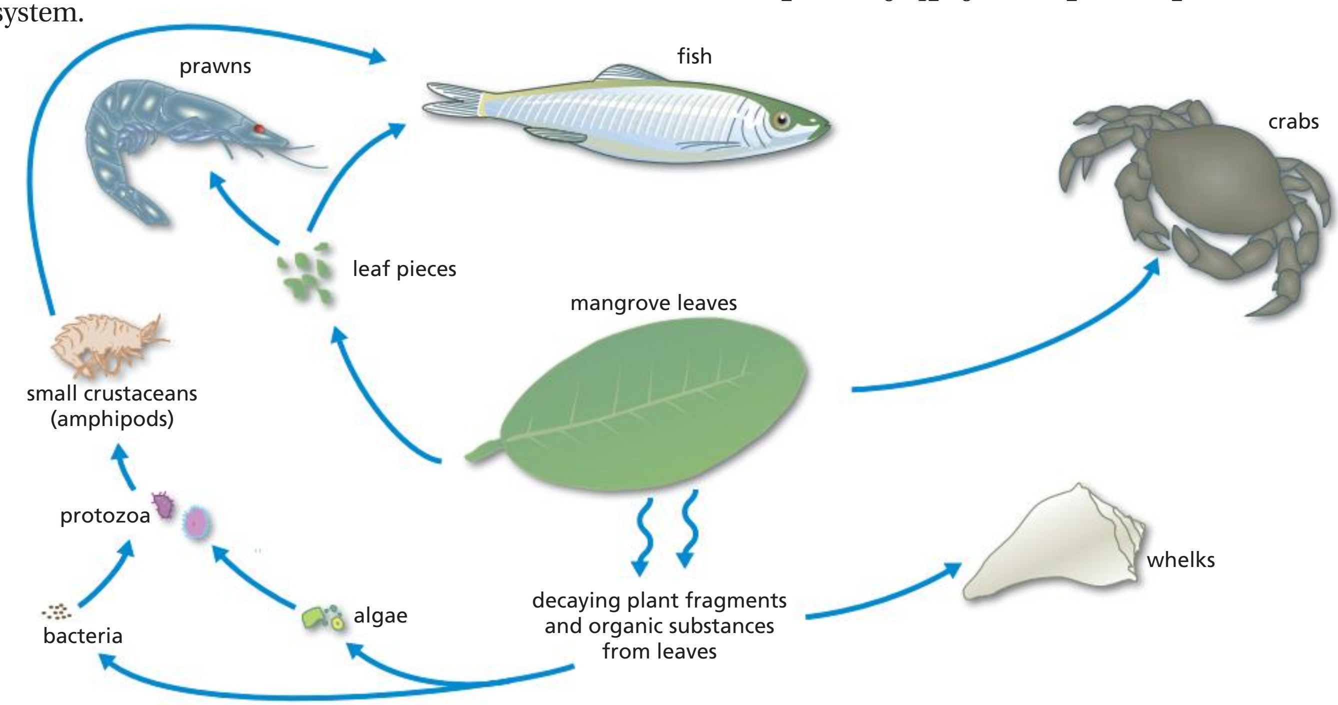
Photosynthesis occurs in the leaves of green plants. Inside most leaf cells are *chloroplasts* that contain *chlorophyll*, a special chemical that enables photosynthesis to occur.

Glucose made in photosynthesis is used to make other carbohydrates such as starch. These carbohydrates, together with elements such as nitrogen from the soil are used by the plant to make proteins. The plant can make all the proteins it needs to survive from the products of photosynthesis and the minerals in the soil. It uses these proteins for the growth of new leaves, roots, stems and buds. The end result is that light energy from the Sun is converted to chemical energy in the plant.

The glucose made in photosynthesis is not all used for the growth and development of a plant. It is also used for respiration to release energy.

oxygen + glucose → carbon dioxide + water + ENERGY

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



Self-sustaining ecosystems

A plant needs energy so that it can carry out all the processes it needs to survive. Carbon dioxide and water are by-products of respiration. They are called wastes and released back into the environment via the leaves of the plant.

When a *first-order consumer* or *herbivore* eats a plant, it receives the carbon, oxygen and hydrogen made during photosynthesis and any minerals that are part of the plant. The herbivore carries out digestion and breaks down the plant to substances it can use. From these substances it assembles its own proteins and substances that it needs to grow and repair its body. Any waste food material passes out of the herbivore as faeces.

The herbivore also uses some of the plant for respiration to release energy, so that all the chemical reactions in its body can take place. Waste from these chemical reactions passes out of the herbivore as urine. Heat is also produced during respiration. If the herbivore is eaten by a *second-order consumer* or *carnivore* (meat eater), the carnivore will use some of the carbon, hydrogen and oxygen incorporated in the herbivore's body to grow and develop. It will also use the energy from the food it has digested to carry out respiration, produce wastes and so on.

Decomposers eventually break down dead plants and animals and use the carbon, hydrogen and oxygen contained in these dead organisms for their own body functioning. In doing so they release these substances back into the environment to be used again by green plants. In this way the matter made in photosynthesis is passed on from one organism to the next.

Elements such as nitrogen that are taken up by a plant's roots and built into proteins in its body are also passed on to other organisms when digestion occurs. In this way the original energy from the Sun is also passed on through organisms, and the wastes are returned to the environment.

Planet Earth consists of four spheres or systems which interact with each other. Matter such as carbon, hydrogen, nitrogen and oxygen is constantly recycled through the *lithosphere* (rocks and soil), the **hydrosphere** (water), the **biosphere** (life on Earth) and the *atmosphere* (air). Matter cannot be created or destroyed, so natural systems today are made of matter that was on Earth millions of years ago.

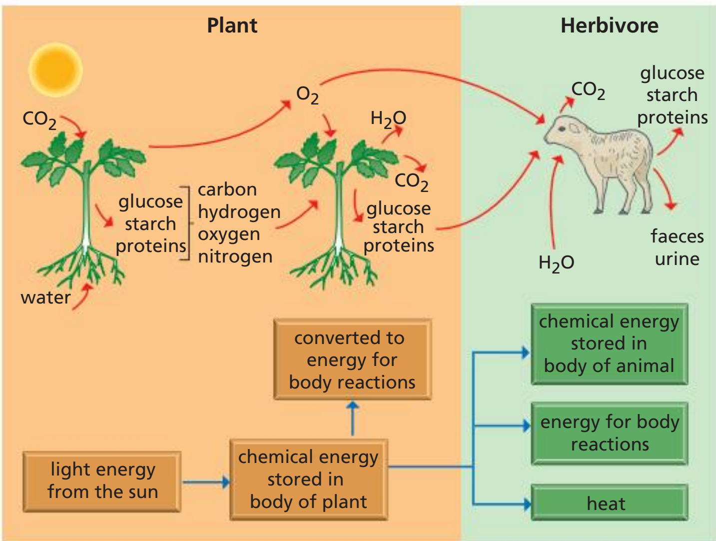
All life on Earth relies on energy from the Sun every single day. Green plants must capture the light energy to maintain life on Earth. As long as this occurs, natural ecosystems are *self-sustaining*, which means they exist by themselves.

INQUIRY 1 *Food chain*

You will need: copy of the diagram on the right, highlighter pens

The diagram shows how matter and energy are passed along a food chain.

1. Using the equations and text on the previous page, state what glucose, starch and protein are made of.
2. Use different highlighter pens to show what happens to matter as it passes along the food chain.
3. How does photosynthesis provide matter and energy for organisms along the food chain?
4. How does a herbivore use matter and energy?
5. Add a carnivore and decomposers to your own copy of this diagram.



INVESTIGATION

1 Model ecosystem

Aim

To measure the inputs and outputs of a model ecosystem.

Risk assessment and planning

Read the investigation and do a risk assessment.

Draw a data table to record your results over a 4-week period. You will need columns in your table for the amount of food and water that you put into your system (inputs). You will also need columns for the amount of wastes produced (outputs), and the mass of the worm farm.

Apparatus

- 500 mL beaker
- 2 × 2 litre soft drink bottles
- scrap vegetables (not fruit)
- balance
- commercial worm farm bedding
- shredded newspaper
- worms
- scissors
- spray bottle of water
- drawing compass
- blender or chopping board and knife

Method

1 Cut the neck off one of the soft drink bottles. Use the drawing compass to make holes in the bottom of the bottle. The holes need to be large enough to let water drain out, but small enough so that the worms can't get through.

2 Place a handful of shredded newspaper in the bottom of the bottle. Three-quarters fill the bottle with moist commercial worm farm bedding and worms. If the bedding looks dry, spray it with water until it is moist, not soaking wet.

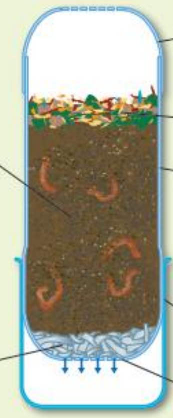
3 Cut a lid from the base of the other bottle and punch some small holes in it.

4 Measure and record the mass of the worm farm.

5 Record the mass of a handful of vegetable scraps. Use a blender or a chopping board and knife to chop the vegetable scraps into a fine mix. Add this to the top of the bottle.

6 Sit your worm farm in a large beaker so that any wastes can drain freely.

Note: You should not need to add any water to your worm farm. If it does become dry, spray water on the top. Record the mass of any water you add. Your finished worm farm should look like this.



7 Place your worm farm in a cool, dark cupboard. It does not need light, only an even, cool temperature.

8 Each week (for 4 weeks), record the mass of the worm farm as you did in step 4. Also record the mass of the waste in the beaker. You will need to measure the mass of the empty beaker first. Tip the waste onto the garden when you have finished. Add blended or chopped food to the farm, but remember to record the mass of any water and food added.

Results

1 How much food and water (if any) did you add to your worm farm over the 4-week period?

2 How much waste did you collect?

3 Did the inputs (food and water) equal the outputs (wastes)? If not, why not?

4 How does the mass of the worm farm at the beginning compare with the mass at the end of the 4 weeks? How can you explain your results?

5 As worms break down food they produce faeces called castings. This forms a rich garden soil. How do you know this process was taking place in your farm?

6 If your worm farm was kept in the dark, where did the energy to keep it going come from?

Conclusion

Explain how your worm farm is a living ecosystem.

Aerobic and anaerobic respiration

When an organism dies, its body is broken down by decomposers. These organisms are usually bacteria and fungi. So a third- or fourth-order consumer is not the end of a food chain; it ends with a decomposer. These organisms grow and feed on the dead material and in doing so break it down. They release simple substances back into the soil or the air, ready to be used again by green plants, and the process starts all over again.

As living organisms, decomposers use some of the food they digest for respiration. For example, like you, some bacteria use oxygen to produce energy from glucose. This is called **aerobic** (air-OH-bic) **respiration**. However, some bacteria get their energy by **anaerobic** (AN-air-OH-bic) **respiration** or respiration that does not require oxygen. It is not as efficient as aerobic respiration since less energy is produced.

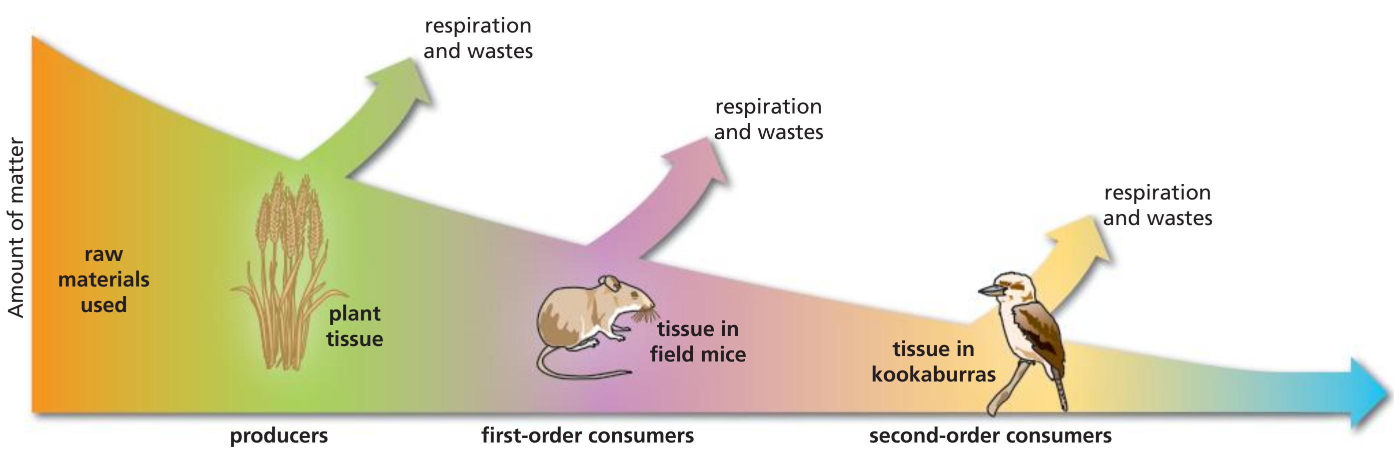
When anaerobic respiration takes place, the end result is not always the same. With many microorganisms, glucose is converted to alcohol, carbon dioxide and energy. With others, acetic acid (vinegar) is produced instead of alcohol.

The cells in your body normally use aerobic respiration. However, when they cannot get enough oxygen they use anaerobic respiration. This occurs during times of extreme exercise, for example when a muscle is overworked. When this occurs, glucose is converted to lactic acid and energy, and no carbon dioxide is produced. This lactic acid causes muscle soreness. In your body aerobic respiration occurs in the mitochondria in your cells, and anaerobic respiration occurs in the cytoplasm.

Bacteria that cause food poisoning carry out anaerobic respiration, which is why they can survive in sealed food containers. The anaerobic production of lactic acid, alcohol, and compounds such as acetic acid is also called *fermentation*. Other organisms such as yeast also carry out fermentation. It is an important process in the food industry because many alcoholic drinks such as beer and wine are made this way.

Over to you

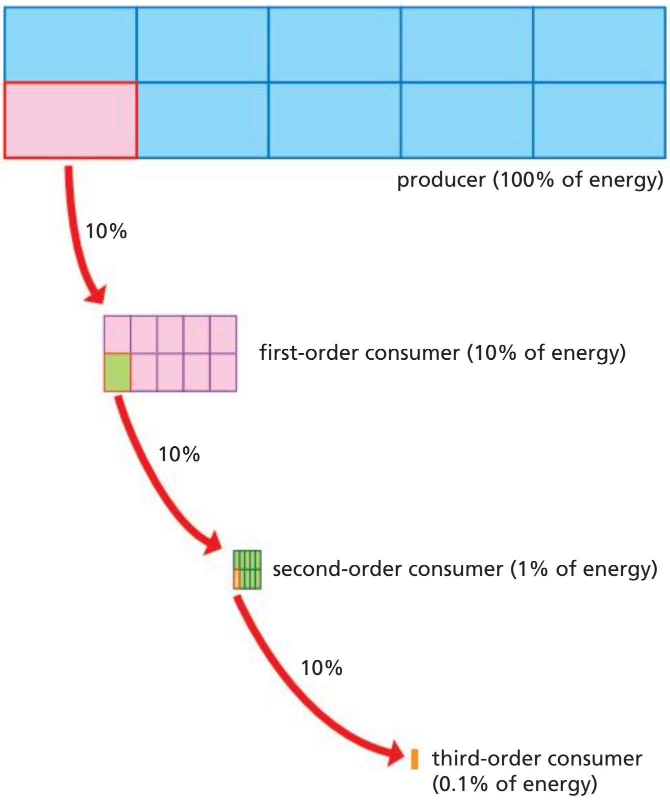
1. How do first-order consumers use the food they obtain from plant bodies?
2. What wastes does a consumer produce?
3. What differences are there between aerobic and anaerobic bacteria?
4. Write out the word equations for anaerobic respiration leading to alcohol, and anaerobic respiration leading to lactic acid.
5. Could life on Earth exist without decomposers? Explain your answer.
6. Look at the diagram below and then answer these questions.
   - **a** What raw materials would be needed to start this food chain? Where would these materials come from?
   - **b** What happens to the matter as it passes from one organism to another along the food chain?
   - **c** Redraw the diagram adding decomposers.
   - **d** The arrows show materials leaving the food chain. What are these materials likely to be, and where do they go?
   - **e** Would the materials that leave the food chain be lost? Explain your answer.



9.2 Energy cycles

Plants capture only 1% of the light energy from the sun that reaches the Earth. How much of this energy is passed on to the first-, second- and third-order consumers? When plants capture the light energy from the sun and make glucose and oxygen, they convert light energy into chemical energy. More than half of this is used by the plant in respiration. The rest is available to be stored in plant tissue. So the first-order consumer does not get all the original energy that was captured by the plant in photosynthesis. In fact only 10% is passed on to the first-order consumer.

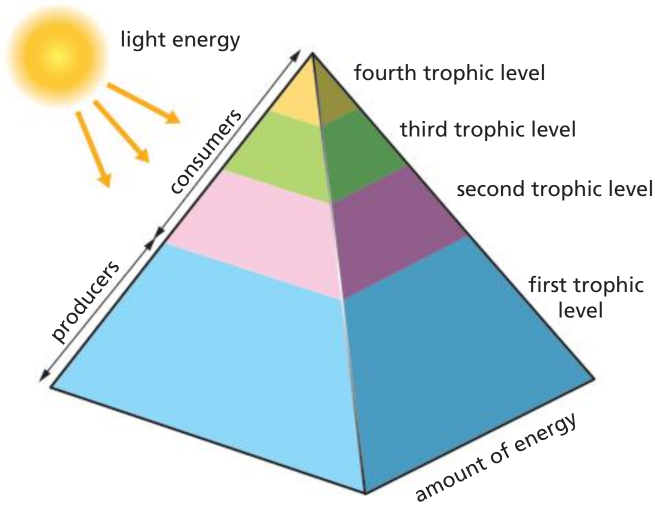
Like the plant, the first-order consumer uses energy for respiration; some is wasted as heat energy, and some is stored as body tissue in the organism. Once again, only about 10% of the energy that the first-order consumer received is passed on to the second-order consumer, and this pattern is repeated between each link in the chain. This can be shown as a diagram.



The producer has all the stored energy available to it, that is 100% of the total energy. The energy the third-order consumer receives is only one-thousandth of the original energy.

Trophic levels

The different levels in a food chain represent different energy levels or **trophic** (TRO-phic) **levels**. These are shown in the diagram below. The trophic levels are often shown in a pyramid which shows that the amount of energy in each trophic level is less and less as you go up the pyramid.



You can now improve your definition of a food chain. A food chain shows how energy is transferred from one organism to the next through a chain of organisms. It shows the flow of energy through the chain. The flow of energy along a food chain is in one direction, from green plants to herbivores and carnivores (consumers) in the direction of the arrows. Each organism obtains energy from the organism before it, and it is then eaten by another organism higher up the chain. Each organism uses some of the energy for respiration and during this energy conversion some energy is wasted as heat. So not all energy obtained by that organism is passed on to the next.

Each organism higher up the food chain has less and less energy available to it. This is why there are a limited number of links in a food chain—usually only three or four. This is also why there are many more producer organisms than herbivores, and far more herbivores than carnivores. For example, if you look at the diagram on the left, only one-tenth of the energy is passed on, so you need to have 10 times as many organisms (at least) at the lower levels. There have to be enough organisms lower down the food chain to provide the energy for the organisms above them.

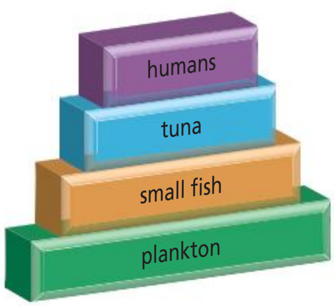
SKILL

Energy pyramids

Biologists draw pyramids like the ones below to represent ecosystems. Each pyramid is built up of rectangular blocks of different sizes. The higher up the pyramid, the smaller the block. The pyramid represents the energy flow of a group of organisms, with a different amount of energy available at each level. If you look at the two pyramids on the right, you will see that the energy levels of the phytoplankton and the green plants are the same. However in Example 1 the frogs are at the fourth level (third-order consumers), while in Example 2 they are at the third level (second-order consumers). So they are at different energy levels, with far less energy available to them in Example 1.

A pyramid can also be drawn to represent the *biomass* of a community, or the total mass of living things at each trophic level. It can even be drawn to represent the numbers of organisms at each level. This is called a pyramid of numbers.

1 Look at the following energy pyramid.



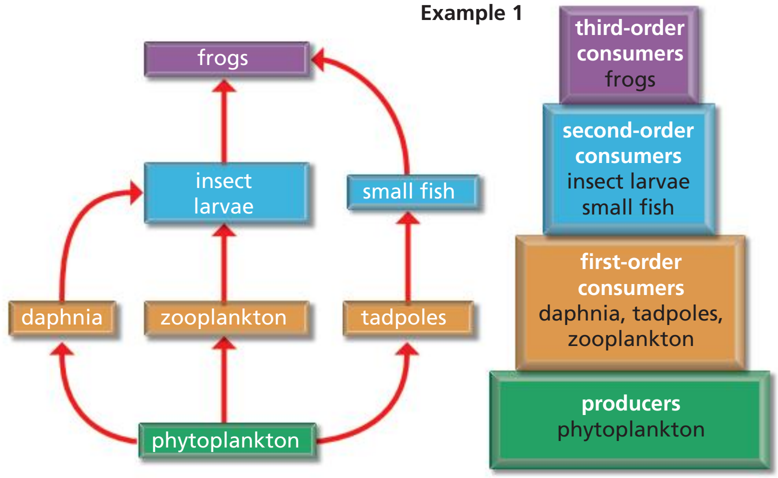
a Copy this pyramid and label the trophic levels from 1 to 4. Also label the producers and the first-, second- and third-order consumers.

b Which trophic level has the most energy? How do you know?

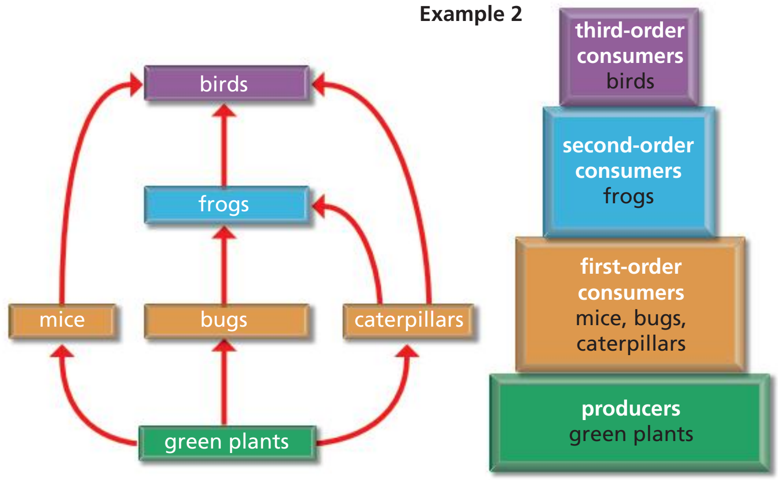
c Estimate how much of the light energy captured by the plankton would be received by the tuna.

d Why do there have to be more plankton than humans in this food chain?

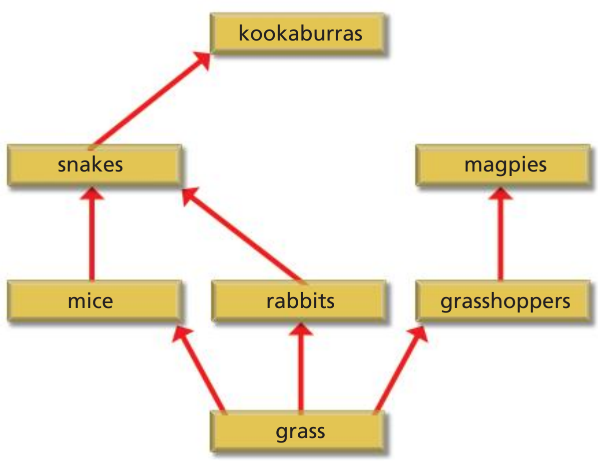
Example 1



Example 2



2 Draw an energy pyramid for the food web below.



INQUIRY 2

Energy in food

You will need: 100 g quantities of the foods listed in the table on the right, copy of healthy food pyramid and food and nutrition plan,

In *Science Essentials 9* you worked out what your own energy needs were and how many servings of the essential food groups you needed for healthy living. In this activity you will look at how much energy is contained in the food you eat.

Use the table on the right to answer the questions below.

1 Which foods in the table contain the most energy per 100 g? What type of foods are they? Do they contain a large amount of fat? Explain.

2 Use the healthy food pyramid to identify the food group of each food listed in the table on the right.

3 If an average student needs about 9000 kilojoules of energy per day to be healthy, which foods would be best to eat? Draw your own food and nutrition plan based on the one you have been given.

4 Why should foods such as chocolate biscuits and potato chips not become regular food items in your diet?

5 Your teacher will give you 100 g of some of the foods listed in the table. Are you surprised by the quantity of food and fat that is contained in 100 g? Would you normally eat more or less than 100 g of each food, if you chose to eat it?

6 Do processed foods have a higher energy content than unprocessed foods? Explain.

7 State how energy from the sun becomes part of:
- a a potato
- b beef
- c an egg

8 Why is there such a difference between the energy contained in potatoes and the energy contained in potato chips?

Type of food	Energy contained (kJ per 100 g)	Amount of fat (grams)
potatoes	295	0
potato chips	1050	11
bread (wholemeal)	900	3
bread (white)	970	2
butter or margarine	3070	81
chocolate biscuits	2180	27
peanut butter	2520	48
peanuts	2450	45
rice	500	0
fried beef	1050	15
roasted chicken	760	8
steamed cod (fish)	340	1
battered cod (fish)	840	10
cabbage	85	0
carrots	130	0
tomatoes	85	0
eggs	630	11
cornflakes and milk	860	4
roasted almonds	2400	56
sugar	1650	0

Over to you

1 What is a trophic level?

2 Explain how a food chain is more than just a chain of organisms that eat one another.

3 Why doesn't a consumer get all of the original energy that was captured by plants in photosynthesis?

4 Why is there a limited number of links in a food chain?

5 If a green plant received 10 000 kJ of energy from the sun, about how much of this would a first-order consumer receive? A second-order consumer? A third-order consumer?

6 Name three different types of pyramids that can be drawn.

7 Use the information contained in the diagram bottom left on page 202 to draw a pyramid of numbers. You will need to convert the energy available at each level into numbers of organisms.

8 Explain if an energy pyramid could ever be drawn with more first-order consumers than producers? Could a pyramid of numbers be drawn this way? Explain with your own drawings.

9.3 Carbon and nitrogen cycles

The carbon cycle

Living things are made up of compounds that contain the element carbon. Animals obtain this carbon through digestion. For example, carbohydrates, proteins and fats all contain carbon. As your body tissue are made from the small molecules produced when food is digested, it will therefore also contain carbon compounds. In the process of respiration, carbon is released as carbon dioxide. When an organism dies the carbon contained in its body is returned to the air and soil by decomposers.

The carbon that has been released back to the air and soil by decomposers is available once again for green plants to use. Through photosynthesis, carbon dioxide is made into glucose and becomes part of plant tissue. As for animals, when plants carry out respiration, carbon dioxide is released back into the air. When plants are eaten by consumers, the carbon in their bodies is passed along the food chain. So there is a continuous cycling of carbon through the air, the soil and the bodies of living things.

Fossil fuels are made from decaying plants that once lived on the Earth millions of years ago. Their bodies contain carbon that was in the atmosphere at that time. When fossil fuels are burnt, the ancient carbon is released back into the atmosphere as carbon dioxide. Burning wood and bushfires are other ways in which carbon is made available for natural ecosystems to use once again.

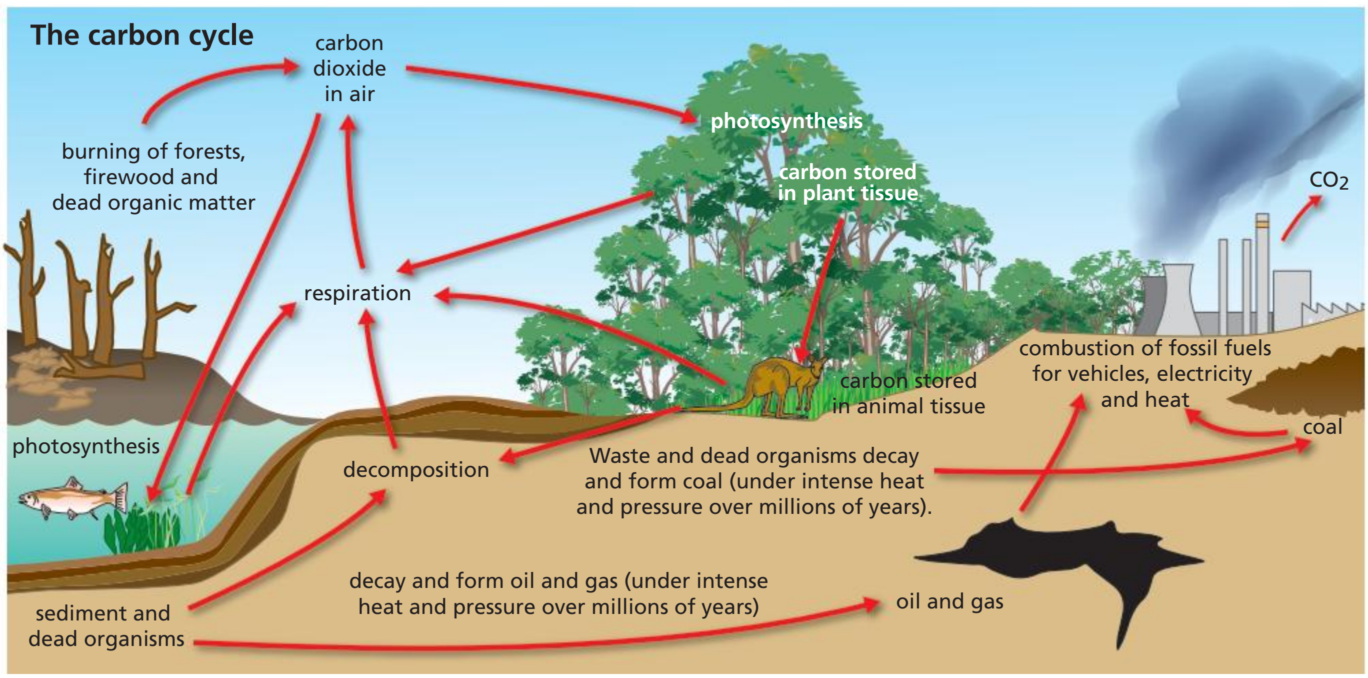
The nitrogen cycle

The element nitrogen makes up 78% of the atmosphere, but is not taken in by animals or plants from the air. Plants take up nitrogen as nitrate compounds from the soil, through their roots. Plants can manufacture all the proteins they need from the carbohydrates they obtain from photosynthesis and the nitrates (and sulfates) they take up from the soil. In aquatic ecosystems, nitrogen is dissolved in water, so plants such as algae can obtain it directly from the water.

Consumers obtain their nitrogen from the plants and other organisms they eat. Proteins (which contain nitrogen) are broken down to amino acids. These are reassembled to make animal proteins, which become part of the body tissue of animals.

Nitrogen is returned to the soil when the bodies of dead organisms are broken down by decomposers. It is also returned to the soil through the urine and faeces of animals, which are then acted on by decomposers.

There are certain bacteria that take nitrogen from their surroundings and turn it into ammonia (NH_3). This ammonia can be made into more complex nitrogen compounds or released as it is. These nitrogen compounds are then available for other organisms to use. These bacteria are called



Root nodules on a plant

nitrogen-fixing bacteria. Some nitrogen-fixing bacteria live in water and soil, and release nitrogen compounds directly into their surroundings. Others live in lumps or knots called **nodules** on the roots of legumes such as wattles, alfalfa (lucerne) and clover. They release the nitrogen compounds into the tissue of the plant on which they live.

Some plants cannot use the ammonia that is made during nitrogen fixation. However, another group of bacteria—the *nitrifying bacteria*—can change ammonia in the soil to nitrates. There are also bacteria that do the opposite. They are called *denitrifying bacteria*. They take nitrogen from the soil and release it back into the air. In this way there is a regular movement of nitrogen from the air into the water and soil, and out of the water and soil back to the air.

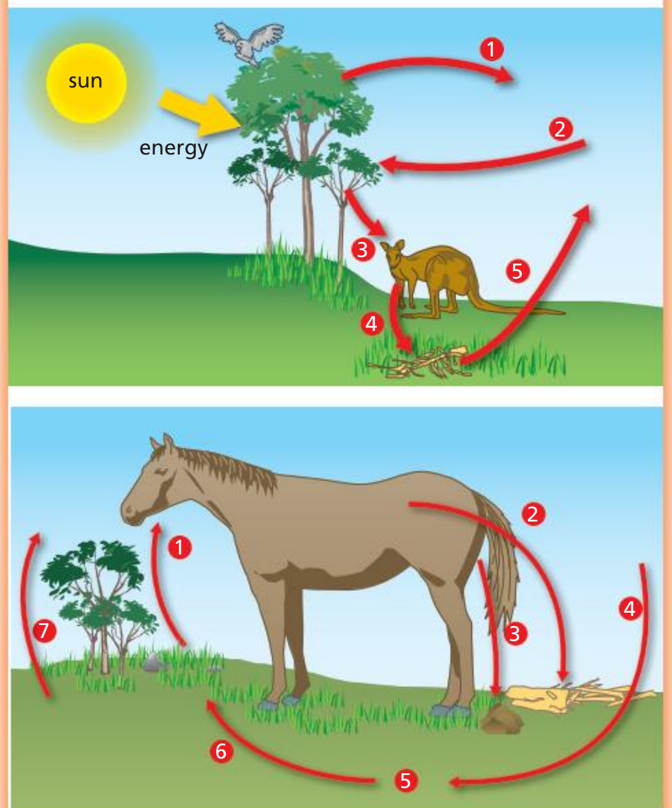
Lightning also forms nitrates as it crackles through the air. When it rains, these compounds dissolve in rainwater and are returned to the soil.

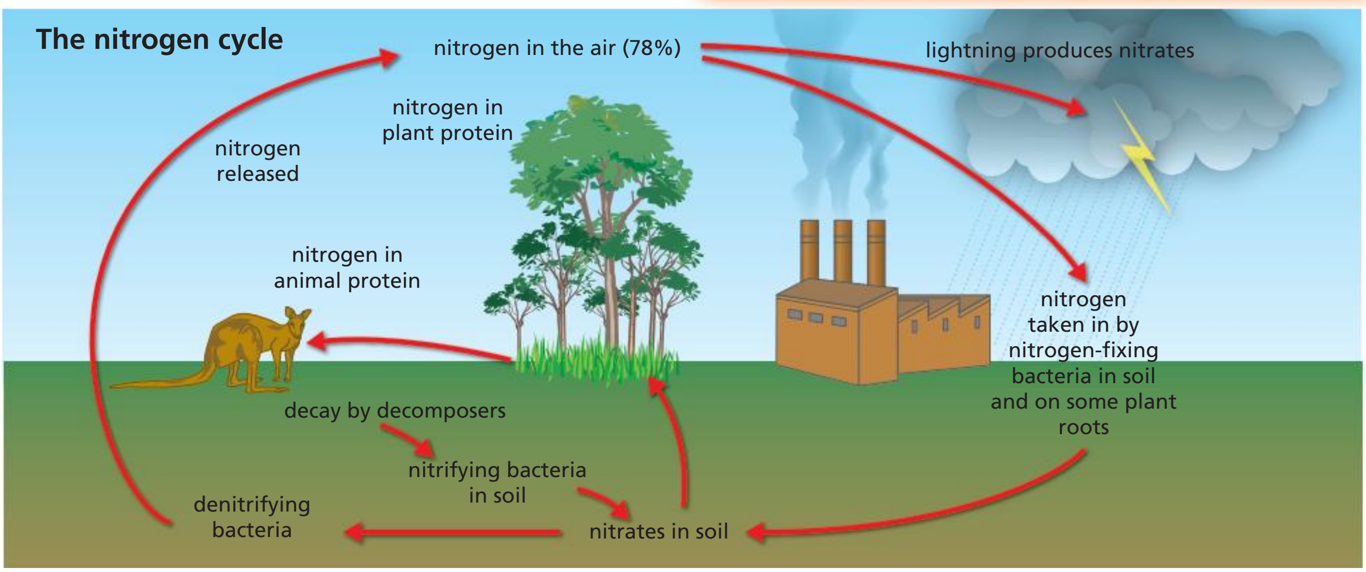
INQUIRY 3 The cycling of matter

You will need: a copy of the diagrams below

1 The labels are missing from the diagrams below. Which diagram represents the carbon cycle and which represents the nitrogen cycle? Add the missing labels to your copy to explain the arrows.

2 Use the diagrams to explain in your own words what happens in the carbon cycle and in the nitrogen cycle.

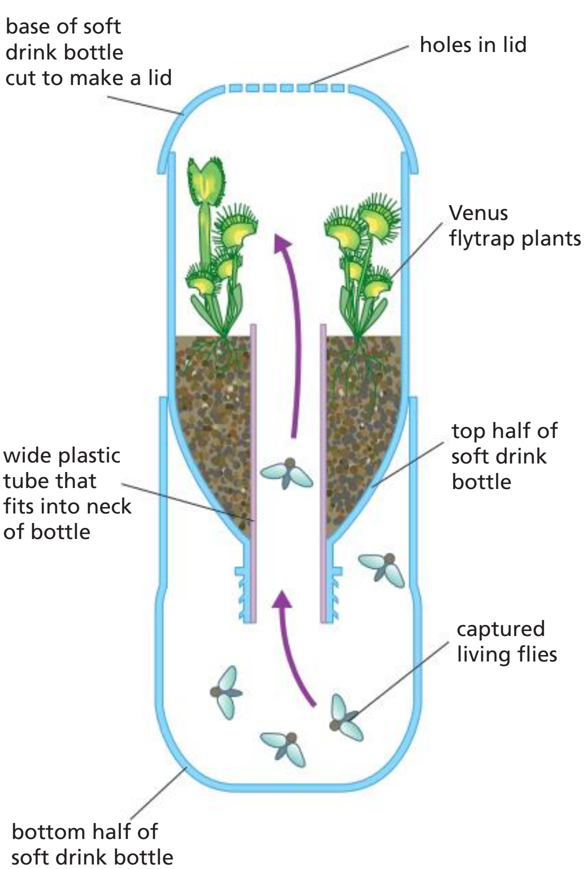




INQUIRY 4 Carnivorous plants

Pitcher plants, sundews and Venus flytraps grow in swamps and soils that lack nitrogen, so they capture insects to get the nitrogen they need. They have special structures that allow them to catch their prey. They produce enzymes which digest the insect. The amino acids obtained from the insect are then used by the plant.

1 Examine a pitcher plant, a sundew and a Venus flytrap and explain how you think they digest insects. Carry out some research to see if your inferences are correct.
2 Draw a diagram to show the nitrogen cycle for these plants. Show how the nitrogen gets into the fly, then the plant. Include decomposers in your diagram.
3 You might also like to make your own 'carnivarium' (a carnivorous plant display). You will need to devise a way to capture flies and insects, then feed them to the plants. You could record the rate of growth of the plants over time, or compare their rate of growth to plants that have not been given any insects.



Over to you

For questions 1–4, choose the best response.

1 Carbon enters an ecosystem when:
A it is taken from the air by plants during photosynthesis.
B it is taken from the air by plants during respiration.
C sunlight hits the Earth.
D carbon dioxide is taken in by plant roots.

2 Nitrogen enters an ecosystem when:
A decomposers break down dead bodies.
B nitrogen-fixing bacteria remove it from the air and incorporate it into the soil.
C plants take up nitrogen through their roots.
D all of the above.

3 Which statement is *incorrect*? Carbon is released back into the atmosphere when:
A green plants carry out respiration.
B decomposers break down dead organisms.
C when you breathe out.
D green plants carry out photosynthesis.

4 Nitrogen is released back into the atmosphere when:
A green plants carry out respiration.
B bacteria living in root nodules release nitrogen to the plant they live on.
C nitrifying bacteria change ammonia to nitrates.
D denitrifying bacteria take nitrogen from the soil.

5 What is the difference between nitrogen-fixing bacteria and nitrifying bacteria?

6 Could life on Earth exist without the carbon and nitrogen cycles? Explain your answer.

7 Draw two overlapping circles. In one circle explain the nitrogen cycle and in the other circle the carbon cycle. In the overlapping part of the circles explain the similarities between the two.

PROBLEM SOLVING

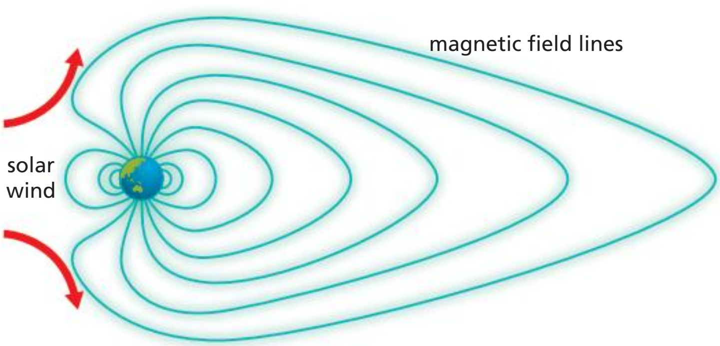
You should now be able to complete some of your chapter problem. From reading sections 9.1 and 9.2 you should be able to describe how matter and energy flow through food chains and webs. From this section you should also be able to describe the carbon and nitrogen cycles.

9.4 Earth's air and oceans

From previous study you know that there are layers that surround the Earth and protect it from the environment of space where UV light, meteors and solar wind are deadly. One important layer that protects the Earth from harmful UV radiation is the **ozone layer**. It is found 15–45 km above the Earth in the upper stratosphere.

The ozone layer contains molecules of ozone, which are three oxygen atoms joined together (O_3). Oxygen in the air we breathe is made up of two oxygen atoms joined together (O_2). UV radiation reacts with oxygen high up in the atmosphere and causes O_2 molecules to split, leaving each atom free to link with other O_2 molecules to form ozone. The ozone then reacts with UV light again, splitting back to O_2 molecules and a single oxygen atom. So ozone is created and destroyed, keeping the ozone layer in balance. In the process harmful UV radiation is absorbed, thus protecting the Earth from its effects. In fact, the ozone layer blocks out about 90% of the harmful UV radiation.

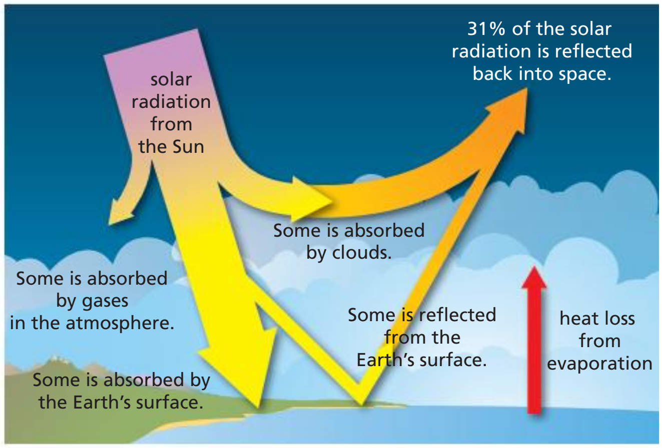
As well as the ozone layer, the Earth is also protected by a magnetic field that extends from the centre of Earth millions of kilometres into space. It is called the **magnetosphere** and forms an invisible bubble around the Earth. The magnetosphere shields the Earth from the solar wind, which is made up of charged particles such as protons and electrons streaming out from the sun at about 450 km/s. Without the magnetosphere our atmosphere would be destroyed. The charged particles that are captured by the magnetosphere create auroras at the poles.



The Earth's magnetosphere protects us from the solar wind.

The Earth as a greenhouse

Our atmosphere is also important because it maintains the range of temperatures needed for life on Earth to survive. Radiation from the sun, which is mostly light, constantly bombards the atmosphere and the Earth. During the day 31% of the solar radiation that enters our atmosphere is reflected back into space. Some of this is reflected from the clouds and the atmosphere, and some is reflected from the Earth's surface. The rest of the solar radiation is absorbed by the atmosphere, the land and the oceans.



Solar energy reaching the Earth during the day

At night, the solar radiation absorbed by the clouds, atmosphere, land and oceans during the day is released as infra-red radiation back into space. As it passes out of the atmosphere some of this infra-red radiation is absorbed by the clouds and gases. It is then re-radiated back to Earth. This maintains the temperatures to which all life on Earth is adapted. If all the energy entering our atmosphere escaped, the Earth would freeze. If too much energy remained trapped and was not reflected back into space, the Earth would heat up.

Imagine the Earth and its atmosphere as a greenhouse (a hot house where plants are kept). In a greenhouse solar radiation is able to enter through the glass walls and roof. This causes everything inside to heat up and emit infra-red radiation. Because infra-red radiation has a longer wavelength than light it cannot pass back out through the glass. Instead it is trapped inside the greenhouse, keeping the temperature inside warm enough for the plants to grow. In the same way, the Earth's atmosphere acts like the glass of a greenhouse, trapping heat inside it. This is called the **greenhouse effect**.

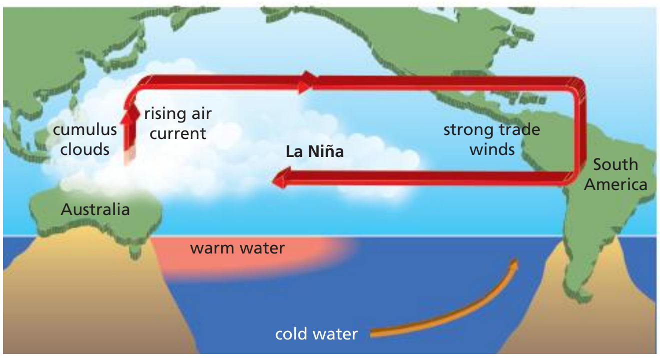
The oceans

The atmosphere and the oceans are interconnected. The oceans absorb and store solar radiation that enters the Earth's atmosphere. However, the water does not heat up evenly, so the temperature of the water varies from place to place. These temperature differences cause ocean currents. Cold water is heavier than warm water. So, cold water sinks, and warm water moves on top of it, causing currents. Surface currents are also caused by winds.

Solar radiation also causes water to evaporate from the surface of the ocean. This affects the amount of water vapour in the atmosphere.

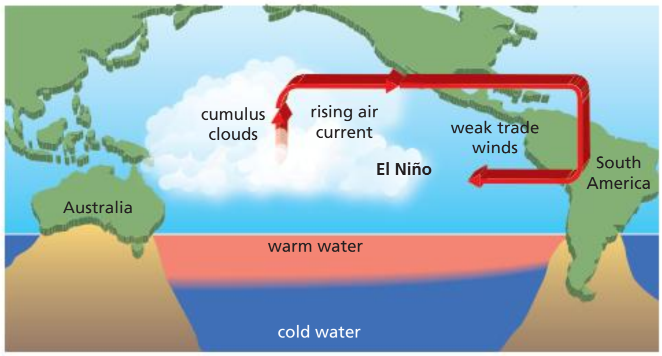
The interconnection between the oceans and the atmosphere can be seen in the La Niña and El Niño effects. Both of these occur because of the warming and cooling of the Pacific Ocean between Australia and South America.

The name **La Niña** (la-NIN-ya) comes from South America and is Spanish for 'the girl'. In La Niña years the surface of the Pacific Ocean near Australia is warm. Water evaporates from the warm ocean and heavy rain clouds develop, causing flooding rains to occur in Australia. In the Eastern Pacific near South America the water is cool, bringing very dry conditions and droughts to Ecuador and Peru, and California.



El Niño (el-NIN-yo) means 'the boy' or 'the Christ child' because this effect takes place around Christmas in El Niño years. El Niño is the opposite of La Niña. The El Niño effect occurs when the surface waters of the Pacific Ocean warm up near Peru. Water-laden clouds develop, bringing heavy rains in South America. These conditions often bring drought and dry conditions to eastern Australia and Indonesia.

The cycles of El Niño and La Niña occur randomly. Scientists give these cycles a number called the Southern Oscillation Index. If this index is 0 then there are no extreme weather changes. A positive index indicates La Niña, and a negative index indicates El Niño. Scientists use these numbers to predict what future weather patterns may be. From 2003 until 2010 eastern Australia experienced an El Niño cycle and droughts. This was followed by a La Niña cycle which peaked in January 2011, bringing floods.



INQUIRY 5 El Niño and La Niña

Use the internet to find out more about El Niño and La Niña. For example:

- How often do these weather patterns occur?
- Find out when Australia has experienced El Niño years and when it has experienced La Niña years.
- Is Australia experiencing El Niño or La Niña weather patterns at present?
- What weather patterns are predicted for the future? Why?

Over to you

1. There are three reactions that occur to create and destroy ozone naturally in the atmosphere. In the first reaction O_2 is split into single atoms by UV radiation from the sun. In the second, a single oxygen atom joins with an O_2 molecule to form ozone. In the third reaction ozone is spit by UV radiation back into O_2 and a single oxygen atom. Write equations for these three reactions. Perhaps you could draw the atoms and molecules.
2. Could life on Earth exist without the atmosphere and the magnetosphere? Explain.

9.5 Human impact

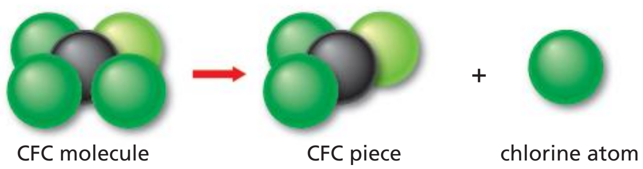
To complete your chapter problem you need to consider the impact of human activity on natural cycles. Let's examine this here.

Hole in the ozone layer

Earlier in this chapter you looked at how important the ozone layer was in preventing harmful levels of UV light reaching Earth. You also learnt how ozone is created and destroyed naturally. However, human activity has upset the equilibrium in the atmosphere by adding gases such as chlorofluorocarbons (CFCs). These gases have destroyed ozone and made a 'hole' in the ozone layer. This is an area where the ozone concentration is less and UV radiation can get through. The equations below show how CFCs break down ozone.

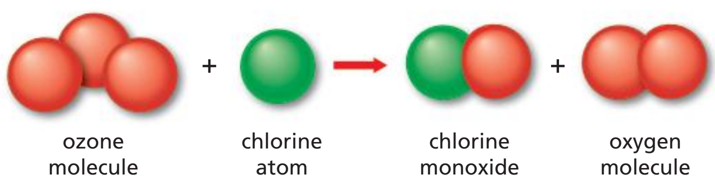
Step 1 UV light breaks up the CFCs, releasing chlorine:

$$CCl_3F + \text{UV radiation} \rightarrow CCl_2F + Cl$$



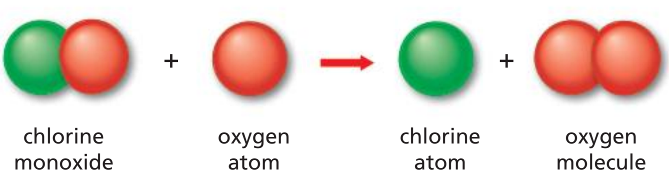
Step 2 The free chlorine atom reacts with ozone to produce chlorine monoxide and oxygen:

$$O_3 + Cl \rightarrow ClO + O_2$$

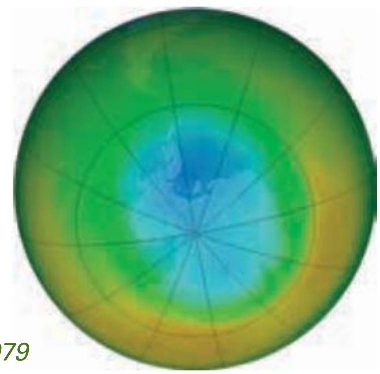


Step 3 The chlorine monoxide then reacts with another oxygen atom, releasing a chlorine atom. This atom can then repeat the reaction with ozone (Step 2) and the whole process starts again.

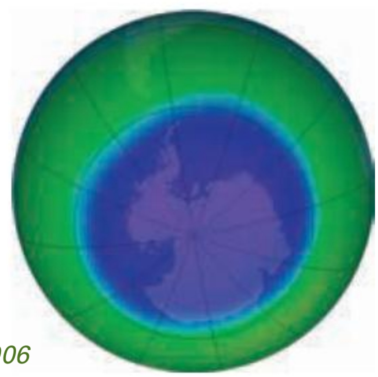
$$ClO + O \rightarrow Cl + O_2$$



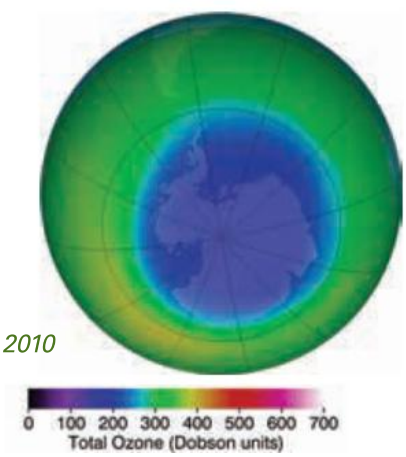
CFCs were discovered in 1928. At the time they were considered to be safe, non-flammable gases that could be used as refrigerants and propellants in aerosols. It wasn't until 1974 that two scientists put forward the idea that CFCs were destroying ozone. They pointed out what effect this could have on the Earth if the use of these gases was allowed to continue. Monitoring of the amount of ozone has confirmed that CFCs have destroyed ozone over Antarctica and the ozone layer in this area has thinned by 60%. At present the hole in the ozone layer is almost three times the size of Australia, or 22 million square kilometres. The satellite pictures below show how the size of the ozone hole has changed. In 1979 the hole (blue) was only small and shallow. Since then it has become larger and deeper. (Check out the website ozonewatch.gsfc.nasa.gov/monthly/SH.html You can download ozone maps to show how the hole in the ozone layer has changed.)



September 1979



September 2006



September 2010

Future possibilities

In 1987, Australia was one of 32 countries that met in Montreal and signed an agreement to eliminate the use of ozone-destroying chemicals. The agreement, called the Montreal Protocol, has meant that chemicals such as CFCs have been replaced with hydrofluorocarbons (HFCs). Other chemicals such as halons (used in fire extinguishers), carbon tetrachloride (a chemical used in dry cleaning) and nitrous oxide are also being phased out of use. Nitrous oxide (N_2O) contains nitrogen and, like carbon dioxide, it is released from burning fossil fuels and wood. It is also used as an anaesthetic called laughing gas.

Even if the use of ozone-destroying chemicals was stopped completely today, they would still take 5–12 years to reach the stratosphere where they may remain for years. The good news is that Australian scientists have already recorded a decrease in the levels of CFCs in the atmosphere over Australia. However, it is predicted that the hole will not disappear completely until 2050 or later.

The problem for living ecosystems is that UV light damages cells that are exposed to it. Australia has the highest rate of skin cancer in the world, and at least 1200 Australians die from this cancer each year. There is a 1 in 2 chance that you will develop skin cancer at some stage in your life. Unfortunately, these figures are not likely to improve any time soon.

With every 1% loss of ozone, there is a 2% increase in UV radiation flooding the Earth, and skin cancer rates increase by 4%. With higher UV levels it is not unrealistic to expect more skin cancers and an increase in eye problems such as cataracts. UV radiation also affects the way in which the body fights infections, so an increase in common diseases could also occur. The big message is that you must wear a hat, 30+ sunscreen, sunglasses and a T-shirt every time you go outside for any length of time.

Greenhouse gases

Since 1978, scientists have recorded the levels of various gases in our atmosphere. To look back at the atmosphere before this time, scientists have examined pockets of air trapped in Antarctic ice. In the past 200 years the amount of carbon dioxide in the air has risen from 280 parts per million (ppm) to 391 ppm. Methane has risen from 0.85 ppm to 1.81 ppm, and nitrous oxide has risen from 0.29 ppm to 0.32 ppm. Methane (CH_4) is a hydrocarbon. It is a flammable, colourless and odourless gas found in natural gas. It is released from boggy ground and rubbish dumps, and by cows and sheep.

These gases are called **greenhouse gases** because they act like a blanket in the atmosphere, trapping heat and causing the temperatures on Earth to rise. They enhance the greenhouse effect.

The rising levels of greenhouse gases in our atmosphere are alarming as they are accelerating the natural cycle of warming that the Earth is presently experiencing. The Earth shows a natural cycle of warming and cooling. For example, the history of the Earth shows that it has been frozen three times. These ice ages occurred 2.3 billion, 750 million and 600 million years ago. Yet 100 million years ago the Earth was 20°C warmer than it is today, and dinosaurs roamed the Earth in the steamy heat. This was a greenhouse age. These super cycles of heating and cooling occur about every 400 million years. At present the Earth is three-quarters of the way through a greenhouse age. In between these super cycles there are mini cycles of heating and cooling that occur every 20 000 years. The Earth came out of a mini ice age 18 000 years ago and is now in a natural cycle of warming.

Predict what changing climates could mean for people living in cities and towns close to the sea. Read on to see if your prediction is correct.

Melting ice

Human activity, however, is speeding up the cycle of warming. Billions of tonnes of carbon dioxide have been added to the atmosphere by burning fossil fuels, and the levels of other gases such as methane have also increased. What impact this will have is unknown. Ice is melting in many areas of the world and it is predicted that the sea levels will rise. The seas have also been getting warmer, which has affected the coral reefs. (See Inquiry 6.)

As well as rising sea levels, melting ice can affect the climate. Ice reflects a lot of the sun's rays back into space. Without ice, the Earth would heat up even more. Also, melting ice produces fresh water that flows into the sea. Fresh water is less dense than salt water and floats on top. This would alter ocean currents and climate. Whether the climate will change gradually or quickly is unknown.

What can be done?

So why doesn't everybody just stop producing greenhouse gases? The answer is that the *infrastructure* or the basic framework underlying such a change does not exist just yet. Let's look at an example of this.

Years ago recycling bins were unheard of. The community had to ask for recycling bins to be provided. This led councils to meet and agree to introduce the new bins. The bins had to be made, distributed and new garbage trucks had to be bought. Changes at the dump had to be introduced. Industries were needed to make recycled products and people had to be educated to use the new bins. For example, pamphlets and fridge magnets were distributed.

It cost the community millions of dollars to set up the support network needed to run the recycling bins. This required *social* (what the people in the community wanted), *political* (council and government approval) and *economic* (money availability) decisions to be made to bring the bins into use.

Reducing greenhouse gases is a much harder problem to solve. It involves world leaders coming together and agreeing to reduce the production of these gases. There have been several international conferences to discuss the problem, but so far the different contries have not been able to agree on what cuts to make to the emissions of greenhouse gases.

INQUIRY 6 *Coral reefs*

Corals are hollow-bodied animals that have tentacles and produce a hard skeleton. Over many years these skeletons have built up to form coral reefs. The Great Barrier Reef is one example. It extends for 1600 km along the north-east coast of Australia. Unfortunately, this reef and others like it are under threat from global warming.

Living within the coral are millions of microscopic marine algae that give the coral its colour. They also give the coral most of its oxygen and food. If the water in which the coral lives becomes too warm the coral expels the algae living within it. This is called coral bleaching because the coral loses its colour and dies. It only takes a 1°C rise in temperature for this to occur. Evidence of coral bleaching has been found in the Great Barrier Reef and the Maldives (islands south of India). It is estimated that if climate change occurs as predicted, then in 30 years all the coral on the Great Barrier Reef could be dead.

1. What is coral bleaching and what causes it?
2. How will reducing the use of fossil fuels and the production of greenhouse gases help the coral?
3. If the climate does get a lot warmer as predicted, is there any way you can suggest to save the coral?
4. What can you do in your home, school and neighbourhood to ensure the Great Barrier Reef is still there to be enjoyed by your children?
5. What effect would it have on Australia if the Great Barrier Reef was destroyed by coral bleaching?

SCIENTISTS AT WORK

Dr Deborah Abbs

Dr Deborah Abbs is a principal research scientist at CSIRO Marine and Atmospheric Research. Her work involves climate modelling using computers to predict future weather patterns and their effects in Australia.

Debbie studied English, Maths, Chemistry, Physics and Zoology at Year 12 and went on to complete a Bachelor of Applied Science at the University of Southern Queensland, majoring in Physics. She chose this course because Physics and Maths were her best subjects at school.

When Debbie started university, she wanted to be a high school teacher, but she changed her mind. Instead Debbie decided to be a scientist in the area of meteorology. With this in mind, she moved to Melbourne and completed an honours year and PhD in the Meteorology Department at Melbourne University. Debbie then completed two years of further research at Colorado State University in the USA.

On returning to Australia Debbie began working for CSIRO. She began computer modelling of the winds in the Latrobe Valley region of Victoria to see how the winds affected pollution concentrations in the air. She was trying to find out under what conditions the winds spread pollution, concentrated it or blew it back over the region.

Debbie's present research is modelling severe weather events such as extreme rainfall, tropical cyclones and hail storms. She uses very complex computer models to simulate these weather patterns. Debbie hopes that she can predict what effect these weather patterns will have on the environment. This would allow more accurate weather forecasts.

Scientists believe that by 2050 the sea level will rise by 10–40 cm, extreme rainfall will become more frequent and tropical cyclones will become more intense. Debbie's research is all about trying to estimate how much heavier the rainfall will be. So far her results suggest that extreme rainfall may become up to 30% more intense and occur more frequently as our climate gets warmer and wetter due to global warming.

Debbie's research is very important for the future, as she explains:

Severe weather events often cost the community a lot of money and sometimes result in loss of life. If changes in those events can be predicted in advance, then some of these losses may be minimised. Engineers need this sort of information when they are planning and designing new infrastructure, ranging from the drainage in a new subdivision, through to the floor level required in houses in these new areas, and designing big projects such as large dams. If we can start to plan and design for climate change now, we will be better placed in 30 years time when we are living in this different climate.

There are good and bad sides to any job and Debbie says her work is no exception. She would recommend it as a career choice for someone interested in using science to solve the issues that face our world today, and for someone who enjoys using theory to solve problems. Debbie works with other scientists in many different areas. She is reasonably well paid and enjoys her lifestyle.

Questions

1 What is Debbie's research all about?

2 What are scientists predicting will happen to our climate and oceans in the next 50 years?

3 How can Debbie's research help with the changes that are likely to take place in the future?

INQUIRY 7 Would you change?

In this hypothetical activity you will see how social, political and economic decisions play their part in bringing about environmental change. The issue is: *Should ethanol be used as a fuel instead of petrol?*

Draw up a table with the following headings:

Evidence to support the use of ethanol as a fuel	Evidence to continue using our present fuels

Read each statement below and place it in the table under the most appropriate heading. Then use your completed table to come to a decision on the issue.

1 Ethanol (ethyl alcohol) can be made from sugar cane. Farmers cannot sell their sugar on the market because there is too much sugar being produced. Using the sugar to make ethanol will give money to farmers.

2 The use of ethanol has been shown to reduce the amount of carbon monoxide, hydrocarbons, formaldehyde, butadiene and benzene emitted into the atmosphere, compared to our present fuels.

3 Ethanol is a renewable fuel.

4 Distilleries and other industries will need to be set up to produce ethanol. This will cost the public sector and the government billions of dollars to establish the infrastructure needed. Taxes may be higher.

5 The ethanol industry will generate new jobs and many new farms will be needed to produce sugar.

6 Natural vegetation may need to be cleared to grow new sugar cane.

7 If ethanol is used, then crude oil may cease to be extracted and refined in large amounts. This may mean that many products obtained from crude oil such as plastic, kerosene, diesel, naphtha and gas will be in limited supply.

8 At present Australia has not signed an international agreement to limit greenhouse gas emissions, so there is no need to do anything.

9 Ethanol as a replacement for petrol may not sell well. Consumers are wary of ethanol in petrol because ethanol blends have been sold without being labelled as such.

10 You may need to make modifications to your car or buy a new car to run on ethanol.

11 Petrol and oil companies employ thousands of people. They will lose their jobs.

12 Petrol and oil companies, along with companies that rely on their resources, sponsor major sporting events.

13 Ethanol is more expensive than petrol, so a litre of ethanol will cost you more. Ethanol also has less energy content than petrol, so more ethanol will be needed.

14 The government of the day does not support the change to ethanol. So a major election will need to be held. This could mean the present government may not be re-elected.

- What was your group's final decision?
- Which of the 14 statements are social statements? Which are political? Which are economic?
- How do social, political and economic pressures influence decision making?
- Explain why it is difficult to cut greenhouse emissions and change to alternative technologies.

Over to you

1 Write explanations of the greenhouse effect and the hole in the ozone layer for a primary school student to understand.

2 It is easy to mix up the greenhouse and ozone problems. Why do you think this happens?

PROBLEM SOLVING

You should now be able to complete your problem and state how human activities are affecting the natural cycles in the ecosystem you have chosen.

INQUIRY

8 Environmental case study

Most people don't think about global warming when they build a new house, or a new shopping centre is developed. However, clearing forests and natural vegetation to make way for new developments removes trees that take carbon dioxide out of the air. Satellite images are used to track the changes to our landscape and allow scientists to predict more accurately how our activities will affect future greenhouse gas levels. These two satellite photos (A and B) show how Noosa in Queensland has developed in the last 10 years. Image B is the more recent photograph.

1 What changes can you see between the two images?
2 Estimate what percentage of the vegetation has been removed in the 10 year period.
3 How do you think these changes affect watercourses? Soil erosion? Air and water quality? Natural ecosystems?
4 On a map, look at the area between the Gold Coast, Brisbane and the Sunshine Coast. This is Australia's fastest growing area. It is estimated that by 2030 these places will all be joined in one 'super city'. Predict what effects this will have on watercourses, soil erosion, air and water quality, and natural ecosystems.
5 Explain how development at Noosa Heads is linked to global warming.

THINKING SKILLS ?

1 Draw a pyramid of numbers, showing 800 producers, 80 first-order consumers, 8 second-order consumers and 1 third-order consumer. Give a real-life example of a living food chain for which these numbers would be realistic.
2 Thrips are insect pests that live on rose bushes. There are far more thrips than rose bushes. What would a biomass pyramid look like for this feeding relationship? Would a feeding relationship for all parasites and their hosts be the same? Explain with examples.
3 Carbon can cycle through living things and back to the environment within minutes, hours, years or millions of years. Use examples to explain how each of these is possible.
4 If the level of carbon dioxide in the atmosphere is increasing, where has this carbon dioxide come from? Has carbon dioxide been created? Explain.
5 Why do you think plants such as legumes make the soil in which they grow more fertile?
6 The moon is the same distance from the sun as the Earth, and yet the moon cannot support life. What makes the Earth different from the moon?
7 Design your own experiment to show that if sea ice melts there will be no change in sea level. Why is this so?
8 The following figures are based on different hot water systems providing 200 L of hot water per household daily.

Hot water system	CO_2 produced per year
electric	5 tonnes
natural gas	1.5 tonnes
solar (electric boosted*)	2 tonnes
solar (gas boosted*)	0.5 tonnes

* If solar energy is unavailable, the system will heat the water using electricity or gas.

Design a poster, magazine article or school assembly presentation to convince your school community to change to solar-powered hot water systems.

Knowing and Understanding

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

1 Over the next 100 years it is predicted that the Earth's average temperature will rise several degrees. This is mainly due to the increase in _______ gases such as carbon dioxide and _______.

2 The energy source for all living ecosystems on Earth is the _______. This energy is trapped by green plants during the process of _______.

3 Different links in a food chain represent different _______ or energy levels. Only part of the energy captured by green plants is passed on along the food chain, because each organism uses more than half of the energy for _______.

4 Carbon and nitrogen are cycled through living things. _______ is taken into plants through the leaves in carbon dioxide. _______ is taken up through the roots of plants. Both elements are passed on to animals when the plants are eaten.

5 The Earth has many layers to protect it from the dangers of UV radiation and space. The _______ , created by the Earth's magnetic field, protects us from the solar wind.

6 The ozone layer protects the Earth from UV radiation. It is thinning because of chemicals such as _______ in the atmosphere.

7 The atmosphere, clouds, Earth and oceans trap and release _______ to maintain the temperature levels required for life on Earth. The burning of _______ is affecting this balance.

carbon
CFCs
fossil fuels
greenhouse
magnetosphere
methane
nitrogen
photosynthesis
respiration
solar radiation
sun
trophic

Self-management

Data tables and questions

You can summarise the chapter with a data table and use each column in the table to develop possible test questions.

1 Copy the data table below leaving lots of room to write your answers. Complete as many boxes as you can, using the information in the chapter. You may need to think of some answers yourself.

2 Once you have finished your table and developed your test questions, swap your work with a partner. See if you can add to their table and answer their questions.

Section in the chapter	What natural cycles are discussed?	What chemicals or chemical reactions are mentioned?	What new words should I know?	How has human activity altered natural cycles?	What two questions could I be asked on a test about this?
9.1 Matter cycles					
9.2 Energy cycles					
9.3 Carbon and nitrogen cycles					
9.4 Earth's air and oceans					
9.5 Human impact					

Checkpoint

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

1 Match the following words with their meanings: trophic, biomass, ozone, ecosystem

- **a** the interactions a group of organisms may have with each other and the environment
- **b** the different energy levels in a food chain
- **c** total mass of living things at each trophic level
- **d** the layer of the atmosphere that protects us from UV radiation

2 The *main* reason why we still emit greenhouse gases into the atmosphere is that:

- **A** it costs too much to stop.
- **B** the infrastructure is not set up to support alternatives.
- **C** people aren't concerned about the environment.
- **D** greenhouse gases are not harmful to life on Earth.

3 The reason why the ozone layer is becoming thinner is that:

- **A** there is too much UV radiation entering the atmosphere.
- **B** the troposphere is not providing enough protection to the stratosphere.
- **C** methane and carbon dioxide levels are increasing.
- **D** CFCs and other chemicals are breaking down ozone.

4 Use the food web below to answer these questions.

- **a** Name two producer organisms.
- **b** How many trophic levels are there?
- **c** Draw an energy pyramid with the names of the organisms in the food web at their correct trophic levels.
- **d** Explain where carbon would enter this food web.
- **e** Explain where nitrogen would enter this food web.

5 What is the difference between El Niño and La Niña? How does each affect our climate in Australia?

6 Use the description of the organisms listed below to draw a food web. Label the producers and the first-, second- and third-order consumers. Which trophic level would have the most energy?

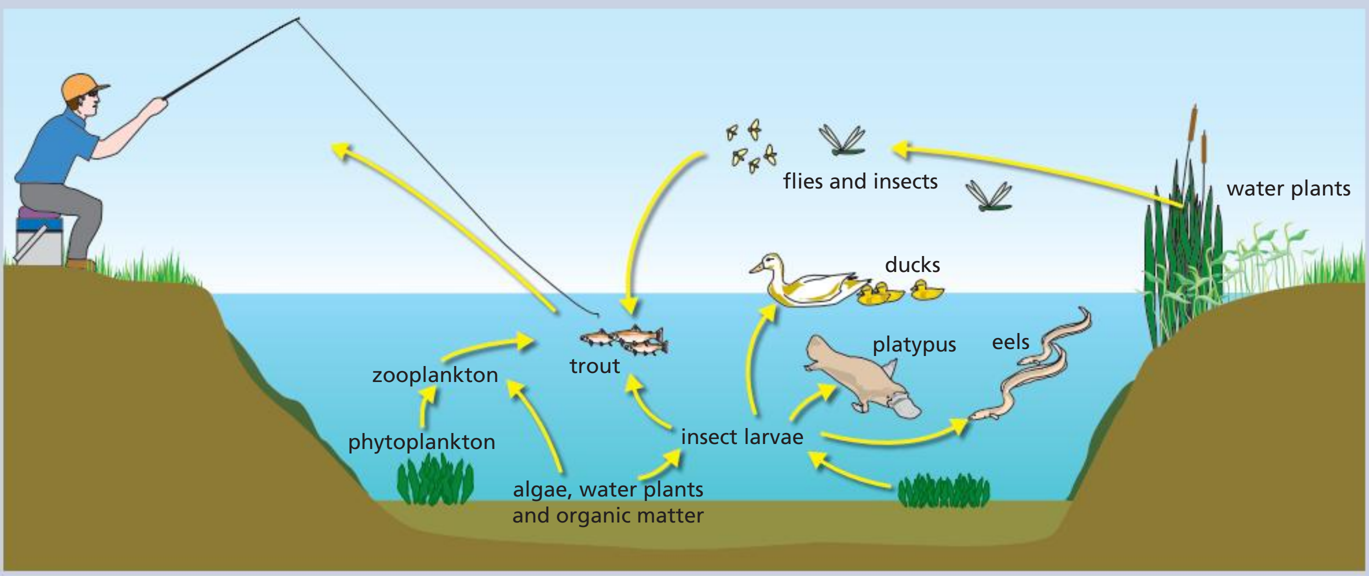
Termites eat all sorts of plant material. Lizards, snakes and frogs feed on the termites. The frogs are then eaten by birds and carnivorous mammals.

7 Give an example of a change in an ecosystem that occurs because of:

- **a** climate change.
- **b** human activity.

8 Greenhouse gases are already increasing in our atmosphere, and global temperatures are rising.

- **a** List two effects that this has already caused on Earth.
- **b** List two possible future effects.



10 Environment case studies

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

Science Understanding

- explore the problem of global warming and ways of combating it

Science as a Human Endeavour

- participate in an inquiry to vote on a proposal to open another uranium mine in Australia

Science Inquiry Skills

- show understanding of a newspaper article by answering questions about it
- use the internet and other resources to research an environmental case study
- design, carry out and evaluate an experiment to investigate ways of cleaning up oil spills
- discuss ways of solving the problem of albatrosses being caught by long-line fishing

LITERACY FOCUS

adsorbent
albatross
biodegradation
carbon credits
case study
chairperson
concentration
dispersant
ecological
emissions trading scheme
global warming
greenhouse gases
groundwater
long-line fishing
pesticides
polymerisation
polyvinyl chloride (PVC)
uranium oxide
viewpoints
yellowcake

Focus for learning

You often see on television or read in the newspapers about problems in the environment. These stories can be used as **case studies** to help us to better understand our environment. If we can see what went wrong in one place, we can learn from this and hopefully avoid the same thing happening elsewhere. Read the article about water pollution in Europe, then answer the questions below.

Knowledge

1 Where is the Tisa River?

2 What caused the pollution of the river?

Understanding

3 Why were the fishermen so upset?

4 If the mine is in Romania, why was there pollution in Yugoslavia and Hungary?

Apply your knowledge

5 Do you think a similar disaster could occur in the Murray River in Australia? Explain your answer.

Golden death flow reaches Danube

Cyanide-polluted water from a mine in Romania has now flowed into the Danube River, exposing one of Europe's biggest waterways to environmental disaster.

Fishermen in the Stari Slankamen region of Yugoslavia, 50 km from Belgrade, were devastated yesterday as cyanide-laced water left tonnes of dead fish in its wake and the government banned fishing in the Tisa River.

'It is a catastrophe. After 30 years of fishing I am unemployed. I have no land and no idea what we are going to live from,' said Misko, a 50-year-old fisherman.

The Romanian mine blamed for the February 1 spill is 50 per cent owned by Australian mining company Esmeralda Exploration. Cyanide is used to separate gold from ore.

The poisoned water had already left what a Hungarian foreign ministry spokesman called a '5 km long carpet of dead fish' floating along the Tisa in his country, where it is known as the Tisza.

Serbia's Environment Minister Branislav Blazic said about two tonnes of dead fish had been taken from the Tisa since the cyanide entered Yugoslav waters on Friday, the state news agency Tanjug reported.

'The Tisa River has been destroyed for several years,' he said.

Dismayed fishermen braved the pungent odours to view the devastation for themselves from their boats.

The Yugoslav Government has banned the use of the Tisa's waters and temporarily outlawed fishing on the river and on a portion of the Danube.

The Courier-Mail **15 February 2000**

PROBLEM SOLVING

Case study

This chapter contains six environmental case studies. As you work through these case studies, choose one to study in more detail. Alternatively, you may want to study one that you know about that is not in this book.

Use the internet or other resources to research the case study you have chosen and then produce a detailed report. Choose the type of report you want to prepare. It could be a written report or you could give a talk to the class. You could do a role play or write a children's book to highlight the issue (like *The Lorax* by Dr Seuss). Try to make it as interesting as possible for your audience.

SKILL

How to do a case study

Doing your research

Once you have chosen a case study you need to research it thoroughly to find out as much information as you can. It helps to have a few questions in mind as you do your research. For example:

- Where and when was this environmental incident?
- Were people affected? Did anybody die as a result of the incident?
- What damage occurred to the environment? Were there short-term or long-term effects?
- What caused the incident? Who or what was to blame?
- Have similar incidents occurred elsewhere in the world?
- What can we learn from this case study? (You will need to do some thinking for yourself here.)

Answer the questions above for the article on the previous page.

To research your case study, follow these steps:

1 Find websites, books, videos and newspaper articles about the incident.
2 Scan the information and decide how useful it is.
3 If the information is relevant and interesting, read it carefully and make notes, using a chart like the one bottom right. Make a note of each source to include in your bibliography.

Different viewpoints

Case studies usually involve some environmental *issue*—something about which people have different *viewpoints* or opinions. For example, a case study can be evaluated from one or more of the following seven viewpoints.

- Try to identify at least one of these viewpoints expressed in the newspaper article on the previous page.

Ecological:
Have living organisms been damaged? Has the balance of natural ecosystems been upset?

Economic:
Will people's livelihoods be at risk? Will jobs be created? Will the economy of the area be affected?

Ethical/moral:
Is it morally right or wrong? For example, should mining companies have to pay to restore the land so it can be used again? Should chemicals that are banned in developed countries continue to be sold in developing countries?

Health related:
Will this affect the health of people locally and globally?

Political:
What will the government, politicians or interest groups such as Greenpeace think of this?

Scientific/technological:
How is scientific knowledge and technology relevant?

Social (not in my backyard):
What will the people who live there think?

Case study chart

Case study ....
....

Source	Where and when?	Effect on people	Damage to environment	Cause	Other incidents
1					
2					

10.1 Botany Bay

Anglers in poisoned paradise

Anglers fishing off a popular Sydney pier are risking a six-month jail sentence as the fallout from Australia's worst ever pollution scandal hits home.

Warning signs banning fishing in Penrhyn Estuary, part of Botany Bay, were erected by the State Government yesterday because of poisonous contamination caused by chemical giant Orica.

A fishing ban was ordered in early November after the full extent of a decades-long toxic spill from the Orica plant was revealed and elevated levels of dangerous chemicals were found in fish and oysters.

***The Daily Telegraph* 11 February 2005**

Botany Bay, where Captain Cook first landed in Australia in 1770, has become polluted. In this case study you will investigate the cause of this pollution and what is being done to fix the problem.

The ICI/Orica site at Botany Bay

In 1944 an international chemical company ICI (now Orica) began manufacturing chlorine gas in the Sydney suburb of Banksmeadow on the northern side of Botany Bay. For 50 years or so they manufactured a range of chemicals, from pesticides to swimming pool chlorine and polyvinyl chloride (PVC) plastics. The pesticides 2,4-D and 2,4,5-T, the same as those used to make Agent Orange for the Vietnam War, were made there. These pesticides are now banned.

Over the years many different chemicals have been stored at the ICI site in Botany Bay. For example, there are about 60 000 barrels of the toxic chemical hexachlorobenzene (HCB). The site also contains a large stockpile of toxic dioxin (see p. 92).

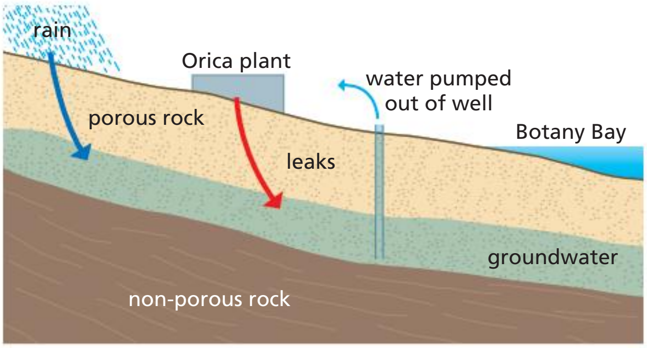
In 1990 it was found that leaks from these stored chemicals had contaminated the soil at the site. Chemicals were also detected in the groundwater around the site. This is water that flows through dense sand under the ground. As a result there is now a large area of polluted groundwater that is slowly spreading. Some of the leaked chemicals have also flowed into Botany Bay via a stormwater drain.

The toxic groundwater contains the suspected cancer-causing chemical ethylene dichloride (EDC). Up until 1996 this chemical was used in the manufacture of PVC plastic. It is no longer used at the plant. In 1997 ICI Australia became Orica. They now have the responsibility of cleaning up the mess.

The area around the Orica plant where the groundwater is polluted is shown in red.

The clean-up

The diagram below shows how the groundwater has become contaminated. The sand near the surface is very porous and any rain that falls soaks in and stays in this layer. It does not escape downwards because there is non-porous rock below it.



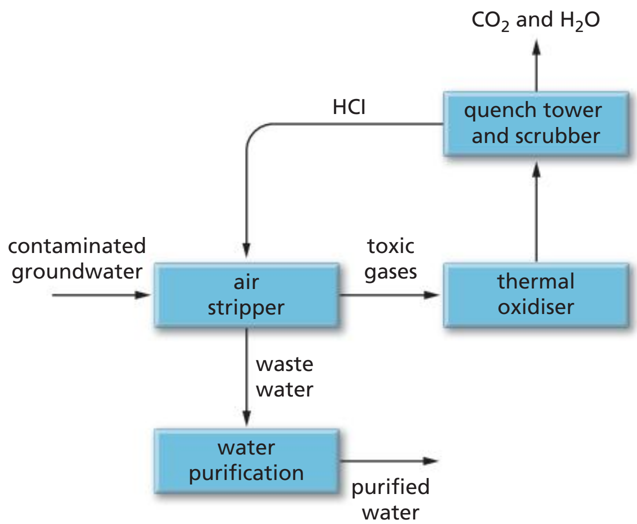
The toxins that have entered the groundwater are being pumped out.

The leaking EDC from the Orica plant has contaminated the groundwater over an area of about two square kilometres and has almost reached Botany Bay. There are many residential bores (wells) in the area around the plant and EDC has been detected at levels above the Australian drinking water standard. As a result, people in the area have been advised not to drink bore water or use it for watering gardens or filling swimming pools.

Orica tried various ways of cleaning up the contaminated groundwater. They tried encouraging soil bacteria which feed on the chemical, but the groundwater seemed to be too heavily polluted for the bacteria. Orica also investigated the idea of a trench of iron filings, which treats the chemicals in the water as it moves across the trench. However, it was decided that the most effective method was to dig a series of wells along the edge of Botany Bay and pump out the contaminated water. This clean-up process was begun in 2004 and pumps out about five Olympic-sized swimming pools each day. No contaminated groundwater is moving past the line of pumps set up between Orica and Botany Bay.

The contaminated groundwater is piped back to the groundwater treatment plant at Orica. Here air is blown through the falling column of water in an air stripper to remove the toxic gases. The leftover water is treated and then used in local factories. The toxic gases are heated to 900°C in a thermal oxidiser where they are converted mainly to carbon dioxide, water and hydrogen chloride. Before being released into the atmosphere these gases are cooled to avoid the formation of toxic dioxin. The hydrochloric acid is removed and reused.

The groundwater treatment plant has been shut down several times when it was suspected dioxin (see p. 92) was being produced, and Orica has admitted the clean up may take 100 years.



Flow diagram of the groundwater treatment plant

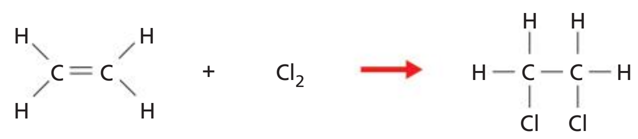
Manufacture of PVC

The EDC that has caused the pollution at Botany Bay was used to manufacture PVC, or vinyl. We use PVC plastic every day. It is widely used to build our homes (e.g. for guttering, pipes and flooring). It is used to store blood and plasma solutions in hospitals. It is used to make computer keyboards, insulation for electrical wires, door panels in cars, mineral water bottles, credit cards, garden hoses, swimming rings, raincoats and soles for shoes.

This swimming ring is made from PVC plastic.

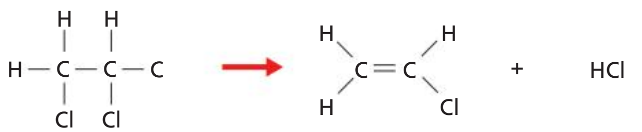
There are a number of steps in the making of PVC. The raw materials are natural gas and salt. The natural gas is passed through a catalytic cracker, where ethylene is separated from the other hydrocarbons in the gas. Ethylene is a flammable gas. The salt is passed into an electrolysis cell to produce toxic chlorine gas (p. 90). Caustic soda and hydrogen gas are useful by-products (unintentional products formed while making the main product).

The ethylene and the chlorine are then reacted together to produce ethylene dichloride (EDC)—the chemical that caused the Botany Bay pollution.



ethylene + chlorine → ethylene dichloride

The EDC is then converted to vinyl chloride by heating, with the loss of hydrogen chloride gas, which dissolves in water to form hydrochloric acid.

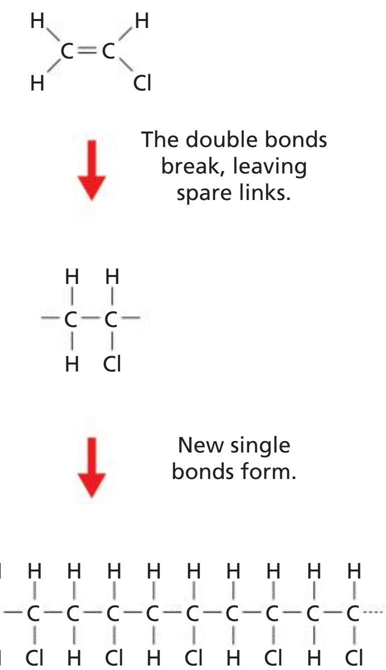


ethylene dichloride → vinyl chloride + hydrochloric acid

The process is a lot more complicated than this, and side reactions occur which lead to various chlorinated hydrocarbons, including minute traces of toxic dioxin.

The vinyl chloride gas is the monomer for making polyvinyl chloride, in the presence of a catalyst, as shown below. This process is called *polymerisation*.

EDC is no longer made by Orica at Botany Bay. Instead, they import vinyl chloride monomer to make PVC.



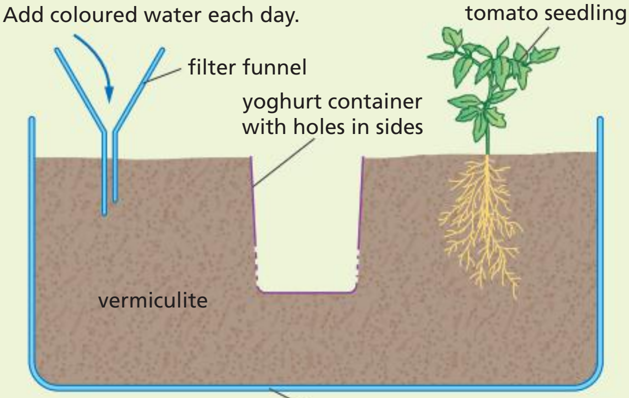
polyvinyl chloride (PVC) polymer

INVESTIGATION 1 Groundwater model

Use the diagram as a guide to design a model of the groundwater around the Orica site.

Add water containing red cochineal food colouring to one side of a pneumatic trough containing vermiculite. This represents the toxic chemicals leaking from the Orica plant. The idea is to see if the red cochineal reaches the other side of the trough and moves up into the tomato seedling. The seedling represents the living things in the Botany Bay environment. The yoghurt container with holes in it allows you to see the polluted groundwater. It represents the residential bores and the wells dug by Orica to remove the toxic groundwater.

You will need to work out the details for yourself; for example, how much water to add, what size yoghurt container to use and the size of the tomato seedling.



It will take at least a week to get results. Write a full report of your investigation.

INQUIRY 1 *Testing for PVC*

You will need: 10 cm piece of copper wire, cork or stopper, Bunsen burner, heatproof mat, blue litmus paper, piece of PVC plastic (look for plastic products with the symbol ♳ or V on them)

1 Insert one end of the copper wire into the cork.

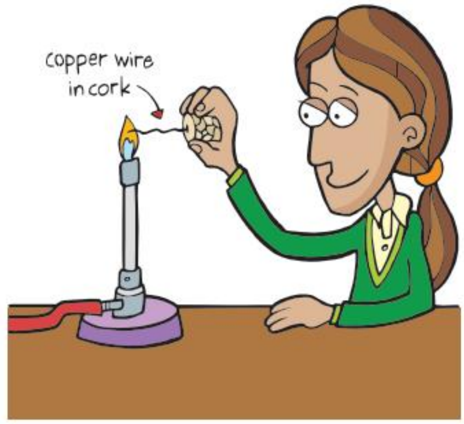
2 Heat the copper wire until it glows red.

3 Touch the wire onto the PVC plastic so that a small amount of plastic is melted onto the wire. Now immediately return the wire to the flame. The flash of green or blue-green colour in the flame is due to a reaction between chlorine (in the PVC) and the hot copper.

- Write an equation for this reaction.

4 Repeat the test, holding a moist piece of blue litmus paper near the burning PVC. What happens?

- Write an inference to explain your observation.



Over to you

Use the Botany Bay case study to answer these questions. The first questions test your memory of key facts, the next questions test your understanding of the case study and the last questions ask you to apply your knowledge.

Knowledge

1 Where is Botany Bay?

2 Why is there a fishing ban in one part of Botany Bay?

3 What is ethylene dichloride (EDC) used for?

4 How did EDC get into the groundwater at Botany Bay?

5 How is Orica cleaning up the contaminated groundwater?

6 How can you test a piece of plastic to see if it is made from PVC?

Understanding

7 What is groundwater?

8 Name the three different elements in ethylene dichloride.

9 Newspaper articles about Botany Bay referred to a 'toxic tide'. Why do you think they used this term?

10 What are the raw materials used to make PVC? What are the by-products?

11 What is the monomer used to make polyvinyl chloride (PVC)?

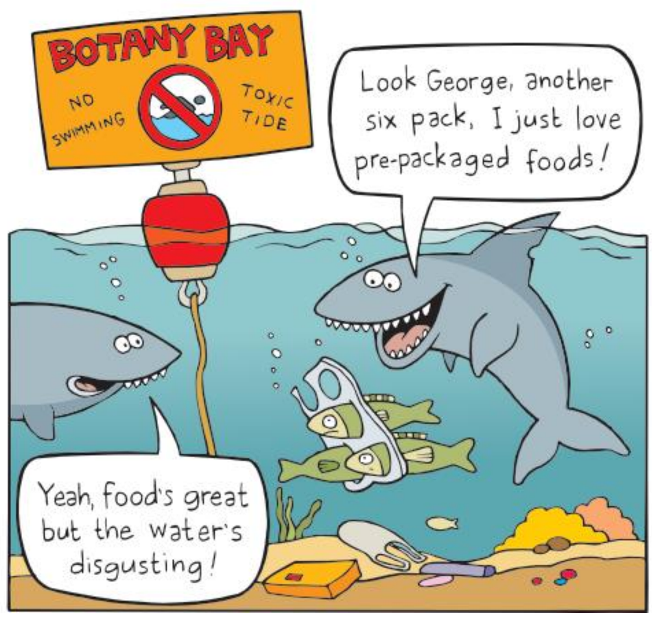
12 What is the element in PVC that gives a green colour when you put it in a flame?

Apply your knowledge

13 Has Orica's clean-up of the contaminated ground-water been successful? Explain your answer?

14 Do you think that the Orica plant should be located so close to the centre of Sydney? Why do you think it was built where it is?

15 To make PVC plastic products, toxic chemicals such as EDC are used. Do you think it is worth the risk?



10.2 Uranium mining

In 1949 a prospector discovered a deposit of uranium ore at Rum Jungle, about 100 km south of Darwin in the Northern Territory. Open-cut mining began in 1954 and finished in 1971. White's Pit was about 100 m deep and is now filled with water (see photograph). There was also a second pit, and a third one from which copper ore was extracted. There was also an ore treatment plant.

The uranium ore taken from the pits was crushed at the mine site and ground to a slurry (a thin paste a bit like porridge). Sulfuric acid was then added to separate the uranium ore from the waste rock. Finally the uranium was recovered from the solution by adding an alkali to form a precipitate. The final product was uranium oxide (U_3O_8), which is called *yellowcake*, even though it is a khaki colour.

When the mine was closed in 1971 the three pits and the waste rock dumps were left as they were. The East Finnis River flows right through the mine site and in the rainy season it flooded the pits. The metals copper, manganese and zinc were leached out of the waste rock dumps and washed down the river. In 1974 the pH of the water in White's Pit was 2.4 (very acidic). Because of the toxic metals in the water there was no life in the river for 8.5 km downstream. Over the next 15 km only some species survived.

Rehabilitation

In 1983–1987 the Australian government spent $18.6 million to rehabilitate the Rum Jungle mine site. The photograph shows the results. The dumps were reshaped and covered with clay to prevent erosion. The third pit was filled with waste rock from the mine site. The water in the other two pits was treated. The Rum Jungle site and the East Finnis River are still monitored regularly to check for heavy metal pollution.

INQUIRY 2 Waste rock dump

In this activity you will simulate the leaching of metals from a waste rock dump.

You will need: coarse-ground coffee beans, sand, dropper, tray

1. Mix thoroughly one teaspoon of ground coffee and 3 teaspoons of sand in a tray.
2. Shape the coffee–sand mixture into a neat pile and squirt about 5 dropperfuls of water onto the middle of the pile. What happens?
3. Investigate one or more of these questions:
   - How does rainfall affect the rate of leaching?
   - Does it matter whether you use whole coffee beans, coarse-ground beans, fine-ground beans or coffee granules?
   - What can be done to slow down the rate of leaching? Test your predictions.

INQUIRY 3 Interpreting a table

Other metals were found with the uranium at Rum Jungle. The table below shows how many tonnes per year of the metals copper (Cu), manganese (Mn) and zinc (Zn) were leached out of the mine site during the 1973–74 wet season.

1 Which metal was leached out in the largest quantities?
2 Where did most of the copper come from?
3 Where did most of the zinc come from?
4 Which of the three pits caused the most pollution?
5 In general, was there more heavy metal pollution from the three pits or from the waste rock dumps?
6 Suggest why there was no zinc leached from White's Pit.
7 Suggest why no uranium was leached out of the mine site.

Mine site	Cu (t/year)	Mn (t/year)	Zn (t/year)
White's Pit	8	30	–
White's waste rock dump	29–53	11–19	17–31
Intermediate Pit	3	3	0.3
Intermediate waste rock dump	16–30	2.5–4.5	13–25
Dyson's Pit	1	3	–
Dyson's waste rock dump	0.2	5	–
Copper heap-leach pile	32–42	–	–
Tailings dam	5	3.5	–
Old acid dam	–	12	–
Total	**95–142**	**70–80**	**30–56**

INQUIRY 4 Internet article

Rainbowfish pass the toxic test

A team of scientists from the University of Technology in Sydney and the Australian Nuclear Science and Technology Organisation have made an interesting discovery. It appears that over time the black-banded rainbowfish in the East Finnis River have adapted to the pollution by developing gills that enable them to survive metal pollution levels deadly to other fish.

During the 1990s the scientists observed that most fish were killed in the first flush of heavy metals downstream at the start of each wet season. However, the black-banded rainbowfish survived despite copper levels being nine times greater than the lethal limit for rainbowfish in other rivers. The scientists compared rainbowfish in the East Finnis River with the same species of rainbowfish in Coomalie Creek, an unpolluted creek nearby. They found 'polluted' fish to be eight times more tolerant of copper than 'unpolluted' fish.

The team used radioactive isotopes of copper (Cu-64 and Cu-67) as 'tracers' to follow where and how much copper was concentrated in the fish. They found that the East Finnis rainbowfish had developed gills that reduced the amount of copper absorbed. This enabled them to halve the amount of copper 'bioconcentrated' in their bodies, compared to rainbowfish elsewhere.

The tests, however, showed that the East Finnis rainbowfish have less genetic diversity than other rainbowfish. In other words, the fish may have developed a copper tolerance at the expense of other characteristics important to their survival, such as their ability to cope with pesticides, turbidity, temperature or salinity.

ABC **October 2002**

1 What is the main cause of pollution in the East Finnis River?
2 Summarise the article in one or two sentences.
3 How did the scientists study the flow of copper in the rainbowfish?
4 Is the rainbowfish's adaptation structural, functional or behavioural?
5 What do you think the term 'bioconcentrated' means? You may be able to work it out from the article.
6 Will the rainbowfish's ability to tolerate copper ensure its long-term survival? Explain.

Uranium inquiry

Australia has huge reserves of uranium—about 27% of the world's reserves. At present only four mines are operating. The first and oldest is the open-cut mine at Ranger, 230 km east of Darwin, surrounded by the Kakadu National Park, a World Heritage Area. The second mine is Olympic Dam, which is roughly in the centre of South Australia. It is the largest known deposit of uranium ore in the world. It also contains copper and is mined underground. The third and fourth mines are at Beverley and Four Mile, not far from Olympic Dam. Here the uranium ore is dissolved underground and pumped to the surface in solution. At present all Australia's uranium is exported. It is almost all used in nuclear power stations throughout the world. Some is used to make medical radioisotopes.

A company called Energy Resources of Australia wants to open a fifth uranium mine at Jabiluka, just north of the present Ranger mine in Kakadu. Different people and different groups have different viewpoints on uranium mining in Australia (see p. 220). Imagine a public inquiry is to be held to discuss the proposal to open the mine and to vote on whether it should be given the go-ahead.

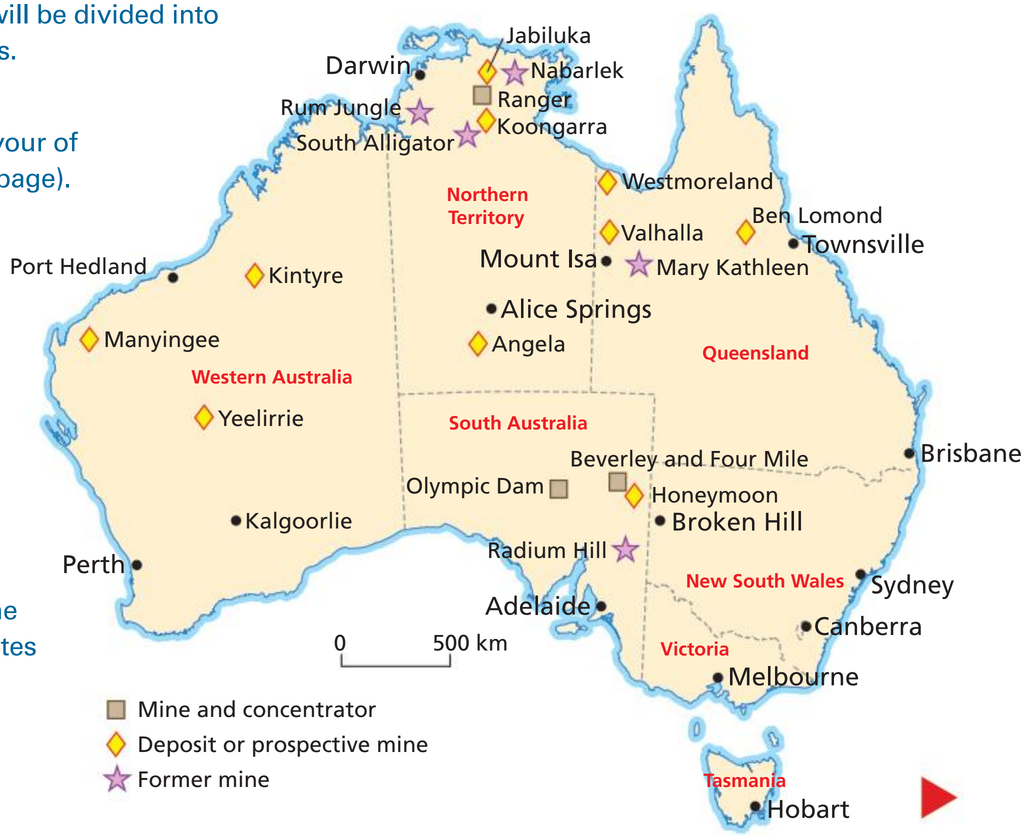
For the inquiry the class will be divided into a number of different groups.

For: Three groups are in favour of the new mine (see the next page).
Against: Another three groups are against the mine.
Undecided: The rest of the class is undecided about the mine and they develop a list of questions to ask the speakers before voting.

Each of the six groups is to prepare a three-minute speech for the inquiry. On the next page are some brief notes to help you prepare your presentation. You will need to do research to add more detail and think of other points for or against the mine development. You will need to elect a speaker to present the case prepared by your group.

A *chairperson* will organise the inquiry and keep order. Each speech should be no longer than three minutes and nobody is to interrupt. Start with a speaker from the 'for' side, then one from the 'against' side, and so on. If there is time you could have a general discussion at the end. Finally, the undecided group votes for or against the new mine.

Jabiluka or Djaar Djaar is the Aboriginal name for this billabong near the proposed mine site.



For

Energy Resources of Australia (ERA)

- The mining will be underground, with little impact on the surrounding area. No sites of cultural importance to the Aboriginal people will be disturbed.
- The uranium ore will be transported 20 km by road to the existing Ranger mine site for processing.
- Mining operations have been carried out at Ranger for 20 years without harming the surrounding Kakadu National Park.

An artist's impression of the proposed Jabiluka mine site

Australian Uranium Association (AUA)

- Jabiluka is one of the world's larger high-grade uranium deposits.
- There is a worldwide demand for uranium for use in nuclear power stations. Australia exports uranium under very strict conditions, which ensure it is used only for peaceful purposes and not military purposes.
- Increased use of nuclear power, which does not produce greenhouse gases, is a possible solution to the threat of global warming.

Northern Territory government

- Jabiluka would bring $3.8 billion in economic benefits to the Northern Territory.
- The mine would make $12 billion over the next 28 years, and create up to 1500 jobs.
- The Aboriginal community would receive $210 million in royalties.

Against

The Mirarr Aboriginal people

- The Jabiluka mine site is very close to the Boywek-Almudj sacred site and other ancient remains and rock art in Kakadu.
- The Mirarr people own the land and have traditionally hunted, gathered, held ceremonies, lived and died in the area. They fear that the wastes from mining could cause radiation sickness among the people.
- Development of the mine and township is likely to cause social problems associated with a decline in traditional living, including alcoholism, community violence, chronic health problems, disinterest in education, and collective despair and hopelessness.

National Parks

- Kakadu is a World Heritage Area that is already under threat from mining. Opening another mine would dramatically increase this threat.
- The mine would produce an estimated 20 million tonnes of radioactive tailings (waste rock). These tailings remain radioactive for hundreds of thousands of years.
- With heavy rainfall in the area, there is a considerable risk of metals leaching from the tailings dumps, as happened at Rum Jungle.

Australian Conservation Foundation (ACF)

- The majority of the community do not want the mine developed. Church, trade union and political groups have all opposed it.
- The nearby Ranger mine has had water management problems since it began, and regularly releases contaminated water into Kakadu.
- In the light of disasters such as Chernobyl in 1986 and Fukushima in 2011, increased use of nuclear power worldwide is too big a risk to take.

10.3 Oil spills

The *Kirki* disaster

On the night of 21 July 1991 the Greek tanker, the *Kirki*, was heading for the BP oil refinery at Kwinana, south of Perth. The 22-year-old tanker was carrying 85 000 tonnes of light crude oil from the Middle East. The sea was very rough and a ballast tank became filled with sea water. The bow (front) of the ship broke off and three oil tanks were cracked. Friction from the tearing metal caused the tanks to catch fire, and oil spewed into the sea.

The ship's captain reported that the tanker was sinking. The crew, including a pregnant woman, tried to escape in a lifeboat but could not because huge waves were crashing over the ship. Several crew said they thought they would die when the spilled oil around the tanker erupted in a wall of flames nearly 15 m high. The fire was eventually put out by the waves, and the crew were rescued by helicopter early the next morning. Fireballs continued to erupt from the tanker throughout the day.

Up to 20 000 tonnes of crude oil escaped from the crippled tanker, about 20 km off the Western Australian coast near Cervantes. This created an oil slick 60 km long and more than 400 m wide, which threatened to destroy the local crayfishing industry.

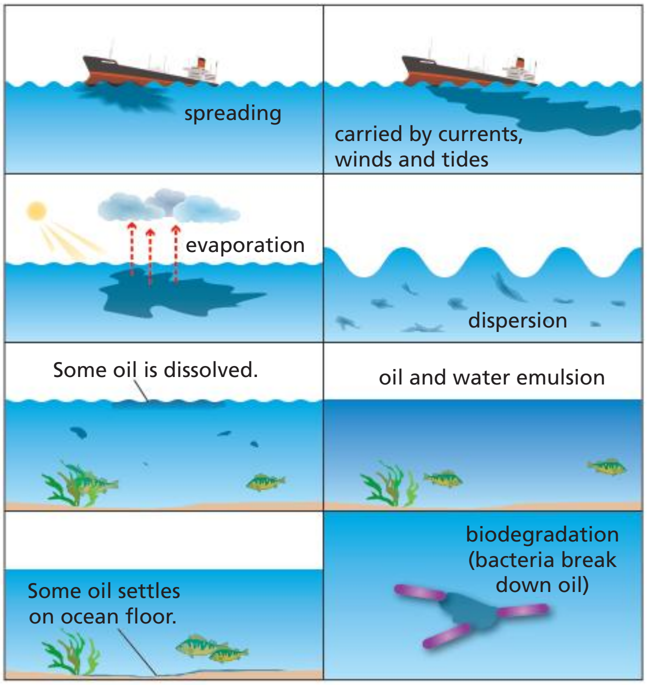
Chemical dispersants (detergents) and oil booms (see next page) were immediately flown to the area, and the stricken tanker was towed out to sea. Six fishing boats were used to run through the oil to break it up. Crop-duster aircraft 'bombed' parts of the oil slick with dispersant, and containment booms were positioned by helicopter around islands near the coastline.

The rough weather soon broke up the spill, and within a few days most of the oil had evaporated, dispersed or dissolved. Some tar balls were washed onto an island and some gooey residue was washed onto the beach at Jurien Bay. However, there was little damage to wildlife. The remaining oil was pumped from the *Kirki* to another tanker, and the *Kirki* was then towed to Singapore to be scrapped.

Quick action avoided an ecological disaster in the case of the *Kirki*, but had the spill happened near the Great Barrier Reef off Queensland's coast, it might have been a different story.

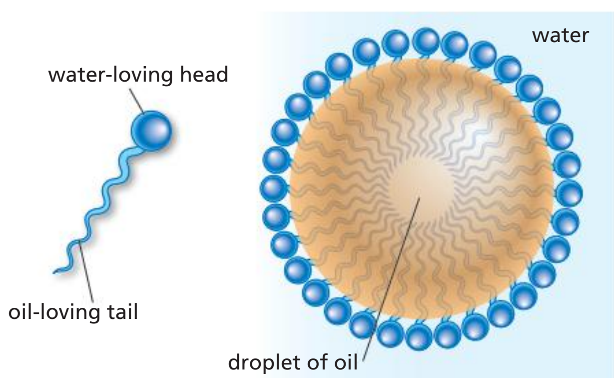
What happens to oil spills?

There are many different processes that occur naturally to clean up oil spills, as shown in the diagrams below. Light oils, like that spilt from the *Kirki*, break up more quickly than heavy oils. If an oil slick does not break up naturally, various other methods can be used.



Dispersants

Dispersants are similar to soaps and detergents. They contain long molecules with a water-loving head and an oil-loving tail. These molecules surround droplets of oil as shown, with their oil-loving tails in the oil and their water-loving heads in the surrounding water. This breaks up the oil and helps it to spread out. Dispersants have to be applied quickly while the oil is fresh. They can, however, affect marine organisms, so they are used sparingly.



Booms and skimmers

Oil floats on water and initially forms a slick that is only a few millimetres thick. Various types of floating barriers, called booms, can be used to surround an oil slick or to stop it reaching the shore. Skimmers suck or skim spilt oil from the water surface so that it can be pumped into storage tanks. However, booms and skimmers can only be used in calm water.

Biodegradation

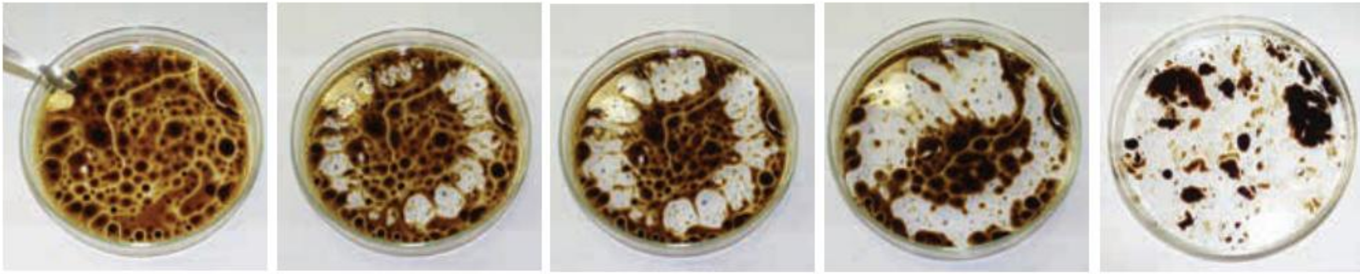
Oil is broken down naturally into harmless substances by bacteria and other microorganisms in water and on beaches. This process is called **biodegradation** and it can be speeded up by adding fertiliser to aid the growth of bacteria.

Adsorbents

Adsorbents are substances that attract the oil to their surface. Various substances have been tried, for example, chicken feathers and cat litter (made from fine clay).

Dr Jock Churchman, formerly from CSIRO Land and Water in Adelaide, has developed a novel adsorbent. He uses the solid wastes left over from the treatment of cooking oils. This idea was first tested and proven by a Year 12 student in the CSIRO Student Research Scheme, in which each selected student completes a project under the guidance of a research scientist.

Cooking oils and fats are normally treated with a clay-based material that adsorbs any unwanted materials in the oil. Dr Churchman experimented with this waste adsorbent. The photographs at the top of the next page show the results of one of his experiments.



0—adsorbent added to oil | 7 s | 18 s | 1 min | overnight

A tiny amount of adsorbent was added to some crude oil floating on water in a large dish. Wherever the adsorbent fell the oil cleared (white areas). These cleared areas increased over time and by the next day the oil had formed into small blobs and could easily be scooped from the surface.

Dr Churchman found that sometimes the adsorbent sank in water, so he developed a netting bag. The bags containing the adsorbent float and remove the oil. CSIRO is presently working with a commercial company to develop clay adsorbent contained in porous bags. The bags could be placed onto or close to an oil spill. Alternatively, they could be connected together to act as a boom to surround the oil. The bags could also be positioned as a barrier around oil pipelines or under and around petroleum storage tanks in case of leaks.

Not only do the adsorbent bags protect the environment from oil spills but they also use a material normally thrown away as waste.

INVESTIGATION

2 Cleaning up oil spills

Aim

To design an experiment to investigate oil spills and ways of cleaning them up.

Planning method

There is no detailed method in this experiment. You will need to work this out for yourself.

Decide what you are going to investigate, then write down your method as a series of steps. Here are some questions you could investigate.

- *What happens when oil is mixed with water?* You could use crude oil (or sump oil) or you could make simulated crude oil by adding cocoa powder to cooking oil.
- *What effect does detergent have on an oil–water mixture?* You could try different amounts of detergent.
- *How long does it take for the oil to disappear? Does wave action speed up the process?* You could do this in a large tray or aquarium.
- *What happens to feathers soaked in oil? What is the best way to get rid of the oil?* You could test the feathers to see if they are waterproof, and you could drop them from a height to see how well they 'fly'.
- *Which materials are the best adsorbents for soaking up oil?* Some materials you could try are sand, sawdust, plaster of Paris, chips of polystyrene foam, cat litter, a mop made from strips of cloth, or shreds of paper in a stocking bag.
- *How can you use a boom to contain oil? How can you scoop up oil?*

Once you have a plan, discuss it with your teacher before you start.

Risk assessment

Discuss with your teacher how to do your experiment safely and without making too much mess.

Apparatus

You will need to work out for yourself what equipment and materials you will need. Some of these could come from home.

Write your report

Write your report under the usual headings, including Results, Discussion and Conclusion. Because you have designed your own experiment, it is essential to have a Discussion to evaluate its success.

10.4 Nightmare in Bhopal

It was just after midnight on 3 December 1984 in the city of Bhopal (bow-PAR) in India. It was a clear night and hundreds of people had gathered for the traditional Sunday evening of songs and poetry. The crowd in Spices Square listened intently as the poets sang of suffering and joy, life and death. In other parts of the city marriage ceremonies were taking place. The bars and restaurants were filled with music and the sounds of celebration.

In contrast to this scene, there was panic at the nearby Union Carbide plant where pesticides were manufactured. There was a serious leak in a storage tank holding 42 tonnes of lethal gas. Within minutes there was a huge explosion and a deadly hurricane of gases spilled out over the half million people in the city.

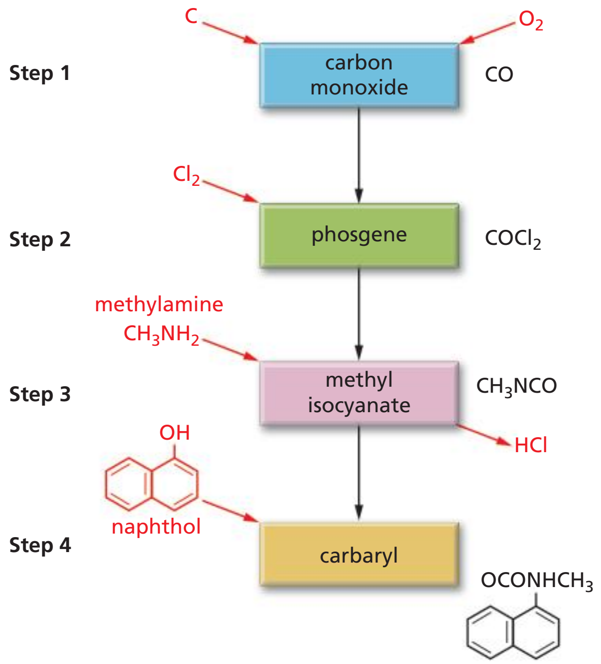
The deadly gas slipped unnoticed through the open windows and doors of the city. For many who were asleep in bed the poison they breathed in meant they would never wake again. By the time the late-night revellers saw the enormous poisonous cloud moving towards them it was too late. The busy restaurants and cafes, the squares and parks that had been filled with the sounds of poetry, music and laughter were now deadly silent. The poisonous gas constricted people's throats and choked their lungs to the point of bursting. Their bodies contorted and writhed in pain, and their eyes were swollen and burning. Most died before they could reach their homes or hospitals.

Nobody from the Union Carbide plant would give any information on the poisonous gas or how to treat the victims. Nobody knows the exact death toll, but it is estimated that about 8000 died in the first three days. At least 10 000 more have died in the years since then, and it is estimated that 10 more die every month due to exposure-related diseases. Many of those who survived suffer from acute breathlessness, brain damage, menstrual irregularity and loss of immunity. One journalist called it 'chemical AIDS'. There is now a third generation of victims who also suffer from genetic abnormalities. These are the children of parents born after the gas leak. The survivors are still struggling for even the most basic medical help, let alone economic and social support.

Children awaiting cremation, Bhopal 1984. A crowd watches as a man pastes identification labels onto dead children's foreheads. So many thousands had died so suddenly that these sorts of drastic measures were necessary to identify and document as many bodies as possible.

Methyl isocyanate

The pesticide made in the Bhopal factory was called carbaryl (CAR-ba-ril). It is a complex molecule containing two carbon rings. It is built up atom by atom in a series of steps, as shown. The gas that caused the disaster is methyl isocyanate (MIC). It is made in Step 3, then used up in Step 4.



Union Carbide built the pesticide factory in Bhopal in the 1970s, thinking they could sell huge quantities of pest control products there. However, Indian farmers struggling to cope with droughts and floods did not have the money to buy the pesticides. The factory ceased active production in the early 1980s but there were still three tanks holding the deadly MIC.

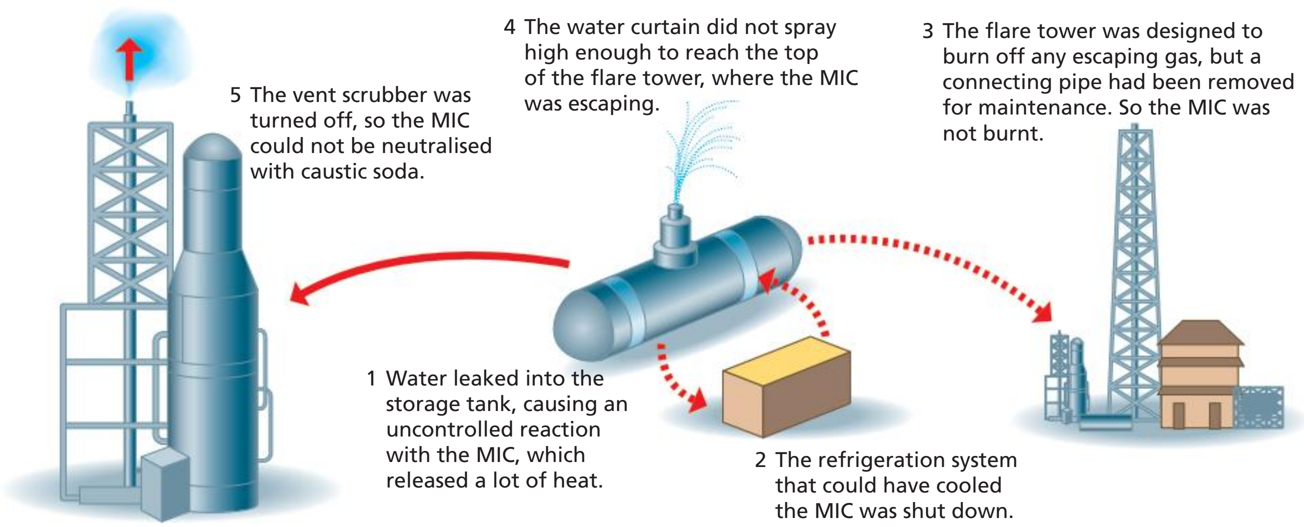
What caused the accident?

The factory had an elaborate safety system to prevent any MIC gas from escaping. However, to cut costs Union Carbide had not done any maintenance on these safety systems. A worker at the factory was flushing out a corroded pipe when several valves failed. This allowed water to flow into a tank of MIC, causing an uncontrolled reaction. At this point all the safety systems failed, as shown in the diagram below.

Who was to blame?

After the tragedy Union Carbide abandoned the factory, leaving behind dangerous poisons and a contaminated local water supply. They claimed that the gas leak could only have been caused by deliberate sabotage—someone purposely put water in the gas storage tank. In 1991 the local government in Bhopal charged Warren Anderson, Union Carbide's Chief Executive Officer at the time of the disaster, with manslaughter. He has never been brought to trial.

In 1989 Union Carbide agreed to pay $470 million in compensation. When this is divided among the many victims it is only $500–$600 per person—about enough to pay five years' worth of medical expenses. In 2001 Union Carbide was purchased by Dow Chemicals, the second largest chemical company in the world. They have continually claimed that they are not liable for the Bhopal accident. Union Carbide has already paid compensation, and that company no longer exists.



2004 hoax

On 3 December 2004, the 20th anniversary of the Bhopal disaster, a man claiming to be a Dow Chemicals representative was interviewed on BBC television. He said his name was Jude Finesterra and that Dow had agreed to fully compensate those harmed in the disaster and to clean up the Bhopal site. Immediately Dow's share price fell $2 billion. Dow quickly issued a statement saying they had no employee by the name of Jude Finesterra and that his claims were a hoax.

It turned out that Jude Finesterra was actually Andy Bichlbaum, a member of the activist prankster group 'The Yes Men'. Two years earlier The Yes Men issued a phoney press release and started up a website designed to look like the Dow website but giving their version of the Bhopal disaster. In 2004 the BBC emailed The Yes Men requesting an interview.

'Jude Finesterra' appearing on BBC television

Bichlbaum later explained how he came up with his fake name. Jude is the patron saint of impossible causes and Finesterra means 'the end of the Earth'. He carried out the prank to bring public attention to the plight of the Bhopal victims.

Over to you

Use the Bhopal case study to answer these questions.

Knowledge

1 Where is Bhopal?

2 How long ago did the disaster occur?

3 What was the Bhopal factory manufacturing?

4 Has the Union Carbide site in Bhopal been cleaned up?

5 Have the victims of the disaster been adequately compensated?

6 **a** What caused the leak of MIC gas from the Union Carbide factory?

b What are the symptoms of poisoning by MIC?

Understanding

7 How many people have died as a result of the Bhopal disaster?

8 Why didn't the safety systems designed to stop the escape of MIC work?

9 Look at the flow diagram on the previous page showing the manufacture of the pesticide carbaryl.

a Five different raw materials are used in the process? What are they?

b Are there any by-products of the process?

c What is the chemical formula of the poisonous gas phosgene?

d Name the elements in methyl isocyanate CH_3NCO.

10 The photograph below shows Greenpeace demonstrators on their way to Dow headquarters in The Netherlands with yellow barrels of 'hazardous waste'. What point are they trying to make?

Apply your knowledge

11 Dow Chemicals refuses to accept any moral responsibility for Bhopal. What does this mean?

12 What do you feel when you look at the photograph on page 232?

13 Why did Andy Bichlbaum choose the name Jude when he played his television prank?

14 Which of the seven viewpoints on page 220 are illustrated in this case study? Explain your answer.

10.5 Save the albatross

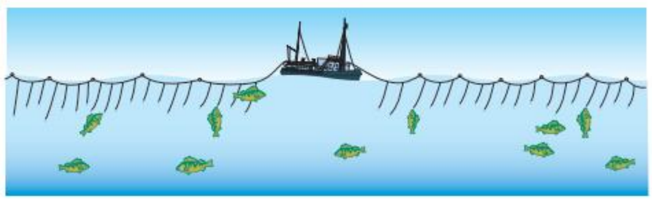
The photograph shows a wandering albatross, the largest flying seabird in the world. It is up to 3.5 m from the tip of one wing to the tip of the other. These birds live for up to 85 years and mate for life. Most albatrosses live in the Southern Ocean, spending most of their time riding the ocean thermals. They come ashore to lay eggs and rear their young on remote islands. The birds spend most of their life gliding over the ocean, usually returning to land only to breed.

Over the past 30 years albatross populations around the world have decreased rapidly. Numbers of the wandering albatross have halved, and some species are approaching extinction. The main problem that seabirds face is death caused by long-line fishing. More than 100 000 albatrosses and petrels may be killed every year in the Southern Ocean by illegal long-line fishing in excess of allowable limits and in protected areas.

Adult albatross and chick

Long-line fishing

Long-line fishing is a commercial technique that uses a line several kilometres long, held up by floats, from which hooks hang every few metres. There may be as many as 20 000 hooks on one line. The fishing boat runs along the length of the line, taking fish off the line at the front and letting the line out again at the back. Seabirds see the baits as an easy source of food and dive for them. Inevitably the birds catch the baits, are caught by the hooks, pulled underwater and drowned.



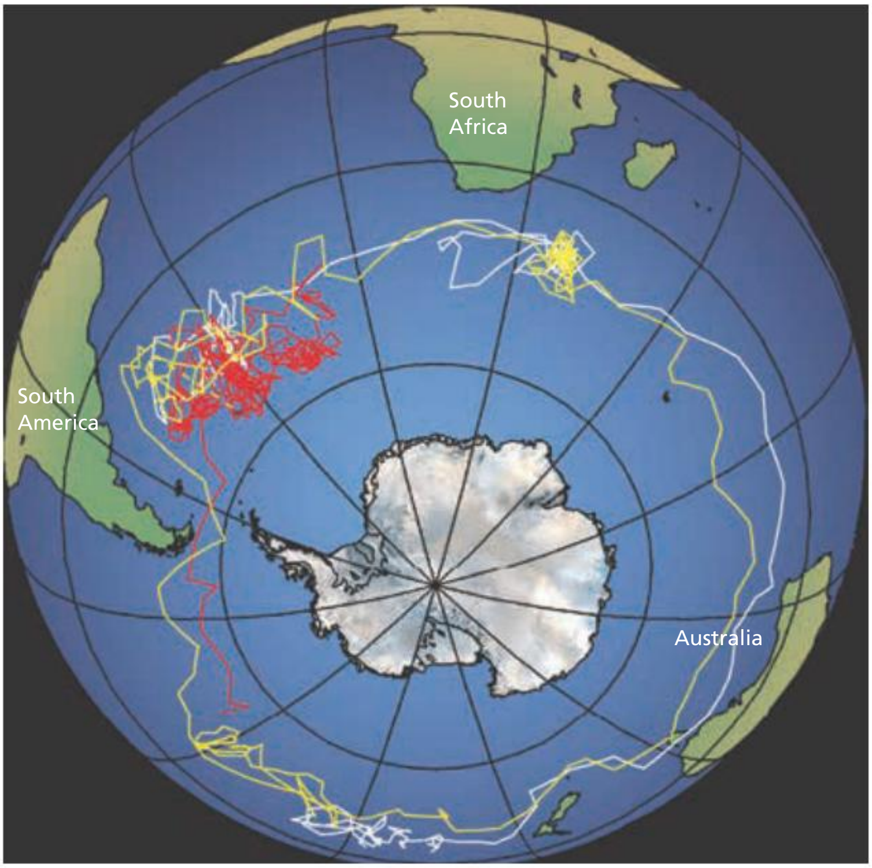
A drowning wandering albatross caught on a long-line hook

Satellite tracking

Scientists have developed radio transmitters smaller than a ballpoint pen that can be taped to the body of an albatross. The radio signals are sent via orbiting satellites back to tracking stations on Earth.

These studies have shown that the birds can fly up to 13 000 km on a single feeding flight. The map shows the movement of a grey-headed albatross over several years. It bred in South Georgia (off South America) in the summers (red lines) and migrated around the world in the winters (white and yellow lines).

In 2004 the British bookmakers, Ladbrokes.com, and the Conservation Foundation organised a Big Bird Race. They put radio transmitters on 18 Tasmanian shy albatrosses. Internet gamblers placed bets on individual birds and tracked them online as they migrated from Tasmania across the Indian Ocean to South Africa. The gamblers lost and won money, but the main aim of the event was to raise awareness of the danger of the magnificent albatrosses becoming extinct.



The path of a grey-headed albatross over several years

What can be done?

The following methods have been suggested to reduce the number of albatrosses being caught by long-line fishing.

1 Weight the lines so they sink quickly and the baits do not attract the birds.
2 Make sure the baits are properly thawed, as frozen baits float longer and attract birds.
3 Set the lines at night when the birds are not feeding, and keep deck lights to a minimum.
4 Set up bird-scaring lines made of multi-coloured plastic streamers. (This is already the law in Australia and New Zealand.)
5 Stop illegal fishing.

These methods are not expensive to implement. They are also in the interests of the fishing industry, as they obviously want to catch fish, not birds. However, the fishing industry seems reluctant to change.

INQUIRY 5 *Your ideas*

Do this activity in small groups.

1 Which of the five methods listed above do you think would be most effective in reducing the number of albatrosses caught by long-line fishing? Order them from most effective to least effective.
2 Brainstorm other ideas to solve the problem. Once you have a list, discuss the ideas and pick the most promising one.
3 Suggest ways of getting the fishing industry to change.
4 Suggest ways of cutting down illegal fishing.

10.6 Global warming

Carbon dioxide (CO_2) makes up less than 0.04% of the Earth's atmosphere. It is a greenhouse gas and keeps the Earth warm by trapping infra-red heat radiated from the Earth's surface in the atmosphere. However, scientists around the world have found that the levels of CO_2 in the atmosphere are increasing rapidly. This is mainly due to the burning of fossil fuels—coal, oil and gas.

INQUIRY 6 Cape Grim graph

The Bureau of Meteorology has a monitoring station at Cape Grim, on the north-west corner of Tasmania. In conjunction with CSIRO it has been measuring the concentration of CO_2 in the air since 1976. Here are their results for the last 25 years, showing the concentration in parts per million (ppm).

1 Plot this data on a graph with years on the horizontal axis. Choose a scale so that you can extend the graph to the year 2020.
   - What can you conclude from this graph?

2 Use your graph to predict what the concentration of CO_2 will be in the year 2015, and the year 2020.
   - Compare your predictions with those made by other students. How can you explain the differences?

3 The CO_2 concentration has a maximum and a minimum during the year. Suggest reasons for these changes.

Year	Average CO_2 concentration (ppm)
1987	344.7
1989	348.7
1991	351.5
1993	354.2
1995	357.4
1997	360.3
1999	365.0
2001	367.6
2003	371.6
2005	375.4
2007	379.4
2009	383.8
2011	386.9

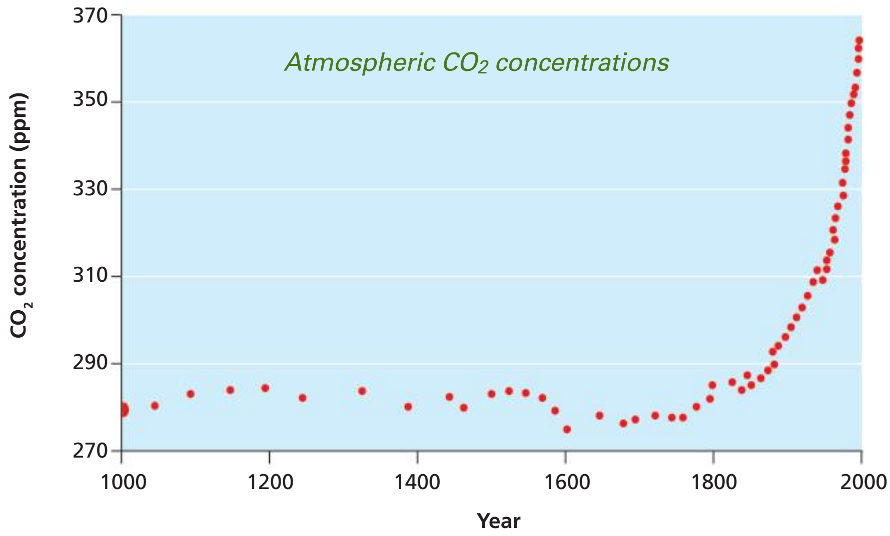
Cap Grim air pollution station

Antarctic ice cores

When the snow fell thousands of years ago on Antarctica, tiny pockets of air were trapped in it. The air that is trapped in ice deep below the surface is older than air in ice at the surface. Scientists have drilled deep into the ice in Antarctica and taken specimens. From these ice cores they have been able to infer CO_2 levels and changes in temperature for the last 400 000 years. These results show that when CO_2 levels rise, so does the temperature. The graph on the next page shows the atmospheric CO_2 concentration during the past 1000 years. For most of this time it has been fairly constant, but it has increased dramatically in the last 200 years.

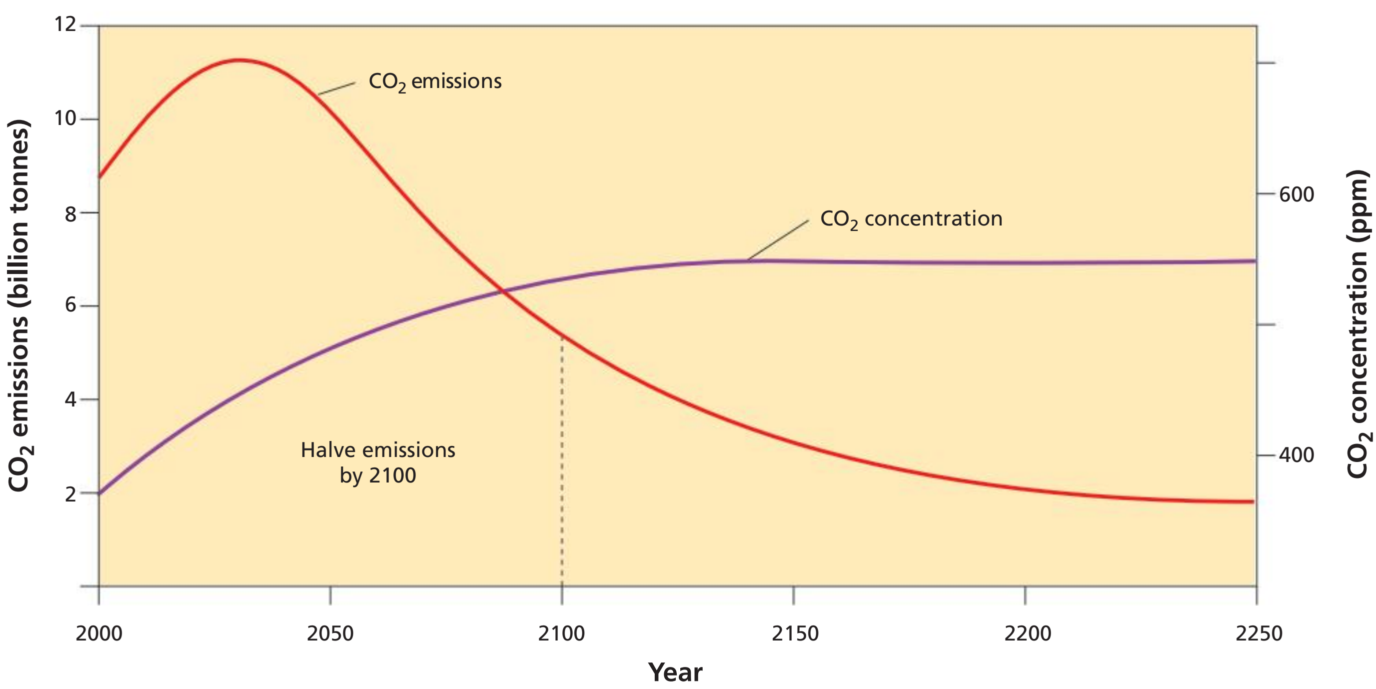
Scientists collecting ice cores in Antarctica

Using complex computer models, scientists have predicted that temperatures around the world will increase over the next 100 years. During the 20th century the world's average surface temperature increased by about 0.6 °C. However, by the end of this century, temperatures could increase by between 1.4 °C and 5.8 °C. This may seem a small change but during the last ice age it was only 5 °C cooler than it is now.

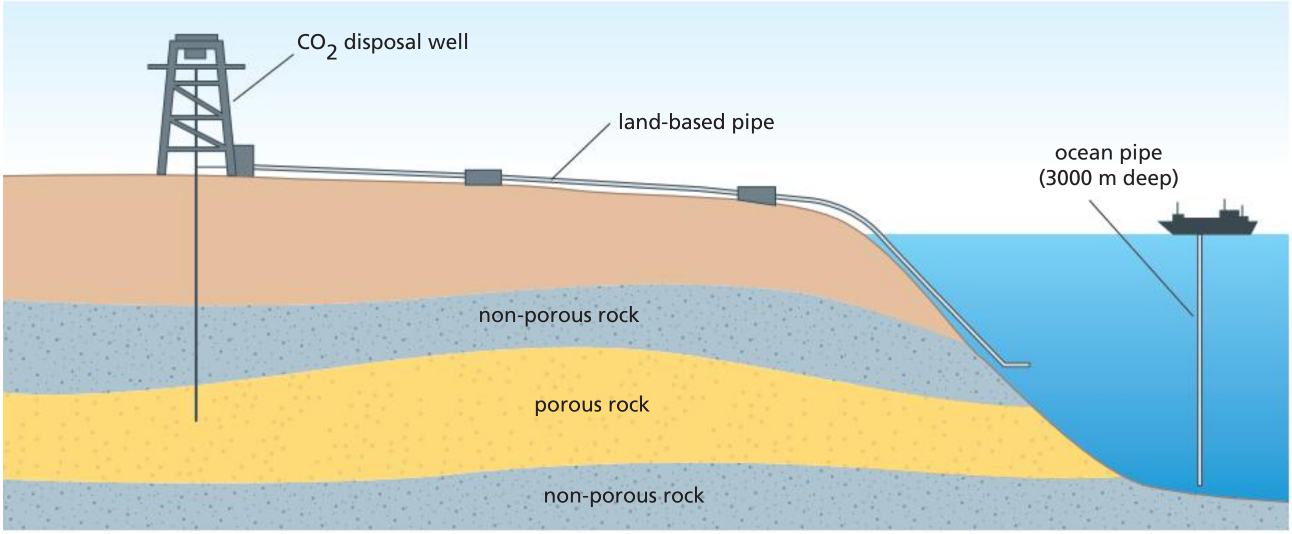


What can be done?

In Australia we produce, on average, 18.5 tonnes of CO_2 per person per year. Other developed countries produce similar amounts. The Kyoto Protocol, which came into force in 2005, is an agreement to reduce emissions of greenhouse gases (including CO_2) to about 5% less than what they were in 1990 by the year 2012. However, these reductions almost certainly will not be enough to stop global warming. CSIRO scientists have estimated that if we could *halve* world emissions of CO_2 by the year 2100, then we could stop CO_2 levels rising above 550 ppm, as shown in the graph below. Even then they estimate that global warming would be 1.5–3.0 °C.



The purple curve shows predicted CO_2 levels if we continue as is. The red curve shows the predicted levels if we halve emissions by 2100.



In carbon sequestration captured CO_2 is dumped deep undergroud or under the ocean.

There is considerable discussion on how CO_2 emissions can be reduced but there are no easy solutions. The biggest problem in Australia is that most of our electricity is generated by burning coal, which produces huge quantities of CO_2. The technology already exists to separate CO_2 from the gas emitted from power stations and factories. However, this is an expensive process and electricity bills could rise by 50%.

The captured CO_2 could be liquefied and stored. It could then be pumped deep underground and stored in geological formations such as empty natural gas reservoirs, as shown above. It may also be possible to pump the CO_2 into the ocean.

Growing trees

Carbon dioxide released into the atmosphere does not stay there forever. The natural processes of the carbon cycle remove the CO_2 from the atmosphere. Trees absorb the CO_2 and convert it into leaves and wood. The oceans also absorb CO_2. However, there is a limit to how much CO_2 plants and the oceans can absorb. So, all around the world there are programs to plant more trees to soak up the excess CO_2 in the atmosphere. This has led to the idea of *carbon credits*.

Suppose a power station somewhere in the world is producing more CO_2 than it is allowed to by law. In the future it might be possible for the power station to buy a carbon credit. It can then use this credit to plant forests somewhere else in the world, thus helping to reduce the CO_2 in the world's atmosphere. It is hoped that the high cost of carbon credits will encourage CO_2 producers to reduce their emissions. If a country cannot meet its target for CO_2 emissions, it could buy carbon credits from countries that are under their targets. In this way it may be possible to control CO_2 emissions throughout the world. Australia is currently introducing a price on carbon, to be replaced by an emmissions trading scheme in a few years.

INQUIRY 7 Planting trees

In this activity you will work out how many trees need to be planted to absorb the CO_2 produced by your family car in one year.

1. Find out approximately how far your family car travels in a year. If you do not know, say 20 000 km.
2. Calculate how much fuel the car uses to travel this distance. To do this you need to know the fuel consumption of the car (e.g. 12 km/L).
3. Calculate how much CO_2 the car releases in one year. Each litre of fuel used by a car releases 2.36 kg of CO_2.
4. How many trees would need to be planted to absorb the CO_2 produced by the car in a year? It has been estimated that 1 hectare of growing trees (1000 trees) absorbs about 20 000 kg of CO_2 in a year.
5. Apart from the car, many of the things you use and do each day produce CO_2 at some stage of their production or manufacture. Make a list of things that would produce CO_2.
6. How many trees would you need to plant to absorb the 24 tonnes of CO_2 each person produces each year?

You may be able to participate in a tree-planting program in your area.

INVESTIGATION

3 Global warming

Choose one of the following questions to investigate.

1 *How can you demonstrate the greenhouse effect in the laboratory?* You need to show how a cover of glass or plastic causes the temperature to increase. For example, you could use two identical containers, such as juice cartons, one with a window and one without.

2 *If global temperatures increase, the oceans will also warm up. Will this cause a rise in sea level?* You need to design a way of showing whether water expands as it warms up. Any change in volume may be quite small, so you will need to work out a way of showing this change.

3 *Any warming of the oceans could cause icebergs to melt. Would this cause a rise in sea level?*

Once you have designed and carried out an experiment to answer one of these questions, try to explain your observations. Write a report of your experiment using the usual headings.

INVESTIGATION

4 Carbon dioxide in the air

Aim

To compare the amount of CO_2 in normal air, air you have exhaled, car exhaust gas and pure CO_2.

Risk assessment and planning

Read the investigation carefully to check for any safety hazards.

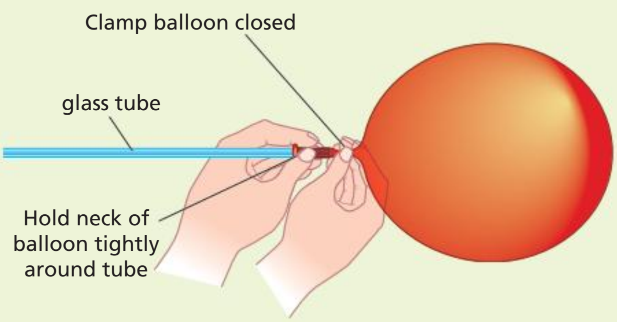
Apparatus

- *dilute hydrochloric acid*
- 4 different coloured balloons
- bromothymol blue indicator
- measuring cylinder (25 mL)
- dilute ammonia solution
- conical flask or bottle
- ruler
- glass tube (20 cm)
- bicycle pump
- 5 test tubes
- test tube rack
- marble chips

Method

1 Add 15 mL of water and 10 drops of bromothymol blue to each test tube. Label the tubes A, B, C, D and Control (to which no gas is added).

2 Label the four balloons A, B, C, D. Use a bicycle pump to add normal air to balloon A until it has a diameter of 10 cm. Hold the balloon closed above its neck.



3 Put the glass tube into the neck of the balloon, then hold the neck tightly around the tube with the fingers of your other hand.

4 Place the other end of the tube into the solution in test tube A. Release your fingers holding the balloon closed, but continue holding the tube in the balloon. Gently squeeze the balloon so that the gas bubbles *slowly* through the solution.

5 Repeat the procedure with the other balloons and test tubes, using the same glass tube.

B (exhaled air): Blow into the balloon.

C (car exhaust): Your teacher will fill a balloon using a filter funnel and give it to you.

D (pure CO_2): Put a few marble chips in a flask and cover them with dilute hydrochloric acid. Let the mixture bubble for a few seconds to drive out the air, then slip the balloon over the neck of the flask to inflate it.

6 Compare the colours of the solutions in the four test tubes, to that of the control. If the colour has changed from blue to yellow, then carbonic acid is present. It is formed when CO_2 dissolves in water.

7 You can make your results more quantitative by neutralising the carbonic acid with dilute ammonia solution. To do this count how many drops of ammonia you need to add to each test tube to change the colour back to blue.

✻ Which balloon contained the most CO_2? The least?

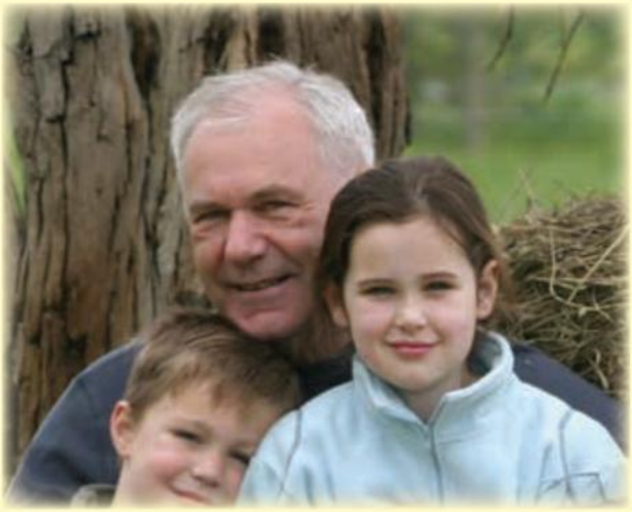
Write your report

Write a report, making sure you explain your results and suggest how you could improve your method.

SCIENTISTS AT WORK

Professor Graeme Pearman

Graeme Pearman went to school and university in Western Australia. In 1971 he joined the CSIRO Division of Atmospheric Research. A US scientist had made some measurements that suggested that CO_2 concentrations in the atmosphere were increasing and Graeme wanted to check these measurements for himself. To begin, he gathered air samples collected by commercial aircraft flying around Australia. Later CSIRO set up a monitoring station at Cape Grim to measure CO_2 and other atmospheric gases.



Graeme reasoned that if the burning of fossil fuels is the main reason for the increase in CO_2, then CO_2 levels should be highest in those parts of the world where most burning was taking place—in the Northern Hemisphere. Also, levels of CO_2 should be lowest over the Southern Hemisphere where most CO_2 is absorbed by the oceans. He and his team developed computer models of the world's atmosphere to simulate winds and the movement of gases in the atmosphere. They were able to track the movement of CO_2 because different sources of CO_2 contain different proportions of carbon-14, which is radioactive, and carbon-13, which is not. They included in these models the absorption and release of CO_2 by the oceans. Using computer models, they were able to predict what would happen in the future if we continue to burn fossil fuels at our present rate. They also used Antarctic ice cores to infer levels of CO_2 during past ice ages.

Graeme and his team at the CSIRO estimated that the burning of fossil fuels worldwide releases about 6 thousand million tonnes of CO_2 into the atmosphere each year. Some of this is absorbed by plants and trees and some is absorbed by the oceans, but about half of it remains in the atmosphere. As a result the carbon cycle is unbalanced and CO_2 levels are increasing.

Asked about his work, Graeme replied 'Doing science is perhaps the most satisfying thing I can imagine one could do. You are trying to find out things about the natural world that no one else understands. Thus when you get an answer, there is a huge buzz. *I've done it. I understand*. On the other hand, few scientists become wealthy and there are times between discoveries where one can become very frustrated. But on balance, this is a great career choice'.

In his position as Chief of the CSIRO Division of Atmospheric Research, Graeme worked hard to tell the general public about climate change. He is very keen that something is done now to prevent major changes to our climate in the future. This is why he is involved with the community organisation called Greenfleet. Its aim is to educate people about climate change and to organise tree-planting programs throughout Australia.

To date, Greenfleet members have planted almost seven million trees throughout Australia.

Checkpoint

Read the following article, then answer the questions below. It does not matter which case studies you have done.

1 What are carbon emissions?
2 Explain what you think is meant by carbon pricing.
3 Who do you think are the 'big polluters'?
4 Why is it that wind farms contribute only 'a smidgin of the electricity available on the grid'?
5 What is fossil-fueled electricity?
6 How does the production of a newspaper result in carbon emissions?
7 List the ways in which fossil fuels are used to make and operate a mobile phone.
8 Do you agree that 'it will be decades before renewable energy can provide electrical energy that your way of life depends upon'? Explain your answer.
9 In a sentence or two, sum up what Simon Grose is saying in this article.

Big Polluters R Us

The buck stops with 'ordinary taxpayers' when it comes to paying for carbon emissions.

Over winter you may find yourself travelling home in a tram reading a newspaper story about the debate over pricing carbon. You may be in a train, reading the story on an iPad or Blackberry. You could be in a car or a bus, listening to the issue being discussed on radio. When you get home you will probably turn on the heating, cook a meal or go out to a restaurant. You could flick on the box to find the carbon pricing debate still beating away, or use a computer to catch up with the debate online and check out Facebook.

When it comes to pricing carbon, one of the phrases you will have heard repeatedly is 'taxing the big polluters'. Sounds good: taxing large, unnamed monsters responsible for dirty deeds. Even better when you hear that the money raised will be redistributed to 'ordinary taxpayers'. Sitting in your train, tram, car or bus you catch glimpses of your reflection in the window framing the dark evening. You may recognise an ordinary taxpayer, but you may miss the background aura of those big polluters.

Your safe and uninterrupted tram or train journey will be dependent on fossil-fueled electricity unless it's a windy night when wind farms are contributing a smidgin of the electricity available on the grid. If you are reading a newspaper it would have been printed on a big press that sucks heaps of electricity, and then distributed around your state by trucks and planes.

If you are using a mobile device it is working because you charged it on the grid, while the data you are reading is available because it is stored on energy-hungry servers in air-conditioned data centres and beamed through the atmosphere on wireless networks powered by the grid. If you are travelling in a bus or car you are burning fossil fuel and your safety depends on the traffic lights and street lights along the way. The radio station you are listening to, the heating and lighting and cooking at home or at the restaurant, all come courtesy of fossil fuels, as do the television program and the receiver you watch it on, your computer and every website you may care to visit.

It goes on. The steel, silicon, aluminium and plastics that make up your vehicle and your electronic devices are only possible due to fossil fuels. Despite what its champions may claim it will be decades—if ever—before renewable energy can provide electrical energy with the heft and reliability that your way of life depends upon. So when you look to see for whom the fossil fuel burns, it burns for thee.

By Simon Grose, *Australasian Science* May 2011

PROBLEM SOLVING

Have you completed your case study? You can choose your own. Alternatively, you can extend one of the case studies in this chapter. For example, you could do Investigation 1 on page 223 or discuss the proposed Jabiluka uranium mine on pages 227–228.

11 The universe

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

Science Understanding

- describe the life cycles of stars, using terms such as supernovas, neutron stars, pulsars and black holes
- describe evidence supporting the Big Bang theory, including Hubble's observations and the detection of microwave radiation

Science as a Human Endeavour

- reflect on human attempts to search for extraterrestrial life
- recognise the significance of Stephen Hawking's work to our understanding of the universe

Science Inquiry Skills

- identify constellations such as the Southern Cross and Orion in the night sky
- apply a knowledge of space to write a plot for a science fiction movie

LITERACY FOCUS

antimatter
Big Bang
binaries
black hole
cosmology
Einstein
extraterrestrial life
galaxy
luminosity
Milky way
nebulas
neutron stars
nuclear fusion
protostar
pulsar
solar flares
solar prominence
sunspots
supernova
white dwarf

Focus for learning

We live on the third planet from the sun in our solar system. Our sun is just one among about 200 billion stars in our galaxy—the Milky Way. However, our galaxy is only one of perhaps 100 billion galaxies in the universe, separated by the vast distances of space.

The photo on the right was taken by the Hubble Space Telescope. It shows a speck of sky, about the size of what you would see if you looked through a drinking straw. It contains at least 1500 galaxies of different shapes and colours.

Imagine if you could travel through this part of the universe. What incredible sights would you see? Would you find planets like Earth? Would you find life on those planets?

PROBLEM SOLVING

Space trek

Many science fiction movies have been made about travelling through space. What are your favourite movies or TV programs about space?

Your task for this chapter is to write a plot for a science fiction, or space trek movie. Don't write the standard story about aliens attacking the Earth or wars in space. Instead, write an interesting story based on correct facts found in this chapter or from your research. You may want to develop characters and describe some of the scenes that will occur in the movie. You may be able to present your story to the class.

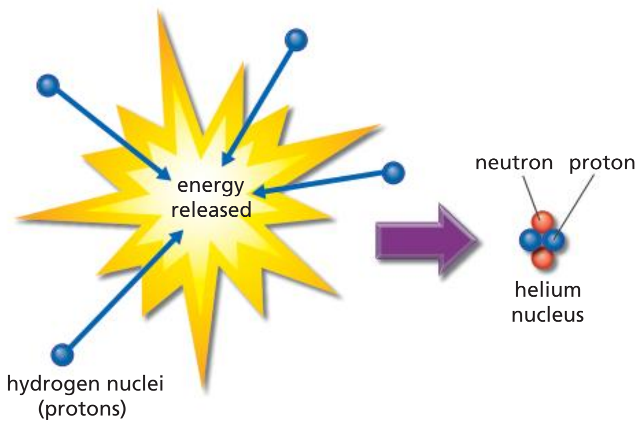
11.1 Our nearest star

The sun is a star, just like the other stars you see at night. The difference is it is much closer to us than the other stars. It is a huge ball of intensely hot gases. It is more than 100 times the diameter of Earth, and contains 98% of the mass of our solar system.

The sun is about 70% hydrogen and 28% helium. Heavier elements make up the other 2%. Because it is so huge it has enormous gravity. This gravity is strong enough to keep all the hydrogen and helium gases together, and to keep all the planets in their orbits around the sun. The sun has been giving out heat and light for more than 4.5 billion years, and will continue for another 5 billion years or so.

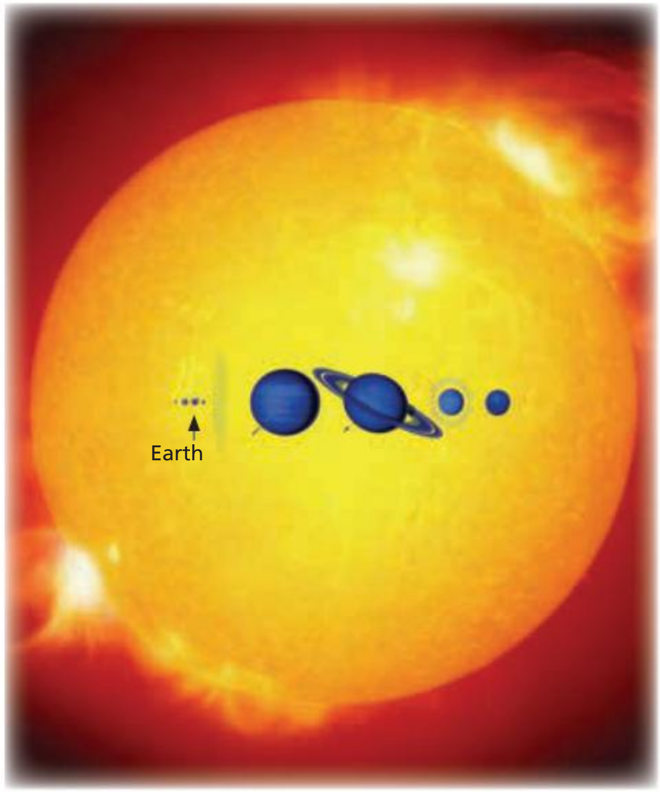
The sun doesn't 'burn' like gas burns. Instead it is like a gigantic nuclear reactor. In the centre of the sun, called the *core*, the temperature is 15 000 000°C. Hard to imagine isn't it! The pressures are also enormous. Under these conditions the electrons are stripped away from the atoms in the core, leaving positively charged nuclei which are moving rapidly. The hot gases are in the fourth state of matter called plasma.

When fast-moving hydrogen nuclei in the plasma collide with each other they undergo a nuclear fusion reaction. Four hydrogen nuclei (protons) react to form a helium nucleus as shown below. In the process an enormous amount of energy is released.



The nuclear fusion reaction that occurs in the sun

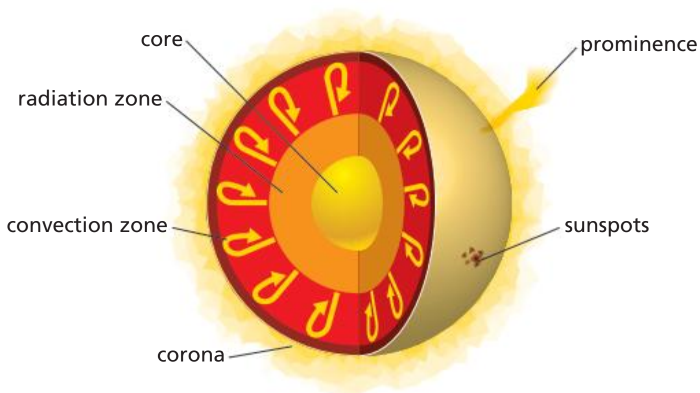
Every second about 700 million tonnes of hydrogen are converted into about 695 million tonnes of helium. The 5 million tonnes of mass that is lost is converted into energy, according to Albert Einstein's famous equation $E = mc^2$. E stands for energy, m for mass and c for the speed of light. Because the speed of light is such a large number



A photo of the sun showing the relative sizes of the Earth and other planets (but they are much further from the sun than this). Solar flares and prominences are explained on the next page.

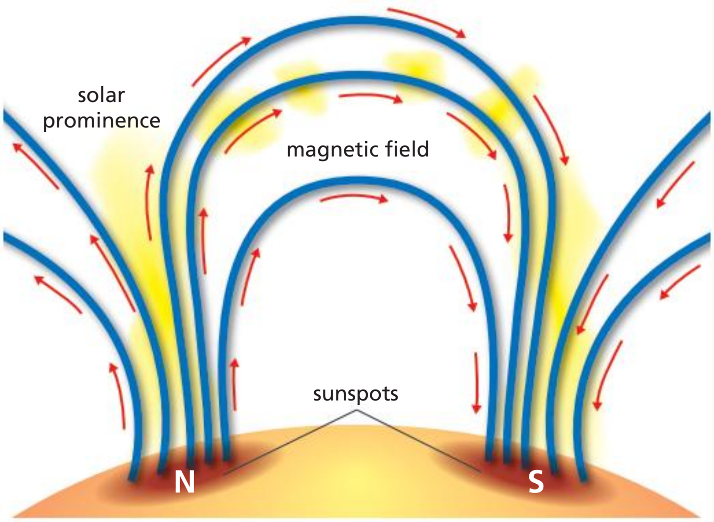
(300 000 km/s), a huge amount of energy is produced from a small mass. All the power stations in the world would take 7 million years to produce the energy the sun releases in 1 second!

The energy produced in the core radiates outwards through the very dense gases that make up the sun. As the energy gets nearer the surface of the sun it is transferred by convection rather than by radiation. This creates huge convection currents that boil up to the surface. The surface of the sun has a temperature of about 5500°C. It appears bubbly, or granulated, like the surface of bubbling soup.



The sun's stormy surface

The moving electrons in the plasma of the sun create electricity, and this generates very powerful magnetic fields. When these reach the surface, huge jets or loops of hot gas called *prominences* erupt into space. They can reach up to 400 000 km (more than 20 Earth diameters) above the sun's surface.



Dark, relatively cool patches on the sun's surface are called **sunspots**. These may be larger than the Earth. They form in pairs or groups, and occur where the magnetic field leaves and rejoins the surface. Rapid eruptions called **solar flare**s also occur near sunspots. Solar flares release huge amounts of radiation. They also release charged particles such as electrons and protons travelling at about 450 km/s. It has been estimated that more than a million tonnes of this material is released every second in what is called the *solar wind*.

Sunspot activity reaches a maximum (called a solar storm) about every 11 years. These solar storms affect the weather on Earth, and cause beautiful flickering patches of light in the sky near the Earth's poles. These are called *auroras*. The solar wind can also cause massive interference to radio communications on Earth. It can also cause power surges and blackouts. Our atmosphere protects us from the solar wind, but astronauts in space need to be shielded from it.

Around the sun is an atmosphere of hot gas called the *corona*. It is very hot (about 1 000 000°C) and extends millions of kilometres into space. It is invisible from Earth, and can only be seen when the moon blocks out the bright disc of the sun during a solar eclipse.

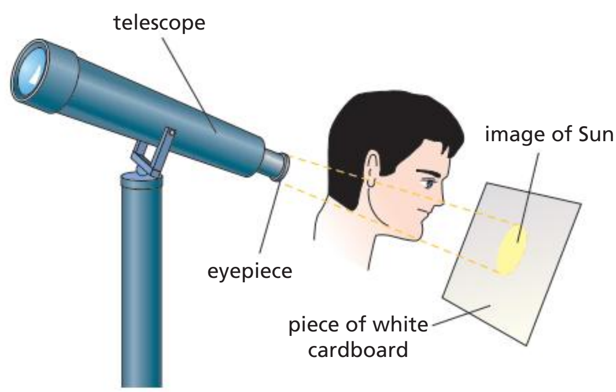
INQUIRY 1 *Observing sunspots*

This is a teacher demonstration.

You will need: telescope or binoculars, piece of white cardboard

1 A safe way to observe sunspots (and eclipses) is to project an image of the sun through a telescope or binoculars onto a piece of white cardboard as shown. If you are using binoculars, it is best to mount them on a tripod and to leave the cap on one of the tubes.

Caution: Never look directly at the sun through a telescope or binoculars. This can cause blindness.



2 On the cardboard you will see a bright circle of light. It is best if the cardboard is shaded from direct sunlight. The image will probably be blurred, so you will need to focus the telescope or binoculars to make it sharp. Can you see any sunspots? (It is possible to project the image of the sun onto a wall or screen using a mirror instead of the piece of white cardboard.)

Over to you

1 The sun is a star and the Earth is a planet. What is the difference between them?

2 A space vehicle sent from Earth could never reach the surface of the sun. Why not?

3 **a** Which two elements make up most of the sun?
b What is the state of the matter in the sun's core?

4 How is it that the sun can go on producing such huge amounts of energy? Will it go on forever?

5 **a** What is the solar wind?
b How does it affect the Earth?

6 Why are solar prominences and the sun's corona easier to see when there is an eclipse of the sun?

11.2 Galaxies galore

On a clear night away from city lights you can see a band of stars across the sky. This band, called the **Milky Way**, is our **galaxy**—a cluster of about 200 billion stars in a sea of gas and dust, all held together by gravity.

Until about 1900 astronomers thought the Milky Way was the whole universe, but in 1923 the American astronomer Edwin Hubble showed that the Andromeda spiral was actually another galaxy and *outside* the Milky Way.

From many different observations, astronomers infer that the Milky Way is a spiral-shaped galaxy. It is a vast disc with a bulge in the middle—a bit like two fried eggs back to back. Because we are inside the galaxy we can't see its shape properly. It's a bit like trying to estimate the size and shape of a house by making observations from a room inside the house. Our sun is about three-quarters of the way towards the edge of the galaxy. The whole galaxy is rotating in space, spinning faster at its centre.

The Andromeda galaxy

Light-years

To get an idea of the size of our galaxy, you need to talk in terms of light-years. This is the distance light travels in 1 year. Travelling at the speed of light, it would take 1.3 seconds to reach the moon and 8 minutes to reach the sun. The solar system is 12 light-hours across, and the nearest star (apart from the sun) is 4.2 light-years away.

The Milky Way galaxy is about 100 000 light-years across, and about 20 000 light-years thick in the centre. The Andromeda galaxy is 2.5 million light-years away. The furthest galaxies are about 10 billion light-years away. This means that the light from these galaxies has taken 10 billion years to reach the Earth. This means that we are seeing them as they were 10 billion years ago. When we look at them we are looking back in time!

Shapes of galaxies

Galaxies come in many different shapes and sizes. More than half of the known galaxies are *spirals*, but the spirals can be tightly wound or loose, while others have a broad bar across their centre. Some of the smaller galaxies have no obvious shape and are classed as *irregular*. The largest of all galaxies are *elliptical*. They are ball or egg-shaped masses of stars with no spiral arms.

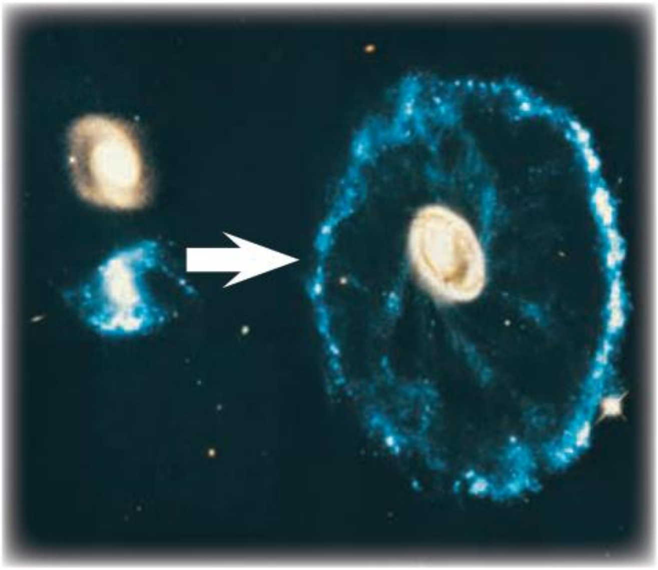
Centaurus A is an elliptical galaxy with a dark band of dust across it. This photo was taken by David Malin using the Anglo-Australian Telescope outside Coonabarabran in western NSW.

INQUIRY 2 Galaxy zoo

Use the internet to research the shapes and sizes of galaxies. Collect photos of the different types.

- Which is your favourite galaxy?

You could make a poster of your galaxy zoo to display in the classroom.



Astronomers infer that the Cartwheel galaxy is the result of a head-on collision between two galaxies—the yellow one and the blue one. Notice the spiral arms coming out from the yellow galaxy, like the spokes from the hub of a cartwheel.

A universe of galaxies

It is estimated that the universe contains about 100 billion galaxies. Each of these is like a gigantic island, separated from other islands by the vast distances of space. Galaxies tend to come in clusters. Some clusters contain just a few galaxies, others may contain thousands. The Milky Way galaxy belongs to a cluster containing about 30 galaxies, including Andromeda and the Magellanic Clouds, which can be seen with the naked eye near the Southern Cross (see page 255).

Nebulas

The space between stars is not completely empty. Here and there it contains faint wisps of gas and tiny pieces of dust. In some places these clouds become dense enough to be detected. They are known as **nebulas**.

One of the most spectacular nebulas is the Orion Nebula, in the handle of the Saucepan. We can see it because of the glowing stars in it. The smaller nebula at the top of the photo has no stars in it, but it reflects the light from nearby stars.

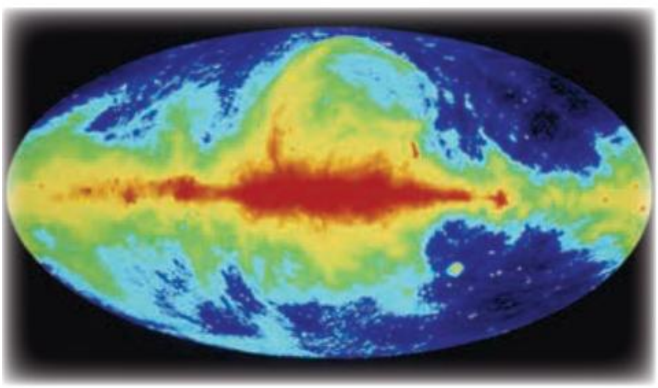
The Horsehead Nebula (also in Orion) is a dark cloud of gas and dust with nothing to make it glow. It can be seen through a telescope only because it blocks out the light from the bright nebula behind it.

Radio telescopes

As well as visible light, stars, nebulas and galaxies emit various forms of invisible radiation, such as radio waves, which have a long wavelength. Because these are not absorbed by the Earth's atmosphere, they can be detected on Earth during the day as well as at night, no matter what the weather.

Some of the furthest objects in the universe can only be detected by the radio waves they emit. The amount of energy emitted as radio waves is extremely small, so astronomers need the largest possible collecting dish. The bigger the dish, the more detail that can be collected. The largest radio telescope at Arecibo in Puerto Rico (an island in the Caribbean) is 308 metres in diameter. An alternative is to connect a series of smaller dishes to act as one. This is what happens at the Australian Telescope Array near Narrabri in western NSW.

Radio telescope array at Narrabri, NSW



The Milky Way galaxy has a magnetic field that produces radio waves which allow astronomers to map it. The most intense radio waves are shown in red, and indicate the bulge in the centre of the galaxy.

Telescopes in space

Telescopes on Earth are built well away from city lights and often on top of mountains where the atmosphere is thinner. In 1990 NASA used the space shuttle to launch the Hubble Space Telescope. Because Hubble is above the Earth's atmosphere, it produces images 10 times better than any from telescopes on Earth. It can also see objects 100 times fainter and further away. As a result it has revealed a vast new range of images from deep space, such as the one on page 244. The Hubble Space Telescope can detect ultraviolet and infra-red radiation, so it can 'see' objects that are invisible to our eyes.

The Hubble Space Telescope

Over to you

1. **a** Why are telescopes often built on top of mountains?
   b What advantages does a telescope in space have over a telescope on Earth?
2. Why is it that we see the Milky Way as a broad band of stars stretching across the sky from one horizon to the other?
3. **a** The brightest star in the Southern Cross is 320 light-years away. If you observe this star tonight, when did the light leave the star?
   b Does this star exist now? Explain your answer.
4. The star Rigel is 900 light-years from Earth. Do you think that it is part of the Milky Way? Explain your answer.

PROBLEM SOLVING

Have the first two sections given you any ideas for your space trek movie? Perhaps you could have an adventure near a star. Will your story be set in our galaxy, or will you leave the galaxy? You could measure how far you travel in light-years.

11.3 Stars

If you look at the night sky you will find that stars differ in brightness and in colour. Astronomers name stars according to their brightness, using the letters of the Greek alphabet. The brightest star in a constellation is called the alpha (α) star, the second brightest the beta (β) star, then gamma (γ), delta (δ) and epsilon (ε).

The brightness of a star depends on how close it is to us. This is why the sun is so much brighter than all the other stars. However, the brightness also depends on the size of the star. For example, the two Pointers near the Southern Cross appear about the same brightness from Earth. They are called α- and β-Centauri. However α-Centauri is only 4.4 light-years away, while β-Centauri is 525 light-years away. So obviously β-Centauri is a much bigger star than α-Centauri and produces much more energy. Astronomers calculate the **luminosity** of a star—the rate at which it produces energy, compared to our sun. The sun has a luminosity of 1. Stars that produce more energy than the sun have a luminosity greater than 1. Those that produce less energy than the sun have a luminosity less than 1.

Stars also vary in colour. Most are white or yellow and are similar to our sun. Others are orange, red or blue. For example, Rigel (RYE-gel), the brightest star in the constellation Orion (above the Saucepan) is blue. Betelgeuse (BET-el-gerz), below the Saucepan, is red. Aldebaran, the brightest star in the constellation Taurus, is orange. The colour of a star tells you how hot it is. Blue stars are the hottest, followed by white and yellow, with red the coolest.

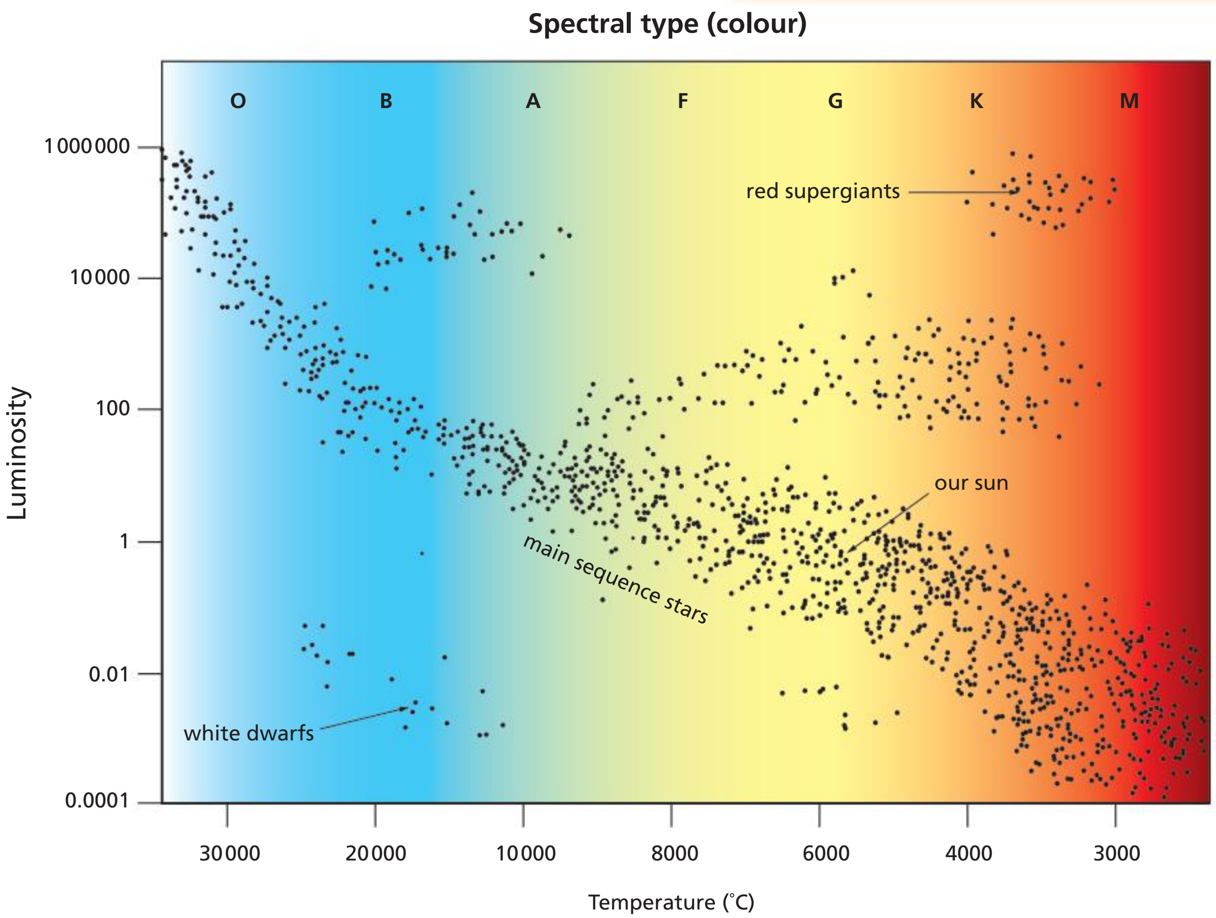
INQUIRY 3 Red hot–white hot

Teacher demonstration

You will need: iron bar, oxyacetylene torch, tongs

Heat the end of the bar, using the oxyacetylene torch.

- How does the colour change as the iron bar gets hotter?
- Which would be hotter—a red star or a yellow star? Explain.



If you plot temperature on the horizontal axis and luminosity on the vertical axis, most stars are on a diagonal band from top left to bottom right (see the graph on the previous page). These are called *main sequence stars*, and our sun is a typical star in the middle of this band. However, you will notice that some stars don't fit this pattern. For example, in the top right are the *red supergiants*. These are very large coolish stars. In the bottom left are the *white dwarfs*—small hot stars.

INQUIRY 4 Star types

Photocopy the graph on the previous page and plot the following stars on it.

Start	Spectral type (colour)	Luminosity
Mintake	O	3000
Rigel	B	50 000
Sirius	A	23
Sirius B	A	0.0025
Procyon	F	7.7
α-Centauri A	G	1.5
Aldebaran	K	360
Betelgeuse	M	55 000

1 Which of the stars you have plotted is a white dwarf?
2 What type of star is Betelgeuse? How many times brighter than the Sun is it?
3 What is the average temperature of a B-type star?
4 What is the colour of Aldebaran?
5 Which of the stars you have plotted are main sequence stars?
6 Which of the stars is most like our Sun (spectral type G)?
7 Is Mintaka larger or smaller than the Sun? Explain.
8 Which star would be hotter—Procyon or Betelgeuse? Explain.

Spectra of stars

White light is made up of all the colours of the rainbow. It can be split into its colours by a prism or a spectroscope. This produces a spectrum with blue at one end, red at the other and all the other colours in between. Red stars produce more red light than any other colour, and blue stars produce more blue light.

Astronomers have also found that the spectrum of a star has thin dark lines along it as shown at top right, as if some parts of the spectrum are missing. These lines are like the lines you get when you look at a hot gas through a spectroscope, as in Investigation 1 (next page). For example, if you look at a sodium flame you get a bright yellow line, rather than a rainbow of colours.

A star's spectrum (top) is a rainbow crossed by dark lines, while that of sodium gas (bottom) is dark with a bright yellow line.

Stars have cooler gases around them which absorb certain colours. So when the light from a star reaches Earth these colours are missing from its spectrum. If there is a dark line where the yellow sodium line should be, you can infer that the star contains the element sodium. So the absorption lines in the spectra of stars are like fingerprints for the various elements.

Birth of stars

Stars are being born and dying all the time throughout the universe. They are born inside dense, dark regions in space called molecular clouds, which are made up mainly of hydrogen gas. Gravity pulls the gas molecules together to form clumps that are denser than the rest of the giant cloud. This process can also be triggered by a shock wave from a nearby exploding star or intergalactic collision.

As a clump forms, its gravity starts to pull in gas and dust from the surrounding cloud. As the mass of the clump increases, the pull of its gravity increases and it attracts more material. The centre of the clump becomes very tightly packed. The particles jostle against each other and heat up. Slowly the clump gets hotter and hotter until its centre starts to glow. It is now called a *protostar*. When its temperature reaches about 10 million °C, nuclear fusion occurs and a new star begins to shine. Sometimes a protostar doesn't get hot enough for nuclear fusion to occur and it turns into a *brown dwarf*, which is invisible in ordinary light.

A number of stars are usually born at the same time, within the same cloud of gas and dust. Star systems with two stars, called *binaries*, are common. The whole process of star formation takes hundreds of thousands of years. However, once formed a star can shine for billions of years.

INVESTIGATION

1 Observing spectra

Aim

To use a spectroscope to observe spectra.

Risk assessment and planning

Read the investigation and do a risk assessment.

Apparatus

- hand spectroscope
- petri dish
- nichrome wire with a small loop in the end and a cork handle
- Bunsen burner equipment
- saturated solutions of sodium chloride and salts of other metals, e.g. copper, barium, strontium

Method

1 Go outside and hold a piece of white paper in bright sunlight. Look at the paper through the spectroscope to observe the sun's spectrum. **Never point the spectroscope directly at the sun.** How does the sun's spectrum compare with the spectrum from an ordinary light bulb or a fluorescent tube?

2 Dip the nichrome wire into some sodium chloride solution in a petri dish, then place it into a blue Bunsen flame. Use the spectroscope to observe the spectrum of the sodium flame.

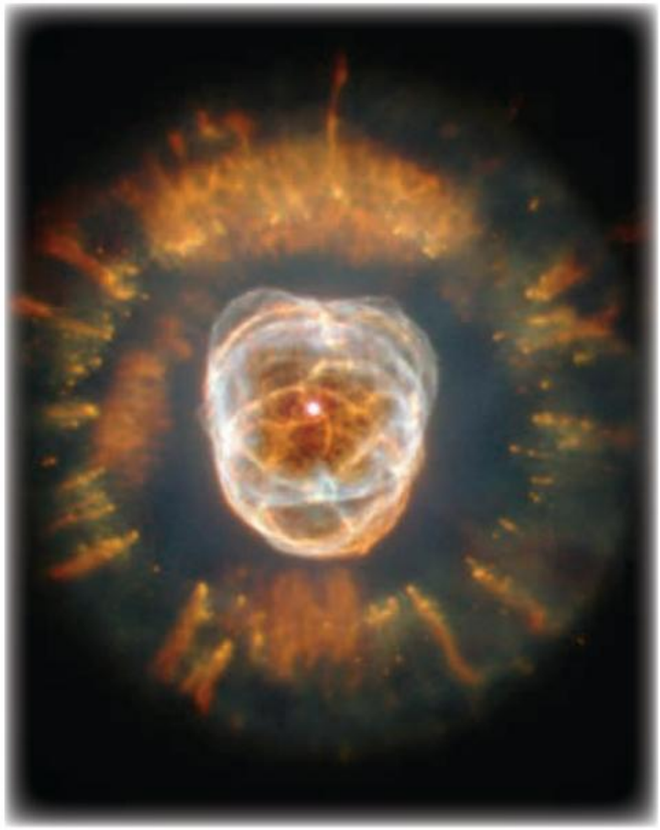
3 Repeat for the other metal solutions, set up at different places around the laboratory.

If astronomers discovered a new star, how could they find out which metals (if any) it contained?

Red giants

A star spends most of its life shining steadily, producing energy by fusing the hydrogen in its core. Eventually, after millions or billions of years, it uses up all the hydrogen and starts to die. The way in which the star dies depends on its mass. Main sequence stars like our sun die relatively quietly. Once the hydrogen is used up, the helium that is left changes to carbon. The star then swells to many times its original size and its surface gets cooler. It is now called a *red giant*. When this eventually happens to our sun in about 4 billion years time, the inner planets will be engulfed by the sun, and the Earth destroyed.

The outer layers of the red giant and the carbon in them are blown away to form clouds in space. New stars can form from these clouds. The expelled gas and dust form a swirling, ever-expanding shell around the white-hot remains of the star. It becomes one of the most beautiful sights in the heavens—a planetary nebula. (It is called this because it looks like a star with planets around it.)



The Eskimo Nebula, a planetary nebula, is so called because it looks like a face inside a fur parka.

The core of matter at the centre of a planetary nebula is only a fraction of the size of the original star. It is called a *white dwarf*. It is usually about the size of the Earth, but very much denser. The electrons in the atoms have been squashed into the nuclei of the atoms. Eventually the star stops producing light and heat and becomes a *black dwarf*, which we can no longer see.

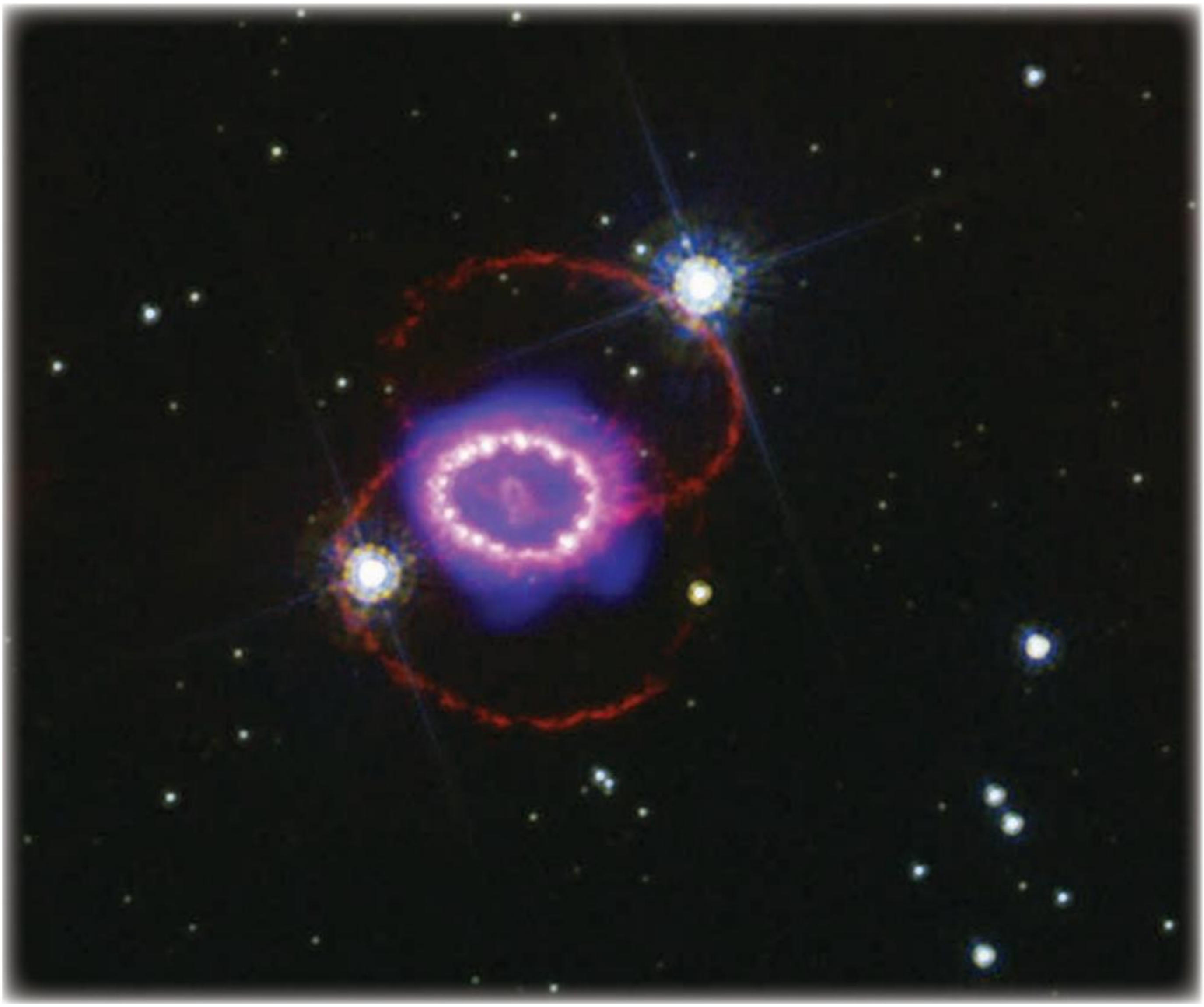
Supernovas

Stars more massive than the sun use up their fuel supply rapidly. Over a period of about 30 million years they swell up to become *blue supergiants*, and then *red supergiants*. Their core temperature is high enough to produce heavier elements such as magnesium, silicon and iron. When the nuclear reactions stop, the core and the outer layers of the star collapse. This process releases huge amounts of energy, causing a fantastic explosion called a **supernova** that rips the star apart. The supernova produces enough energy to trigger new fusion reactions. Astronomers infer that all the heavier elements in the universe were made during these explosions. So, when you see something made of silver or gold, remember that the metal was probably created in a supernova.

The Crab Nebula is the result of a supernova explosion witnessed by Chinese astronomers in the year 1054. It was estimated to be brighter than 100 million suns, and was visible even during the day.

Another supernova was witnessed in 1987 in the Large Magellanic Cloud. It is 170 000 light-years away, so the explosion occurred 170 000 years ago! The photo below was taken by the Hubble Space Telescope. Astronomers infer that the bright central yellow ring is gas ejected by the star before the explosion. They are not sure what the two red outer rings are. The two fuzzy white stars are between us and the supernova.

After a supernova, what remains is a **neutron star**. As gravity pulls the centre of the massive star in on itself, the atoms are crammed closer and closer together. The electrons collide with protons and form neutrons, and all that is left is an extremely dense mass of neutrons. A neutron star is usually about the size of a city, but has the mass of several suns. A spoonful of matter from a neutron star would weigh a billion tonnes!



Supernova photographed by the Hubble Space Telescope in 1987

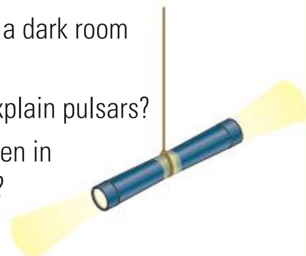
Pulsars

When she was only 24 years of age, Joselyn Bell was using a radio telescope to study a small white star in the Crab Nebula. She found it was sending out radio pulses thirty times a second. At first astronomers thought the only possible explanation was intelligent life in space, so the star was called LGM 1 (Little Green Men). However, astronomers eventually worked out that the strange star was a special neutron star called a **pulsar**. All neutron stars have a magnetic field and this produces two beams of radio waves, one from each pole. As the neutron star spins, these beams sweep around the star like light beams from a lighthouse, and appear to pulse on and off. Only if the beams hit the Earth do we observe the pulsar.

INQUIRY 5 A model pulsar

You will need: 2 pen torches, adhesive tape, string

1. Use the adhesive tape to join the pen torches back to back as shown.
2. Tie the torches to a piece of string and hang them up somewhere.
3. Now turn on the torches in a dark room and spin them.
   - How does your model explain pulsars?
   - Would your pulsar be seen in all parts of the universe? Explain.

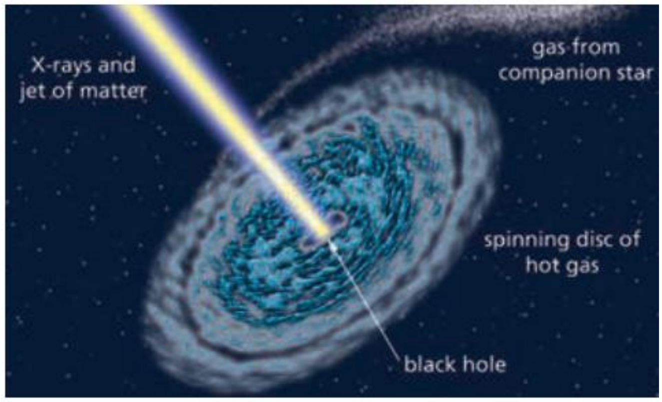


Black holes

The biggest stars have cores more than three times the mass of our sun. When the core of one of these giants collapses, it goes beyond the neutron star stage. Even the neutrons are squashed as the star is reduced to a point smaller than the point of a needle. The density and gravity are unimaginably huge. The immense gravity prevents anything, even light, from escaping, so what is left of the star is invisible. This is why it is called a **black hole**, even though it isn't a hole. The black hole swallows up any matter that comes near it. The more mass it has, the greater the effect it has on its surroundings. Some of the largest black holes are thought to have a mass 100 billion times that of our sun!

If black holes are invisible, how then do astronomers detect them? They can detect a black hole indirectly when it has a close companion star (a binary). The black hole's powerful gravity pulls matter from the companion star, and this matter forms a whirling disc around the black hole. Friction within this disc makes the gas incredibly hot. As a result X-rays and jets of matter shoot from the poles as shown. So astronomers can detect black holes by observing X-ray emissions and the behaviour of nearby stars. It is now thought that there is a black hole in the centre of our own Milky Way galaxy!

Black holes are probably the most frightening objects in the universe. If an astronaut was unfortunate enough to fall into a black hole, they would be stretched out long and thin like spaghetti and squeezed out of existence. So it would be wise not to get too close to a black hole.



Over to you

1. As the temperature of a star increases, what happens to its colour?
2. Two stars in the constellation Centaurus are called α-Centauri and β-Centauri. Can you tell from their names which star is closer to Earth? Explain your answer.
3. What is the difference between a star's brightness as seen from Earth and its luminosity?
4. Briefly describe how astronomers think our sun formed and how it will die.
5. Explain what a supernova is and what eventually happens to it.
6. **a** How is a black hole formed?
   b Why has nobody ever seen a black hole?
   c Could our sun become a black hole? Explain.
7. The radio waves from a pulsar look as though they are being switched on and off. But are they really pulsing like that? Explain.
8. Use a library to find out what a quasar is.

SKILL

Observing the night sky

The millions of stars in the night sky are all different. They are different colours, and they vary in brightness. They can also be grouped into constellations. If you know where to look you can see star clusters, nebulas and even galaxies.

Some of these objects in space can be seen with your own eyes. You need a clear night with no moon. Also, you will see many more stars if you can get away from city lights. Camping in the bush is a good time to observe the stars.

You will see more stars by using binoculars (7 × 50). To keep them steady, mount the binoculars on a camera tripod. You can also take photos of the stars by using a long exposure time. For example, the photo below shows the Southern Cross near the middle and the Pointers on the left. The dark patch just to the left of the Cross is a dark nebula called the Coal Sack.

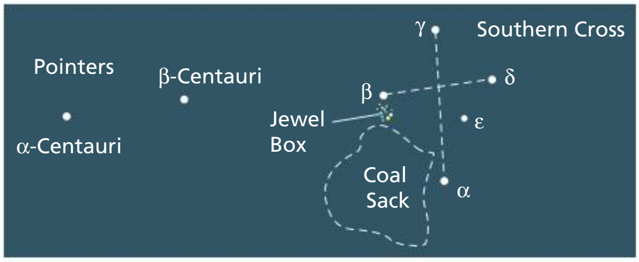
The school may have a telescope you can use and your teacher may be able to organise a star viewing night. You may even have your own telescope, or know someone who has.

To find your way around the sky it is handy to have a *sky chart* or map. The stars move throughout the year and during the night, so you need to set the chart for the date and time you are viewing. Sky charts are published in science magazines and on the internet.

Try to find the following objects in the night sky.

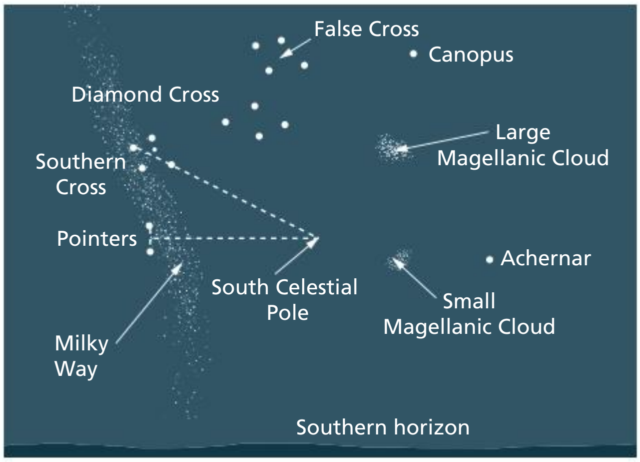
1 Southern Cross

There are five stars in the Southern Cross. α-Crucis (the brightest) is bluish-white. It is actually a binary—two stars orbiting each other. γ-Crucis is an orange colour because it is cooler than the other stars. Between α- and β-Crucis is a dark gap in the Milky Way. This is the *Coal Sack*—a cloud of gas that blocks the light of the stars behind it. Between the Coal Sack and β-Crucis is an open cluster of different-coloured stars called the *Jewel Box*.



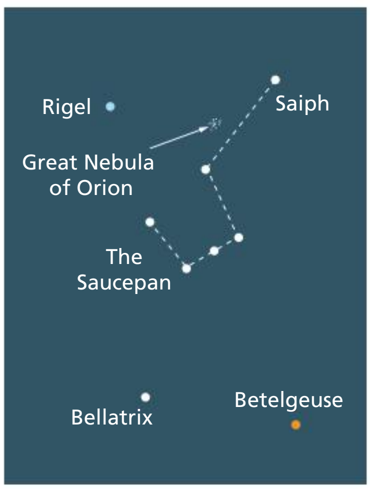
2 Magellanic Clouds

The Large Magellanic Cloud is the closest galaxy to the Milky Way. It is 160 000 light-years away and is estimated to contain 20 billion stars. The Small Magellanic Cloud is another galaxy further away. These galaxies are on the opposite side of the South Celestial Pole to the Milky Way. The diagram below shows how to find the South Celestial Pole.



3 Orion

In Australia the constellation of Orion is called the Saucepan. You can see it fairly high in the sky in summer and early autumn. Above the saucepan is the bluish-white star Rigel. Below the Saucepan is the red supergiant Betelgeuse. Near the middle star in the handle is the Great Nebula of Orion, which has a shape like a butterfly or an open fan when seen through a telescope.

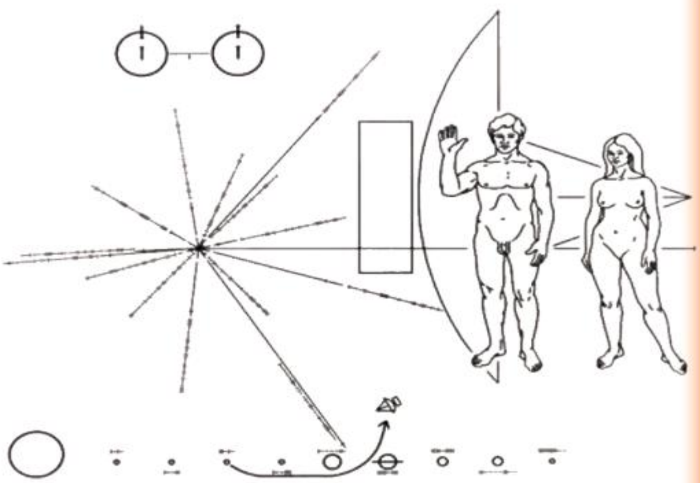


11.4 The search for ET

Is there life beyond the Earth; that is, **extraterrestrial life** (or ET)—as in science fiction movies? Some people have reported seeing 'flying saucers', which they believe come from other worlds. But so far there is no real evidence that beings or things from outer space exist, have visited Earth or tried to communicate with us.

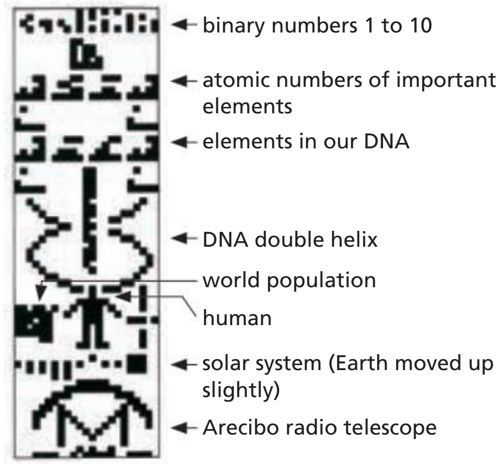
ET, from the Steven Spielberg movie of the same name

Pioneer 10, launched in 1972, was the first space probe to leave our solar system. It carried a plaque, which, it was hoped, could be interpreted by alien intelligences. The *Voyager* probes launched in 1977 carried a gold-plated record called *The Sounds of Earth* with instructions for use. As well as saying hello in 60 different languages, it also included music from different cultures and sounds made by various Earth animals.



The message plaque from Pioneer 10 shows the figures of a man and woman drawn to scale next to the space probe. At the bottom is a sketch of the solar system, showing Pioneer's path. The radiating lines represent the positions of 14 pulsars, with our sun in the middle. The two circles at the top represent a molecule of hydrogen, the most common element in the universe.

The trouble with space probes, however, is that they travel slowly. They are likely to travel for thousands, perhaps millions of years through space, but the distance they will travel is only a tiny way through our vast universe. Astronomers decided that a speedier way to send a message is to put it onto radio waves that travel at the speed of light. In 1974 they used the Arecibo radio telescope to send a message towards a cluster of stars 25 000 light-years away. The message consisted of 1679 ones and zeros in the pattern shown below. However, it will take the message 25 000 years to reach its destination.



INQUIRY 6 Communicating with ET

A Suppose the *Pioneer* space probe is intercepted by aliens on another planet.
- How could they work out where the probe came from?
- How would they know how big Earth people are? (Look at the plaque on the left.)

B Suppose the Arecibo message is received by aliens.
- How could they work out where the message came from?
- Which parts of the message do you think would make the most sense? Why?

C Design your own message for ET. In a group discuss what would be the most important things to tell them about ourselves and our world. How are you going to send your message? Will you use a space probe, or a radio message or…?
- Now design the message. Remember it needs to be fairly easy to decode (work out the meaning).
- Finally, try out your message on another group. Can they decode it?

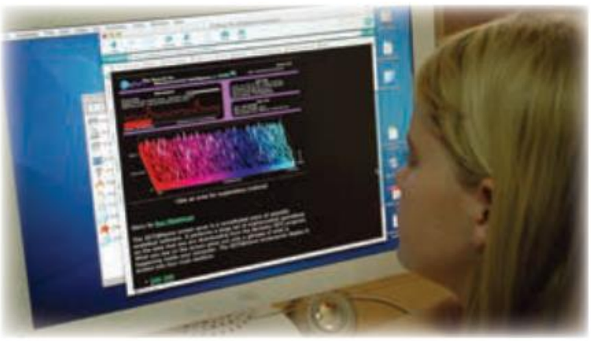
SETI

As well as sending out radio messages, astronomers around the world are involved in a **S**earch for **E**xtra **T**errestrial **I**ntelligence (SETI). They use radio telescopes such as those at Arecibo in Puerto Rico and Narrabri in NSW. They point the telescope at stars they think could have Earth-like planets orbiting them. Computers monitor more than a thousand of these stars and millions of different radio frequencies, since no one knows what frequency ET is likely to use. The search has been made easier by the internet, anyone can help to analyse radio signals from space.

INQUIRY 7 SETI at home

Use a computer to connect to www.setiathome.berkeley.edu. Then report to the class what you find out.

It is possible to download and install the program which acts as a screensaver. When you aren't using your computer it sorts through chunks of radio telescope data looking for possible signals from ET. When it has analysed a chunk of data it returns the results for SETI scientists to check, then downloads a new chunk of data. The program shuts down when you use the computer again, so while you are having a snack or sleeping, your computer will be helping in the search for ET.



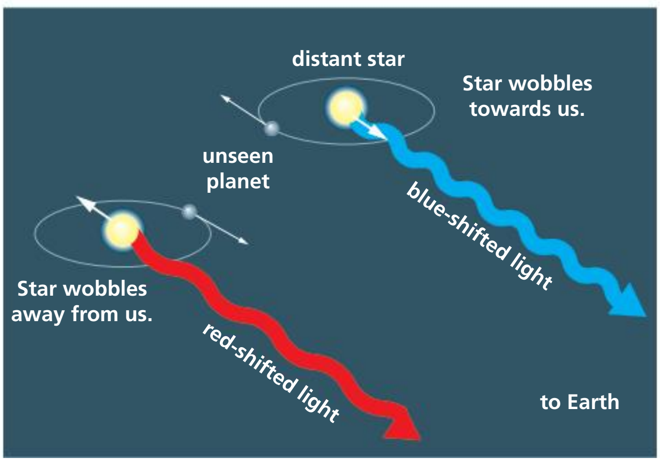
Hunting for planets

Since 1995 astronomers have found over 550 planets orbiting stars beyond our solar system. For example, in 2007 they discovered a planet near a cool red dwarf star called Gliese 581. This is 20 light years away. Astronomers estimate the planet is much bigger than the Earth, but closer to its sun than Earth is to our sun. So far six planets have been found orbiting Gliese 581.

Gliese 581g is the most likely planet so far discovered that might have life on it. In this artist's impression of the planet, the red dwarf sun can be seen setting on the horizon.

No planets outside our solar system have ever been observed directly by a telescope. They cannot be seen because of the brilliant glare from their suns. They have only been detected because their suns 'wobble'. As an unseen planet orbits a distant star, the gravitational forces cause the star to move back and forth slightly in space. This wobble creates a Doppler effect (just as happens with sound).

When the star is moving towards the Earth, the light waves from it are squashed together slightly. As a result the wavelength of the light emitted is shorter. The dark lines that you see in the spectrum (see p. 251) are shifted towards the blue end of the spectrum. This is called a *blue shift*. Similarly, when the star is moving away from the Earth, the waves are spread out and the wavelength is longer. The lines in the spectrum are shifted towards the red end. This is called a *red shift*. These changes in wavelength can be detected from Earth.

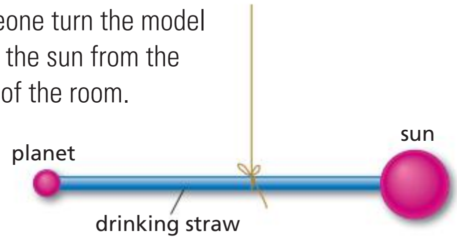


INQUIRY 8 **Wobbling star**

You will need: drinking straw, plasticine

1 Use plasticine to make a model of a star with one planet as shown. Make the star about the size of a golf ball, and the planet the size of a marble. Adjust the position of the string so the straw is horizontal.

2 Have someone turn the model and watch the sun from the other side of the room. Can you see a wobble?

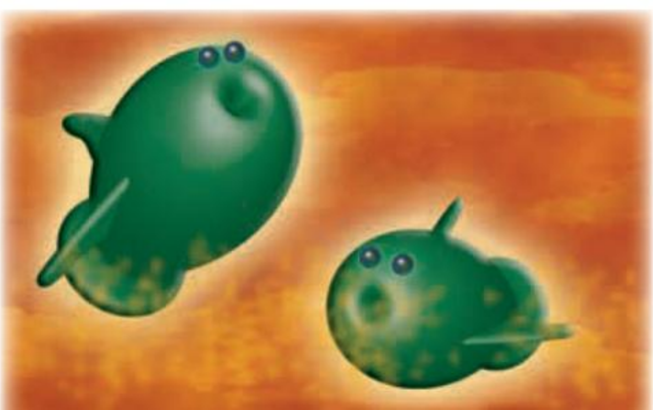


3 Hold a second straw vertically at arm's length between your eye and the spinning solar system. Can you see the wobble now?

Alien life

Nobody knows whether any of the planets being discovered by astronomers could support life of any kind. Astronomers believe that life is likely to exist only within a narrow range of conditions. These conditions are found in our solar system in a belt extending from just inside the orbit of Venus to just outside the orbit of Mars. Within this belt, the temperature range can be tolerated by living organisms (they think).

If there are aliens out there, what would they be like? There is no reason to expect life elsewhere to look anything like reptiles or insects or humans—even with minor adjustments such as green skin, pointed ears or antennae. Life on Earth is based on the element carbon, but life elsewhere could be based on a different element, such as silicon or boron. And instead of being based on water, which all life on Earth needs to survive, extraterrestrial life could be based on a different substance such as liquid ammonia.



Life forms anywhere would need to do some of the same things as humans. They would probably need to move about, sense their environment, eat and defend themselves. They would probably have a front and a back, but eyes, hands and so on could all be replaced by other parts. Also, these parts wouldn't necessarily be in pairs as they are in humans.

Any creature would also need to be adapted to its environment. For example, the drawing bottom left shows imaginary creatures that could live on a gas planet such as Jupiter. Like jet engines with eyes, they inhale hydrogen and other gases from the atmosphere through their mouths and move forward by expelling gases from the rear. The hydrogen gives them shape and holds them up in the atmosphere. Like whales eating plankton, they would take in material from the atmosphere as food. But would these creatures be intelligent, and would they be able to travel to other worlds?

Over to you

1 Suppose astronomers have just detected radio signals from a pulsar which is 1300 light-years from Earth.
   - **a** How long ago did the signals leave the pulsar?
   - **b** If the astronomers send a signal back, in which year will it reach the pulsar?
   - **c** What do your answers tell you about the difficulty of communicating with other civilisations?

2 Design an alien that is adapted to life on one of the other planets (other than Jupiter) in our solar system.

3 Should we be trying to contact ET? Justify (give reasons for) your answer.

PROBLEM SOLVING

You should now have lots more ideas for your space trek movie. There are all sorts of stars you could visit—red giants, red supergiants, white dwarfs, neutron stars, pulsars … You might witness a supernova as a giant star explodes, or you might encounter a frightening black hole.

The characters in your movie could visit a planet orbiting a star many light-years from Earth. You might even encounter some form of extraterrestrial life. If you do, try to design your aliens to suit the conditions on the planet. Don't just copy something you have seen in a movie.

11.5 The Big Bang

The expanding universe

People once thought the Earth was the centre of the universe, but astronomers now say there really is no centre. The universe is as big as we can see. As we have looked further into space with better telescopes, we have had to increase our estimate of the size of the universe. For example, the Hubble Space Telescope is finding more and more distant objects, up to 14 billion light-years away.

In 1929 Edwin Hubble discovered that the spectra of light from most stars and galaxies had a red shift. From this it can be inferred that the galaxies are moving away from us. He also found that the further away a galaxy is, the faster it is moving away. The more distant ones are travelling at up to a quarter of the speed of light. These observations suggest that the universe is expanding. Just as the raisins in a cake that is being baked move further apart as the cake 'rises', so the galaxies in our universe are moving apart.

The Steady State theory

To explain the expanding universe, astronomers came up with two different theories. Fred Hoyle, a British astronomer, suggested that the universe has no beginning and no end. It has always existed and will always be much the same overall. As the galaxies move away from each other, new hydrogen is mysteriously formed in space. Eventually new galaxies are formed to take the place of those that are disappearing into the distance and dying out. This is called the *Steady State* theory.

Other astronomers had a different theory. They suggested that the universe started as a cosmic egg, so tiny that you cannot start to imagine it. This exploded to form the universe we know today. Hoyle used the description **'Big Bang'** to make fun of this opposing theory, and this name is still used.

INQUIRY 9 Expanding universe model

You will need: balloon and marking pen

1 Draw several galaxies on the uninflated balloon. Label one the Milky Way.

2 Blow up the balloon gradually and watch how the galaxies move.

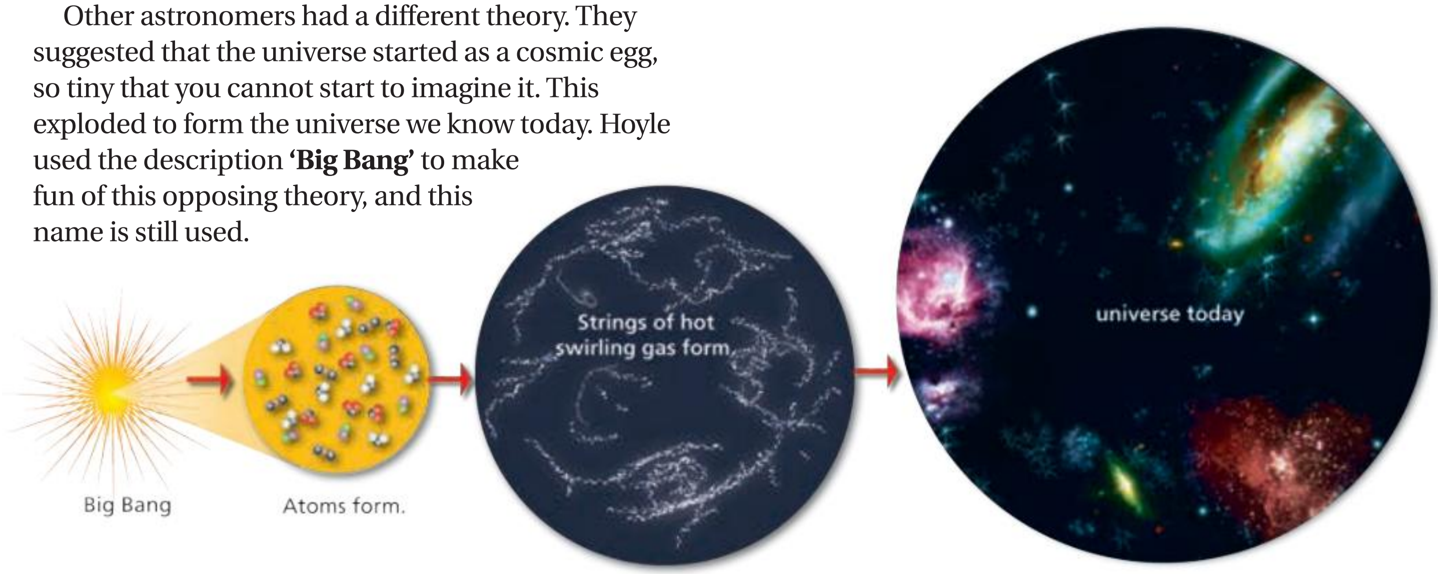
- How did the other galaxies move in relation to the Milky Way? Would your answer be different if you were in a different galaxy?

3 What happens to the 'universe' when you let the air out?

The Big Bang theory

Play a movie backwards and everything moves in reverse. Astronomers asked 'If you had a film of the expanding universe, what would happen if you ran it backwards?' They inferred that this film would show the galaxies rushing together to form a cosmic egg smaller than a pinhead. The furthest we have been able to see into space is about 14 billion light-years. We see these distant objects as they were 14 billion years ago. So astronomers infer these objects show us what the universe was like soon after it was created.

Before the Big Bang there was no space or time. Then the cosmic egg exploded. It was unbelievably hot, and energy was converted to matter and vice versa, according to Einstein's equation $E = mc^2$. Within a fraction of a second, the universe exploded outwards and became billions of times bigger.



It contained particles of matter and particles of *antimatter* (with charges opposite to those of ordinary matter). When particles of matter and antimatter meet, they annihilate each other, releasing a burst of light. A small excess of matter was left over and became the building blocks for today's universe.

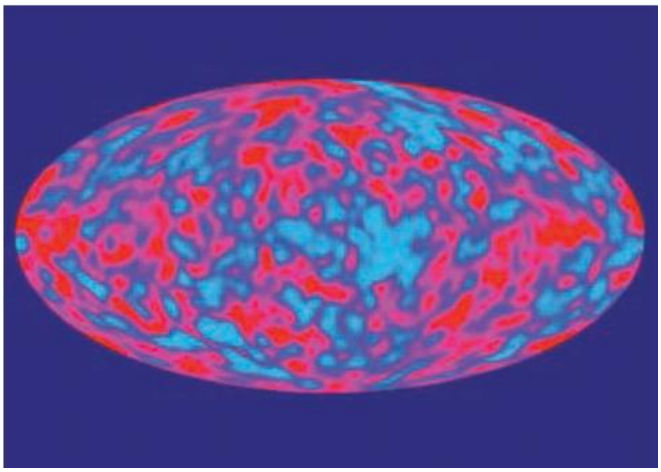
After one second, astronomers infer the universe had cooled to 10 billion °C. At this temperature sub-atomic particles called quarks began to clump together to form protons and neutrons. Eventually, after 300 000 years, the temperature of the universe had fallen to 3000°C. At this temperature the protons combined with electrons to form hydrogen atoms. They also combined with neutrons to form the slightly larger helium atoms. These are the two most common elements in the universe.

Strings of hot swirling gas clouds soon filled the universe, all expanding rapidly. Millions of years after the Big Bang, the first galaxies began to form. True galaxies like the Milky Way appeared after about a billion years.

Evidence for the Big Bang

In 1965 American physicists Arno Penzias and Robert Wilson were testing a sensitive new radio antenna. They found a strong background noise coming from all over the sky. They couldn't work out what was causing the noise. They even cleaned the pigeon droppings off the antenna, but the noise was still there. Eventually they worked out that what they were hearing could be an echo of the Big Bang explosion from 14 billion years ago.

The **Co**smic **B**ackground **E**xplorer (COBE) satellite was launched to study this radiation. In 1992 it produced the map of the universe below. The warmer areas are pink and the cooler areas are blue.



Astronomers infer that the warmer areas are where the gas strings formed that would later become galaxies. Because the Big Bang theory predicted this background radiation, most astronomers think that the Big Bang theory is presently the best explanation for the origin of the universe.

How the solar system formed

Astronomers think the sun and its planets all formed at the same time—about 4.6 billion years ago. They were formed from a nebula. The nebula rotated in space, slowly getting more dense as its gravity pulled material in towards its centre. As the nebula contracted it became very hot. Most of the material condensed to form the sun in its centre, where it was hottest. As the nebula slowly cooled, the gases condensed around tiny particles of dust which stuck together to form larger and larger pieces. In this way the planets were formed around the central sun. See an artist's impression of how this happened, on page 243 (top right).

This explanation of the origin of the solar system is only a theory. Astronomers have never seen a solar system form. However, this is the best explanation they have, based on present observations.

The future of the universe

Astronomers are not at all sure about the future of the universe. It will depend how dense it is. Provided the universe isn't too dense, it will keep expanding forever. New stars will continue to form, but eventually all their fuel will be used up. The last of the stars will die and all life everywhere will come to an end. Everything will become incredibly cold.

If the universe is dense enough, expansion will eventually stop. Gravitational attraction between matter will pull it all closer together, just as gravity attracts objects towards the Earth. If this happens, the universe will become smaller and smaller, and hotter and hotter. Black holes will join together, sucking in more and more matter until the final 'Big Crunch' packs everything into a single black hole. This is a bit like what happened when you let the air out of the balloon in Inquiry 9.

The Big Crunch would be the end of the universe. But then again, perhaps not. One suggestion is that after the Big Crunch there would be another Big Bang and so on. This is the Oscillating Universe theory.

Time travel

The idea of travelling into the future or back into the past has always fascinated science fiction writers. Some scientists think time travel may be possible.

When we look into space we don't see objects as they are now. We see them as they were when light left them millions of years ago. So space and time are related. If we can travel backwards and forwards in space, why not backwards and forwards in time? In his Theory of Relativity Einstein suggested that space and time can be combined into *space–time*, which has four dimensions. Physicists think of space–time as something like a piece of sponge rubber—as in Inquiry 10.

INQUIRY 10 Space–time

You will need: piece of high-density sponge rubber, marble, steel ball

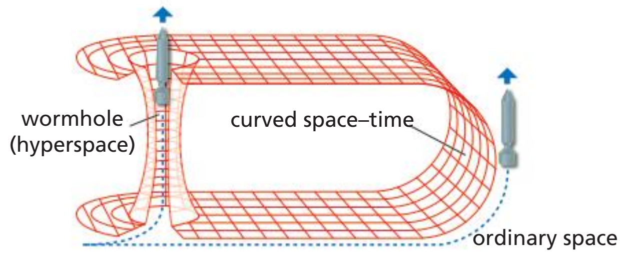
1. Roll the marble across the sponge rubber, which represents space–time.
2. Put the steel ball in the middle of the sponge so that it creates a depression around it. It represents a large mass in space, such as a star or a black hole. Watch what happens now when you roll the marble across the sponge.
   - What happens if the marble gets too close to the steel ball?
   - What happens if the marble just skirts around the edge of the depression? Does the speed of the marble make any difference?

Wormholes

Einstein said that because the universe is full of heavy objects, everything has to follow curved paths in space–time. We know Einstein was right about this because astronomers sometimes see a distant star that ought to be blocked by a nearer object such as the sun. Instead of travelling in a straight line, the light from the star bends around the heavy mass. This is like the marble curving around the steel ball in Inquiry 10.

Black holes have huge masses. They don't just make a depression in the imaginary sponge rubber of space–time. They make a tunnel that goes right through and opens out on the other side. This 'other side' could be somewhere else in space–time, either in the future or the past, or even in another universe! If you could take a spaceship through such a tunnel, or *wormhole*, you would have discovered the secret of space–time travel, as in *Stargate* or *Star Trek: Deep Space Nine*.

Einstein's Theory of Relativity says that you cannot travel at or beyond the speed of light. Even if you could travel at close to the speed of light, it would still take millions of years to get far into our vast universe. We therefore need shortcuts through space. Look at the diagram below, which shows a wormhole, leading to another part of space. Obviously, travelling through the wormhole (through hyperspace) would be quicker than travelling through ordinary space. While these ideas sound like science fiction now, who knows what will be possible in the future.



Over to you

1. What is a red shift? What does it tell you about how a star is moving relative to the Earth?
2. How are the galaxies in the universe moving relative to each other?
3. a What are the major differences between the Steady State and Big Bang theories?
   b What idea do the two theories have in common?
   c Which recent observation has supported the Big Bang theory?
4. Explain in your own words how planet Earth was formed.
5. There are three theories to explain the future of the universe. What are they?
6. What is the possible relationship between black holes and space–time travel?

PROBLEM SOLVING

If you are going to explore the far reaches of the universe in your movie, your spaceship will need some sort of warp drive or hyperdrive to enable you to travel faster than the speed of light. You may want to build your story around the idea of space–time travel.

SCIENTISTS AT WORK

Stephen Hawking

Stephen Hawking was born on 8 January 1942 in Oxford, England, exactly 300 years after the death of Galileo. At school he was a slow reader and some of his classmates did not believe he could do well in life, although they gave him the nickname of Einstein. He always wanted to study science, and when he was 17 he and some friends built a simple computer that worked.

Hawking went to university, but he found that he was always bumping into things. His hands trembled and he had difficulty tying his shoelaces. When he was 21, doctors told him he had motor neurone disease and had only two years to live. This disease destroys neurones in the brain and spinal cord that control muscles and allow movement, speech, breathing and swallowing. This bad news made him depressed, but he was determined to continue his research into cosmology—the origin and future of the universe. After his marriage his illness slowed down, and he was able to continue his studies. However he had to use an electric wheelchair.

Hawking is a theoretical scientist. Rather than working in a laboratory, he works with a computer. He spends his time explaining other scientists' observations. He develops theories and makes predictions for other scientists to test. He worked with Roger Penrose to show that Einstein's Theory of Relativity meant that space and time would have a beginning in the Big Bang and end in black holes. He then concentrated on black holes. It had always been thought that nothing could escape from a black hole, but Hawking suggested that under certain conditions a black hole could emit subatomic particles. This is now known as Hawking radiation. In 1979 he was appointed Lucasian Professor of Mathematics at Cambridge University, the position held by Sir Isaac Newton 300 years earlier.

In 1985 Hawking got pneumonia and doctors had to cut an opening in his throat to save his life. As a result he lost his voice. From then on he needed 24-hour nursing care. For a while the only way he could communicate was to spell out words letter by letter, by raising his eyebrows when someone pointed to the right letter on a spelling card. However, a small portable computer and a speech synthesiser were fitted to his wheelchair. By operating a switch in his hand he can manage up to 15 words a minute. Using this system, he has continued to give lectures and to write books.

In 1988 Hawking wrote *A Brief History of Time*, which explains the origin and future of the universe in simple terms. It sold 25 million copies and was made into a TV series. He appeared in an episode of *Star Trek: The Next Generation*, in which he played poker in the Holodeck with Commander Data, Einstein and Newton. He also made an appearance in an episode of *The Simpsons*.

Hawking has three children and travels throughout the world giving lectures. He once said: *I'm sure my disability has a bearing on why I'm well known. People are fascinated by the contrast between my very limited physical powers, and the vast nature of the universe I deal with.*

Questions

1 Why does Stephen Hawking need a wheelchair and a speech synthesiser?

2 What has Hawking contributed to our knowledge of science?

3 Hawking is a theoretical scientist. What does this mean?

4 Explain in your own words what Hawking's quotation above means.

THINKING SKILLS ?

1 Suggest why it was not until 1923 that the Andromeda spiral was found to be a galaxy and not a star.

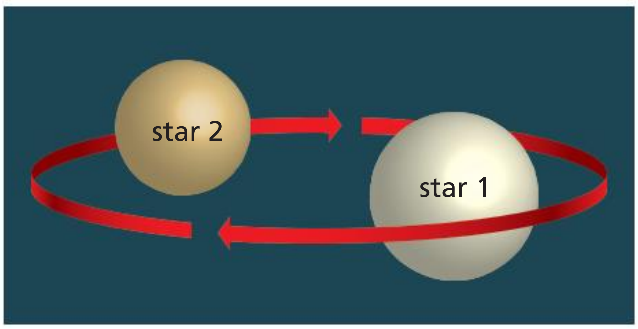
2 Supernovas were thought to be fairly rare events. Until the 1900s only three had been recorded. Now, however, a number of them are recorded each year. Suggest a reason for this.

3 Astronomers think that wherever you go in the universe it appears that you are in the centre of the universe. Suggest a reason for this.

4 Suppose you are looking up at a star in the sky and someone says to you ‘That star may not actually be there any more.’ Could they be right? Explain.

5 Explain how matter is recycled in the universe through the action of supernovas.

6 The diagram below shows a binary—two stars orbiting each other. Star 1 is the brighter star. When viewed from Earth, the brightness of the binary seems to change. Suggest a reason for this.



7 Imagine you live on a planet orbiting a star in the Andromeda galaxy, 2.5 million light-years from Earth. How would your view of the universe compare with the view you have from Earth?

8 If you were in a spaceship that travelled at 50 000 km/h, how long would it take you to travel from Earth to the other side of the Milky Way galaxy through the centre? (Remember that the sun is about 32 000 light-years from the centre and that the galaxy is about 100 000 light-years in diameter.)

9 Describe how you think the Milky Way would appear in the sky if our sun was:

a on the very edge of our galaxy instead of three-quarters of the way towards the edge

b in the centre of the galaxy.

10 If you made a model using saucers to represent galaxies such as the Milky Way and Andromeda, how far apart would they be in space?

11 In a group, discuss why we have not been able to make contact with extraterrestrials.

12 **a** Chinese astronomers observed an exploding star in 1054. This star is now called the Crab Nebula. It is 6300 light-years away. In which year did the star actually explode?

b The Crab Nebula has been observed expanding at a speed of 1300 km/s. How many light-years has the nebula expanded since the original supernova explosion was first observed?

13 How have scientists gained their knowledge of the life and death of stars if the processes involved take millions of years to occur?

14 How do astronomers measure the distances to stars? Use library research to find out.

15 Imagine you are walking through the bush and you find a spacecraft with markings on its side like the ones on *Pioneer 10* (page 256). Write a short story starting with ‘Hey Jack, look at these strange markings on the side ...’

16 View a science-fiction movie. Using the information in this chapter, make a list of things in the movie that are scientifically correct and another list of things that are incorrect.

Knowing and Understanding

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

1 Our sun is the closest star to Earth. Its heat and light are produced by nuclear ______ reactions. The sun's surface is stormy, with ______ and solar flares, which affect the Earth.

2 A ______ is a cluster of stars in a sea of gas and dust, held together by ______. There are billions of galaxies of various shapes throughout the universe. Our galaxy is called the ______.

3 Stars vary in colour and ______ (rate at which energy is produced). Blue stars are hotter than yellow stars which are hotter than ______ stars. The closer a star is to Earth the ______ it appears.

4 Stars are born in ______, which are clouds of gas and dust in space. When their nuclear fuel runs out their ______ tend to collapse and the outer layers are blown off into space.

5 A ______ is a collapsed star, whose gravity is so strong that nothing can escape, not even ______.

6 There may be extraterrestrial life on Earth-like ______ around other stars. Humans are attempting to make contact with ______ life elsewhere in the universe.

7 There are several theories to explain the origin of our universe, which is _____. The ______ theory says that the universe began as a massive explosion about 14 billion years ago.

Big Bang
black hole
brighter
cores
expanding
fusion
galaxy
gravity
intelligent
light
luminosity
Milky Way
nebulas
planets
red
sunspots

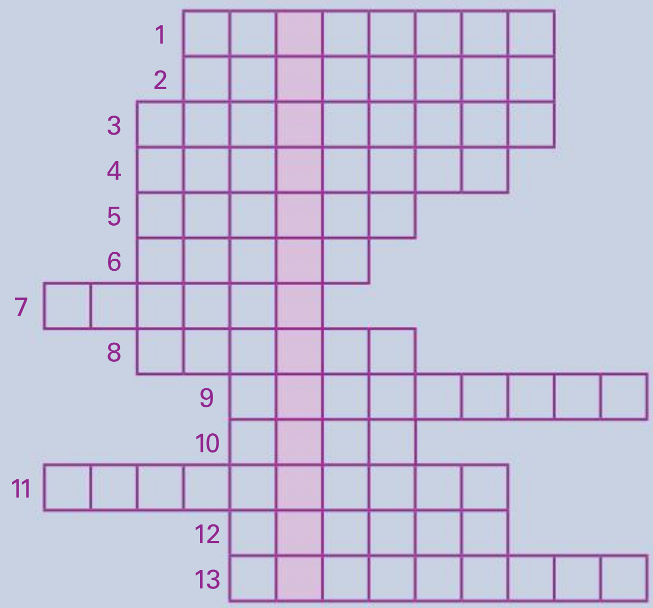
Self-management

Acrossword

Photocopy the Acrossword on the right and use the clues below to complete it. Some of the answers are two words. Then rearrange the letters in the blue column to create two words that tell you what causes the sun to shine.

1 Our galaxy
2 Scientist who invented the equation $E = mc^2$
3 There may be one of these in the centre of our galaxy
4 The fuel for nuclear fusion in the sun
5 Cluster of billions of stars held together by gravity
6 Constellation called the Saucepan
7 Subatomic particles created in the Big Bang
8 Birthplace of stars
9 Unit used to measure distances in space
10 Search for extraterrestrial intelligence
11 A storm or eruption of hot gases on the sun
12 Neutron star that sends out pulsing radio waves
13 Spiral galaxy nearest to Milky Way

Make your own Acrossword using words from the chapter not used here.



Checkpoint

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

1 Place the following in order, from the smallest to the largest:

cluster of galaxies	solar system
galaxy	star
planet	universe

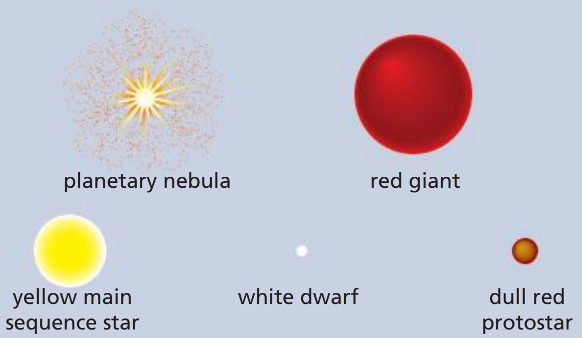
2 What you are really observing mostly when you look at the stars at night:

A planets **C** suns
B satellites **D** galaxies

3 Which one of the following is the most common element in the universe?

A hydrogen **C** carbon
B helium **D** water

4 The diagrams below show five stages in the life cycle of a star like our sun. Arrange the diagrams in their correct order.



5 The table below lists some bright stars, their colours and their temperatures. Use the table to answer the questions below.

Star	Colour	Surface temperature (°C)
Betelgeuse	red	3000
Aldebaran	orange-red	3700
Capella	yellow	5300
Canopus	white	7000
Sirius	blue-white	9000
Spica	blue	16000

a Antares is a red star in the constellation Scorpio. Predict its approximate surface temperature.
b Rigel has a surface temperature of 12 400°C. Predict its colour.
c Which of the stars is closest in colour and surface temperature to our sun?
d What pattern can you see in the table?

6 **a** What is the luminosity of a star?
b Explain why some stars appear to be very bright yet are known to have a low luminosity.

7 By observing the light from distant stars astronomers have estimated the speed at which the stars in the table below appear to be moving away from the Earth. Use the table to answer the questions below.

Star	Distance from Earth (light-years)	Speed (km/s)
Indi	11.5	270
Capella	46	1080
Fomalhaut	23	540

Which one of the following generalisations correctly summarises the data in the table?
A The closer the star, the greater its speed.
B The more distant the star, the greater its speed.
C All stars travel at about the same speed.
D There is no link between a star's speed and its distance from Earth.

8 Which of the following is true when you observe α-Centauri, which is 4.4 light-years away?
A You see the star as it is at the instant you look at it.
B You see the star as it was 4.4 years ago.
C You see the star as it was a few minutes before the light reached you because light takes some time to travel from the star to you.
D You see the star as it will be 4.4 years after you observe it.

9 Which of the following are true and which are false? Correct the false ones.
a The Doppler effect occurs only with sound.
b Stars moving towards us will have their spectrum shifted towards the red end.
c Stars further away from us are moving away faster than those closer to us.
d The universe is getting smaller.
e The wavelength of light from a wobbling star varies slightly.

10 Why is space travel to the nearest stars not the best way to discover extraterrestrial life in our lifetime?

11 Explain what the universe is in a way a young child would understand.

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 Using science

1 **a** True

b True

c False—inferring is when you try to explain your observations

d False—this type of test is called a *subjective test*

e True

f False—all except one of the variables must be controlled

2 **a** In each test Eddie was altering the brand of the hose.

b Possible answers could be:

Test 1: same car used, ensure hose is completely squashed in the same place under the tyre, time 20 minutes accurately, time how long it takes the hose to return to its original size accurately, test each hose at the same temperature.

Test 2: Ensure the hose is in a circle shape, ensure the circle is about 80 mm in diameter, test each hose at the same temperature.

Test 3: Roll each hose up in exactly the same way, keep each hose coiled for 24 hours at the same temperature, uncoil each hose, stretch it out and measure the length of it in the same way.

c Yes. Eddie did not have three trials and did not average his results. There could have been errors in timing in test 1, errors in measuring the diameter of the hose in test 2 and errors in measuring the length of the hose in test 3.

d Eddie's tests are probably not reliable. Others could repeat his procedure and probably not get exactly the same results. For example, how the hose is rolled up could make a difference. Errors in measurement will have affected his results.

3 **a** Brand B was the most effective as it only took 3 weeks to kill all the weeds.

b Brand C was the most ineffective because even after 4 weeks there were still 12 weeds that had not died.

c Than drew the correct kind of graph because a line graph shows how the number of weeds changed over the 4 weeks.

d The different brands of weed killers.

e Than appeared to control all the variables as well as she could. It would be very hard to get weeds that were exactly the same growing in a garden bed in exactly the same conditions.

f Yes, Than can make valid conclusions because she has designed a fair test with the variables controlled.

4 It is important to repeat the testing so that the results are more accurate. If you can repeat the tests and obtain the same results over and over again the results are more reliable.

5 The scientific method is a cyclical process because observations lead to hypothesis making, then testing, followed by hypothesis modification and further testing in a continuous cycle, as shown on page 8.

Chapter 2 Chemical reactions

1 **a** A precipitate was formed.

b Heat was produced.

c A gas was produced.

d There was a colour change.

2 D

3 **a** slows it down

b speeds it up

c speeds it up

d speeds it up

e slows it down

f slows it down

4 The fruit juice started to ferment. This was a chemical reaction which produced new substances. Some of these new substances were gases which caused the bottle to bulge.

5 The single page burns quickly because it has a greater area of paper in contact with the fire. The telephone book burns slowly because only the outside is in contact with the fire.

6 **a** exothermic (releases energy)
b endothermic (takes energy from your mouth)
c endothermic (needs light)
d exothermic (releases light, sound and heat)
e endothermic (needs electricity)

7 According to the law of conservation of mass, the total mass of the flask will not change. The gas produced stays in the flask.

8 Test **D** is the best design because Brandon has changed only the temperature of the water and kept everything else the same.
A The nail does not have time to rust as you heat the water.
B This is a fair design but involves only two temperatures.
C There is an uncontrolled variable (whether or not you use oil to keep out the air).

Chapter 3 The periodic table

1 **C**—it is made up of calcium ions and carbonate ions

2 **A**

3 **A**—since calcium has a valency of 2+ and iodine has a valency of 1–

4 **C**

5 **a** three—magnesium (Mg), sulfur (S), oxygen (O)
b magnesium ions Mg^{2+} and sulfate ions SO_4^{2-}
c ionic because it is made up of magnesium ions and sulfate ions

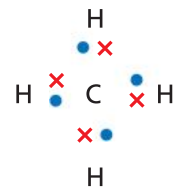
6 **a** C and G since they are in the same column (group)
b B and C, or D, E, F and G since they are in the same row
c B
d A
e E and F
f D
g D
h The reactive metals on the left (B and D) are likely to react with the non-metals on the right (C and G).

7 **a** False—since calcium carbonate and lead carbonate are insoluble
b True
c False—since calcium nitrate and calcium chloride are soluble
d True—since lead nitrate is soluble
e True

8 **a** calcium chloride + sodium hydroxide → calcium hydroxide + sodium chloride
(the ions swap partners, as on p. 65)
b $CaCl_2 + NaOH \rightarrow Ca(OH)_2 + NaCl$
c $CaCl_2 + 2NaOH \rightarrow Ca(OH)_2 + 2NaCl$

9 **a** lead ions (Pb^{2+}), nitrate ions (NO_3^-), sodium ions ($Na+$), carbonate ions (CO_3^{2-})
b If the ions swap partners, lead carbonate is formed, which is insoluble and forms a precipitate.
c $Pb(NO_3)_2 + Na_2CO_3 \rightarrow PbCO_3 + 2NaNO_3$

10 Carbon has four electrons in its outer shell and hydrogen has one. By sharing electrons with four hydrogen atoms, the carbon atom has a full outer shell of eight electrons (see pp. 55–56).



Chapter 4 Using chemistry

1 **D** (see p. 83)

2 **B**—is the most reactive metal (see activity series on p. 78)

3 **A**—there must be two different metals (electrodes) in a liquid that conducts electricity (electrolyte)

4 **C**—to electroplate the nail with lead, the positive electrode needs to be lead and the electrolyte needs to contain lead ions, which lead nitrate does (see p. 89)

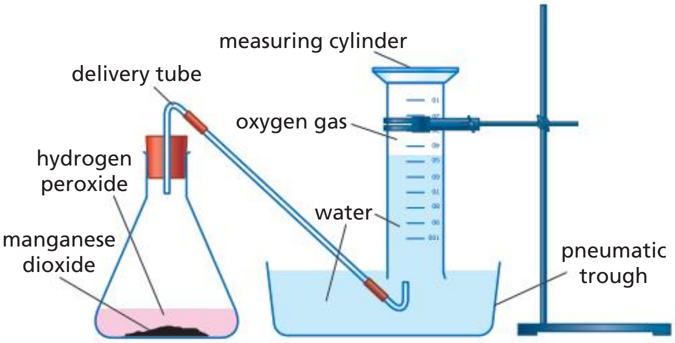
5 **C**—you need a metal that is more reactive than aluminium—magnesium or sodium; you cannot use sodium, however, because it reacts violently with water

6 **B**—each magnesium atom loses two electrons ($2e^-$) to form a magnesium ion (Mg^{2+})

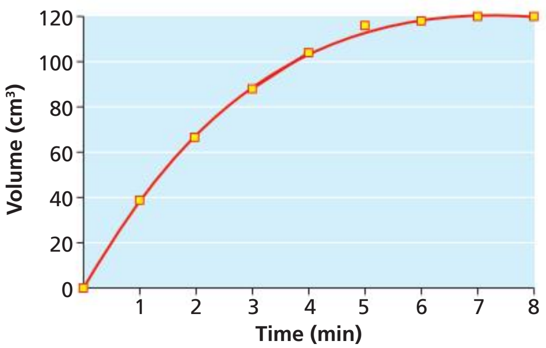
7 Aluminium is much more reactive than silver. If you add hydrochloric acid, the aluminium will react but the silver will not. Aluminium will displace copper from copper sulfate but silver will not.

8 **a** Magnesium reacts with dilute hydrochloric acid to produce hydrogen gas.
b A test tube of hydrogen 'pops' when you put a burning taper in the mouth of the tube.
c $Mg + 2HCl \rightarrow MgCl_2 + H_2$

9 a You could use apparatus similar to what you used in Investigation 3 on page 77.



b



c Oxygen gas is produced rapidly to start with (steep slope on graph). The reaction then slows down (graph not so steep). The reaction is complete after 7 minutes as no more oxygen is produced.

10 During rusting each iron atom loses two electrons to form a positive ion (Fe^{2+}).

$Fe \rightarrow Fe^{2+} + 2e^-$

Because the iron loses electrons, it is oxidised.

Chapter 5 DNA and genetics

1 a chromosome
b allele
c zygote
d heterozygous

2 a True
b False—*incomplete* dominance occurs when the offspring show a blend of the characteristics of the parents
c True
d True

3 a The pictures inside the circle represent chromosomes.
b The letter A stands for a dominant form of a gene or a dominant allele.
c The diagram shows meiosis.
d This process would take place in the ovaries of a female.
e There would be 46 chromosomes in cell 1 and 23 chromosomes in cell 4.

4 a 'Pure-breeding tall pea plants' means that the genes for height that these plants carry are all the same, that is tall. Another name for 'pure' is homozygous.
b The genotypes and phenotypes would be:
Parents: TT tall + tt dwarf

		Parent 2	
		T	**T**
Parent 1	**t**	Tt	Tt
	t	Tt	Tt

1st generation offspring: all Tt tall

The two offspring that are crossed would be: Tt tall + Tt tall

		Parent 2	
		T	**t**
Parent 1	**T**	TT	Tt
	t	Tt	tt

2nd generation: 25% TT tall, 50% Tt tall, 25% tt dwarf

c This type of inheritance is called dominant and recessive inheritance. You know this because the recessive characteristic (dwarf) is hidden in the first generation and reappears in the correct proportions in the second generation.
d Gregor Mendel

5 a The diagram represents a DNA molecule.
b bases (A adenine; T thymine; C cytosine; G guanine)
c Each set of three bases codes for an amino acid.
d Each set of three bases codes for an amino acid.

Chapter 6 Evolution

1 **a** False
b True
c False
d True
e True

2 **C** Correct
A Incorrect: Change is needed, but this does not describe natural selection.
B Incorrect: Natural selection discusses 'survival of the fittest'. It is not about the fittest person winning a race.
D Incorrect: While it is true that variations are necessary, this does not describe natural selection.

3 **D** Correct
A Incorrect: Organisms don't just replace others.
B Incorrect: The environment can change without organisms becoming extinct.
C Incorrect: The size of the organism is not the only characteristic that affects the survival of an organism.

4 **A** Correct
B Incorrect: Species need to be isolated so that interbreeding stops and two separate gene pools are created. Over millions of years the species may then become different.
C Incorrect: New species don't just appear automatically, no matter what the time frame.
D Incorrect: Life on Earth doesn't appear to be fixed. There are many examples of it changing.

5 **B** Correct
A Incorrect: A gene pool refers to a group, not a single organism.
C Incorrect: Sharing resources has nothing to do with it.
D Incorrect: A gene pool refers to genotypes, not phenotypes.

6 Natural: moving continents, changing climates, glacial and interglacial periods, rising and falling seas.

Unnatural: being hunted, pollution of the environment, destruction of the environment for development.

7 **a** Lamarck
b Charles Darwin agreed that the environment was the factor that caused organisms to change. He would also have agreed that characteristics could be inherited. However, the organism could not just develop characteristics at will and then pass these on to its offspring.
c Evolution is only a theory because it occurs over millions of years and no-one has been able to observe life on Earth for this length of time. The evidence available is very limited and many inferences have to be made to complete the picture.

8 **a** The fossil record shows that many organisms have become extinct and many new ones have appeared. It shows that organisms have gone through changes in structure. It shows that there appear to be links between groups of organisms and common ancestors.
b The embryos of birds, reptiles, amphibians and mammals go through similar stages of development, suggesting they may have a common ancestor.
c DNA comparisons show that many organisms have large amounts of DNA in common, suggesting they may have a common ancestor.

9 One positive argument for new organisms is that we are able to make organisms that we were unable to make before. Another is that we can genetically change organisms in a short period of time. Such changes would have taken generations to achieve using selective breeding.

A negative argument is that we are not sure what effect genetically modified organisms will have on the natural environment. Another is that we are altering the natural evolution of organisms that has been taking place for millions of years.

10 You could answer that the genetically modified corn should not be produced because it may alter populations of monarch butterflies. The butterflies are part of a natural food web and if they are wiped out this could have disastrous effects on natural ecosystems.

You could also argue that genetically modified corn should be produced because it will require less insecticide to be used by farmers to produce a crop of corn. The butterfly is already living on the milkweed outside corn farms, so the butterflies will not be affected.

Chapter 7 Forces and motion

1 **A**

2 **D**

3 **B**

4 **C**

5 100 km/h

6 First convert 120 minutes to 2 hours. The answer is then 90 km/h.

7 712 km

8 0.6 m/s^2

9 **C**—no motion

10 **A**—travelling at a constant speed

11 16 500 N

12 Newton's first law of motion states that an object will remain at rest or continue to move in a straight line unless acted on by a net unbalanced force. An example is a boy riding a bicycle who stops suddenly. He will continue to move forward at the speed he was travelling and probably go over the handlebars.

Newton's second law of motion describes the relationship between force, mass and acceleration, using the formula F = ma. An object accelerates more rapidly when a larger force is applied. Larger masses accelerate less rapidly than smaller masses acted on by the same force.

Newton's third law of motion states that for every action there is an equal and opposite reaction. When the space shuttle is launched, the firing of rockets backwards propels the shuttle upwards.

13 The woman was moving at the same speed as her car and when the car crashed her inertia caused her to move forward at the same speed. It was 1969 so the woman was probably not wearing a seat belt. She was propelled into the dashboard. Her body exerted a force on the uncovered radio knob on the dashboard, and the knob exerted a force on her.

14 You are stationary and your body tends to remain in this position, so when a car hits you from behind, your head moves backward. If you do not have a headrest you could get whiplash.

Chapter 8 Alternative energy sources

1 **a** GJ = gigajoules (10^9 joules or one thousand million joules)

PJ = pentajoules (10^{15} joules)

b Residential energy consumption means how much energy is used in the home.

c The amount of energy per person in Australia is increasing each year. This can be explained because households are using more appliances.

d Australia is one of the highest users of energy in the world (see table p. 181).

e The proportion of total energy has decreased because more energy is used in other areas. For example, it is predicted that transportation will consume 38% of the total energy by 2015, with cars accounting for 72% of the total energy consumption for transport.

f Australian households use the most energy in the generation of electricity.

2 **a** NSW = 1.5 PJ, Qld = 1.0 PJ, WA = 2.8 PJ, SA = 0.4 PJ, NT = 0.3 PJ

b The use of solar energy will increase in each state in the next 10 years, with WA and NSW showing the greatest rises.

c We need to use renewable rather than non-renewable sources. We need to cut down our emissions of greenhouse gases.

d Households can at present use solar power to heat water and to dry their clothes instead of using a clothes dryer. We can also use solar cells.

e In the time period predicted Victoria will still rely heavily on coal and gas for its fuel. Tasmania gets almost 80% of its power from hydro-electricity. Its infrastructure at present is set up for this renewable energy resource, not solar energy.

3 **a** About 52% of inputs into electricity generation were produced by black coal and 32% by brown coal in 2000. These proportions are predicted to be 47% and 27% respectively in 2020.

b Coal will continue to be used because Australia has huge coal reserves and electricity can be made cheaply from it.

c About 10% of inputs into electricity generation were supplied by natural gas in 2000. This is predicted to increase to 20% in 2020.

d Australia has large reserves of natural gas, and it is a cleaner fuel to use than coal to generate electricity. More people will use natural gas in industry and the home in the future.

e Renewable energy made up about 5% of inputs in 2000 and this is expected to change to about 8% in 2020.

f Renewables are not predicted to make a significant rise because Australia will still continue to use coal and natural gas.

g Owing to our increased use of oil, our resources will run out and we will be forced to import it.

4 Switch off appliances that are not needed, install compact fluorescent lights, hand wash and dry dishes, avoid using the clothes dryer, install a solar hot water system, walk or ride your bicycle instead of using the car.

5 Ethanol, methanol, hydrogen and electricity are all possible alternatives to replace oil. They are more environmentally friendly and reduce greenhouse gas emissions.

Chapter 9 Earth systems

1 **a** ecosystem **c** biomass
b trophic **d** ozone

2 **B** Correct: The infrastructure is not set up to support alternatives.

A Incorrect: People will lose money changing over to alternatives that don't emit greenhouse gases, but the benefit to the environment is worth it.

C Incorrect: Most people are concerned about the environment, and would change if the alternatives were cheap and accessible.

D Incorrect: Increasing levels of greenhouse gases *are* harmful to life on Earth.

3 **D** Correct: CFCs and other chemicals are breaking down ozone.

A Incorrect: This doesn't explain why the ozone layer is becoming thinner.

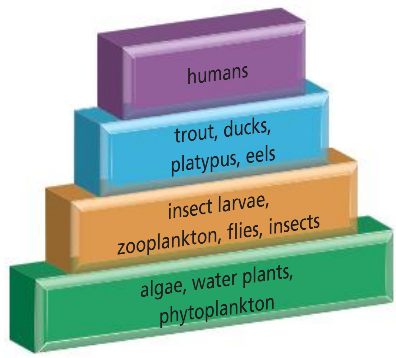
B Incorrect: The troposphere does not shield the stratosphere.

C Incorrect: Methane and carbon dioxide levels are increasing, but this is not affecting the ozone layer.

4 **a** Producer organisms are water plants, algae and phytoplankton.

b There are four trophic levels.

c



d Carbon would enter this food web in carbon dioxide used in photosynthesis by water plants, phytoplankton and algae.

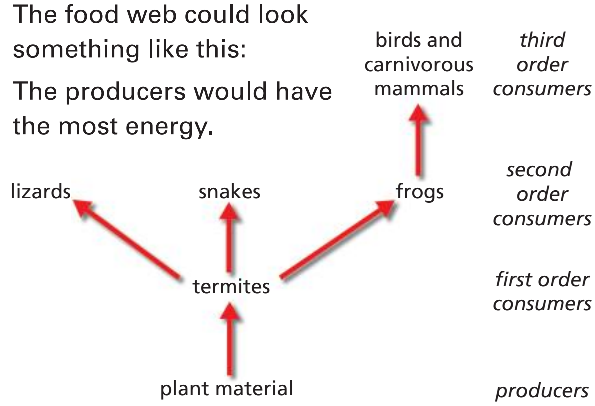
e Nitrogen would enter this food web as nitrates from dead organisms.

5 El Niño occurs when the surface waters of the Pacific Ocean warm up near Peru. This affects climate because water-laden clouds develop, bringing heavy rains to South America. The waters near Australia are cooler. This brings drought and dry conditions to eastern Australia and Indonesia.

La Niña occurs when the surface of the Pacific Ocean near Australia is warm. This affects climate because water evaporates from the warm ocean and heavy rain clouds develop, causing flooding rains to occur in Australia. In South America the water is cool, bringing very dry conditions and droughts to Ecuador and Peru. California also experiences drought.

6 The food web could look something like this:

The producers would have the most energy.



7 There are many possible examples. Here are some.

a *climate change*

Loss of different organisms e.g. loss of animals in water when it is warmer.

b *human activity*

Cutting down trees for housing developments leads to loss of habitat for the organisms that live there.

Erosion of soil can cause run-off and the build-up of sediments in dams, rivers and streams. This can affect the amount of light and oxygen in the water.

Increase of gases in the atmosphere, pollution of land and waterways.

8 a An increase in temperature has led to the melting of ice, and to coral bleaching.

b It may lead to the death of many organisms that cannot cope with the temperature change, destruction of many different environments such as coral reefs due to loss of organisms and warmer temperatures, loss of land due to rising sea levels.

Chapter 10 Environment case studies

1 Greenhouse gases—mainly carbon dioxide, but also methane and nitrous oxide (see p. 211)

2 Carbon pricing is setting a price for emitting greenhouse gases. So industries have to pay a price for the greenhouse gases they produce. The more they produce, the more they have to pay. The aim of carbon pricing is to encourage industry to reduce emissions and to encourage the development of alternatives that don't produce greenhouse gases.

3 The 'big polluters' are industries that emit large amounts of carbon dioxide, for example coal-burning power stations, iron, steel and aluminium manufacturers, transport.

4 Huge numbers of wind farms would be necessary to produce a significant proportion of our electricity needs. However, only certain places are suitable for wind farms, and they only generate electricity when the wind blows. They also need a large amount of land.

5 It is the electricity produced in power stations that burn coal, oil or gas.

6 The printing press used to produce the newspaper uses electricity. To distribute the newspaper around the state requires transport, and this burns fossil fuels.

7 Electricity (probably from fossil fuels) is used to make the mobile phone from steel, silicon, aluminium and plastics.

Materials and electricity are used to make the rechargeable battery

Electricity is used to charge the mobile phone.

Electricity is used to power mobile phone towers and the telephone network.

8 At present renewable energy sources provide only 6% of our total energy needs (see pie chart on p. 177). This use of renewable energy is increasing only slowly and this is why Simon Grose said it will be decades—if ever—before renewable energy supplies a significant proportion of our electricity needs.

9 What Simon Grose is saying is that we tend to blame the coal-burning power stations and industry for carbon pollution. However, it is *us* who use the electricity, fuels and materials they produce. The big polluters are only producing what we want. In other words, the *big polluters are us*. If a carbon tax is introduced in Australia, it is only fair that this extra cost will be passed on to us—the consumers.

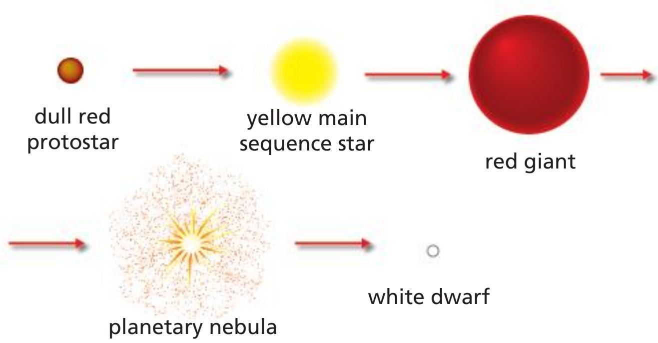
Chapter 11 The universe

1 planet — smallest
star
solar system
galaxy
cluster of galaxies
universe — largest

2 C

3 A

4 See pages 251–252.



5 **a** If Antares is red then its surface temperature will be about 3000°C, the same as Betelgeuse.

b Rigel's temperature is between that of Sirius and Spica, so it will be blue in colour.

c The sun is yellow, with a surface temperature of 5500°C. So Capella is closest in colour and temperature to our sun.

d As the surface temperature increases, the colour changes from red at one end of the visible spectrum, to blue at the other end.

6 **a** The luminosity of a star is the rate at which it produces energy.

b The apparent brightness of a star depends on how close it is to the Earth. A star that appears bright may have a high luminosity, or it may be close to Earth, or both.

7 **B**

8 **B**

9 **a** False: The Doppler effect occurs with both sound *and light*.

b False: Stars moving towards us will have their spectra shifted towards the *blue* end.

c True

d False: The universe is *expanding*.

e True

10 At present space probes can travel at only a tiny fraction of the speed of light. So a return trip even to the nearest star (4.2 light years) would probably take more than a lifetime. So space travel to the nearest stars does not seem a practical way to search for extraterrestrial life.

11 Planet Earth is one of eight planets around the sun—our nearest star. There are about 200 billion stars like our sun in our galaxy—the Milky Way. However, there are billions of these galaxies in our universe, separated by vast empty spaces. The universe seems to be getting bigger and bigger.

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, El Niño (el-NIN-yo).

acceleration the rate at which speed increases; measured in m/s^2 158

action and reaction Newton's third law of motion states that objects exert forces on each other that are equal and opposite in direction 147

activity series a list of the metals arranged from the most reactive to the least reactive 78

aerobic respiration (air-OH-bic) where glucose reacts with oxygen to produce energy 201

alkali metals very reactive metals in Group 1 of the periodic table (e.g. sodium, potassium) 49

alkaline earth metals reactive metals in Group 2 of the periodic table (e.g. magnesium, calcium) 50

alleles (al-LEALS) different versions of a gene 107

anaerobic respiration (AN-air-OH-bic) the process in which glucose can be broken down to produce energy without the use of oxygen; fermentation is an example of anaerobic respiration 201

Big Bang theory which suggests that the universe was formed in a single gigantic explosion about 14 billion years ago 259

biodegradation the chemical breakdown of materials by living organisms (e.g. bacteria) in the environment 230

biodiversity the variety of all life on Earth 140

biomass living material or organic matter; biomass energy is energy produced from living things 185

biosphere the thin layer in which life exists on Earth 199

black hole an invisible collapsed star that is so dense that not even light can escape its gravity 254

carbon cycle the cycling of the element carbon between the atmosphere, biosphere, hydrosphere and lithosphere 205

case study an in-depth study of one particular situation for the purpose of gaining understanding of the issues involved 219

catalyst (CAT-a-list) a substance that speeds up a chemical reaction, without being used up itself 38

chromosomes thread-like bodies seen in the nucleus of a cell when it is about to divide; made up of DNA 98

clone an individual made by asexual reproduction, or a cell produced by mitosis 97

co-dominance a type of inheritance pattern where the offspring shows characteristics of both parents 110

combustion (burning) a rapid chemical reaction that occurs when a substance reacts with oxygen in the air, producing heat and light energy 30

conservation of energy this law says that energy cannot be created, destroyed or lost—it can only be changed from one form to another 165

conservation of mass 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 43

corrosion a redox reaction in which water and the gases in the atmosphere react with metals; rusting is the corrosion of iron or steel 82

covalent bond a force holding two atoms together; it is formed by the sharing of electrons from the outer shell of each atom 55

decomposition a chemical reaction where a substance breaks down to simpler substances 81

displacement reaction a reaction in which one metal displaces another metal from a compound (e.g. aluminium + iron oxide → iron + aluminium oxide) 76

DNA (**deoxyribonucleic acid**) the genetic material that makes up a chromosome; it is shaped like a twisted ladder 101

dominant type of characteristic produced by a gene that covers or masks a recessive one 107

efficiency a measure of how well a machine uses the energy put into it; a perfect machine would have an effciency of 100% 165

electrochemical cell a device that converts chemical energy into electrical energy using redox reactions 84

electrode electrical conductor that allows electric current to flow into or out of the electrolyte in an electrochemical cell, or during electrolysis or electroplating 84

electrolysis (ee-lek-TROL-e-sis) the process of passing an electric current through an electrolyte to produce chemical reactions at the electrodes 87

electrolyte (ee-LEK-tro-lite) a substance that when in solution or molten conducts an electric current and is decomposed by the current 84

electron shells (energy levels) regions around the nucleus of an atom where electrons are found; different shells have different energies and contain different numbers of electrons 50

electroplating depositing a thin layer of metal on another metal using electrolysis 89

El Niño (el-NIN-yo) an effect that occurs when the surface waters near South America are warm; this tends to cause heavy rains in South America and drought in Australia 209

endothermic reaction a reaction during which energy is absorbed; energy must be supplied to keep the reaction going 30

environment the term used to describe all the factors, both living and non-living, that affect an organism where it lives 198

enzyme (EN-zime) a biological catalyst that speeds up (or controls) a chemical reaction in an organism 40

evolution the theory that says that organisms alive today have developed from common ancestors, becoming more complex through a process of gradual change over millions of years 120

exothermic reaction a reaction that releases energy 30

extinction the dying out of a group of organisms so that there are no more representatives of that group left on Earth 131

extraterrestrial life (ET) alien life found outside the Earth 256

fossil fuels fuels such as coal, oil and natural gas which take millions of years to be made by processes in the Earth 177

fuel cell an electrochemical cell that converts the chemical energy of a fuel (e.g. hydrogen) and an oxidiser (e.g. oxygen) to electrical energy 86

galaxy a collection of millions or billions of stars, gas and dust, separated from other galaxies by empty space 247

gene a unit of inheritance; a sequence of bases on a DNA molecule that codes for a particular characteristic 101

gene pool all the different genes in a group of organisms 132

gene technology (genetic engineering) rearranging DNA to alter the genetic make-up of organisms 139

genetic variation differences between individual organisms 99

genetics the scientific study of how characteristics are inherited 97

genotype (GEE-no-type) the genetic make-up of an organism 108

geological time scale a timeline of events in the history of the Earth, presented as a chart with the oldest events at the bottom and the present at the top 128

geothermal energy heat from hot areas underneath the Earth's surface 185

greenhouse effect the atmosphere acts like a greenhouse, trapping heat around the Earth 208

greenhouse gases gases in the Earth's atmosphere that absorb solar energy and hence contribute to the warming of the Earth (e.g. carbon dioxide, methane) 211

halogens very reactive non-metals in Group 17 of the periodic table (e.g. chlorine, iodine) 50

hydrosphere all the water on Earth; this includes oceans, lakes, rivers, groundwater and water in the atmosphere 199

hypothesis an educated guess or idea, based on observations and knowledge, that can be tested 8

incomplete dominance a type of inheritance pattern where the offspring show a blending of the parents' characteristics 110

inertia the tendency of a body to remain at rest or continue to move in a straight line unless acted on by an outside force 163

inhibitor a substance that slows down a chemical reaction 41

ionic bond a force holding two atoms together; it results from the attraction between positive and negative ions 54

jargon special language of a subject, trade or profession 16

La Niña (la-NIN-ya) an effect that occurs when the surface of the Pacific Ocean near South America is cool; this this tends to cause flooding rains in Australia and droughts in South America 209

luminosity the rate at which energy is produced by a star; it is different from the brightness, which depends on the star's distance from Earth 250

magnetosphere the magnetic field of the Earth which protects us from the solar wind 208

meiosis (my-OH-sis) the process that occurs to produce sex cells with half the number of chromosomes found in body cells 98

metallic bond force of attraction between positive metal ions and the free electrons between them 57

Milky Way the galaxy in which the Earth and our solar system is located; includes about 200 billion stars in a sea of gas and dust 247

mitosis (my-TOE-sis) a process in which a single cell divides to produce two identical daughter cells 98

mutation the process in which offspring become different from their parents because the DNA or genetic information has changed by chance 113

natural selection the process by which those organisms better adapted to the environment are more likely to survive, reproduce and pass their successful characteristics on to their offspring 122

nebula a large cloud of gas and dust in space; nebulas are thought to be the birthplace of stars 248

neutron star an extremely dense core left behind after a star explodes in a supernova; it is composed almost entirely of neutrons 253

nitrogen cycle the cycling of the element nitrogen between the atmosphere, biosphere, hydrosphere and lithosphere 205

noble gases unreactive gases in Group 18 of the periodic table (e.g. helium, neon) 50

nodules lumps or knots on the roots of plants such as legumes, wattles, alfalfa, clover and beans that contain nitrogen-fixing bacteria 206

non-renewable resources that are not replaced as they are used (e.g. coal, oil) 172

objective based on measurements rather than people's opinions 16

oxidation the loss of electrons during a reaction; this often occurs when a substance combines with oxygen 81

ozone layer a layer containing ozone about 30 km from Earth in the stratosphere; this layer protects the Earth from harmful UV radiation 208

particle theory the theory that all matter is made up of particles (atoms and molecules) that are too small to be seen and which are always moving 36

pedigree a family tree diagram that shows how a particular genetic characteristic or disease is passed on 111

periodic table an arrangement of the elements in order of their atomic numbers; elements are grouped according to their chemical properties 49

phenotype (FEE-no-type) the characteristics that an organism displays 108

precipitate (pre-SIP-it-ate) an insoluble solid that forms as a result of mixing two solutions 63

pulsar a spinning neutron star that is detected on Earth by beams of radio waves that pulse on and off 254

Punnett square a table that is used to show the possible outcomes of different genetic crosses 109

reaction rate the speed of a chemical reaction 34

recessive type of characteristic produced by a gene that is 'hidden' by a more dominant one 107

redox reaction a reaction in which reduction and oxidation occur together 81

reduction the gain of electrons during a reaction; this is the opposite of oxidation 81

reliable results are reliable if they are the same when the experiment is repeated many times 9

renewable resources that are replaced as they are used (e.g. solar energy) 172

sex-linked inheritance a type of inheritance pattern in which the characteristic or disease concerned is carried on one of the sex chromosomes (X or Y) 111

solar flare a sudden eruption of intense high-energy radiation from the sun's surface; associated with sunspots and radio interference on Earth 246

species a group of organisms that are similar in structure and can mate to produce fertile offspring 121

speed (average) the distance travelled divided by the time it takes to cover the distance; it is measured in km/h or m/s 151

subjective based on people's opinions rather than measurements 16

sunspots dark relatively cool areas on the surface of the sun, associated with magnetic storms 246

supernova a giant exploding star, much brighter than a normal star 253

survey a process for gathering information from a group of people through interviews or questionnaires given to a sample of the group 15

transition metals metals found in the middle of the periodic table (e.g. iron, copper, silver) 50

trophic levels (TRO-phic) the different energy levels in a food chain 202

valency the combining power of an atom; it is the number of electrons the atom gains, shares or loses when combining with other atoms 59

valid the results of an experiment are valid if they are logical and relevant to what you are trying to find out 9

velocity speed in a particular direction (e.g. 100 km/h north) 151

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