Macmillan

Australian Curriculum



Science Essentials 8

Australian Curriculum edition

Ken Williamson Anne Garton

Macmillan

Australian Curriculum

Science Essentials 8

Australian Curriculum edition

Ken Williamson Anne Garton

Consultant: Debbie Baulch, Dandenong High School

First published 2011 by
MACMILLAN EDUCATION AUSTRALIA PTY LTD
15–19 Claremont Street, South Yarra, VIC, 3141
Visit our website at www.macmillan.com.au
Associated companies and representatives throughout the world.
Copyright © K L Books and Anne Garton 2011
The moral rights of the authors have been asserted.

All rights reserved.
Except under the conditions described in the
Copyright Act 1968 of Australia (the Act) and subsequent amendments,
no part of this publication may be reproduced,
stored in a retrieval system, or transmitted in any form or by any means,
electronic, mechanical, photocopying, recording or otherwise,
without the prior written permission of the copyright owner.

Educational institutions copying any part of this book
for educational purposes under the Act must be covered by a
Copyright Agency Limited (CAL) licence for educational institutions
and must have given a remuneration notice to CAL.
Licence restrictions must be adhered to. For details of the CAL licence contact:
Copyright Agency Limited, Level 15, 233 Castlereagh Street, Sydney, NSW 2000.
Telephone: (02) 9394 7600. Facsimile: (02) 9394 7601. Email: info@copyright.com.au



National Library of Australia
cataloguing in publication data

Author: Williamson, Ken. 2011
Title: Science Essentials 8 / Ken Williamson and Anne Garton.
Edition: 1st Australian curriculum ed.
ISBN: 978 1 4202 2974 5 (pbk.)
Notes: Includes index.
Subjects: Science--Textbooks (Secondary)
Science--Problems, exercises, etc--Juvenile literature (Secondary)
Science--Study and teaching (Secondary)
Other authors/contributors: Garton, Anne.
Dewey number: 500

Publisher: Colin McNeil
Project editor: Liz Filleul
Editor: Emma de Smit
Proofreader: Laura Howell
Illustrators: Vaughan Duck and Guy Holt
Cover designer: Dimitrios Frangoulis
Text designer: Dimitrios Frangoulis
Production control: Aiden Langford, Loran McDougall
Photo research and permissions research: Kate Chisolm
Typeset in Utopia 10.5/13.5pt by Nikki M Group Pty Ltd
Cover image: Shutterstock/Irina Tischenko

Printed in Malaysia

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

Getting to know the book v
Links to the Australian Curriculum vii

1 Fair tests 1

PROBLEM SOLVING *Be a scientist* 2
SCIENTISTS AT WORK *Sir Alexander Fleming* 3
1.1 Science is observing . . . 4
1.2 Inferring and predicting . . . 6
1.3 Hypotheses and fair tests . . . 9
1.4 Designing your own experiment . . . 13
1.5 Writing reports . . . 17
SKILL *Writing better practical reports* 19

2 Particles of matter 24

PROBLEM SOLVING *Soap films* 24
2.1 Properties of matter . . . 26
SKILL *Measuring mass* 27
2.2 The particle theory . . . 30
2.3 Solutions . . . 35
2.4 Using the particle theory . . . 38
2.5 Atoms and molecules . . . 42
SCIENTISTS AT WORK *Seeing atoms* 42

3 Elements and compounds 47

PROBLEM SOLVING *Iron for breakfast* 48
3.1 Elements . . . 49
SCIENTISTS AT WORK *Buckyballs* 54
3.2 Compounds . . . 56
SKILL *Writing formulas* 58
3.3 Making and breaking compounds . . . 60
3.4 Ionic compounds . . . 64

Each chapter starts with Problem solving. For example, in Chapter 3 you investigate whether breakfast cereal contains metallic iron. As you work through the chapter you learn things that will help you with this task



4 Useful materials 70

PROBLEM SOLVING *Glue goo* 71
4.1 Carbon compounds . . . 72
SKILL *Making molecular models and drawing structural formulas* 73
4.2 Plastics . . . 76
4.3 Rubber . . . 81
4.4 Fibres . . . 83
4.5 Materials—old and new . . . 86
SCIENTISTS AT WORK *Safety glass* 87



In Chapter 4 you work out how to make glue goo and suggest uses for it.

5 Cells—units of life 93

PROBLEM SOLVING *Skin cancer* 93
5.1 Microscopes . . . 95
SKILL *Using a microscope* . . . 95
SCIENTISTS AT WORK *Invention of the microscope* 99
5.2 Plant and animal cells . . . 101
5.3 Types of cells . . . 104
5.4 Cell processes . . . 107
5.5 Cell division . . . 109
SCIENCE AS A HUMAN ENDEAVOUR *The stem cell debate* 111

6 Plant and animal systems 115

PROBLEM SOLVING *The human body* 115
6.1 Materials needed to survive . . . 117
SKILL *Designing your own experiment* 120
6.2 The digestive system . . . 122
6.3 The respiratory system . . . 125
6.4 The excretory system . . . 128
SCIENTISTS AT WORK *Leonardo Da Vinci* 130
6.5 The reproductive system . . . 131
6.6 Plant reproduction . . . 135

7 Heart and blood 141

PROBLEM SOLVING *Model heart* 143
7.1 What's in blood? . . . 144
7.2 Blood pressure . . . 147
SKILL *Interpreting data* 150
7.3 The heart . . . 152
SCIENTISTS AT WORK *Chang, Keogh and Timms* 155
7.4 Circulatory systems . . . 158
SCIENTISTS AT WORK *William Harvey* 160

8 Using energy 164

PROBLEM SOLVING *Building a mousetrap racer* 164
8.1 Forms of energy . . . 166
8.2 Energy changes . . . 169
8.3 Energy from food . . . 174
8.4 Energy comes and goes . . . 176
SCIENTISTS AT WORK *Maria Skyllas-Kazacos* 179
8.5 Doing a project . . . 180

9 Heat energy 186

PROBLEM SOLVING *Building a solar water heater* 187
9.1 Conduction of heat . . . 188
9.2 Convection of heat . . . 193
9.3 Heat radiation . . . 196
9.4 Not too hot, not too cold . . . 199
9.5 Controlling heat . . . 202
SKILL *Interpreting diagrams* 204
SCIENCE AS A HUMAN ENDEAVOUR *Water bag, Coolgardie safe and Solar ice maker* 205

10 Rock hunting 209

PROBLEM SOLVING *Collecting rocks* 210
SKILL *How to be a rock-hound* 211
10.1 Rocks and minerals . . . 212
10.2 Weathering and erosion . . . 215
10.3 Sedimentary rocks . . . 219
10.4 Igneous rocks and metamorphic rocks . . . 222
SCIENTISTS AT WORK *Dr Cindy Werner* 225
10.5 The rock cycle . . . 227



A rock cycle?

11 Mining 232

PROBLEM SOLVING *A resource* 233
11.1 Ores, minerals and metals . . . 234
11.2 Extracting the ore . . . 237
11.3 Processing the ore . . . 240
11.4 Mining and the environment . . . 244
SCIENTISTS AT WORK *Dr Graham Taylor* 246
SCIENCE AS A HUMAN ENDEAVOUR *Aboriginal mining* 247

12 Investigating space 251

PROBLEM SOLVING *Space tourism* 252
12.1 Stars . . . 253
12.2 Exploring space . . . 256
SCIENTISTS AT WORK *Caroline Herschel* 257
12.3 The planets . . . 259
SKILL *Understanding on three levels* 260
12.4 Close encounters . . . 264
12.5 The universe . . . 267

Checkpoint answers 273
Glossary 280
Index 284
Acknowledgements 289

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.

PROBLEM SOLVING

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 12 page 252 you design a tourist brochure for trips to the planets. As you work through the chapter you will learn things that will help you with your problem.

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

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

Inquiries and investigations

INQUIRY 1

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

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

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

- Have a look at *Investigation* 1 on page 10.

SKILL

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 12 you design a tourist brochure for trips to the planets.

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.

THINKING SKILLS

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.

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 6 on page 138. 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.

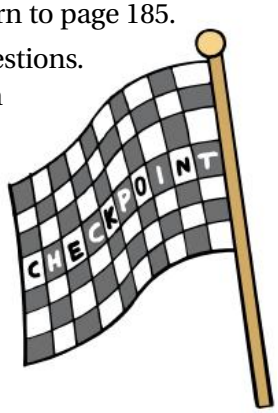
- Turn to page 139. Check the *Knowing and Understanding* where you use the words on the right to fill in the gaps. See if you can do any of them.
- What is the purpose of the *Self-management* section on page 139?



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 185.

- Try one or more of these questions. Then check your answers on page 277.
- 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 280. 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
  - skin cancer
  - making nylon
  - the human digestive system.

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 8*.

Science Understanding	*Science Essentials 8* Elaborations
Science Understanding is fully integrated with Science Inquiry Skills, as indicated in the elaborations.	
Biological sciences Cells are the basic units of living things and have specialised structures and functions (ACSSU149)	**Chapter 5 Cells** correctly use a microscope to examine a variety of cells and single-celled organisms describe and distinguish between plant and animal cells identify structures within cells and describe their function explain how cells are grouped to form tissues, which work together to form organs and systems use a diagram to show how cells divide, and apply this knowledge to explain how cancer spreads in the body
Multi-cellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (ASSSU150)	**Chapter 6 Plant and animal systems** name the organs that make up human body systems and describe their structure and function compare digestive and respiratory systems in different animals identify similarities and differences between structures involved in reproduction in plants and animals distinguish between asexual and sexual reproduction **Chapter 7 Heart and blood** describe the structure of each organ in the human circulatory system and relate its function to the overall function of the system investigate how the circulatory system works, for example by measuring heartbeat and blood flow build a model to show how the circulatory system (or part of it) works
Chemical sciences The properties of the different states of matter can be explained in terms of the motion and arrangement of particles (ACSSU151)	**Chapter 2 Particles of matter** use models to show the arrangement of particles in solids, liquids and gases use the particle theory to explain solids, liquids and gases and how they can change from one state to another write inferences to explain various properties of matter, e.g. dissolving, in terms of particles
Differences between elements, compounds and mixtures can be described at a particle level (ACSSU152)	**Chapter 3 Elements and compounds** use models to show the arrangement of particles in elements and compounds locate elements in the periodic table use chemical symbols to represent elements and to write simple formulas, e.g. water H_2O

continued >>>

Chemical change involves substances reacting to form new substances (ACSSU225)	**Chapter 3 Elements and compounds** investigate the making of a compound and the breaking of a compound into its elements **Chapter 4 Useful materials** give examples of how the chemical properties of a substance affect its use give examples of how everyday materials such as soap and plastics are made using chemical reactions **Chapter 11 Mining** apply a knowledge of chemical reactions to the processing of ores
Earth and space sciences Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales (ACSSU153)	**Chapter 10 Rock hunting** use granite to show that rocks are a collection of different minerals simulate the formation of sedimentary and igneous rocks use the rock cycle to develop an understanding of the timescales involved in the formation of igneous, metamorphic and sedimentary rocks **Chapter 11 Mining** distinguish between a rock, a mineral and an ore recognise that some rocks and minerals, such as ores, provide valuable resources
Physical sciences Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems (ACSSU155)	**Chapter 8 Using energy** recognise that kinetic energy is the energy possessed by moving bodies recognise that potential energy is stored energy, such as gravitational, chemical and elastic energy give examples of how heat energy is produced as a by-product of energy transfer, e.g. in a car engine use energy chains to show changes between different forms of energy **Chapter 9 Heat energy** investigate heat transfer by conduction, convection and radiation in everyday situations

Science as a Human Endeavour	*Science Essentials 8* Elaborations
Science as a Human Endeavour is integrated with Science Understanding.	
Nature and development of science Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world (ACSHE134)	**Chapter 1 Fair tests** pages 2–4 describe the work of Alexander Graham Bell, Sir Alexander Fleming and Edward Jenner **Chapter 3 Elements and compounds** pages 49, 52 describe how Mendeleev organised the elements into a periodic table **Chapter 12 Investigating space** pages 253, 256–257, 264 describe how people through history have made inferences to explain their observations of the night sky **Scientists at work** pages 42, 99, 130, 160, 257

Science knowledge can develop through collaboration and connecting ideas across the disciplines of science (ACSHE226)	**Chapter 3 Scientists at work** page 54 trace the development of buckyballs and reflect on their possible uses **Chapter 7 Scientists at work** pages 155–156 describe the contributions of three Australians to medical research
Use and influence of science Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (ACSHE135)	**Chapter 4 Scientists at work** page 87 read and understand an article on the historical development of safety glass **Chapter 5 Stem cell debate** pages 111–112 form an opinion on whether stem cells from embryos should be used in medical research **Science as a human endeavour** page 205
Science understanding influences the development of practices in areas of human activity such as industry, agriculture and marine and terrestrial resource management (ACSHE136)	**Chapter 11 Science as a human endeavour** page 247 explore the use of geological resources by Australian Aboriginal people **Chapter 11 Mining** pages 244–246 investigate ways in which the environmental impact of mining can be minimised
People use understanding and skills from across the disciplines of science in their occupations (ACSHE227)	**Chapter 10 Scientists at wor**k page 225 discuss the career of a scientist studying active volcanoes **Chapter 8 Scientists at work** page 179 discuss the work of Maria Skyllas-Kazacos in developing the vanadium battery

Science Inquiry Skills	*Science Essentials 8* 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 Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS139)	**Chapter 8 Doing a project** pages 180–182 work in a team or by yourself to complete a science project **Chapter 5 Investigation 4** page 110
Planning and conducting Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS140)	**Chapter 1 Fair tests** make qualitative and quantitative observations **Chapter 4 Useful materials** make alcohol, soap and rayon thread without hurting yourself or others **Chapter 9 Investigation 4** page 203 build a model house to investigate ways of keeping it warm or cool **Chapter 10 Rock hunting** pages 211–212, 214 use a hand lens to observe the properties of rock and mineral specimens

continued >>>

In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS141)	**Chapter 1 Fair tests** identify variables to be changed, measured or controlled for a fair test design an experiment to test a hypothesis **Chapter 2 Particles of matter** use specialised equipment to measure mass, volume and density accurately **Chapter 6 Plant and animal systems** pages 120–121 design a fair test, identifying variables to be changed, measured and controlled **Chapter 9 Inquiries 1 and 2** page 188 measure temperature using your skin and thermometers
Processing and analysing data and information Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate (ACSIS144)	**Chapter 2 Investigation 2** page 33 draw and interpret a line graph of the temperature as ice melts to water and then boils **Chapter 7 Skill** pages 150–151 interpret data in tables and graphs **Chapter 12 Inquiry 9** page 268 calculate how long it would take to travel to nearby stars
Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions (ACSIS145)	**Chapter 1 Fair tests** make inferences and generalisations to explain observations and make predictions **Chapter 4 Useful materials** relate the properties and uses of soaps, plastics and rubber to their chemical structure **Chapter 12 Inquiry 6** page 262 interpret planetary data and draw graphs to analyse the data
Evaluating Reflect on the method used to investigate a question or solve a problem, including evaluating the data collected, and identify improvements to the method (ACSIS146)	**Chapter 1 Investigation 1** page 10 suggest improvements to an experiment to obtain more reliable results **Chapter 9 Problem solving** pages 187, 197, 207 work in a group to design, build and test a solar water heater **Chapter 4 Investigation 4** page 85
Use scientific knowledge and findings from investigations to evaluate claims (ACSIS234)	**Chapter 4 Useful materials** discuss the advantages and disadvantages of plastics and decide whether they can be used sustainably **Chapter 12 Skill** page 260 assess the difficulty of making Mars suitable for humans to live
Communicating Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS148)	**Chapter 9 Skill** page 204 interpret illustrations **Chapter 11 Inquiry 2** page 238 use a flow diagram to show the steps in obtaining useful materials from mining **Chapter 12 Problem solving** pages 252, 263 create a tourist brochure about a trip to a planet or moon in the solar system

Source: Australian Curriculum, Assessment and Reporting Authority (ACARA)

1



Fair tests

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

Science as a Human Endeavour

- describe the work of Alexander Graham Bell, Sir Alexander Fleming and Edward Jenner

Science Inquiry Skills

- make qualitative and quantitative observations
- make inferences and generalisations to explain observations and make predictions
- identify variables to be changed, measured or controlled for a fair test
- design an experiment to test a hypothesis
- suggest improvements to an experiment to obtain more reliable results

LITERACY FOCUS

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

apparatus
conclusion
controlling the variables
data
experiment
experimental control
fair test
generalising
hypothesis
inference
investigation
prediction
relationship
risk assessment
scale
scientific method
telegraph
vaccination
variables
verified

Focus for learning

Do you think about science when you use a telephone? Probably not, but you should thank a scientist for it! Can you imagine what life would be like without it?

Before the telephone, messages were carried by foot, on horseback or by ship and could take months to be delivered. However three important discoveries led to the invention of the telephone. First, Benjamin Franklin (1706–1790) discovered that an electrical charge could move along a metal wire. Michael Faraday (1791–1867) then demonstrated that there was a link between electricity and magnetism, which are both needed for the telephone to work.

With this knowledge Samuel Morse (1791–1872) worked out a way to pass signals along a wire by using electrical pulses. The signals were a series of dots and dashes which he used to transmit a message. His invention was called the telegraph and the signals were referred to as Morse code. The first Australian telegraph was set up in Melbourne in 1854 and a telegraph line linked Australia to Britain in 1872.

The Morse code alphabet is shown here with the dots and dashes used for each letter.

Morse code alphabet

A ·—	J ·———	S ···
B —···	K —·—	T —
C —·—·	L ·—··	U ··—
D —··	M ——	V ···—
E ·	N —·	W ·——
F ··—·	O ———	X —··—
G ——·	P ·——·	Y —·——
H ····	Q ——·—	Z ——··
I ··	R ·—·	

On 10 March 1876 Alexander Graham Bell (1847–1922) made the first telephone call to his assistant, Thomas Watson, in the next room. Bell had spilt some acid on his trousers and called out 'Mr Watson, please come here, I want you'. Watson heard him on the invention they were working on—the telephone!

Instead of dots and dashes Bell's telephone could pass many messages along a wire at the same time. Its earpiece and mouthpiece were combined. These were separated in the telephone designed by Thomas Alva Edison (1847–1931).

The invention of the telephone shows how science works, which is what this chapter is all about. Bell had an idea, which he developed using the knowledge he gained from other scientists, and by experimenting himself. The communication of his ideas then sparked bright ideas in others.

The next time you use the telephone thank Mr Bell for his invention, because without it life today would be very different.

INQUIRY 1 **Using Morse code**

Communicate a message to a partner by using the Morse code alphabet. Devise your own method of transmitting the message. For example:

- You could use a series of claps and bangs to indicate dots and dashes.
- If you know how to build electric circuits you could build one with a light or buzzer and a switch. You could then use different flashes for dots and dashes, or different sounds.

PROBLEM SOLVING

Be a scientist

Your task in this chapter is to use the scientific method to design your own experiment.

You should present your findings as a correctly written investigation report.

To get started on this task, read the chapter. It will review what you should know about the scientific method and give you some suggestions for your own experiment.

SCIENTISTS AT WORK

Sir Alexander Fleming (1881–1955)

Alexander Fleming was born in Scotland and as a boy lived on a farm. At the age of 14 he moved to London, where he went to school. He won a scholarship to St Mary's Hospital Medical School in London and went on to the Royal College of Surgeons to complete his medical training. His area of interest was immunology, the study of how the body fights disease.

From 1928 to 1948 Fleming worked as a professor at St Mary's Hospital Medical School, and it was here that he made his most important discovery. He was carrying out research on influenza. He had grown bacteria (disease-causing organisms) on petri dishes in his laboratory and noticed that one of the dishes had mould growing on it and that the bacteria around it were dead. The mould was *Penicillium notatum*, which is one of a group of fungi known as green mould.

Fleming wrote a paper on this, which he titled 'Antibacterial Action of Cultures of *Penicillium*'. It was read by the Australian scientist Howard Florey (1898–1968). From this Florey and his colleague Ernest Chain (1906–1979) decided to examine *Penicillium* further. In 1939 Florey and Chain produced a drug called penicillin, which killed germs in the body. Florey and Chain also designed a way to produce this substance in large quantities. Penicillin was used to cure many deadly and previously untreatable diseases. It was also used to treat soldiers in World War II. Today, penicillin is used to treat many types of infections.

Fleming and Florey were knighted in 1944 for their work. Fleming shared the 1945 Nobel Prize in physiology and medicine with Florey and Chain for the development of penicillin.



Alexander Fleming in his laboratory

Scientific method

What you have read about Fleming and Bell demonstrates a series of processes that is called the **scientific method**. It is outlined below using the discovery of penicillin.

- **Observation** Fleming *observed* a mould growing on one of his petri dishes, and noticed that the bacteria around it were dead.
- **Questions** Fleming may have asked 'What type of mould is it? Why are the bacteria around the mould dead? Did the mould kill the bacteria? Can the mould kill germs in the body?'
- **Inferring and predicting** Fleming may have tried to explain what he observed and to predict future observations.
- **Hypothesis** Fleming may have written down a possible answer to his questions: '*Penicillium* is a mould that can kill bacteria'.
- **Design and testing** Fleming grew *Penicillium* and found that the mould killed the bacteria, even if diluted. So it seems his hypothesis was correct.
- **Conclusion** Fleming concluded that the mould killed bacteria and reported this in his paper 'Antibacterial Action of Cultures of *Penicillium*'.
- **Further investigation** Can a drug be made from *Penicillium* and produced in large quantities? Will it kill disease in humans? Florey continued Fleming's work by trying to answer these questions.

1.1 Science is observing

Your senses of smell, taste, hearing, sight and touch give you information about the world. Observations are made using these senses, although in science the sense of taste is only used when it is safe to do so.

Investigations usually start with observations. For example, Edward Jenner (1749–1823) is famous for developing a vaccination against the deadly smallpox disease. It had been observed that milkmaids who got a disease of cattle called cowpox never developed smallpox. Cowpox was like smallpox, and infected people developed spots, but cowpox was much milder and they recovered from it.

One question Jenner must have asked was whether this observation was correct. He must also have questioned whether there was something in cowpox that gave the sufferer some protection against smallpox. Could there be something in the cowpox spots, perhaps in the pus? If this was right, then perhaps he could infect a person with pus from cowpox and they would not get smallpox.

Jenner tested this by injecting James Phipps, an eight-year-old boy, with pus from cowpox. Phipps developed cowpox. When he recovered, Jenner injected him with smallpox, but Phipps did not get smallpox at all. Jenner called his procedure *vaccination* from the Latin word for cow (*vacca*) and from cowpox (*vaccina*).

Observations lead to questions. Scientists find the answers to these questions by performing experiments. These are carefully thought-out, well-designed tests.

Observations are made throughout the experiment and they are recorded or written down as *data*. These observations can be *qualitative* (QUAL-i-tate-ive), when they are recorded as a written description, or they can be *quantitative* (QUANT-i-tate-ive), when they are recorded as measurements. Both types of observations are data.

Are you good at observing? Carry out the next few activities and see if you are.

INQUIRY 2 Where did the shell go?

You will need: a raw egg, beaker, 0.5 M hydrochloric acid



1. Place an unbroken egg in a beaker.
2. Cover the egg with hydrochloric acid and leave it for 24 hours.
3. Record your observations when the egg is first placed in the acid and again after 24 hours.
4. Did you make qualitative or quantitative observations in this activity?



Edward Jenner vaccinated his own son, as well as James Phipps.

INQUIRY 3 Blowing up balloons

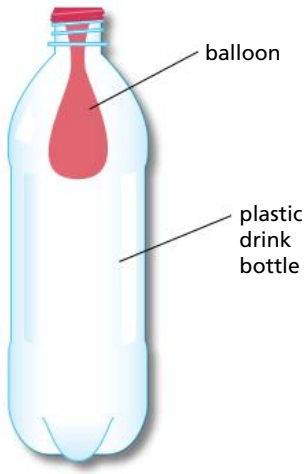
You will need: 1 L plastic soft drink bottle, 2 balloons

1 Place the balloon inside the bottle. Make sure the balloon is over the lip of the bottle as shown in the diagram.

2 Try to blow up the balloon.

- Record your observations.

3 From this activity do you think you could put one balloon inside another and blow up the inside balloon or both balloons? Try it.



INQUIRY 4 Sticky cups

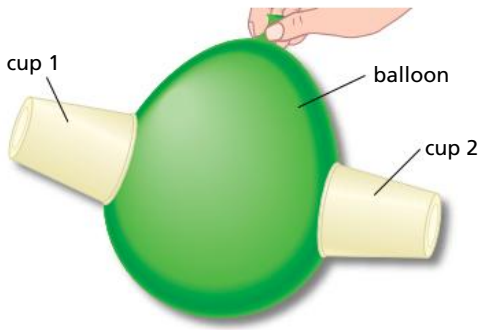
You will need: 10 plastic cups, balloon

1 Partly blow up a balloon.

2 Ask a partner to hold two cups on either side of the balloon, so that the cup opening is against the balloon. As they hold the cups against the balloon, blow it up to full size.

3 Ask your partner to let go of the cups. What happens to them?

- How many cups can you stick to the balloon?



INQUIRY 5 How observant are you?

When you walked into this laboratory what did you notice? Answer these questions without looking around.

a How many sinks are there in the laboratory?

b How many gas taps are there?

c How many posters are on the walls?

d How many windows are there?

e Where is the fire extinguisher?

f How many desks are there in the room? Are they all filled now everyone is seated?

g What colour eyes does your teacher have?

h How many fair-haired students are there?

i What colour are your teacher's shoes?

j How many people are not wearing a watch?

Over to you

1 What is hidden in the picture below? How many are there?



2 Outline the steps followed by Edward Jenner to invent vaccination.

3 James Phipps was probably unaware that he risked his life to test Jenner's vaccine. How do you think Jenner felt about his procedure? Imagine you are Jenner. Write a short story explaining what you did to Phipps and the feelings you had about it.

4 What observation did Alexander Fleming make that led to the discovery of penicillin?

5 List the processes of science that Alexander Graham Bell may have used.

6 Is it true to say that 'Without observation there can be no science?' Explain your answer.

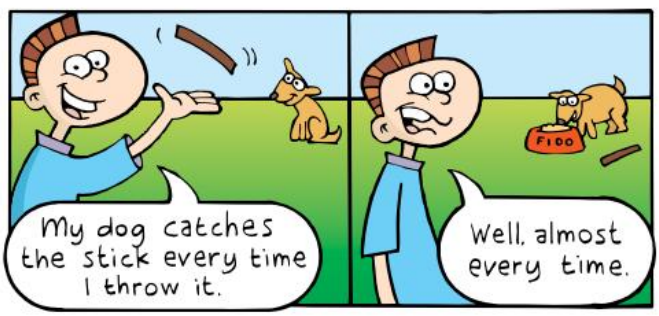
1.2 Inferring and predicting

In Inquiries 2–4 you were asked to make careful observations. The next step in the scientific process is to try to explain what you have observed. This is called making an **inference**. You do this based on what you already know, and make a 'guess' based on this knowledge. For example, in Inquiry 3 you could explain your observations by saying that you could not blow up the balloon in the bottle because the air pressure inside the bottle pushes against the balloon and prevents you from doing so.

From your observations you can also make a **prediction** or forecast of what a future observation might be. For example, if you are unable to blow up the balloon inside the bottle, then a prediction could be that you will not be able to blow up a balloon inside another balloon.

In Inquiry 4 you may have observed that the two cups stuck to the sides of the balloon and that they did not need to be held there. You can infer that the air pressure inside the cups has been reduced, so the outside pressure keeps them in place. A prediction from this would be that it is possible to stick three or four cups to the balloon in the same way.

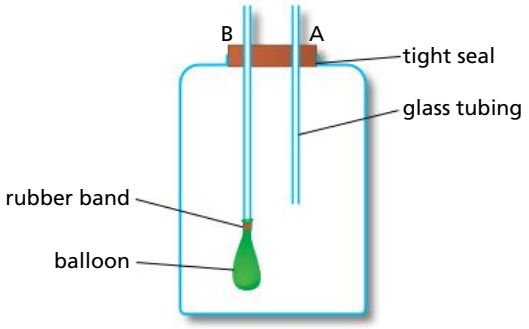
In Inquiry 2 you would have observed that bubbles were formed when the egg was placed in the acid. The eggshell is made of calcium carbonate and it reacts with the acid to produce the gas carbon dioxide. In the process the shell disappears. From this you could predict that the acid will react with other things made of calcium carbonate, such as seashells. You could also make a general statement that acids react with calcium carbonate to produce carbon dioxide. In this case you are **generalising** or making a statement that is true most of the time.



A generalisation is a statement that is true most of the time.

INQUIRY 6 Blowing and sucking

You will need: the equipment as pictured



- Predict what you think will happen when you blow into tube A. (Hint: Think about what happened in Inquiry 3.)
- Was your prediction correct? Make an inference to explain your observations.
- Predict what will happen if you suck on tube A instead of blowing. Try it.

INQUIRY 7 Does it burn?

You will need: piece of cotton material, twenty-cent coin, mosquito coil, matches

1. Place the coin in the centre of the piece of material and wrap the material firmly around the coin. The material must be tight across the coin as shown.
2. Break off a piece of mosquito coil and light it. Blow out the flame so that the end of the coil is smouldering.
3. Predict what you think will happen when you touch the smouldering end of the coil to the middle of the cotton material wrapped around the coin. Test your prediction.

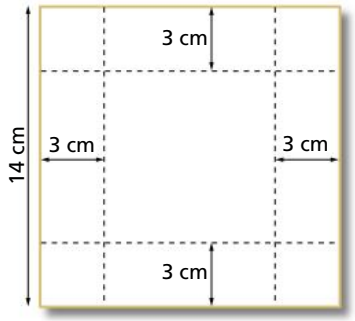


   - Was your prediction correct? Make an inference to explain your observation.
   - Do you think this will happen if, instead of the coin, you use objects made of different materials? Make a generalisation and test it.

INQUIRY 8 Paper magic

You will need: candle stuck to the lid of a jar, paper, 4 paperclips, scissors, matches, balloon

1 Make a paper tray with the dimensions shown.







2 Fold up the edges to form a tray with walls. Make triangular folds at the corners and hold these in place with paperclips. When your tray is ready, fill it with water to a depth of about 1 cm.

3 From what you learnt in the last activity, predict what you think will happen when you hold the tray so that the bottom of it touches the top of the candle flame. Test your prediction.

- Was your prediction correct? Make an inference to explain your observation.

4 Predict what you think will happen if you use a balloon full of water instead of a paper tray with water in it. Test your prediction. Were you right?

INQUIRY 9 Dent the can

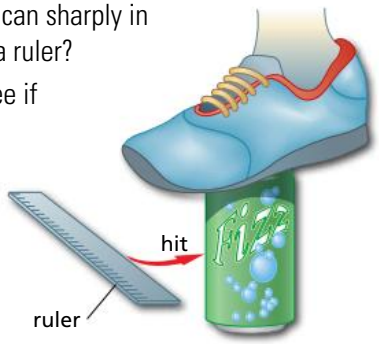
You will need: empty aluminium can, ruler

1 Place a can with no dents in it on the floor.

2 Put your weight on the can, holding on to a chair or bench to steady yourself.

- What do you predict will happen if you get another person to hit the can sharply in the middle with a ruler?

3 Now try it and see if your prediction was correct.



INQUIRY 10 Sugar and soap

You will need: bowl, flat thin toothpicks, sugar cube, small piece of soap

1 Break the toothpicks with your fingers into small pieces.

2 Sprinkle them on top of the water in the bowl.

- Predict what you think will happen to the sticks when you hold a piece of soap so that it just touches the surface of the water. Explain your prediction.

3 Now test your prediction.

4 Repeat this activity using a sugar cube instead of soap.

- Try to explain your observations.



Over to you

1 Read the following advertisement.

There is nothing like a car with a soft-top. When the top is down the air blows through your hair and in your face, your body releases adrenalin and you feel happy.



At the touch of a button the fully automatic soft-top glides and disappears without a sound. In just 24 seconds the top is back and you are out there, among it all. You will enjoy the freedom and the 160 kW 3 litre V6 engine provides effortless power that will set your heart racing.

- **a** What observations are made about this car?
- **b** What predictions are made in the advertisement?
- **c** What inferences are made in the advertisement?

2 Emily has a small, brown terrier called Kip, which has an unusual habit of snapping her jaws together when someone approaches. Kip started doing this when she was the smallest of four dogs Emily's family owned. Emily thinks Kip snaps her jaws to get attention, or maybe all terriers do this.

- **a** What observation can be made about Kip?
- **b** What inference did Emily make to explain this observation? What other inferences could be made to explain Kip's behaviour? List as many as you can.
- **c** What generalisation did Emily make about her dog?

3 Look at this photograph.

- **a** Make five observations about this scene.
- **b** Make three possible inferences to explain what you can see.



4 Look at the following cartoon.



- **a** What observation was made by the students in the cartoon?
- **b** What inferences were suggested to explain this observation?
- **c** Were any generalisations made? Explain.
- **d** If the last student was correct and water vapour in the air condenses when it hits a cold surface, what do you predict will happen when steam from a kettle hits a cold window pane?

1.3 Hypotheses and fair tests

Generalising is useful in science because a general statement can be tested. For example, Don noticed that the mango trees on his farm did not produce much fruit in hot, dry summers. His neighbour had noticed the same thing. Don made the generalisation that *'Mango trees need warm, wet summers to produce a lot of fruit'*. A generalisation like this that can be tested is called a **hypothesis** (high-POTH-e-sis). The plural of hypothesis is hypotheses. Don could now record the temperature and rainfall over a number of years and make a note of the amount of fruit produced by his trees.

A hypothesis is an explanation or an idea based on careful observation and prior knowledge that explains why something might always happen. It is different from an inference, which is an explanation of one particular observation. A hypothesis is made after looking at *many* observations and considering all the information and evidence available. A hypothesis can also be an answer to a question.

The following cartoons are examples of how observations lead to inferences, generalisations and hypotheses. For each, find an observation, an inference, a generalisation and a prediction.



Find an observation, an inference, a generalisation and a prediction.



Find an observation, an inference, a generalisation and a prediction.

In both these examples an observation led to several different inferences. In the first example one inference was that the bike needed oil.

In the second example the lemon tree had fruit on one side only, so the inference was that part of the plant was in shade. The hypothesis made from this was that *Lemon trees need sun to produce fruit*. From this hypothesis Karen then predicted that the tree would produce fruit all over if she moved it into the sun. This prediction could then be tested.

Changing variables

Once a hypothesis has been suggested the next step is to design an experiment to test it. There are many factors that can affect the outcome of an experiment. These factors are called **variables**. For example if you wanted to see which sunscreen was the best for preventing sunburn, the type of sunscreen, the amount of sunscreen and how thickly it is applied would be some of the variables affecting the outcome of the experiment. In Investigation 1 and Inquiries 11–13 you will see how variables affect the outcome of a test.

INVESTIGATION

1 Controlling variables

Aim

- To measure how quickly heat travels along a length of a copper rod.
- To examine how variables affect the outcome of an experiment.

Risk assessment and planning

1 Review the safety rules for using and lighting a Bunsen burner.

2 Read this investigation and list any other safety precautions you think are necessary.

3 Copy the following table to record the results or use a spreadsheet.

Group number	Time (in seconds) for thumb tack to fall off rod
Group 1	
Group 2	
Group 3	

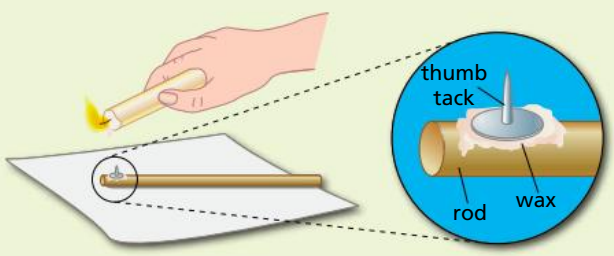
Apparatus

- copper rod 25 cm long
- thumb tack
- candle
- box of matches
- newspaper
- stopwatch
- retort stand and boss head
- heatproof mat
- Bunsen burner equipment

Method

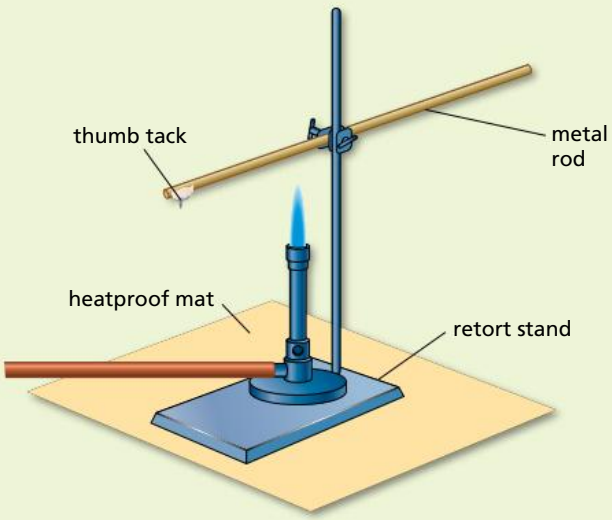
1 Work in groups of three.

2 Collect a copper rod, a thumb tack and a candle. Use candle wax to stick the thumb tack to the copper rod.



3 Attach the copper rod with its thumb tack to the retort stand and position it so that the rod is above the Bunsen burner flame.

DO NOT touch the copper rod when it is heated.



4 Commence heating the rod and record the time it takes for the thumb tack to drop off the rod.

Results

Place each group's result in the table.

Discussion

1 Did each group measure the same length of time before the thumb tack dropped off the rod? Which group had the fastest time? Which group had the slowest time? How can you explain these differences?

2 What variables were controlled in this experiment? That is, what did each group do that was the same?

3 Which variables were not controlled in this experiment? That is, what did each group do that was different?

4 How did changing these variables affect the results?

5 Could you say for certain how long it takes for heat to pass from one end of a 25 cm copper rod to the other, using the results you obtained? Why or why not?

6 How would you change the experiment so the results could be relied upon? Repeat the experiment to see how successful the changes are.

Conclusion

Write a sentence explaining why it is important to alter only one variable in an experiment and to control all the other variables.

INQUIRY 11 Expansion race

You will need: 250 mL conical flask, balloon, large bowl, stopwatch

1. Put a balloon over the neck of the conical flask and stand the flask in the bowl.
2. Pour hot water into the bowl around the flask. What do you predict will happen to the balloon? Was your prediction correct?
   - What variables affect how big the balloon gets? Discuss these.
3. Your task is to get the biggest balloon in 5 minutes. You cannot alter the type of balloon you are given, but you can change any other variables to produce the best result.

   Think about what you will do before you start. When everyone in the class has discussed what they will do, the teacher will start timing. Who had the largest balloon at the end of 5 minutes? What variables did you alter and why?



INQUIRY 12 Dissolve it quickly

You will need: stopwatch, sugar cube, 250 mL beaker, thermometer, other equipment of your choice

1. Place 200 mL of water in the beaker.
2. Record the temperature of the water.
3. Drop the sugar cube into the water and time how long it takes the cube to dissolve completely.
4. Your task is to make the sugar cube dissolve as fast as possible. Your challenge is to beat the other students in the class, who will be trying to dissolve their cube faster than you do.
   - List the variables you altered to dissolve your cube as quickly as possible.
   - Who won the competition? What variables did they alter that were different from yours?

INQUIRY 13 Mouldy race

You will need: snap-lock sandwich bag, piece of bread, sticky tape.

1. Your teacher will give every student in your class a snap-lock sandwich bag and a piece of bread.
2. Your task is to produce as much mould on your bread as you can in two weeks. You can do whatever you like to the bread, except change the type of bread or bag you are given. Seal the bag with sticky tape.
3. You will be asked to bring your mouldy bread back to be judged in two weeks.
   - List the variables you altered to grow your mould.
   - Who won the mould competition? What variables did they alter that were different from yours?

Do not open the bag. Give it to your teacher for safe disposal.



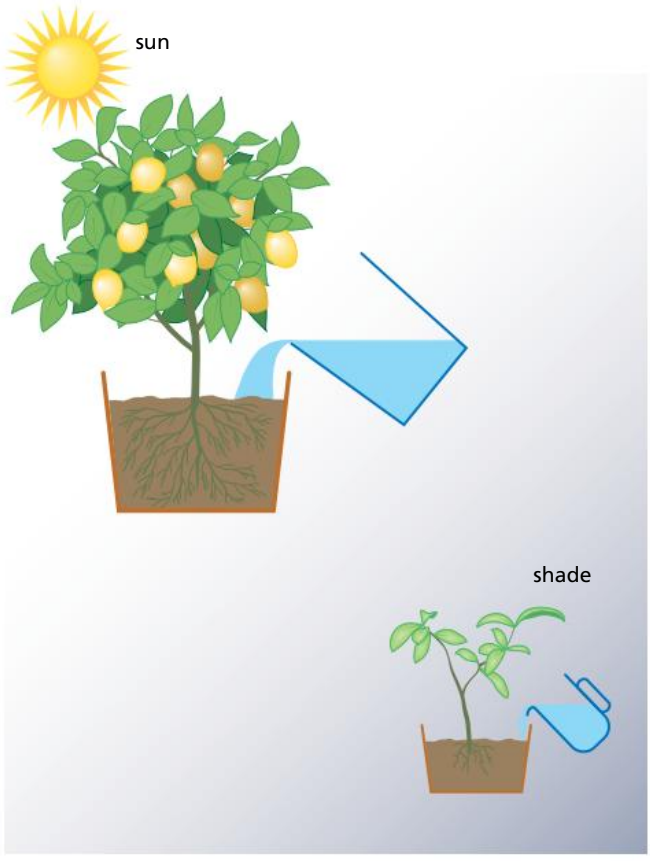
Designing fair tests

In Investigation 1 and Inquiries 11–13 many variables were changed. This affected the results of the tests performed. A scientific test should be designed so that only one variable is changed or tested at a time.

Think back to Karen's problem with her lemon tree on page 9 (top right). She could place a lemon tree in full sun and a lemon tree in the shade to test her hypothesis. In this case the variable that she is changing or testing is the amount of sunlight. She needs to have two plants so that she can compare one with the other. The plant in the shade in this example is called the **control**. The results for the plant in sunlight will be compared against this.

To be able to compare the results of one plant with the other Karen would need to alter only the amount of sunlight for both plants and keep all other variables the same. This is called **controlling the variables**. Both lemon trees would have to have the same number of leaves, the same sized pot, the same amount of water, the same type and amount of soil, grow in the same place and so on. If all of these variables were controlled and the lemon trees produced fruit differently, then Karen could say with little doubt that the one factor causing the difference was the amount of sunlight.

If Karen did not control all the variables, for example if the lemon trees received different amounts of water as well as sunlight, then she could not be sure that it was the sunlight alone that caused the difference. When designing an experiment to test a hypothesis you must change or test only one variable and keep all the other variables the same or controlled. In this way the experiment is said to a **fair test** and the results can be relied upon. You also usually need to have a point of comparison or control, in this case the plant in the shade.



Why is this not a fair test?

Over to you

Consider the three situations below.

a Draw a cartoon for each situation. Show observations in blue, inferences in green, hypotheses in black and predictions in red.

b Design a test for each hypothesis, stating the variables you need to control and the one variable you are going to test.

A 'You know, every time I eat pizza the skin on my fingers gets itchy,' said Rebecca.

'The tomato on the pizza is a fruit, and aren't you allergic to fruit?' said Brittany.

'Yes, fruit makes me scratch.'

'I won't eat any tomato for a week and if you are right, Brittany, my fingers will stop itching.'

B 'I think the plant on the front verandah is too close to the door,' said Ahmet.

'Why do you think that?' replied Elijah.

'Well, the leaves near the door are dropping off, so I think that when we open the door we're damaging the overhanging branches,' Ahmet said.

'OK, opening the door damages the plant, so stop opening the door!' said Elijah.

'Don't be stupid Elijah. I'll move the plant, and if I'm right no more leaves will drop off.'

C Samuel woke up sneezing.

'Oh I think you have a cold from swimming yesterday,' said his mum.

'No, the jasmine outside his window is flowering and he slept with the window open last night. I think he has hay fever,' said his dad.

'So jasmine gives me hay fever,' said Samuel.

'Let's get rid of the plant and see if his hay fever stops,' his father said, grinning.

'I know you don't like the jasmine dear, but I think closing the window might be the first thing to try. What do you think?'



PROBLEM SOLVING

Have you thought of an experiment to do? Can you alter some of the activities in this chapter to make your own experiment? Start by writing down the steps you will need to follow.

1.4 Designing your own experiment

Designing an experiment is a process that must be well thought out. Experiments are carried out to solve problems, and there are a number of steps in the scientific method that scientists usually follow. These steps are outlined below with an example.



Step 1
Making observations

Susan develops eczema if she eats food with wheat in it, because she is allergic to it. However, she noticed that although she ate nothing with wheat in it, she still had eczema during summer.

Step 2
Asking questions

What do I do differently in summer to the rest of the year? Is it something I eat or do in summer? Is it the warmer weather?

Step 3
Making inferences, generalisations and predictions

One thing that I do in summer is use a waterproof suntan lotion because I go swimming a lot. It could be the suntan lotion, so if I stop using it the eczema may go away.

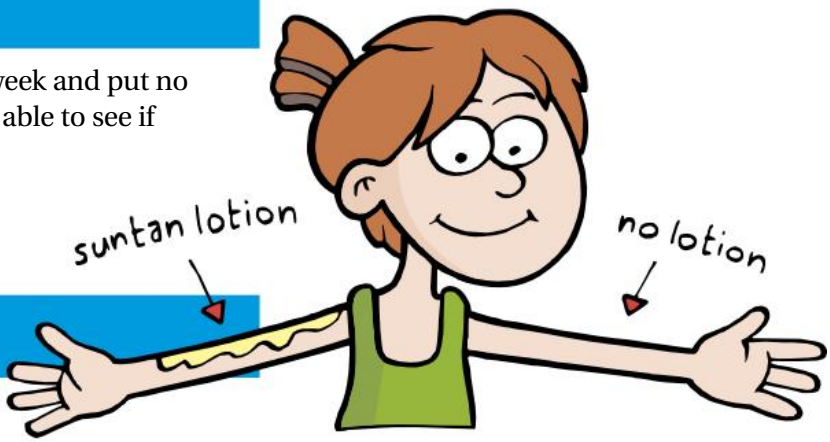


Step 4
Suggesting a hypothesis

The waterproof suntan lotion causes eczema.

Step 5
Designing an experiment

If I put the suntan lotion on one arm for a week and put no suntan lotion on the other arm, I should be able to see if there is a difference.



Step 6
Obtaining results

Both arms still have eczema and there is no difference between the two.

Step 7
Do the results support the hypothesis?

Yes → What further investigation does this lead to?

No

Step 8
If no, changing or modifying the hypothesis.

Something else must be causing the eczema in summer. Could it be the chlorine in the swimming pool? A new hypothesis is needed: *Chlorine in the swimming pool causes eczema.*

Step 9
Designing a new experiment to test this hypothesis

Step 10
Do the results support the new hypothesis?

Yes → What further investigation does this lead to?

No Keep trying

PROBLEM SOLVING

This page gives you some suggestions for your own experiment. There is a range of investigations that you can do. For example, some investigations start with a question or a problem, some involve designing a useful item, and others involve testing a hypothesis that is already written for you. Of course you can also write and test your own hypothesis. Follow the steps outlined on the previous page to plan and carry out your own experiment. Section 1.5 will help you write your report.

1 Design a device to dislodge a ball from a tree and catch it.



2 Design a container to keep a takeaway cup of coffee as hot as possible.



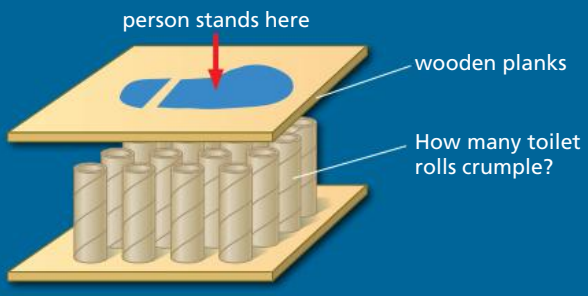
3 Design an experiment to show which paint colour is the best to use on the walls of a swimming pool to keep the water as warm as possible.



thermometers fruit cans paint

4 Design a container to keep an ice cube from melting for as long as possible.

5 Design a way to get a rough idea of a person's weight.



6 Design an experiment to measure which soft drink contains the most sugar.



7 Stefanie made a plant sprayer to water her plants. Design an experiment to see if the length of the straws makes a difference to how far the water is sprayed.



8 Design an experiment to keep an apple, a pear or a banana from going brown for as long as possible.

9 Design a material that can be added to pot plants to absorb water, so that you don't have to water the plants as often.

CSIRO CREST AWARDS (CREATIVITY IN SCIENCE AND TECHNOLOGY)

Once you have designed your own experiment you might like to be part of the CSIRO CREST Awards. CREST is organised by CSIRO (Commonwealth Scientific Industrial Research Organisation) to get students like you involved in scientific research. When you join CREST, you get a handbook that gives you some guidelines to help with your investigation. You can earn certificates and medallions as you work through different levels of the Awards. You will need to contact CSIRO in your state, if you are interested. Here is an example of the type of thing you can do for CREST.

The science of spaghetti stains



Everybody loves tinned spaghetti. Especially Daniel Mullens' little brother. He loves it so much that everytime he's given some he throws it everywhere, making a terrible mess on the tablecloth! This is why Daniel, aged 11, decided to do this Blue CREST Award project on spaghetti stains; which brands of spaghetti stain and which don't.

To test the different brands he cut up a hankie and smeared spaghetti sauce from a different tin onto each piece. "That was the most fun because it was all gooey," he says. After washing and drying the hankies, Daniel discovered the Thomas the Tank Engine spaghetti came out the cleanest. It took Daniel six months to finish his project, and as well as getting his Blue CREST Award, it looks like Daniel and his brother will be getting Thomas the Tank Engine spaghetti for dinner from now on.

Scientriffic, No. 3, September/October 1999, p. 30, reprinted with permission of CREST.

Over to you

1 Effie read an advertisement for a face cream, which suggested that there would be a noticeable difference in the texture of her skin after using the cream for eight days.

a Design an experiment to test this claim.

b What is the variable being tested?

c What variables must be controlled?

2 When designing your own experiment, what is the correct order for the following?

- results
- hypothesis
- observation
- design own test
- modify hypothesis
- prediction

(You may want to use the word 'observation' more than once.)

3 Whenever Gino feeds the dogs in the evening he leaves the dog food can sitting outside. The following morning Jan often finds the can covered with ants, and a skink (lizard) near the can.

a What are two possible inferences to explain the presence of the skink?

b What could you do to see which inference is correct?

4 The results of an experiment you have designed support your hypothesis; however, you know that you didn't control all the variables properly. What should you do? Discuss your answers in a group and present your reasoning to the class.

5 Adrian wanted to see if the temperature of the water used to water a pot plant makes a difference to how well the plant grows.

a Write a hypothesis for Adrian.

b Design an experiment to test this hypothesis.

c What variables would you need to control?

1.5 Writing reports

Your chapter task is to perform your own test and present the findings as an investigation report. Let's review how to write up a report.

1 **Aim or hypothesis** Write a statement that describes why the experiment is being done, or state the hypothesis being investigated.

2 **Risk assessment and planning**
- Identify any risks with the experiment such as electrocution, inhalation of gases, exposure to hot and cold things, explosions.
- Plan ahead and list any personal protective equipment needed, e.g. safety glasses.
- Work out what you will need to record, and how to do this.

3 **Apparatus** List all the materials and equipment to be used in the experiment.

4 **Method** Explain how to carry out the experiment. The instructions should be written like a recipe, with each step described clearly. If you design your own experiment this is very important, so that the experiment can be repeated by others and the results **verified** or found to be true.

5 **Results** Record any data. Remember observations can be qualitative or quantitative. Use tables and graphs wherever possible.

6 **Discussion** Analyse the results and the method used, and discuss how accurate you think the results are. In some investigations in this book there will be questions to answer, which form the discussion.

If you design your own experiment, write a discussion by answering each of these questions:

a Were the results what you expected? Explain.

b If the results were not what you expected, why do you think they were different? Explain.

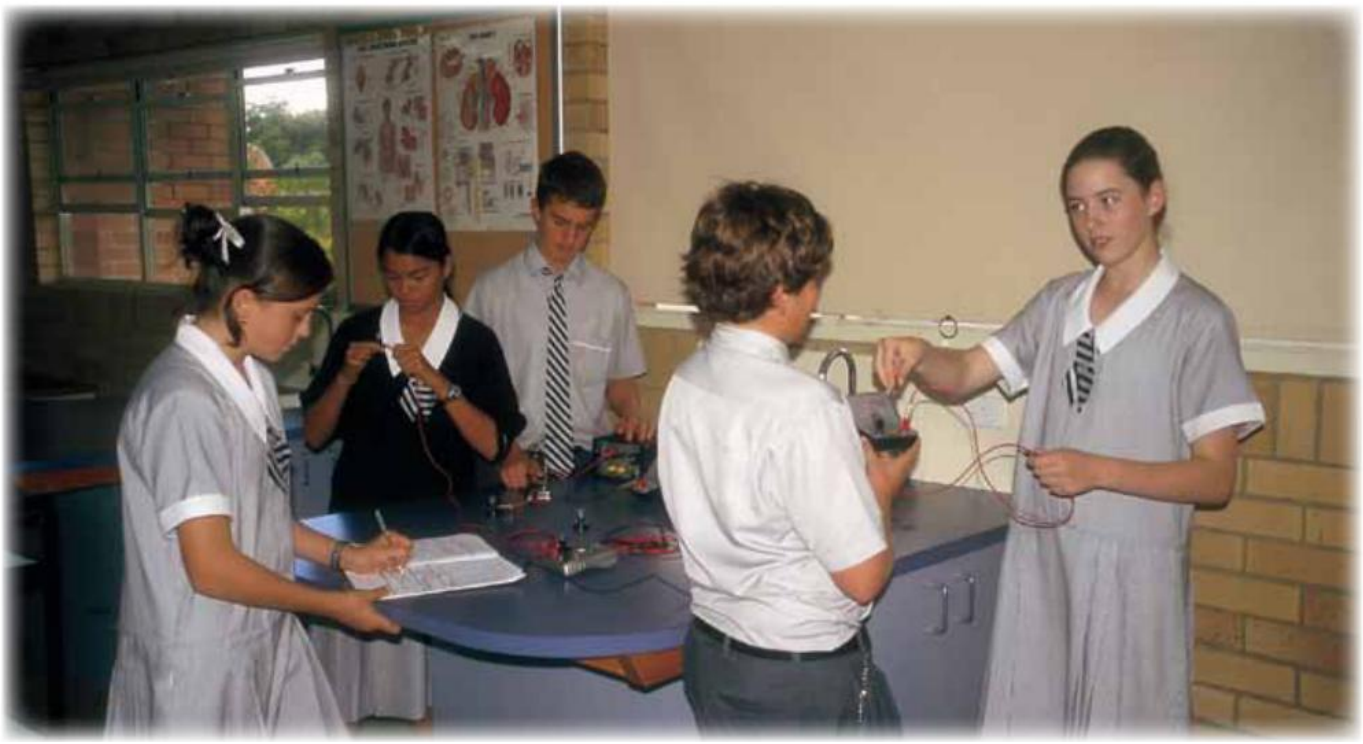
c Which variable did you purposely change? Which variable did you measure?

d Which variables did you control?

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 controlled and you need to repeat the experiment, suggest improvements you could make.

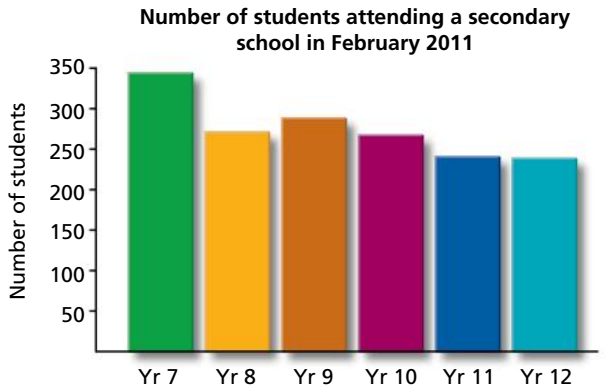
7 **Conclusion** Write a statement summarising your findings or a generalisation about the results of the experiment. This should also include a statement of where to go from here. Is further testing needed to check the results? Do the results suggest another test that could now be done?



Students doing an electricty investigation

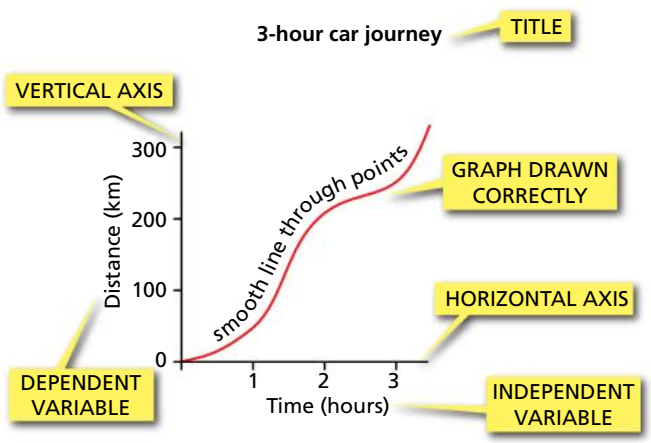
Drawing graphs

Graphs are often used to display the results of experiments. Let's review how to interpret column, bar and line graphs. Column graphs run vertically and bar graphs run horizontally. Both types of graph are used to show groups of things that are counted or measured at a given time.



Line graphs are used when two variables are measured. For example, a graph can show the distance a car travels and the time it takes to make the journey. The two variables are time on the horizontal or *x*-axis and distance on the vertical or *y*-axis. Remember also that time in this example is the *independent variable* because the person making the test can decide what to choose or select for its value. For example, they could decide to take measurements at 2 minute intervals or 4 minute intervals. This variable is deliberately changed and controlled by the tester.

The distance travelled is the *dependent variable* and is plotted on the *y*-axis. In the above example its value will *depend* on the time chosen. An example of a line graph is shown below.



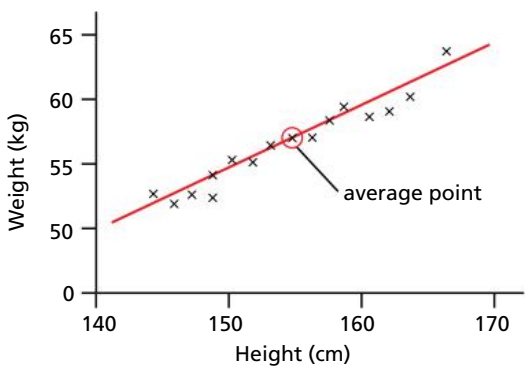
Remember that all graphs no matter what type should:

- have a title
- have labels on both the *x*- and *y*-axis
- be plotted accurately with a ruler in the case of column and bar charts, and a smooth line in the case of a line graph
- have a suitable scale on each axis. To do this look at the largest and the smallest numbers in the measurements and space these out along the axes.
- be drawn as large as possible.

Line of best fit

Often in science it is interesting to see if there is a relationship between the variables measured. Let's say you want to know if the height of a person affects their weight. Each student in a particular class measures their height and records their weight. Neither height nor weight is set or controlled, so there is no dependent or independent variable. In this case a *line of best fit* is drawn. To do this you need to follow these steps:

1. Plot the values for each student on the graph as shown below.
2. Take an *average* of each set of measurements. For example, calculate the average height, then the average weight and plot these points on the graph. (Remember, to take an average you add up all the measurements and divide this by the total number of measurements taken.)
3. Draw a line of best fit through the points, making sure it goes through the average point. The line doesn't need to go through all the points, but it should pass as close as possible to all of them. There should be as many points above the line as below it.
4. If you can draw a line of best fit, then there is a relationship between the variables. In this case the graph tells you that the taller you are the more you weigh.



SKILL

Writing better practical reports

Some common mistakes in practical reports occur when recording observations, drawing graphs and writing conclusions. The following activities will help you.

Recording observations

Look at this example of a student's results:

> *Mrs Cooper gave us two test tubes. Lucy filled one with potassium iodide solution and I filled the other with lead nitrate solution. We poured the two together. It went all yellowy and thick like paint. Mrs Cooper said this was a precipitate.*

When recording your observations as results:

- Avoid describing what you did. Leave this for the Method section.
- Avoid personal language such as names (I, we or they).
- Make simple precise statements. Leave out irrelevant or unnecessary information.

Here's how the above example should be written.

> *When potassium iodide solution and lead nitrate solution were mixed, a yellow precipitate was formed.*

Rewrite the following results leaving out any irrelevant information.

a We added marble chips into a 500 mL beaker which was too big, so we got a smaller beaker instead. Mark then got the hydrochloric acid and poured it on the chips, he should have used a dropper and Mr Timms wasn't happy. The marble chips really fizzed and carbon dioxide was given off I think.

b Lan looked at the thermometer in the beaker as it was being heated and measured the temperature. It had only changed a couple of degrees from 23°C where it started. We then waited another 10 minutes until the water boiled, taking measurements every 2 minutes. This wasn't very exciting.

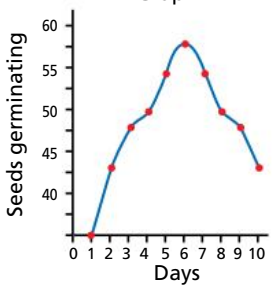
c Jake attached the crocodile clips to the steel wool and then we switched on the power pack to 12 volts. Wow, you should have seen the steel wool. It went red hot and burst into flames. James forgot the heatproof mat so we burnt the bench. The steel wool was all black and charred when we had finished, so was the bench.

Drawing graphs correctly

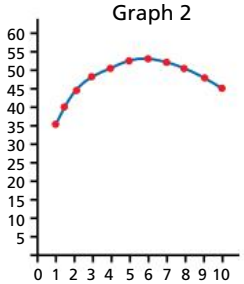
1 Each pair of graphs below shows the same data, but they are drawn differently. For each pair of graphs state which graph is more correct and give reasons for your answer.

Pair 1

Graph 1



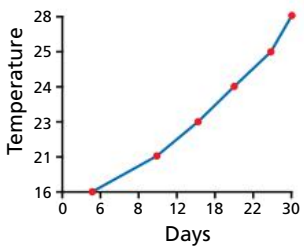
Graph 2



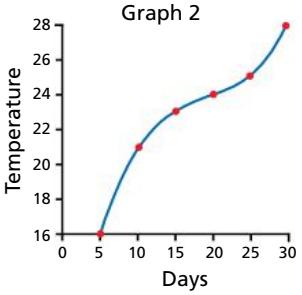
Day	1	2	3	4	5	6	7	8	9	10
Seeds germinating	35	43	48	50	54	58	54	50	48	43

Pair 2

Graph 1



Graph 2

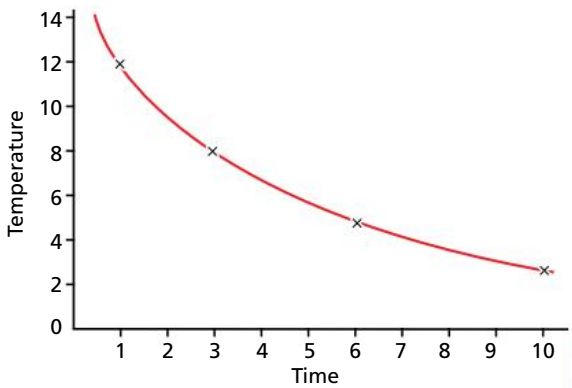


Day	5	10	15	20	25	30
Temperature	16	21	23	24	25	28

2 Aaron wanted to show how long milk lasts at various temperatures. His graph is presented below.

a Explain why this graph is incorrectly drawn.

b Draw the graph as it should be drawn.



SKILL

continued

Writing conclusions

Look at this example of a student's conclusion:

We wanted to test the hypothesis that taller people will be able to exhale a larger volume of air in one breath than shorter people. The class results proved this hypothesis. We did have a problem though, we found that the tube we were blowing into had a slight crack and air was escaping, we don't know when the crack occurred. Improvements could be to check the equipment after each student.

When writing a conclusion:

- Do not repeat the results. They should be in the results section.
- Avoid personal language such as names (I, we or they).
- Avoid saying 'This proves…'. Instead say whether or not the results support the hypothesis (if there is one).
- Discuss errors only if they affect your results and you cannot make a valid conclusion. Otherwise discuss errors in the *Discussion* section.
- Make simple precise statements.

Here is the above example as it should be written.

The hypothesis that taller people will be able to exhale a larger volume of air in one breath was supported. However this was only tested in one class. A crack in the tube used could have affected the results.

Rewrite the following conclusions as simply as possible.

a Our hypothesis was that different liquids will expand at different rates. This was true and correct because the methylated spirits really whooshed up the tubing whereas the water was a lot slower and the kerosene really moved too. We didn't realise that our tubing was different sizes. The water tube that Paige got was much thicker than the others. We have to make sure this is looked at next time.

b Slaters react to light was our hypothesis and this was proven because whenever Tracey put the torch near the slaters they ran away into the dark. We also found that they like to be under things because they ran to corners with newspaper not the bare ones. We could test this next time.

Over to you

1 What is the difference between:

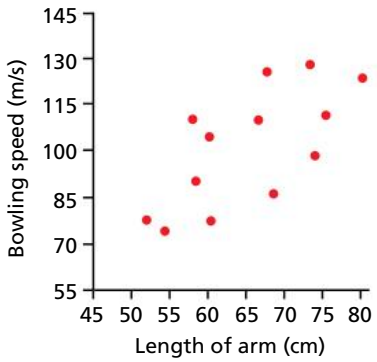
a an Aim and a Conclusion?

b the Method and the Results?

c the Results and the Discussion?

d the independent and the dependent variable?

2 Look at the following graph.



a What is missing from the graph?

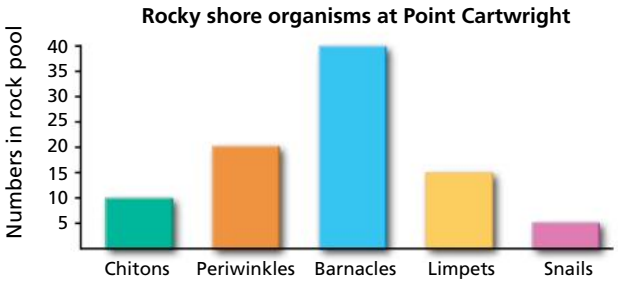
b Copy the graph and plot the calculated averages: length of arm 65 cm, bowling speed 100 m/s.

c Draw a line of best fit and state the relationship between length of arm and bowling speed.

3 Look at the following graph.

a What type of graph is this?

b Explain why this type of graph has been used to display this information.



PROBLEM SOLVING

You need to write an investigation report for your own experiment. Remember to include all the sections, beginning with the hypothesis (Aim) through to the Conclusion. Use graphs to display your data and be careful to avoid the types of errors you have looked at in the Skill section. Complete your task now.

THINKING SKILLS

1 Read the following statement written by Sir Howard Florey. Explain in your own words his reason for working on penicillin.

'People sometimes think that I and the others worked on penicillin because we were interested in suffering humanity. I don't think it ever crossed our minds about suffering humanity. This was an interesting scientific exercise, and because it was of some use in medicine is very gratifying, but this was not the reason that we started working on it.'

2 'Serendipity' is a term used to describe scientific discoveries that are made by accident. Lewis Thomas, an American science writer, doesn't believe in serendipity because 'as you get research going ... things are bound to begin happening. If you've got your wits about you, you create the lucky accidents.'

Louis Pasteur said 'In the field of observation, chance favours only the prepared mind.'

a Explain in your own words what Thomas is saying.

b Explain in your own words what Pasteur is saying.

c Does Pasteur agree or disagree with Thomas? Explain.

d Do scientific discoveries happen by chance or do scientists create their own accidents? You may like to hold a class debate on this issue.

3 A woman was admitted to hospital because she was dehydrated. She was told she could go home when she passed 700 mL of urine each hour for six consecutive hours. Here are her results:

Time	Volume of urine (mL)	Time	Volume of urine (mL)
9 am	100	2 pm	700
10 am	150	3 pm	700
11 am	300	4 pm	700
12 am	450	5 pm	700
1 pm	600	6 pm	650

a What type of graph could you draw to display this data? Why?

b Which is the independent variable? Which is the dependent variable?

c Draw a graph of the patient's results and say whether she can go home.

4 In England when it snows, salt is sprinkled on the roads to make the ice melt. Salt lowers the freezing point of water so that it does not form ice at 0°C.

a Design and carry out an experiment to show the effect of salt on the freezing point of water.

b When water freezes it expands and can crack the radiator of a car. A commercial antifreeze can be added to the radiator to stop the water freezing. Infer how the antifreeze works. How could you test your inference?

c Snow gums and many alpine plants in Australia have fluids inside their cells which act like antifreeze. Explain how these plants survive the cold.



5 Design a way to work out how many sheets of toilet paper there are in a roll without unravelling the whole roll.

6 Choose a famous scientist. Present a brief history of their life and an outline of the processes they used to make their discovery. Here are the names of some scientists to start with: John Tebbutt, James Watt, Elizabeth Kenny, Robert Van de Graaff, Michael Faraday, Dorothy Hill.

7 Thomas Edison made this famous quote: 'Genius is one per cent inspiration and ninety-nine per cent perspiration.' What do you think he meant by this? Give an example. Research other famous quotes scientists have made. You could include these in your school newsletter or magazine.

Knowing and Understanding

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

1. _____ are made using smell, taste, hearing, sight and touch. Observations may start an investigation and lead to _____ and _____.
2. Scientists find the answers to their questions by carrying out carefully thought-out and well-designed _____.
3. Observations are made throughout an experiment and they are recorded or written down as _____.
4. A general statement that can be tested is called a _____.
5. A practical _____ written correctly is made up of several parts. A discussion is where the results are analysed and a _____ summarises the main findings.
6. Data can be recorded as a column, bar or _____ graph. A line of best fit on a graph can show the relationship between two _____.
7. In a fair test only one variable is altered and the other variables are kept the same or _____. This makes the results more reliable.

conclusion
controlled
data
experiments
hypothesis
inferences
line
observations
predictions
report
variables

Self-management

Science charades

1. Your teacher will divide the class into groups of five.
2. Each group will be given 10 white postcard-sized cards and a marker pen.
3. On each card your group has to write a sentence about this chapter that can be acted out without words. The sentence may be about
   - **a** a famous person, e.g. Alexander Graham Bell invented the telephone
   - **b** the processes involved in science, e.g. *Science is observing*
   - **c** a scientific word, e.g. *A prediction is a future observation.*
4. Once each group has prepared their cards they are given to the teacher.
5. Your teacher will then present one person in your group with a card from another group. The person with the card has 3 minutes to act out its meaning for their own group members. They may say whether it is a person, a process or a word but nothing else. If the group guesses what the sentence is about they get 10 points.
6. The group can buy a hint at a cost of 2 points.
7. At the end of the game the group with the most points is the winner.



Checkpoint

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

OneStopScience

1 Copy and complete the following sentences with words from this chapter.

a A general statement that can be tested is called a _____.

b A _____ is a future observation.

c A statement that is true most of the time is called a _____.

d Any factors that can alter the outcome of an experiment are called _____.

e An _____ is an explanation of an observation.

2 Give an example of how an observation can start an investigation. Use the following words in your answer:

observation, prediction, hypothesis, inference, test

3 Cameron noticed that aspirin tablets dissolved faster in hot water than in cold water.

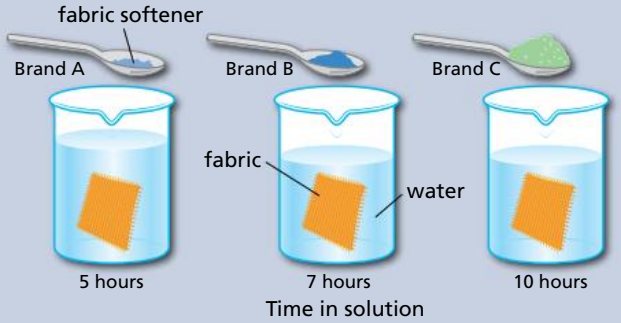
a State a possible hypothesis Cameron could test.

b Design an experiment to test this hypothesis.

c What variable would you purposely change in the experiment?

d What variables would you control?

4 Debbie wanted to see which fabric softener was the best to use. She set up the following apparatus. However she did not control all the variables she was supposed to.



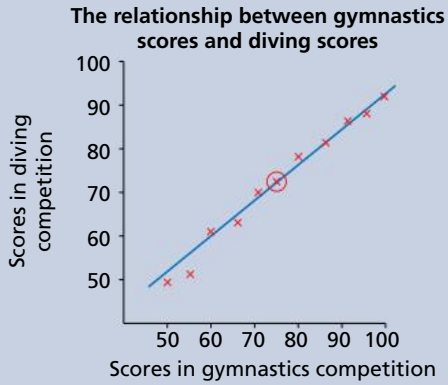
a What is the one variable Debbie should be testing?

b Which variables has she controlled?

c Which variables has she *not* controlled?

d If Debbie found that brand C fabric softener was the best, would you accept her results? Explain.

5 Look at the following graph.



a What type of graph is this?

b What is the average gymnastics score?

c What is the average diving score?

d Why has a straight line been drawn, rather than drawing a curved line through all the points?

e What is the relationship between a person's gymnastics score and their diving score?

6 What is the difference between

a qualitative and quantitative data?

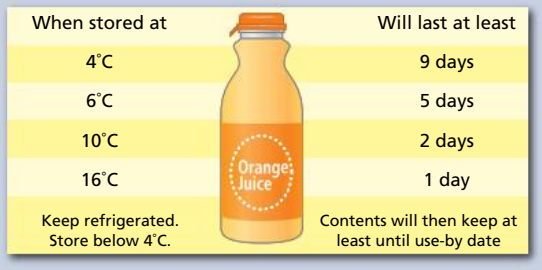
b an independent and a dependent variable?

c column graphs and line graphs?

d a discussion and a conclusion?

e a hypothesis and a guess?

7 Look at the following information on a bottle of fresh orange juice.



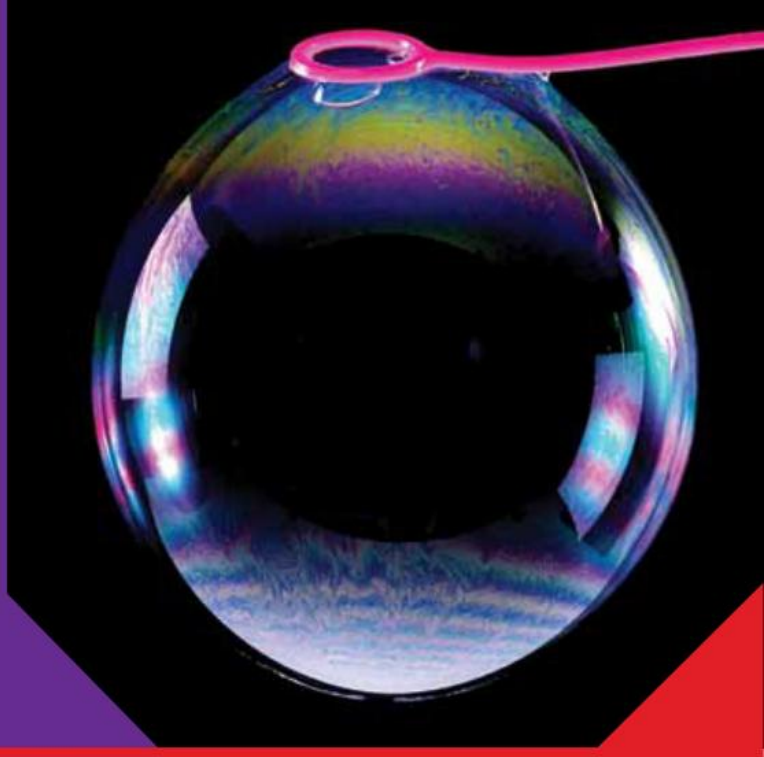
a From the information on the label, write an observation about the fruit juice.

b What prediction can be made about the orange juice if it is stored at 4°C?

c What hypothesis could be made using the information presented here?

d If the orange juice is kept at 16°C it is likely to last only one day. Write an inference to explain this.

2



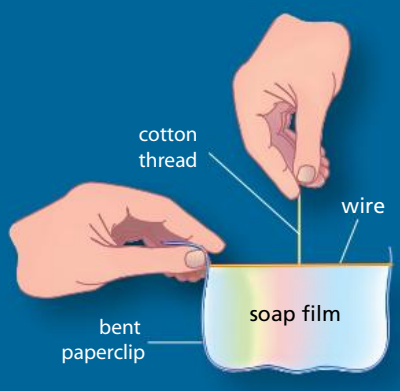
Particles of matter

PROBLEM SOLVING

Soap films

You will need: large paperclip, piece of thin wire (e.g. fuse wire) about 6 cm long, piece of cotton thread about 7 cm long, soap solution

1 Bend the paperclip into a U-shape frame with a handle, as shown. Attach the thin wire so that it slides easily along the sides of the frame. Then tie the piece of cotton thread to the thin wire.



2 Dip the frame into some soap solution.

3 Pull the thread and stretch the soap film without breaking it. Then release the thread. What happens?

4 Try to explain what happened to the soap film. Does the idea that matter is made of particles and that these particles attract one another help your explanation? Keep your explanation because you can return to it as you study this chapter.

5 Make a frame for blowing bubbles, and design an experiment to test one of these questions.

- Is a round bubble the only possible shape for a bubble?
- Can you make bigger or longer-lasting bubbles by changing the soap solution? For example, try adding a little glycerine.
- What size and shape of frame makes the biggest or longest-lasting bubbles?

Focus for learning



More than 2000 years ago in ancient Greece a philosopher called Democritus suggested that *everything, living and non-living, is made of tiny particles too small to be seen*. His idea was that if you kept cutting something into smaller and smaller bits you would eventually come to the smallest possible particles—the building blocks of matter. We use the word **atom** to describe these tiny particles. It comes from the Greek word *atomos* which means 'cannot be divided'.

Democritus' idea has since been supported by many experimental results and is called a **theory**. So the idea that matter is made up of tiny particles too small to see is now called the **particle theory** of matter. It includes the idea that the particles attract each other.

In this chapter you will use the particle theory to explain many everyday things, e.g. the formation of soap films and bubbles.

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

Science Understanding

- use models to show the arrangement of particles in solids, liquids and gases
- use the particle theory to explain solids, liquids and gases and how they can change from one state to another
- write inferences to explain various properties of matter, e.g. dissolving, in terms of particles

Science Inquiry Skills

- use specialised equipment to measure mass, volume and density accurately
- draw and interpret a line graph of the temperature as ice melts to water and then boils

LITERACY FOCUS

atom	dissolve	molecule	solute
chemical bond	electrons	neutrons	solution
concentrated	evaporation	particle theory	solvent
density	mass	protons	suspension
diffusion	matter	saturated	theory
dilute	model	sediment	volume

2.1 Properties of matter

Matter is the stuff that everything is made of. Everything around you is made up of matter—this book, your shirt, your body, the water in a swimming pool, even the air you breathe. All matter has two important properties—it has mass and it occupies space. **Mass** is the amount of matter in an object, and it is measured using a balance. The amount of space an object occupies is called its **volume**.

All matter can be sorted into one of three main groups: solids, liquids and gases. These are the three states of matter.

Solids

Solids include such things as steel girders, your desk, and most of the objects you can see. The shape of most solids is not easily changed, and neither is their volume.

Some solids are made of tiny pieces, for example sugar, powder, sawdust. These solids take the shape of their container but the pieces themselves don't change shape.

Liquids

Water, soft drink and oil are all examples of matter in liquid form. The volume of a quantity of liquid does not change, but its shape may. For example, pour some soft drink from a can into a glass. The volume of the soft drink doesn't change, but its shape does. And if you spill it on the floor it has another shape.

Gases

The air around you is a gas. In fact, it is a mixture of gases, mainly nitrogen and oxygen. Gases do not have a fixed shape or volume. They fill a container no matter what its shape or size. For example, helium gas fills a metal gas cylinder. The gas can be let out through the tap to fill balloons of various shapes and sizes. If the gas escapes it will spread out into the air. Gases can also be compressed (squeezed) into a smaller volume like the helium in the cylinder. You can't do this with liquids and solids.

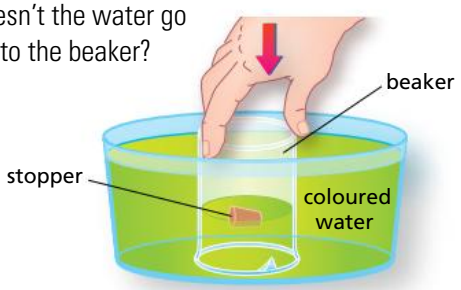
INQUIRY 1 Solids, liquids and gases

You will need: small beaker, stopper, food colouring, large container, syringe (without needle)

A Fill the large container with water and add a few drops of food colouring. Put a stopper in the water.

Put the mouth of the beaker over the stopper and push it down as shown.

- Can you force the stopper to the bottom of the beaker?
- Why doesn't the water go up far into the beaker?

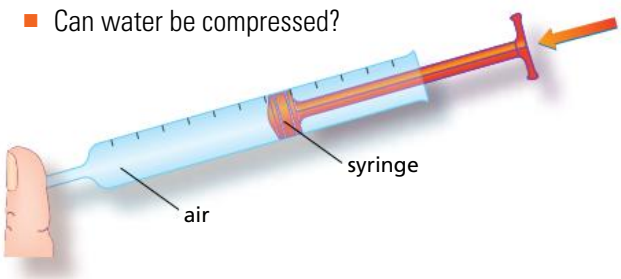


B Place your finger over the end of a syringe. Try to push the plunger in.

- Can air be compressed?

Draw up some water into the syringe.

- Can water be compressed?



C To summarise what you have learnt about solids, liquids and gases in this activity, copy the table below. Complete it by putting a ✓ or a ✗ in each box.

States of matter	Properties of matter				
	Can be weighed	Occupy space	Fixed shape	Fixed volume	Can be compressed
solids	✓				
liquids	✓				
gases	✓				

SKILL

Measuring mass

Mass is measured in grams, using a balance. A commonly used balance is the suspended-pan balance, with three or four arms and sliding masses. Electronic balances have a digital readout, like a digital watch.

To use a suspended-pan balance, follow these steps.

1. Make sure the balance pan is empty, then move all the sliding masses to the zero position. If the pointer on the balance does not line up with the zero mark, the balance needs adjusting. See your teacher about this.
2. Put a small object in the balance pan. The pointer on the right will move up above the zero mark.
3. Slide the large mass along the back arm. When the pointer falls below zero, slide the mass back one notch. (This may be back to the zero position.)
4. Repeat Step 3 for the middle arm(s).
5. Finally, adjust the sliding mass on the arm nearest you to balance the object as accurately as you can. It is balanced when the pointer lines up with the zero mark. If the pointer is above the zero mark you need to move the mass to the right. If the pointer is below the mark you need to move the mass to the left. Read the scales on the arms, and work out the total mass. If the arms are balanced as shown below the mass is 184.9 g.

Arm 1	100.0 g
Arm 2	80.0 g
Arm 3	4.0 g
Arm 4	0.9 g
	184.9 g

To use an electronic balance, follow these steps.

- First set the balance on zero.
- Put the object on the balance and read it when the digits stop changing. If the digits keep changing, read the one you see most often.



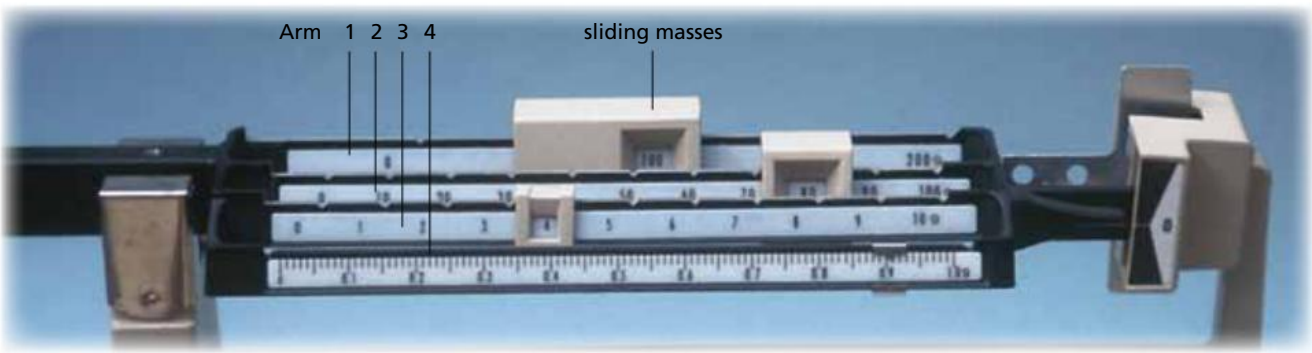
A suspended-pan balance



An electronic balance

When measuring the masses of laboratory chemicals, you should always use a container.

- How can you measure out exactly 1 g of sugar?
- How can you use a beaker and measuring cylinder to find the mass of 50 mL of water?
- What errors of measurement could occur when using a balance?



Density

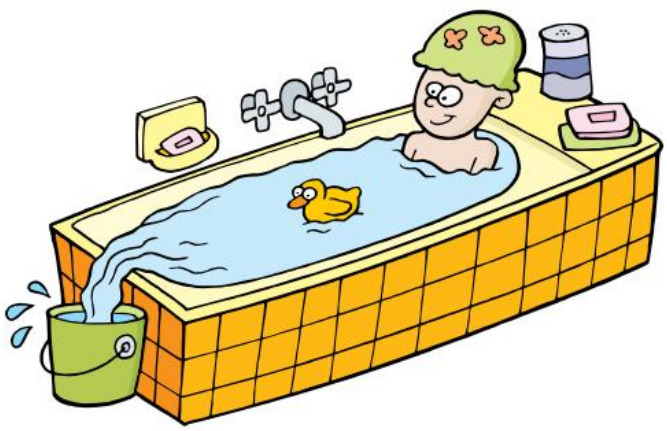
An important property of matter is its **density**. It can be explained using this example. Which would you rather carry up steps—a suitcase filled with lead, or the same suitcase filled with feathers? The feathers and the lead take up the same space, but the suitcase of lead is much heavier than the suitcase of feathers. This is because lead is denser than feathers.

Similarly, iron is denser than wood. A 1 cm cube of iron and a 1 cm cube of wood take up the same amount of space, so they both have the same volume (1 cubic centimetre). However the iron cube has a greater mass than the wooden cube. It has more mass packed into one cubic centimetre, so its density is greater than the density of wood.

Density is how much mass is packed into a measured volume. It is usually measured in grams per cubic centimetre (g/cm^3). To find the density of something you need the following formula:

$$\text{density } (g/cm^3) = \frac{\text{mass (g)}}{\text{volume } (cm^3)}$$

To find the volume of a block of wood you use the formula volume = length × width × depth. But how can you measure the volume of an odd-shaped object like your body? The secret is to drop the object into water and measure the volume of water it displaces (pushes out of the way). This method was discovered by Archimedes in Greece in 250 BC when he had to measure the volume of a crown to see if it was pure gold. (See Thinking skills on page 44.)



How to measure your volume by displacement

The table top right lists the densities of some common substances. Anything will float in water if its density is equal to or less than the density of water, that is 1 g/cm^3.

Table of densities (g/cm^3)			
helium gas	0.00018	water	1.0
air	0.0013	sea water	1.03
styrofoam	0.1	aluminium	2.7
cork	0.2	iron	7.8
pine wood	0.4	nickel	8.9
petrol	0.7	lead	11.3
polythene plastic	0.9	gold	19.3
ice	0.9	osmium	22.5

Over to you

1 For each of the following say whether it is a solid, a liquid or a gas.

a air
b frozen ice-cream
c milk
d nail polish
e nail polish remover
f sand
g string
h sugar
i the smell of onions
j melted ice-cream

2 Copy and complete these sentences.

a All matter has _____ and takes up _____.
b The three states of matter are _____, _____ and _____.
c A _____ can be squeezed into a smaller volume, but a solid or a _____ cannot.
d Mass is measured in _____.
e Density is how much mass is packed into a measured _____.

3 In which state is a substance if it has

a no fixed volume?
b a fixed volume and shape?
c a fixed volume but takes the shape of its container?

4 Which properties allow you to tell the difference between the substances in each of the following pairs?

a chalk and snow
b rubber and aluminium
c soft drink and water
d salt and sugar
e wood and plastic

5 It is easier to float in sea water than in fresh water. Use your knowledge of density to explain this.

6 Look at the data table below.

	Mass (g)	Volume (cm^3)
Object A	39	6
Object B	6	5
Object C	54	20

a Which object is the heaviest?
b Which object is the most dense?

INVESTIGATION

1 Measuring density

Aim

To compare the densities of various fruit and vegetables.

Risk assessment and planning

Read the investigation carefully.

1 Which type of balance will you be using?

2 Draw up a data table to record your results. You will be measuring the mass and volume of each fruit and then calculating its density.

Apparatus

- different types of fruit and vegetables, e.g. apple, orange, pear, potato, tomato, banana, onion
- pneumatic trough
- balance
- large measuring cylinder
- displacement can
- piece of wire

Method

1 Fill the pneumatic trough with water.

2 Examine the fruit and vegetables you have been given. Hold each in your hand. Based on your observations, predict which fruit or vegetables will be the most dense and sink when placed in water.

3 Place each fruit into the water. Were your predictions correct?

4 Using the balance, measure and record the mass of each fruit.

5 To find the volume of a piece of fruit you will need to measure how much water it displaces. To do this you need a displacement can. If you don't have one you may be able to use a large beaker.

With your finger over the spout, fill the displacement can above the level of the spout. Put the can on a level surface and let the excess water drain out into a sink.

6 Put the measuring cylinder under the spout as shown and carefully lower the fruit into the water. If necessary, push the fruit gently under the surface of the water using a piece of wire.

7 Measure the volume of water you caught in the measuring cylinder. This volume is equal to the volume of the fruit.

✻ Record the volume in your data table.

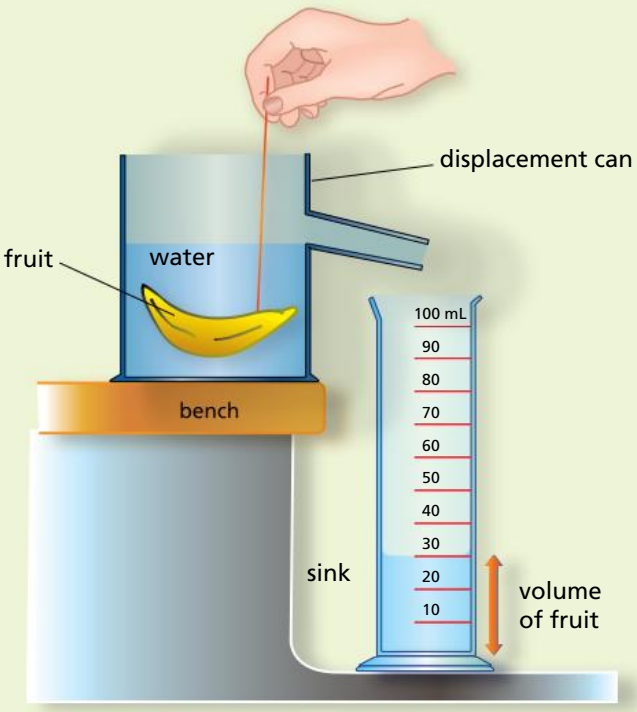
8 Find the volumes of the other fruit and vegetables in the same way.

9 Calculate the density of each object using the formula:

$$\text{density} = \frac{\text{mass of object (g)}}{\text{volume of object (cm}^3\text{)}}$$

Give your answer to the nearest 0.1 grams per cubic centimetre.

(Note: 1 millilitre = 1 cubic centimetre)



Results

1 Compare your results with those found by other students. If they are different, suggest possible reasons.

2 Which fruit or vegetables are the most dense?

3 For objects that will fit in the measuring cylinder you don't need the displacement can to measure their volume. See if you can work out how to do this for yourself.

Write your report

Write your report using the usual headings, including a conclusion.

2.2 The particle theory

Changes of state

The three different states of matter can be changed from one to another by adding or removing heat. Such changes are called changes of state. They are physical changes that can easily be reversed.

If you heat a solid it will form a liquid. For example, ice melts to produce water. Metals such as iron and gold also melt if you heat them enough.



Gold melts at about 1000°C. The liquid gold can then be poured into moulds to make ingots.

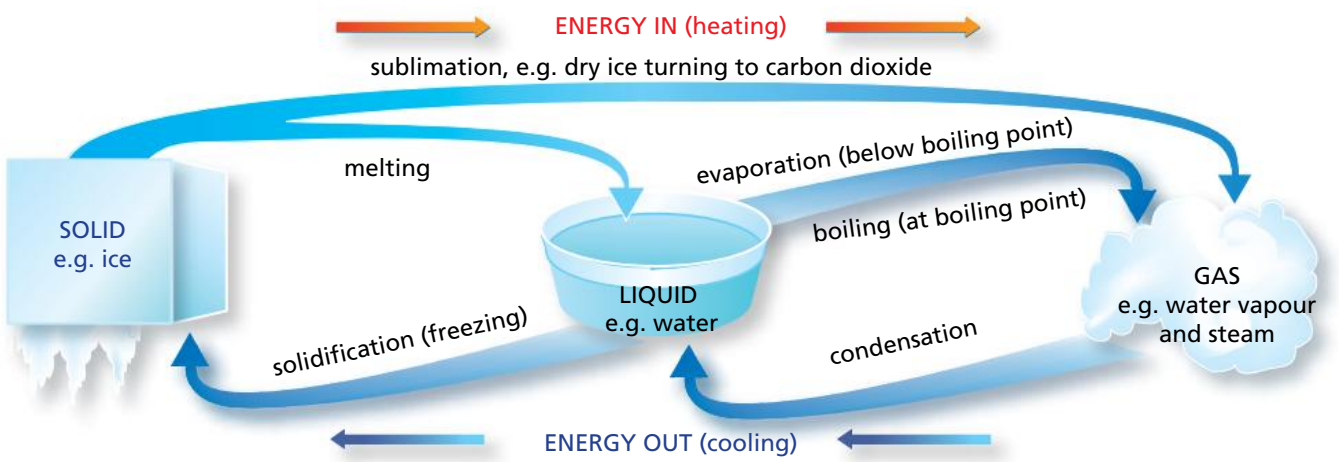
Heating also causes **evaporation** (e-VAP-or-AY-shun), where a liquid changes to a gas. For example, water evaporates to form water vapour, which is a gas. The hotter the water gets, the more quickly it evaporates. When bubbles of water vapour appear in the water it is said to be *boiling*. This happens at 100°C. At this temperature the water vapour forms more quickly, and is now called steam. Water can evaporate at any temperature, but boiling occurs only at the boiling point. So steam is produced only at 100°C. At temperatures below this gaseous water in the air is called water vapour.

Cooling causes gases to condense and form liquids. Steam is invisible, but when it meets cooler air it condenses to form tiny droplets of water. It is these droplets that we see as a cloud of 'steam'. A similar thing happens in the bathroom when you have a hot shower. Some of the hot water evaporates and changes into water vapour. Because the air in the bathroom is cooler, the water vapour condenses to form tiny drops of water that float in the air and 'fog up' the mirror. Similarly, as water from the Earth's surface evaporates it forms water vapour. As this water vapour rises it becomes cooler and may condense to form clouds and perhaps rain.

Cooling also causes water to freeze or *solidify*. This occurs naturally when snow and hail form. We use the same process to make ice blocks and ice-cream. We make candles from melted wax which hardens into any shape we wish to make.

Some solids do not change to a liquid when they are heated. Instead they turn straight into a gas in a process called *sublimation*. For example, 'dry ice' is solid carbon dioxide. When left at room temperature it soon warms up and changes directly into gaseous carbon dioxide.

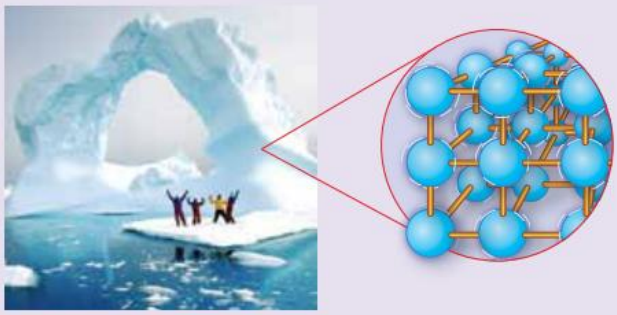
Look at the diagram below. To change state by going to the right, heat energy must be added to the matter—it must be heated. To change state by going to the left, heat energy must be taken from the matter—it must be cooled.



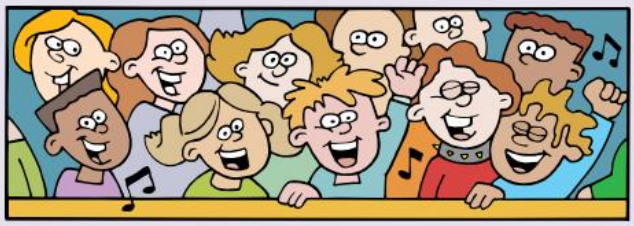
The particle theory

Changes of state can be explained in terms of the particle theory, which says that:

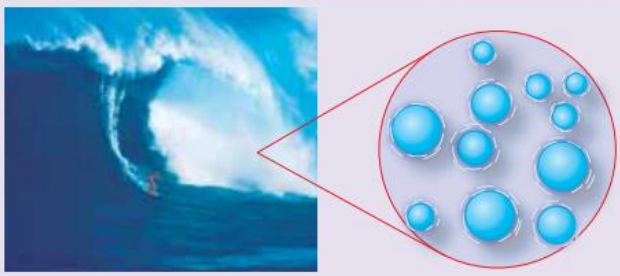
1. All matter is made up of tiny particles too small to see.
2. There are spaces between the particles.
3. There are attractive forces between the particles. When the forces are strong the particles are close together. When the forces are weak the particles are further apart.
4. The particles are always moving.
5. The particles move faster at high temperatures than they do at low temperatures.



The particles in a solid (e.g. ice) are packed tightly in a fixed pattern. There are strong forces holding them together, so they cannot leave their positions. The only movements they make are tiny vibrations to and fro.



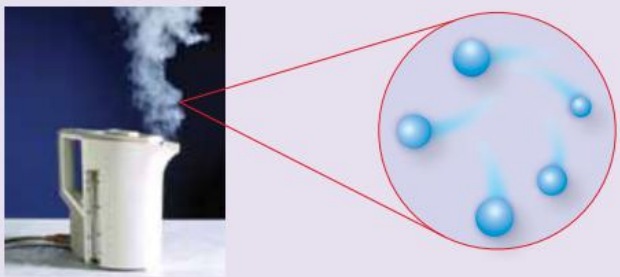
We cannot see these invisible particles but we can use a **model** to represent them. For example, the particles in a solid are like the people at a rock concert. The crowd near the stage is so packed the people are more or less in fixed positions. They move back and forth a little, but they don't move out of their positions.



The particles in a liquid (e.g. water) can move about and slide past each other. They are still close together but are not in a fixed pattern. The attractive forces between them are less than in a solid because the particles are further apart.



A liquid is like an area of the rock concert crowd where you can move about a bit. You are still jostled by other people, but you can make your way through. You aren't stuck in one position all the time.



The particles in a gas (e.g. steam) are far apart, and they move about very quickly. The attractive forces can be ignored because the particles are so far apart. The particles collide with each other and the walls of the container, and bounce off in all directions.



When the concert is over and the crowd is leaving the venue, people are no longer crowded together. They are moving rapidly in all directions—like the molecules in a gas.

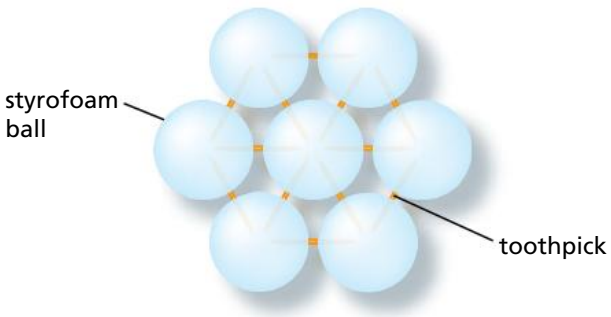
INQUIRY 2

Models of solids, liquids and gases

You will need: 20 styrofoam balls, toothpicks, small clear plastic container with lid, marbles or small ball bearings, balloon

A Solids

1 Use styrofoam balls and toothpicks to build a layer of particles packed together closely.



2 Build a second layer where the balls sit in the gaps in the bottom layer.

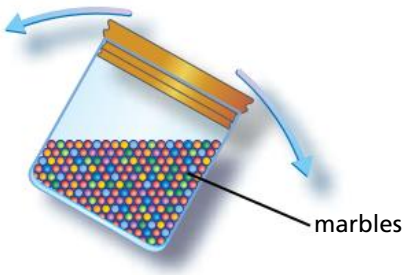
3 Build a third layer the same as the bottom layer.

- Draw a view of your model of a solid looking from the side.
- What do the toothpicks represent?
- Explain whether you think your model is a good representation of a solid.

B Liquids

1 Half-fill a small clear plastic container with marbles.

2 Gently tip the container from side to side and observe what happens.



- Which properties of a liquid does your model explain?

C Gases

1 Put two or three marbles in a balloon.

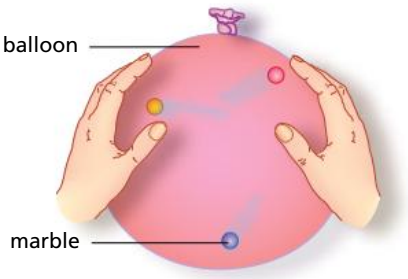
2 Blow up the balloon and tie a knot in it.

3 Hold the balloon in front of a window or a bright light and shake it rapidly in all directions. In case the marbles break the balloon, wear safety glasses.

4 Observe how the marbles move and feel them hitting the sides of the balloon. Do they ever hit each other?

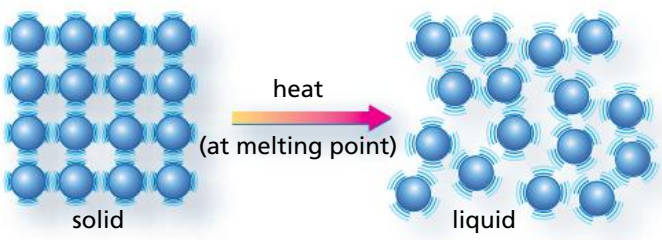
- Why do you think you only need to use two or three marbles?





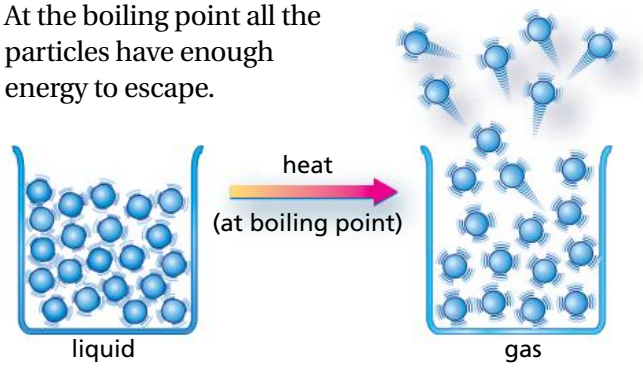
Explaining changes of state

You can use the particle theory to explain changes of state. When a solid is heated, its particles gain more energy and vibrate more. This makes the solid expand (get bigger). Note that the particles themselves don't get bigger—they just take up more space. At the melting point the particles vibrate so much that they break out of their positions. When this happens the solid becomes a liquid—it melts.



When a liquid is heated, its particles have more energy and move faster. They bump into each other more energetically and bounce further apart. Some have enough energy to break the bonds holding them together and escape (evaporate).

At the boiling point all the particles have enough energy to escape.



INVESTIGATION

2 Heating water

Aim

To measure and graph the temperature as ice melts to water and then boils.

Risk assessment and planning

1 Study the drawing below. How can you reduce the risks involved in using this apparatus?

2 What are the variables you will be measuring? Design a data table with columns for these two variables.

If a datalogger (hand-held computer) is available you can connect it to a temperature probe to measure the temperature electronically.

Apparatus

- small beaker, e.g. 250 mL
- crushed ice
- thermometer (–10 to 110°C)
- burner, tripod, gauze and heatproof mat
- stopwatch
- stirring rod
- retort stand and clamp
- cotton wool
- graph paper

Method

1 Set up the apparatus as shown.



2 Half-fill the beaker with crushed ice, and measure its temperature.

✻ Record the temperature of the ice in your data table.

3 Light the burner and turn it to a blue flame. Then adjust the flame to a medium size by turning down the gas at the tap. Put the burner under the beaker and start timing immediately.

4 Every minute stir the water gently and measure the temperature. Continue your measurements until the water has been boiling for about 5 minutes.

✻ Record your data in the data table.

5 Graph your results with time on the x-axis and temperature on the y-axis.

Results

1 Complete these sentences:

a The temperature when ice changes from a _____ to a _____ is called its melting point.

b The melting point of ice is _____°C.

c The temperature when water changes from a _____ to a _____ is called its boiling point.

d The boiling point of water is _____°C.

2 What caused the ice to melt?

3 What did you notice about the temperature as the ice melted?

4 Did the temperature change as the water boiled?

5 Predict the temperature of the water 10 minutes after it started to boil.

6 When you draw a line through the points on your graph you should have two flat sections joined by a slope. What does it mean where the graph is flat? On the graph, mark when the ice is melting and when the water is boiling.

7 The temperature did not increase until all the ice had melted—even though there was a constant supply of heat energy from the burner. Use the particle model from the previous page to infer how that energy was being used.

Also explain why the temperature did not increase once the water started to boil.

Conclusion

In a couple of sentences write a conclusion for this investigation.

INQUIRY

3 Writing about solids, liquids and gases

Write your own *What am I* question or a poem about solids, liquids and gases changing state. Here are two examples to get you started.

What am I?

I melt very easily and can be poured into moulds. I have a low melting point, but it takes a lot of heat to make me boil. I am very useful as a solid and often hold a wick. I shed a lot of light on any subject I am near when my wick is lit.

Answer: candle wax

A poem

My particles are tightly packed
when in the solid state.
It only takes a little heat
to make them all vibrate.

If they are heated strongly
the particles slip and slide.
The solid becomes a liquid,
with spaces nice and wide.

When lots more heat is added
the liquid changes state.
The particles dance and move on out,
in other words, evaporate.

Over to you

1 Which type of matter (solid, liquid or gas) will be formed when a
- **a** gas condenses
- **b** liquid freezes
- **c** solid melts
- **d** liquid boils.

Write your answers as complete sentences.

2 Name the change of state that occurs when
- **a** dew forms on the grass
- **b** a puddle of water on the road disappears when the sun shines
- **c** lava flows from a volcano and slowly forms a rock called basalt
- **d** a lump of dry ice left on the bench is gone after a few minutes
- **e** someone opens a bottle of perfume and you can smell it on the other side of the room.

3 The table below lists five changes of state. For each change decide whether heating or cooling is needed. Copy the table and tick the correct columns.

Change of state	Heating	Cooling
a liquid to gas		
b liquid to solid		
c gas to liquid		
d solid to liquid		
e solid to gas		

4 Say whether each of the following statements is *true* or *false*. If the statement is false, rewrite it so that it is true.
- **a** All matter consists of particles.
- **b** Condense is the reverse of evaporate.
- **c** If water boils for a long time, its temperature rises above 100°C.
- **d** Melting occurs when a solid changes to a liquid.
- **e** Solids have a definite shape because their particles are free to move around.
- **f** The particles of a gas are so far apart that they don't attract each other at all.
- **g** The particles of a solid do not move.
- **h** To change a liquid to a gas you have to cool it.
- **i** Water evaporates more quickly in hot weather.

5 **a** In which state of matter do the particles move the fastest?
- **b** In which state are the particles closest together?
- **c** In which state are the particles close together but not arranged in a regular pattern?
- **d** In which state are the bonds between the particles strongest?

6 Amza wears glasses. He finds it hard to see when he enters a hot steamy bathroom. How can you explain this?

7 If gases and liquids are both made of particles, why are they so different? Explain in terms of particles and the forces between them.

8 Why do clothes dry faster on a windy day than they do on a calm day?

2.3 Solutions

If you stir sugar in a glass of water it disappears. We say it **dissolves** in the water. The sugar and water have mixed to form a **solution**. Solutions are very important in your life. The food you eat is digested and dissolved in water. It is then carried around your body in your blood, which is a solution consisting of about 90% water. The wastes produced by your body are also carried away in solution as urine.

A solution is a special mixture that looks and behaves like a single substance. It consists of a liquid and the dissolved substance which is spread evenly through it. Think about what happens when instant coffee dissolves in hot water. The substance that dissolves (the coffee) is called the **solute**. The substance that does the dissolving (the water) is called the **solvent**. So the solute dissolves in the solvent, forming a solution.



A substance like sugar or coffee that dissolves in water is said to be *soluble*. A substance like chalk that will not dissolve in water is *insoluble*. Some insoluble substances sink in water (settle out), and others float on top. If you shake up an insoluble solid such as chalk dust with water it may seem to dissolve at first, but if you look closely you will see that the mixture is cloudy. The tiny bits of chalk dust are held up by the moving water. Such a mixture is not a solution but a **suspension**. The chalk dust will settle to the bottom of the container if you let it stand for a while. Muddy water is another example of a suspension. The solid that settles to the bottom of a suspension is called a **sediment**.



A suspension such as flour in water (left) settles out on standing. A solution such as tea (right) does not.

Two liquids can also form a solution. For example, wine is a solution of alcohol (solute) in water (solvent). Fuel for two-stroke motor mowers and outboard engines is a solution of oil in petrol.

A substance may dissolve in one solvent but not in another. For example, salt is soluble in water but insoluble in alcohol. Water is an excellent solvent, but there are some things it won't dissolve, for example oil and grease. To dissolve these things you have to use other solvents. Some commonly used solvents are listed in the table below.

Solute	Solvent
ballpoint pen stains	methylated spirits
grease marks on clothes	eucalyptus
nail polish	nail polish remover
oil-based	turpentine
styrofoam	petrol
tar on car paintwork	kerosene

INVESTIGATION

3 Is it soluble?

Aim

To test various everyday substances to see if they are soluble in water and in alcohol.

Risk assessment and planning

You must not touch iodine with your fingers since it stains and is poisonous. Wear gloves when handling it.

1 Your teacher will tell you how to dispose of any leftover iodine. Why is it important not to wash it down the sink?

2 Why should you never use flammable liquids such as alcohol near a flame?

3 Read through the investigation, then prepare a data table like the one below. Will you need another data table for Part B or can you put all your results in one table?

Substance	Is it soluble?	Observations
salt		
sugar		

Apparatus

- test tubes (at least 6)
- test tube rack
- spatula
- felt pen
- *alcohol or methylated spirits (in a dropping bottle)*
- samples of various everyday substances, e.g. ballpoint pen spot on small piece of paper, grass (ground up), jelly crystals, sugar, coffee, chalk, salt, *iodine (solid)*





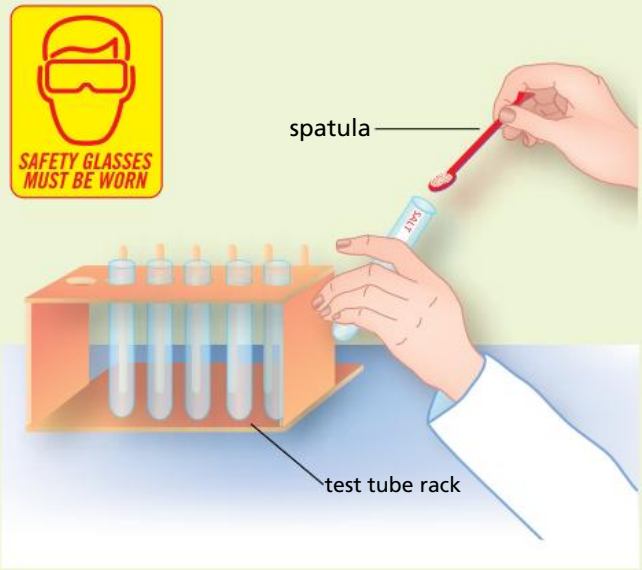
Method

PART A: Is it soluble in water?

1 Use the spatula to pick up a small amount of salt and put it in a test tube, as shown. Use the marking pen to label the tube.

2 One-third fill the test tube with water and shake it for about 30 seconds.

- Record whether the substance is *soluble, slightly soluble* (a bit dissolves) or *insoluble*.
- Record any other observations you make. If a solution was formed, what colour was it? Was a suspension formed?



3 Repeat for each of the other substances.

PART B: Is it soluble in alcohol?

Test all the substances again using alcohol or methylated spirits instead of water.

Results

1 Which substance dissolved most easily in water?

2 What observations did you use to decide whether a substance dissolved or not?

3 Did any of the samples form suspensions? Which ones?

4 Compare the solubilities of the substances in water and in alcohol.

- a Which substances were soluble in water but not in alcohol?
- b Which substances were soluble in alcohol but not in water?
- c Were there substances which did not dissolve in either water or alcohol? Which ones?

5 If you had a ballpoint pen stain on your clothes, how could you remove it?

PART C: Removing stains

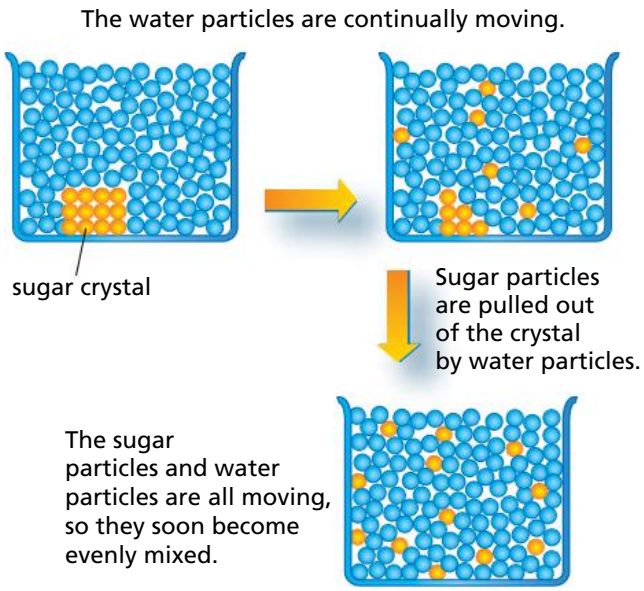
Some common stains on clothes are beetroot, red wine, curry powder and ink. Experiment to see how you can remove these stains from an old cotton T-shirt. Which solvents will you use? You could also try some commercial stain removers, e.g. *Preen* and *NapiSan*.

Report on which solvents you used and which worked best.

Explaining dissolving

You have used the particle theory of matter to explain changes of state. You can also use it to explain dissolving.

Consider what happens when you add sugar to water. Each little sugar crystal contains millions of little particles that are being constantly bumped by water particles. The water particles have a special shape that helps them to pull the sugar particles off the crystal. Because the separated particles are so small they cannot be seen in the water solution. They fit into the spaces between the water particles, as shown.



Dilute and concentrated

A cup of coffee is like any liquid solution. It comes in many different strengths. If you like your coffee stronger, add more coffee powder. If you like it weaker, add less coffee.

We use the terms **dilute** (dye-LOOT) and **concentrated** (CON-cen-tray-ted) to help us compare the strengths of solutions. A dilute solution like weak coffee contains only a small amount of solute in a given volume of solvent. A concentrated solution like strong coffee contains a large amount of solute in the same volume of solvent. So in science we talk about dilute and concentrated solutions, not weak and strong solutions.

The colour of some solutions can tell you how concentrated they are. The darker the colour, the higher the concentration.

Saturated and unsaturated

There is a limit to the amount of solute that will dissolve in a solution. When no more solute will dissolve, the solution is said to be **saturated**. This is like your clothes when they can't hold any more water.



Over to you

1 Copy and complete these sentences in your notebook, using the words you have learnt.

- **a** When sugar is stirred in water, it _____. This shows that sugar is _____ in water.
- **b** In a cup of coffee, the coffee is the _____, and the water is the _____.
- **c** Chalk is _____in water.
- **d** Salty water is a _____, but muddy water is not.
- **e** The solute in a solution does not settle out, but the solid in a _____ does, forming a _____.
- **f** A solution which contains only a small amount of solute is _____. If more solute is added, the solution becomes more _____.

2 For each of the following solutions say what the solute is and what the solvent is.

- **a** dirty bath water
- **b** a chocolate milkshake
- **c** sea water
- **d** soft drink
- **e** water in which you have just cleaned a paint brush

3 When you leave a glass of freshly made fruit juice on the table you end up with clear liquid on the bottom and fruit pulp at the top. Is the fruit juice a solution? Explain.

4 Explain in your own words the difference between dissolving and melting.

5 Sugar is more soluble in warm water than in cold water. Use the particle theory to explain this.

6 Why does sugar dissolve more quickly in tea or coffee when you stir it?

2.4 Using the particle theory

You have used the particle theory to explain solids, liquids and gases, and how they can change from one state to another. In this section you will try to use it to explain some other properties of matter.

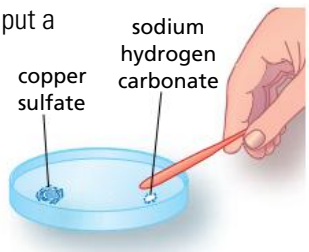
INQUIRY 4 Spreading blue

You will need: copper sulfate, sodium hydrogen carbonate (baking soda), petri dish, spatula

1 Fill the petri dish with water and put it where it won't be knocked or shaken.

2 Using the spatula, gently put a small amount of copper sulfate into the water on one side of the dish.

3 Gently put a small amount of sodium hydrogen carbonate into the water on the other side of the dish.



- Record your observations.
- Write inferences to explain your observations in terms of particles.

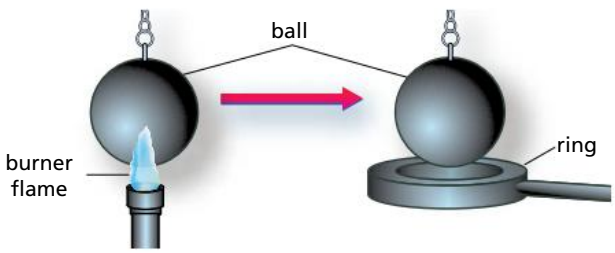
4 Predict what you think will happen if you use hot water in the petri dish. Test your prediction.

INQUIRY 5 Ball and ring

You will need: ball and ring apparatus, Bunsen burner

1 Using the ball and ring apparatus, put the ball through the ring. Then heat the ball strongly and try to put it through the ring again.

- Try to explain what happened.



2 What do you predict will happen if you heat the ring and try again? Try it.

- Was your prediction correct?

Diffusion

If someone opens a bottle of perfume you can soon smell it in other parts of the room. The fragrance spreads through the air in all directions, from where it is highly concentrated to where it is less concentrated. This gradual mixing of substances is called **diffusion**.

How can you explain how perfume diffuses? When the lid is on, the gas particles remain inside the bottle. When the lid is taken off, the liquid perfume evaporates easily since there are only weak forces between its particles. These particles spread rapidly away from the crowded bottle and eventually are mixed evenly throughout the air in the room.

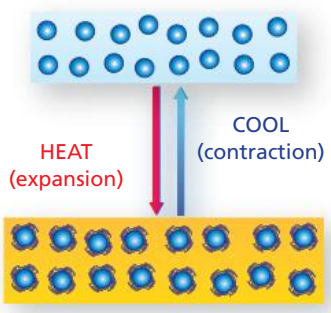
In Inquiry 4 you would have observed the blue colour as the copper sulfate dissolved in the water. This colour diffused towards the middle of the dish. The sodium hydrogen carbonate was invisible when it dissolved, but it also diffused. When the particles of the two different substances met in the middle they reacted to form a light blue insoluble substance. In hot water the particles diffused more quickly.

Expansion and contraction

In Inquiry 5 the ring expanded when you heated it. This is why the ball fitted through it. In general solids expand when they are heated. That is, they occupy more space. Similarly, when they are cooled they contract (get smaller) and occupy less space.

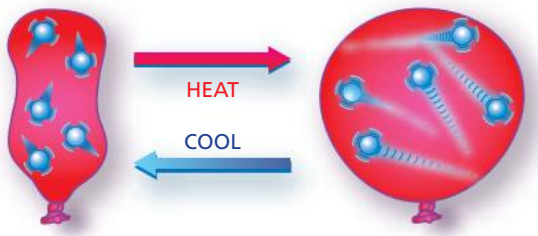
In solids the particles vibrate in fixed positions. As the solid is heated the particles absorb energy, vibrate more and start to bump into each other. This causes them to move further apart so that they have more room to vibrate. As a result, the solid as a whole expands. When the solid cools down energy is transferred to the surroundings. The particles vibrate less and move closer together.

Expansion and contraction of liquids and gases can be explained in a similar way.



Air pressure

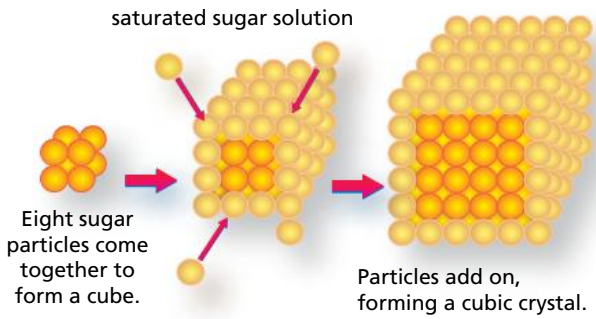
The particle theory can also be used to explain what happens when you blow up a balloon. What keeps the balloon inflated is **air pressure**. The invisible particles of air are only tiny but they move very rapidly—about the speed of a rifle bullet. Air pressure is the result of these tiny bullets bombarding the walls of the balloon. If you leave the balloon in the sun it expands. This is because the air particles are moving more rapidly and hitting the walls of the balloon more often and more violently. The air pressure inside the balloon has increased. If you now put the balloon in the freezer it contracts and the air pressure decreases. This is because the air particles are now moving more slowly and not hitting the walls as often or as violently.



Crystals

If you look at some sugar through a microscope you will find that the tiny grains have definite shapes with flat surfaces and straight edges. These tiny pieces of sugar are called crystals. Different substances have different-shaped crystals. But why are crystals shaped like this?

Suppose you have a solution of sugar. The dissolved sugar particles are too small to be seen since they are spread throughout the solution. Let's imagine eight particles somehow come together and form a cubic crystal as shown. If more particles then add on, the crystal grows. And if a complete layer of particles is added all around, the crystal keeps its cubic shape. Eventually the crystal is big enough to see. Depending on how the particles come together you can get various shapes.



Viscosity

Honey is much thicker than water—it does not flow easily. We say it has a high **viscosity**. Water flows easily and is said to have a low viscosity.

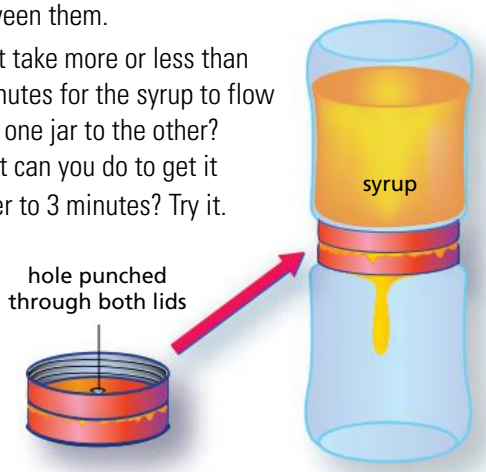
Differences in viscosity can be explained in terms of the attractive forces between the particles in the liquids. For example , the forces between honey particles are much stronger than the forces between water particles can't move past each other very easily. This is why honey flows so slowly.

INQUIRY 6 Making an egg timer

In a normal egg timer, sand takes 3 minutes to flow from one container to another. In this activity you can make one that uses syrup or honey instead of sand.

You will need: maple syrup or honey, stopwatch, 2 jam jars and lids with holes in them, glue

1. Take the two lids off the jam jars and glue them together. Once the lids are dry, fill one jar with the amount of syrup you think you need and screw the lid on.
2. Screw the empty jar on last. Then tip the jars upside down and time how long it takes the syrup to flow between them.
3. Did it take more or less than 3 minutes for the syrup to flow from one jar to the other? What can you do to get it closer to 3 minutes? Try it.



- How accurate was your timer? How could you make it more accurate?
- Predict whether temperature affects the rate of flow of the syrup. Design an experiment to test your prediction.

Did you know that a timer like the one you have just made was set up at the University of Queensland in 1927? It contains pitch oil which is so viscous the oil has dripped only eight times since the timer was set up.

INVESTIGATION

4 Growing crystals

Aim

To grow crystals and observe their shapes.

Risk assessment and planning

Read the investigation carefully. What risks are there and how can you minimise them?

Apparatus

- copper sulfate
- spatula
- stirring rod
- small beaker
- petri dish
- microscope
- microscope slide
- test tube holder
- Bunsen burner, tripod and gauze
- hand lens

Method

1 Heat some water in a small beaker. Use the spatula to add copper sulfate a bit at a time while stirring. Keep heating and adding copper sulfate until no more will dissolve no matter how much you stir it. The solution is now *saturated*. Allow it to cool.

2 Pour a thin layer of the saturated solution into a petri dish. Keep the rest for Step 6.

3 Leave the copper sulfate solution to evaporate. It may take a few days before crystals start forming.

4 When the crystals form, pour off any remaining solution and examine the crystals with a hand lens.

✻ Sketch some of the crystals in your notebook.

5 Warm a microscope slide gently over a small, blue flame.

6 Clip the slide to the microscope stage. Using the stirring rod, place a drop of the solution from Step 2 onto the slide.

7 Observe carefully through the microscope.

✻ Try to draw pictures of what you see.

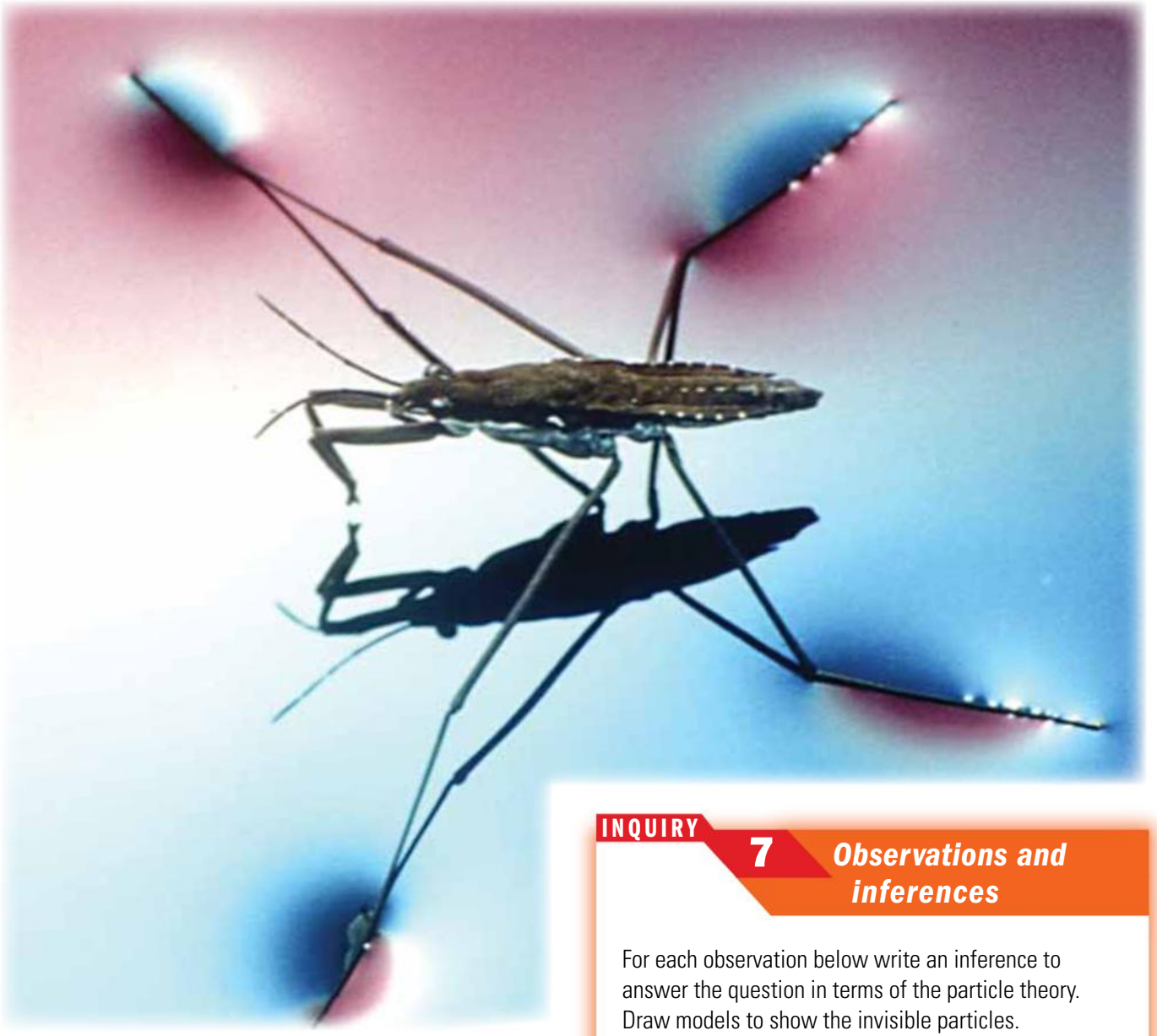
Repeat the activity with other chemicals, using clean slides. Some you could try are alum, hypo and salol (phenyl salicylate). Compare the shapes of the different crystals.

Write your report

Use the usual headings, including a conclusion.



These cystals of gypsum, found in a cave in Mexico, are the largest ever found.



How can this water strider sit on the surface of a pond?

PROBLEM SOLVING

Now that you have had lots of practice explaining the properties of matter using the particle theory, go back to your soap film task on page 24. Can you now explain the behaviour of the soap film? Your teacher may have a contest to see who can come up with the best explanation.

How is your bubble blowing experiment going?

INQUIRY 7 Observations and inferences

For each observation below write an inference to answer the question in terms of the particle theory. Draw models to show the invisible particles.

1 **Observation:** Lead is four times denser than aluminium.

Question: How can you explain this?

2 **Observation:** You can pour water from one container to another, but honey is much harder to pour, especially when it has been in the fridge.

Question: How can you explain this?

3 **Observation:** Hold your finger over the end of a bicycle pump and push in the plunger. When you let the plunger go it moves back out.

Question: What pushed the plunger back?

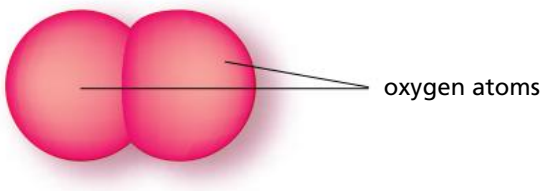
4 **Observation:** Look at the photo above of a water strider walking on water.

Question: Why doesn't the water strider sink?

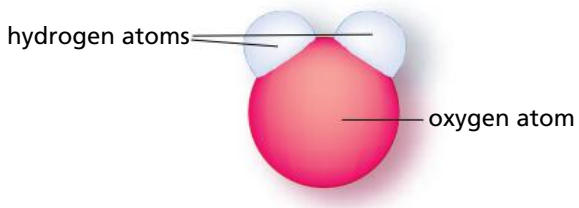
2.5 Atoms and molecules

You have learnt in this chapter that all matter is made of particles. These incredibly small particles are called atoms. To give you some idea of their size, about 10 million atoms would fit side by side across the head of a pin!

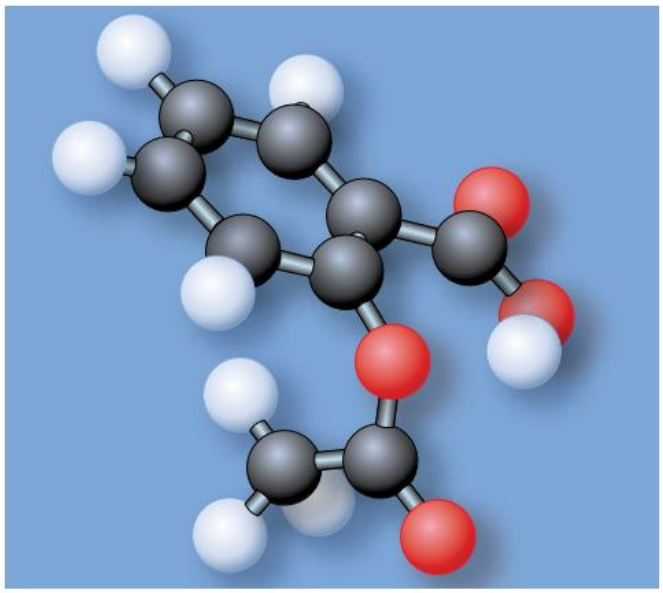
Atoms often join together to form **molecules**. For example, an oxygen molecule consists of two oxygen atoms held together by a **chemical bond**. A water molecule is made up of two hydrogen atoms bonded to one oxygen atom. This means water contains two different types of atoms.



An oxygen molecule



A water molecule



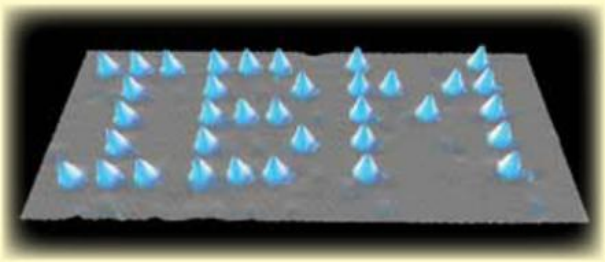
An aspirin molecule contains nine carbon atoms (black), eight hydrogen atoms (white) and four oxygen atoms (red) bonded together like this.

Molecules vary in size from tiny hydrogen molecules up to the huge protein molecules in your body. Each of these protein molecules contains about half a million atoms. Only in recent years have scientists been able to use special microscopes to 'see' atoms and molecules.

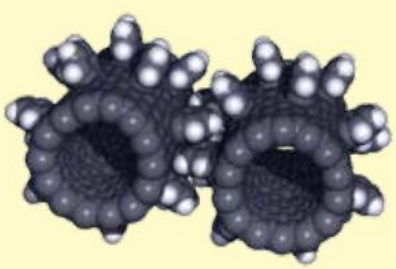
SCIENTISTS AT WORK

Seeing atoms

You cannot see atoms with an ordinary light microscope. However, in 1982 Gerd Binnig (German) and Heinrich Rohrer (Swiss) invented a new type of microscope called the scanning tunnelling microscope (STM). This earned them the 1986 Nobel Prize for Physics. With this device they were able to see individual atoms! Then in 1991 a team of scientists at IBM in California used an STM to move individual atoms and place them exactly where they wanted them. They used 35 atoms of xenon to write the letters IBM as shown in this computer image.



This discovery has opened up a whole new area called nanotechnology. At present we make things by roughly pushing piles of atoms together, but imagine if we could build things one atom at a time. For example, nanogears like the ones shown below could be used to construct a matter factory that could use atoms of different types to build whatever we wanted. Scientists believe this could be possible in a few decades.

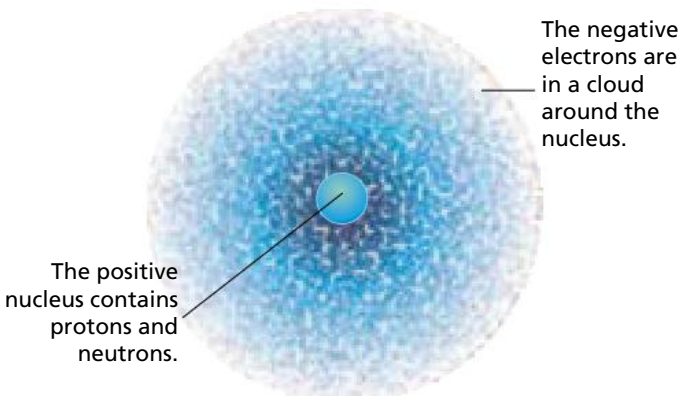


Inside the atom

During the 20th century scientists discovered particles smaller than the atom. From these discoveries they have been able to put together the following picture of what atoms are like. There are three kinds of particles inside atoms—protons, neutrons and electrons. The **protons** have a positive charge and the **neutrons** have no charge. The **electrons** have a negative charge and are much smaller than the protons and neutrons. The protons and neutrons are packed together closely in the centre of the atom, called the **nucleus**. The electrons move very rapidly around the nucleus and are attracted by the positively charged nucleus, because positive and negative charges attract each other.

Different atoms have different numbers of protons, neutrons and electrons. For example, hydrogen atoms have only one proton, but uranium atoms have 92. The number of electrons is always the same as the number of protons. This means that the positive and negative charges balance each other, and the atom has no overall charge.

Imagine an atom was enlarged to the size of a large football stadium. The nucleus would be the size of a small marble in the centre of the stadium. The electrons would be moving rapidly around the stadium, but even at this scale they would be too small to see. So most of the atom is empty space!



Over to you

1 Which of the following are true and which are false? Rewrite those that are false.
- **a** There are particles smaller than atoms.
- **b** Molecules are usualy smaller than atoms.
- **c** An oxygen atom contains two oxygen molecules.
- **d** A molecule of water contains three atoms.

2 What is the difference between an atom and a molecule?

3 What are the similarities and differences between an aspirin molecule and a water molecule?

4 Name the three particles found inside atoms. Which of these are in the nucleus? What charges do they have?

5 What makes one atom different from another?

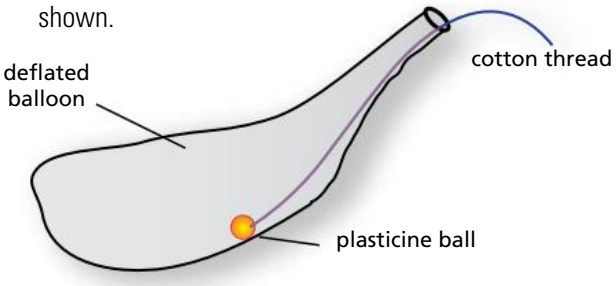
6 Has anyone ever seen a single atom? Explain.

INQUIRY 8 Models of atoms

You will need: plasticine (two different colours), cotton thread, 3 round white balloons

1 Make a tiny ball about 2 mm in diameter out of coloured plasticine (e.g. red). This represents a proton.

2 Attach the plasticine ball to a piece of cotton thread about 20 cm long, and put it in a round balloon as shown.



3 Blow up the balloon and tie it so that the 'proton' hangs on the thread in the middle of the balloon. You now have a model of the smallest atom—hydrogen. The plasticine ball represents the nucleus. Note that there are no neutrons. The balloon represents the electron cloud—the area where the single electron might be found. Note that most of the model atom is empty space.

4 Make a second hydrogen atom. Then push the two balloons together to make a hydrogen molecule H_2.

5 Make a model of an oxygen atom with eight protons and eight neutrons. Use a different- coloured plasticine (e.g. blue) to make neutrons—the same size as the protons. Push the protons and neutrons together to form the nucleus. Note that an oxygen atom is almost twice as big as a hydrogen atom, so you will need to blow up the balloon more. (The number of electrons is the same as the number of protons.)

6 Make a model of a water molecule H_2O (see the previous page).

THINKING SKILLS

1 How could you show that air has mass?

2 Which would evaporate more quickly: water in a flat tray, or water in an open bottle? Explain in terms of the particle theory. You could test your prediction.

3 On a hot day you perspire (sweat). As this perspiration evaporates it cools you. Use the particle theory to explain how evaporation produces cooling.

4 Emil read somewhere that most things dissolve more easily in hot water than in cold water. He decided to do an experiment at home to test this. He measured the number of teaspoons of sugar that dissolved in 100 mL of water at different temperatures. His results are shown below. Emil doesn't have the result for 60°C because his little brother tore off part of his results.

a Draw a graph of Emil's results.

b From your graph, work out what the result for 60°C should have been.

c Do Emil's results show that things dissolve more easily in hot water? Explain.

Temperature °C	Number of spoonfuls of sugar that dissolved
10	3
20	7
30	10
40	14
50	18
60	
70	21
80	24
90	28

5 Archimedes was asked to find out if the crown belonging to the king of Syracuse (in ancient Greece) was made of pure gold. The king thought that the goldsmith may have added silver to the crown and kept some of the gold for himself. Archimedes decided to use his knowledge of density to solve the problem. First he found the volume and mass of the crown. Then he found the mass of an equal volume of pure gold. Here are his results.

volume of crown = 100 cm^3

mass of crown = 1500 g

mass of 100 cm^3 of pure gold = 1930 g

a What is the density of pure gold in g/cm^3?

b What was the density of the crown?

c Was the crown made from pure gold?

6 Dry ice is often used to create fog and mist on stage. If carbon dioxide is invisible, how can you see the dry ice fog?

7 Car tyres can blow-out on a long drive on a hot day. Use the particle theory to explain how a blow-out can occur.

8 Someone tells you that a can of Coke sinks in water but a can of Diet Coke floats. Test this for yourself and try to explain why this happens.

9 Does a fresh hen's egg sink or float in water? Try it. Now add salt to the water, stirring carefully until the egg starts to float. How can you explain this? A rotten egg floats in fresh water. Suggest why.

10 Blow through a straw into a soap solution. Bubbles will form on the surface and join together to form a bubble raft as in the photo. This growing bubble raft is a good model for the growth of crystals.

How can you use the bubble raft model to explain why most crystals have some flaw, such as an uneven edge or a slight crack?



11 Which will dissolve more quickly—a cube of sugar or sugar crystals? Make a prediction.

Now design an experiment to test your prediction. Show your design to your teacher, then try it. Don't forget to write a report of your experiment, and try to explain your results.

Knowing and Understanding

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

1 Matter has _____ and takes up space (its volume). There are three _____ of matter: solids, liquids and gases.

2 Mass is the amount of matter in an object: it is measured in _____ using a balance. _____ is how much mass is packed into a measured volume.

3 Matter can be changed from one state to another when _____ is added or removed.

4 The particle _____ of matter states that all matter is made of particles too small to see. These particles:

- have spaces between them
- _____ each other
- are constantly _____ and
- move faster as the temperature increases.

5 When a substance _____, it is said to be soluble. Substances which do not dissolve are _____.

6 A _____ is a substance that dissolves in a _____ to form a solution. A _____ solution contains only a small amount of solute in a given volume of solvent. A _____ solution contains a larger amount of solute.

7 A _____ is two or more atoms joined together by chemical bonds.

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

attract
concentrated
density
dilute
dissolves
electrons
grams
heat energy
insoluble
mass
molecule
moving
nucleus
solute
solvent
states
theory

Self-management

1 For this quiz the class will be divided into two teams (Team A and Team B). You will need two boxes and a blank card for each person in the class. You will also need to select a quiz master and a scorer.

2 On one side of your blank card you write a question about something in this chapter. On the other side you write the correct answer.

3 Team A students put their cards in the Team A box and Team B students put theirs in the Team B box.

4 The quiz master selects a question card from the Team A box and asks Team B to answer it.

5 If Team B answers correctly the scorer awards one point to them. Each person is allowed to answer only one question.

6 Team B keeps answering questions until they get one wrong. When this happens it is Team A's turn to answer questions.

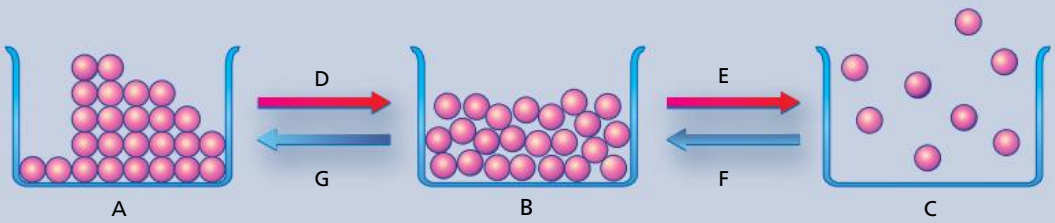
7 When all question cards have been used, the team with the highest score wins.



Checkpoint

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

OneStopScience



1 Copy the diagrams above and label them by replacing each of the letters A to G with one of these words: condensation, evaporation, gas, liquid, melting, solid, solidification.

2 Which one of the following is correct? When you dissolve a tablet in water, the water is the

A solvent

B solute

C solution

D suspension.

3 When water changes to water vapour, which one of these statements is incorrect?

A The change can be caused by heating the water.

B The vapour takes up more space than the water.

C There are bigger spaces between the particles in the vapour.

D There are stronger forces between the particles in the vapour.

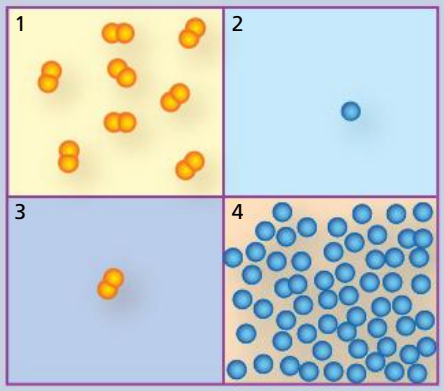
4 Which diagram below best represents

a an atom of aluminium

b a molecule of oxygen

c part of some melted aluminium

d part of some oxygen gas.



5 Draw a diagram to show the difference between a dilute solution and a concentrated solution. Show the dissolved particles.

6 Draw a diagram to show how the volume of a soft drink doesn't change but its shape can.

7 **a** A piece of fruit has a mass of 240 g and a volume of 280 mL. What is its density?

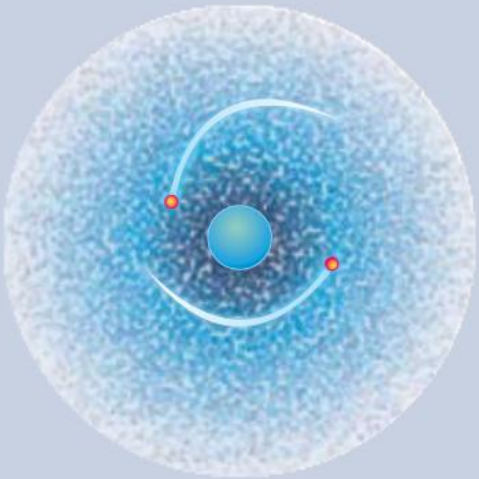
b Will the fruit sink or float in water? How do you know?

8 Copy the diagram of a helium atom below.

a Label the nucleus and the electrons.

b How many electrons are there?

c Predict how many protons there are in the nucleus.



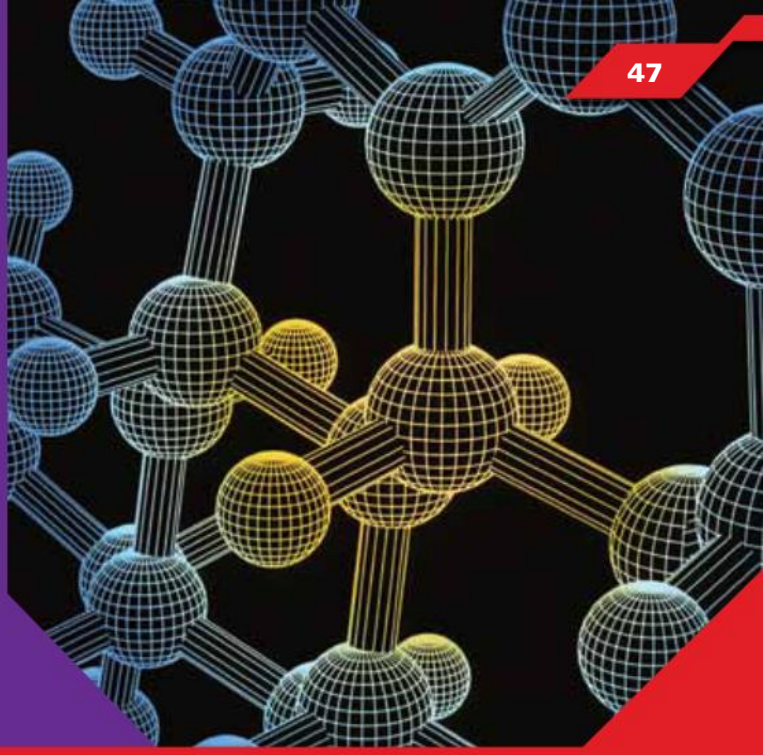
9 Use the particle theory to explain each of the following.

a Gases have much lower densities than solids and liquids.

b Substances usually dissolve more quickly in warm water than in cold water.

c Liquids containing large molecules are usually more viscous than those containing small molecules.

3



Elements and compounds

Focus for learning

As Isabella eats her Corn Flakes for breakfast she studies the nutrition information on the side of the packet.

She knows that her body gets energy from food in the process of respiration. And she has heard of carbohydrates, fats and proteins—substances her body needs to be healthy. But Isabella is confused. Corn Flakes contain sodium, but her teacher did a demonstration in which he dropped some sodium into water and it reacted so violently it burst into flames. They wouldn't put sodium in Corn Flakes, would they?

Isabella also knows that her body needs iron because **red blood cells** need it to be able to carry oxygen around her body. But iron is a metal. Surely she isn't eating that for breakfast!

Nutrition information	Per 30 g serve
Energy	483 kJ
Protein	2.3 g
Fat	0.1 g
Carbohydrate	
- Total	26.0 g
- Sugars	2.4 g
Dietary fibre	0.8 g
Cholesterol	0 mg
Sodium	240 mg
Potassium	25 mg
Thiamine (Vit B1)	0.28 mg
Riboflavin (Vit B2)	0.4 mg
Niacin	2.5 mg
Vitamin C	10.0 mg
Folate	100 µg
Iron	3.0 mg
Zinc	1.8 mg



PROBLEM SOLVING

Iron for breakfast

You can answer Isabella's question by testing some breakfast cereal that contains iron. Any metallic iron in it will be attracted to a magnet.

You will need to work out the details of your investigation, but here are some hints.

- Crush up the cereal. You can do this with a mortar and pestle. (You may need to remove any bits of fruit.)
- Add water to the crushed cereal and stir thoroughly to make a slurry—like a milkshake. If you have a blender, you can combine these steps.
- You need as strong a magnet as possible. (Neodymium magnets are the best.) You can hold it on the outside of the blender or a transparent container holding the slurry. Alternatively you could use the magnet to stir the mixture, but put it in a plastic bag or you will have trouble getting the tiny bits of iron off the magnet.
- There are only about 3 mg of iron per serving of cereal, so you will need to look carefully for any sign of iron.

LITERACY FOCUS

ammonia
buckyball
carbon dioxide
chemical formula
compounds
conductivity
electrons
elements
ion
iron sulfide
lustre
malleability
metals
non-metals
periodic table
phosphorus
protons
semiconductor
silicon
sodium chloride

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

Science Understanding

- use models to show the arrangement of particles in elements and compounds
- investigate the making of a compound and the breaking of a compound into its elements
- locate elements in the periodic table
- use chemical symbols to represent elements and to write simple formulas, e.g. water H_2O

Science as a Human Endeavour

- describe how Mendeleev organised the elements into a periodic table
- trace the development of buckyballs and reflect on their possible uses

3.1 Elements

Once humans discovered fire they soon found substances, such as iron, that could not be broken down into other simpler substances. If you heat sugar, for example, you end up with a black substance called carbon. This carbon cannot be broken down chemically to any simpler substances. Such substances are called **elements**. The first elements known were the metals gold, tin, copper and iron. Over the years more and more elements were discovered.

Atoms

In about 1800 John Dalton, an English schoolteacher, explained the 30 or so known elements in terms of **atoms**—incredibly small particles too small to be seen with a normal microscope. Dalton said these atoms were the building blocks of all matter. For example, a piece of gold is made up of millions of invisible gold atoms—all exactly the same. A piece of silver is different from a piece of gold because it is made of silver atoms, which are not the same as gold atoms. Everything could be made from these 30 or so different types of atoms. Dalton used symbols to represent these atoms. Later, a Swedish chemist, Jons Berzelius, suggested using letters as symbols for the names of the elements, and we still use his symbols today.



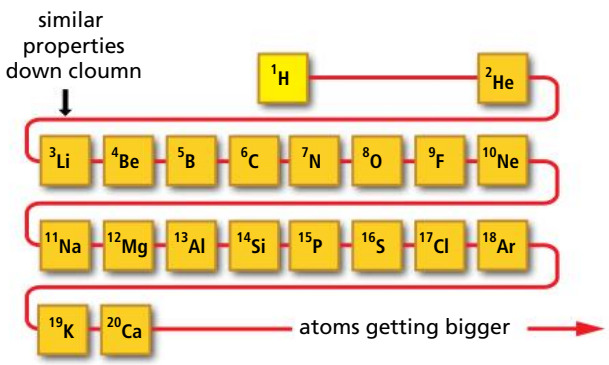
Sometimes the symbol is the first letter of the English name of the element, for example carbon C. However, some elements such as carbon and calcium have the same first letter. In these cases a second letter is used—calcium Ca. Note that the first letter is a capital, but the second letter is not. In some cases the symbol comes from a Greek or Latin word. For example, the symbol for iron is **Fe**, which comes from the Latin word for iron—*ferrum*. Some elements are named after places, for example californium. Others are named after famous people. Curium is named after Marie and Pierre Curie who discovered the radioactive element radium.

The periodic table

As scientists discovered more and more elements they found that these elements could be grouped into families with similar properties. For example, lithium, sodium and potassium are all soft metals that react quickly with water.

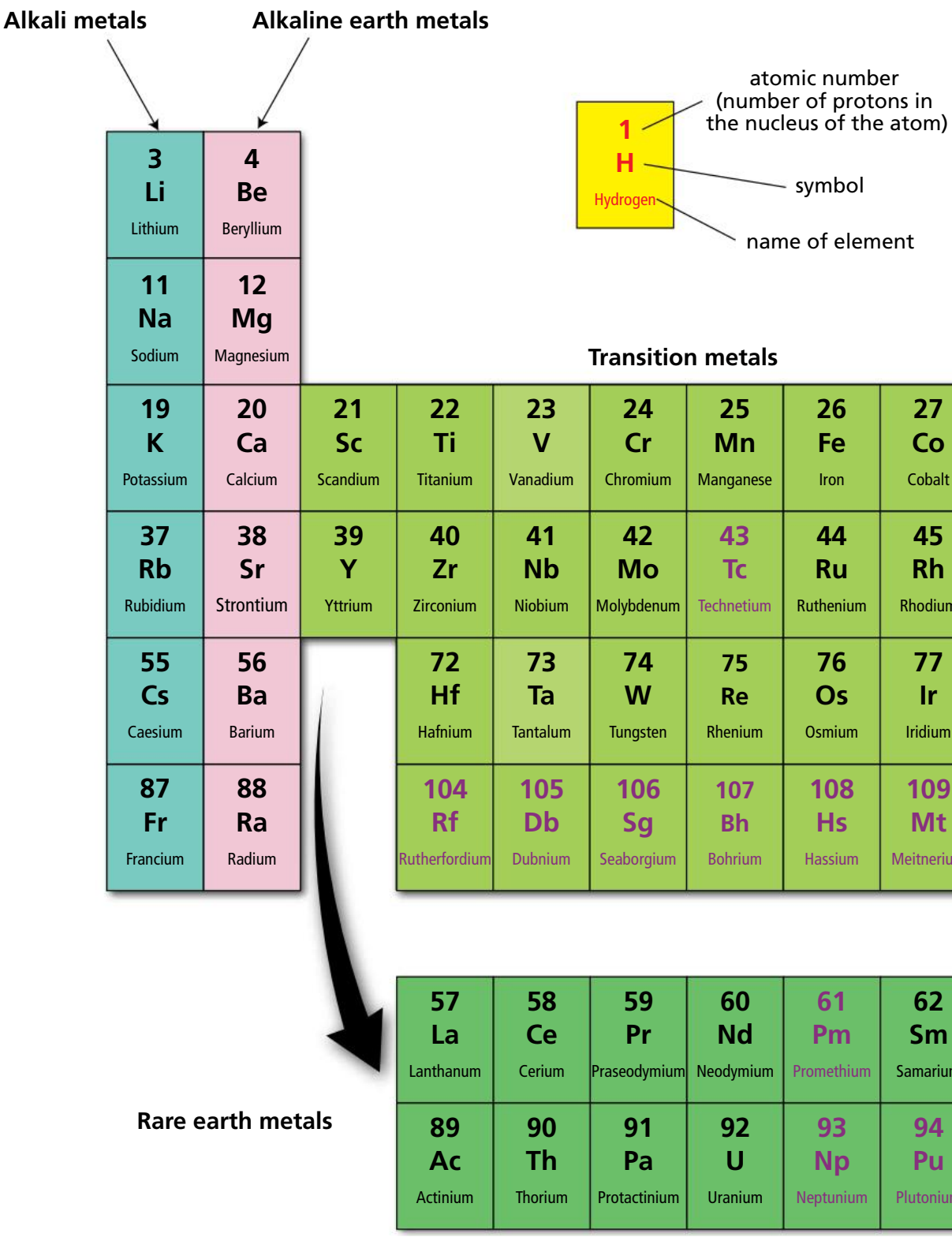
Scientists tried different ways of grouping the elements, and in 1869 Dimitri Mendeleev (MEN-de-LAY-if), a Russian chemist, came up with a new way of doing this. He put the elements in order, according to the size of their atoms. He started with hydrogen, whose atoms are the smallest. It has an atomic number of 1, which means it has one positively charged proton in its nucleus—the solid part in the centre of the atom.

Mendeleev put the names of the known elements on separate cards and arranged the cards so that elements with similar properties were underneath each other. He found that the best arrangement was to place the elements in rows and columns. When you move from left to right along a row the size of the atoms in the elements increases. When you move down a column you find elements with similar properties, for example, lithium (Li), sodium (Na) and potassium (K). It's a bit like a calendar where the dates increase across the rows and all the Sundays are in one column. Mendeleev called this a **periodic table**.



The periodic table on the next page shows all the elements. There may also be one in your laboratory. Elements with similar properties are grouped together in vertical columns, with different colours.

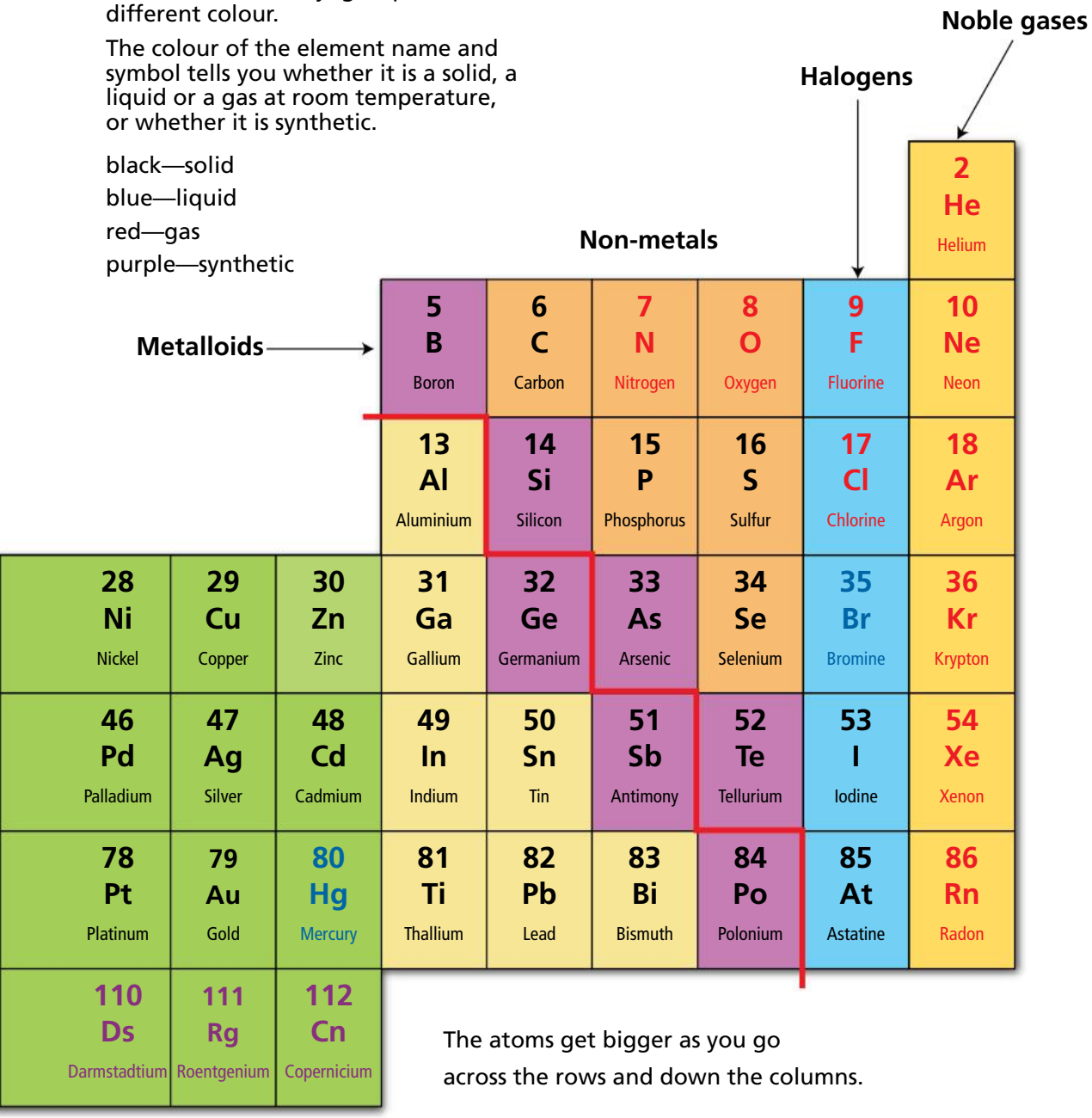
Periodic table of the elements



Each chemical family (group) has a different colour.

The colour of the element name and symbol tells you whether it is a solid, a liquid or a gas at room temperature, or whether it is synthetic.

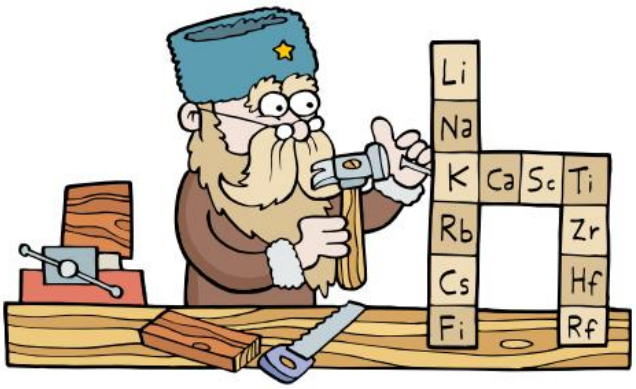
black—solid
blue—liquid
red—gas
purple—synthetic



The atoms get bigger as you go across the rows and down the columns.

63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

To make his periodic table work properly Mendeleev made the bold prediction that there must be still more elements to be discovered. He left gaps in his table where he thought these elements should be—like missing pieces in a jigsaw puzzle. He even predicted the properties of these elements, based on the known elements they were grouped with. These elements were soon discovered and Mendeleev was proved right. His periodic table was so useful that a modified form of it is still used today.



Dimitri Mendeleev constructs a periodic chair.

We now know that 90 elements exist naturally. No other elements have been found anywhere. For example, moon rocks contain the same elements found in rocks on Earth. In recent years scientists have made a number of *synthetic* elements. For example, in 1940 scientists bombarded uranium with high-speed neutrons and created a new element they called neptunium, after the planet Neptune.

Metals and non-metals

The elements fall into two main groups—**metals** and **non-metals**. Towards the right of the periodic table you will see a heavy zigzag line. The elements above and to the right of this line are non-metals, for example carbon, nitrogen, oxygen and chlorine. The other elements (about 80% of them) are metals. Metals and non-metals have different properties, as shown in the table on the right.

Elements next to the zigzag line in the periodic table are neither metals nor non-metals. They are called *metalloids* or *semiconductors*, because they conduct electricity a little. They show some of the properties of both metals and non-metals. This group includes boron, silicon, germanium and arsenic. These are the elements used to make electronic components.

INQUIRY 1 Research an element

Select an element and use the internet to find out what you can about it. Everyone in the class should select a different element and find out:

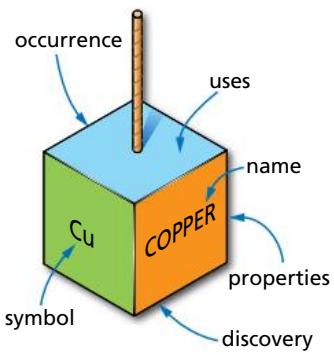
1. who discovered the element, when, and any details about the *discovery*
2. how the element got its *name*
3. its *symbol*
4. its *occurrence*—how common it is in the Earth's crust and in the human body, where it is found and how it is obtained
5. its *properties*
6. its *uses*.

Enter the name of the element in the internet search engine or look under *periodic table*. You can then usually click on each element in the periodic table provided for information on it.

Once you have collected all the information on the element, work out a way to display it or present it to the rest of the class. You could make a hanging cube or mobile like this and write the details of its name, symbol, discovery, occurrence, properties and uses on the six sides of the cube. You could also use a colour code to show whether the element is:

a. a metal or a non-metal
b. a solid, a liquid or a gas
c. natural or synthetic.

If everyone makes a cube, you could almost turn the classroom into a periodic table.

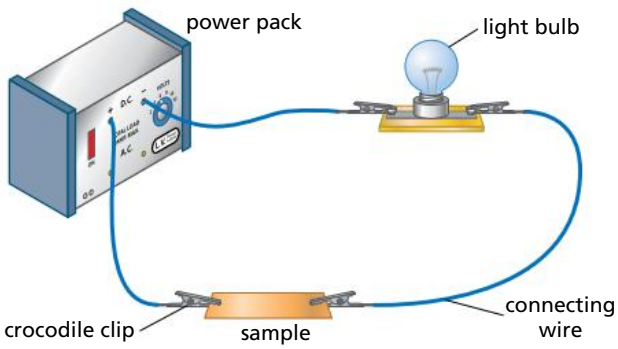


Metals	Non-metals
All are solids at room temperature, except for mercury which is a liquid	Can be solids, liquids or gases at room temperature
Usually have a shiny appearance	Usually dull
Good conductors of heat and electricity	Poor conductors of heat and electricity
Can be hammered into sheets (malleable) and stretched into wires (ductile)	Those that are solid are brittle

INQUIRY 2 Metals and non-metals

You will need: samples of metals and non-metals (e.g. aluminium, carbon, copper, iron, magnesium, tin, silicon, sulfur, zinc), sandpaper, pliers, power pack, connecting wires with crocodile clips, 6 volt light bulb in holder.

1. Draw up a table to record the properties of the elements you are going to test. The properties you will be testing are:
   - lustre—is it shiny or not?
   - malleability—can it be bent or is it brittle?
   - electrical conductivity—does it conduct electricity?
2. Look at each sample. Is it shiny or dull? If the surface isn't shiny to start with, is it shiny after you rub it with sandpaper?
3. Try to bend each sample using pliers. If it can be bent you can say it is malleable. If it breaks into pieces, you can say it is brittle.
4. To test the electrical conductivity of the samples, set up the electric circuit shown. Set the power pack on 6 volts DC. First test whether the bulb glows when you touch the crocodile clips together. Connect the samples between the clips. If the bulb glows when the power pack is turned on, the sample is a good conductor. If the bulb doesn't glow, it is a poor conductor.



- Which of the samples are metals and which are non-metals?
- Are there any elements that are difficult to classify? Explain.

Metals produce different colours in a flame and you can investigate this in Inquiry 3. This is how the different colours in fireworks are produced.

INQUIRY 3 Metal flame tests

You will need: toothpicks, Bunsen burner and heatproof mat, metal tongs, solutions of the following metals—barium, calcium, copper, lithium, sodium and strontium

1. Soak toothpicks in the different solutions for 24 hours.
2. Using tongs, hold a toothpick from one solution in a blue Bunsen burner flame. Note any change in the colour of the flame.
3. Test all the solutions and record the flame colour for each metal.
4. Now that you know the colour each metal produces in a flame, your teacher will give you a toothpick soaked in an unknown solution. Test it and infer which metal it contains.

Over to you

1. Use the periodic table on pages 50–51 to find the symbols for these elements:

aluminium	lead	silver
chlorine	magnesium	sodium
copper	nitrogen	tungsten

2. Which elements do these symbols represent?

C	Fe	Hg	K
Ca	H	I	Mn

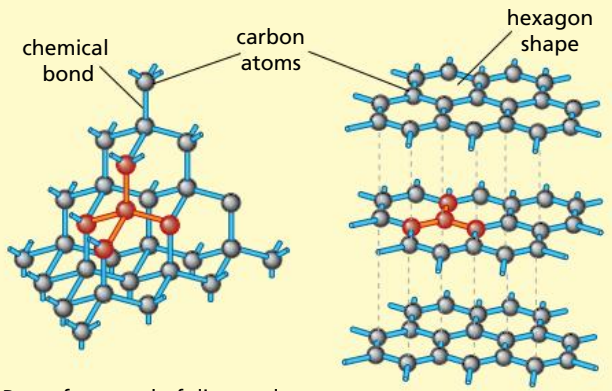
3. Use the periodic table to find
   - **a** at least three elements named after countries or places
   - **b** at least three elements named after scientists
   - **c** three elements named after planets.
4. Use the periodic table to find an example of
   - **a** a synthetic element
   - **b** a solid non-metal
   - **c** a gaseous non-metal
   - **d** a metalloid
   - **e** a liquid metal.
5. Copper is said to be an element. What is meant by the word *element*?
6. What is the difference between an atom and an element?
7. Hayden tested a piece of eggshell, a marble chip and some plaster of Paris. He dissolved each in hydrochloric acid and used the solutions for flame tests. He observed the same orange-red flame for all three solutions. What can he conclude from this? (You could try this yourself.)
8. What discovery did Dimitri Mendeleev make?

SCIENTISTS AT WORK

Buckyballs

Until recently scientists knew of only two forms of the element carbon—diamond and graphite (used in 'lead' pencils). Both these substances consist of carbon atoms, but the atoms are linked together differently to form different types of molecules. In diamond each carbon atom is bonded (linked) to four other carbon atoms to form a giant three-dimensional molecule. This structure makes diamond extremely hard.

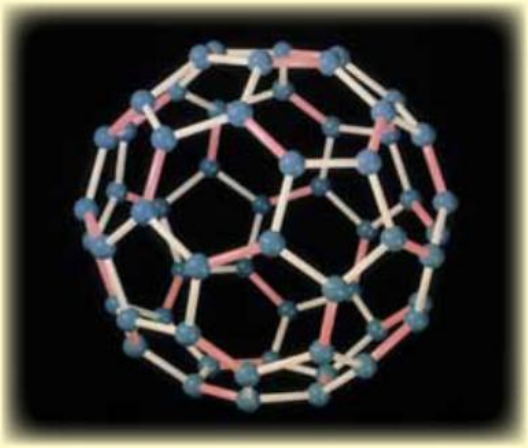
In graphite the carbon atoms are arranged in sheets of linked hexagons—like chicken wire. Each carbon atom has strong bonds to three other carbon atoms in the sheet, but the stacked sheets are only held together by weak bonds. This means the sheets can slide past each other, giving graphite its soft, greasy feel.



Part of a crystal of diamond

Part of a crystal of graphite

In 1985 British chemist Harry Kroto was studying strange chains of carbon atoms that had been found in space, using a radio telescope. Kroto thought these chains might be formed near red giant stars. He visited two scientists, Richard Smalley and Robert Curl, in the United States. Together the three scientists tried to create in the laboratory the extreme temperatures found near red giants. They used a powerful laser to change graphite into a gas, and produced many new carbon molecules. One of these molecules contained 60 carbon atoms. Its properties led them to infer that it must be spherical, and they made a model using bubble gum balls and toothpicks. They also used computer modelling. However none of the models worked. In the end, Smalley cut a sheet of paper into five-sided shapes (pentagons) and six-sided shapes (hexagons). He eventually managed to stick these shapes together to make a soccer ball shape, with 60 corners where the carbon atoms should be.



A buckyball

The three scientists named their new C_{60} molecule a buckminster fullerene, after the American architect Buckminster Fuller, who suggested that houses would be lighter, stronger and cheaper if they were built in a dome shape. The name is usually shortened to fullerene or buckyball.

Buckyballs have been found to exist naturally, for example in the soot from a candle flame and in the dust of space. In recent years other buckyballs have been discovered. There are buckybabies, with fewer than 60 carbon atoms, and a buckyball with about 70 carbon atoms that is shaped a bit like an Aussie Rules football. There are giant fullerenes that contain hundreds of carbon atoms, and it is possible to make buckytubes.

Buckyballs have an unusual hollow cage-like shape. Scientists around the world are trying to create new molecules by joining other molecules to the outside of a buckyball. They are also investigating the idea of trapping smaller molecules inside a buckyball.

Buckyballs can be used as tiny chemical sponges, mopping up dangerous chemicals from brain tissue in people who have head injuries. Buckyballs only allow a certain amount of light to pass through them, and they could be used to make 'bucky glasses'. They could also be used in photocopiers instead of drops of ink, and, because they are like tiny ball bearings, they could be used as lubricants, for example in engine oil.

INQUIRY 4

Make a buckyball

1 To make a model of a buckyball, photocopy the hexagons below onto stiff paper or light cardboard.

2 Cut out the three strips of hexagons, but don't cut along the dashed lines.

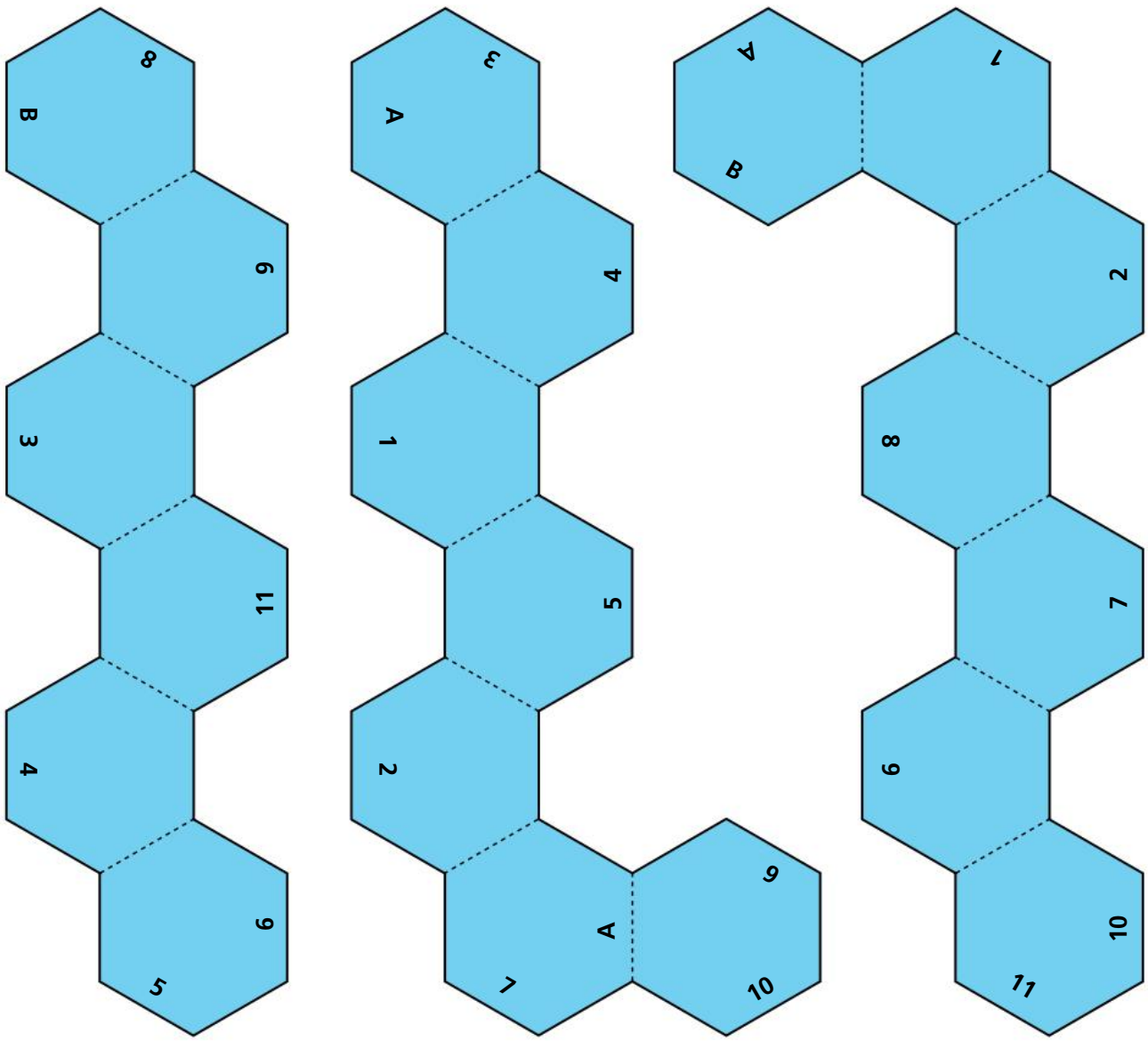
3 Fold the strips along the dashed lines.

4 Tape together the two edges labelled A, and the two edges labelled B.

5 Now tape together the two edges labelled 1. Continue doing this from 1 to 11.

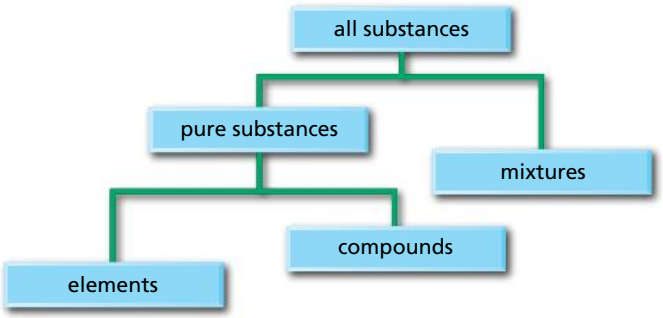
- How many hexagons are there in your buckyball? How many pentagons? (In this model the pentagons are five-sided holes.)
- If each corner represents a carbon atom, how many carbon atoms are there in a buckyball? You could mark these on your model.
- Why is the symbol C_{60} used for the buckyball?
- Is your buckyball stable? For example, does it spring back into shape after being gently squeezed? Does it bounce?

You could compare your buckyball with a soccer ball.

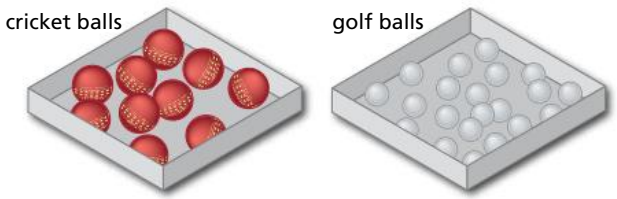


3.2 Compounds

All materials can be classified into two groups—pure substances and mixtures. Pure substances contain atoms or molecules that are all exactly the same. Mixtures contain different types of atoms or molecules. The pure substances can be divided into elements and **compounds**. Compounds can be broken down into simpler substances but elements cannot.

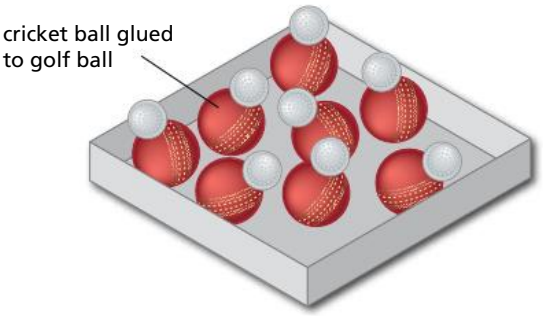


To understand the differences between elements, compounds and mixtures we will use a model. An element is made up of atoms that are all the same and can be represented here by a box of cricket balls. Each cricket ball represents one atom. The box containing many balls represents an element. A second element can be represented by a box of golf ball atoms. Each of the elements is a pure substance because the atoms (balls) in it are all the same. If you glue two or more cricket balls together you have a molecule of this element. Similarly, if you glue two golf balls together you have a molecule of this element.



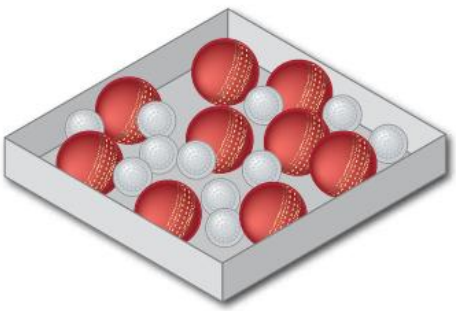
Each box of balls represents an element. Each ball represents one atom of that element.

Molecules can also be made of *different* atoms. For example, if you glue a cricket ball to a golf ball you have a molecule containing one cricket ball atom and one golf ball atom. This joining of different atoms to form molecules occurs in chemical reactions. A box of these molecules represents a compound. It is a pure substance because every molecule in the compound (box) is the same. Each molecule does contain two different types of atoms, but these have all been joined together in the same way. Each molecule contains one cricket ball for every golf ball, so the *ratio* of cricket balls to golf balls is 1:1. Of course, if you glued two golf balls to each cricket ball you would end up with a different molecule. And a box of these would represent a different compound, containing *two* golf balls for every cricket ball.



A box of cricket balls glued to golf balls represents a compound. Each cricket ball–golf ball combination represents one molecule of the compound.

If you simply throw the cricket balls and golf balls into a box you end up with a mixture, containing two different types of balls not joined together. There has been no 'chemical reaction'. Throw in a few more golf balls and it is still a mixture of cricket balls and golf balls, but it is different from the first mixture.



A box containing a random mixture of cricket ball and golf balls not glued together represents a mixture.

As you learnt in Section 3.1, there are only 90 naturally occurring elements, and therefore only 90 different types of atoms. However, there are 20 million chemical compounds registered with the Chemical Society. New compounds are being registered at the rate of 4000 every day!

How can the millions of different substances around us be made from just 90 different types of atoms? Inquiry 5 should help you answer this question. You will use nuts and bolts to represent atoms. Of course atoms don't look like nuts and bolts, but they do join up with each other to form molecules.

INQUIRY 5 Molecules game

The aim of the game is to see who can make the most 'molecules' by joining nuts and bolts (atoms). You can play with one or more partners.

Rules

1 Two or more atoms joined together make a molecule. To be a molecule, the nuts and bolts must be held together by the threads on the bolts as shown. The position of the nuts on the bolts does not matter.



2 Once you have made a molecule, draw it and then take it apart to make another different one.

3 See how many different molecules you can make and draw in the time allowed. To save time, make your drawings simple. For example:

a square nut on a short bolt





a short bolt and a long bolt joined by a hexagonal nut

Game 1 Time limit: 5 minutes

For game 1 you and your partner(s) will each need: 2 short bolts and 4 square nuts

After 5 minutes check how many different molecules you have made. How many did other groups make?

Game 2 Time limit: 15 minutes

For this game you and your partner(s) will each need: 2 short bolts, 2 long bolts, 4 square nuts and 4 hexagonal nuts

You can't use any of the molecules you made in game 1.

How many different molecules did you make in 15 minutes? How many did the other groups make?

- Match up the models on the left with what they represent on the right.

short bolt	compound
box of square nuts	mixture
square nut on a short bolt	atom
box of short bolt-square nut combinations	element
box of short bolts and long bolts	molecule

- If you had 90 different nuts and bolts, would you be able to make millions of different 'molecules'? Explain.

Living and non-living

From a limited number of nuts and bolts you can make thousands of different models. Similarly, the many different compounds in the human body and the Earth's crust are made from the same 90 elements. You may be wondering whether the substances in living things are different from those in non-living things. The table below gives the top 10 elements in the human body and the top 10 elements in the Earth's crust.

Top 10 elements in human body (%)		Top 10 elements in Earth's crust (%)	
oxygen	65	oxygen	46
carbon	18	silicon	28.2
hydrogen	10	aluminium	8.3
nitrogen	3	iron	5.6
calcium	1.5	calcium	4.2
phosphorus	1.2	sodium	2.4
potassium	0.2	magnesium	2.3
chlorine	0.2	potassium	2.1
sulfur	0.2	titanium	0.57
sodium	0.1	hydrogen	0.14



INQUIRY 6 Pie charts

Use the data in the table to draw pie charts to show the difference between the main elements in the human body and in the Earth's crust. So that the slices aren't too small, it is a good idea to combine the less common elements at the bottom of the list.

Carbon makes up 18% of our body, but only a tiny fraction of the Earth's crust. Why is carbon so important in living things? The answer is that carbon atoms can join together to form long chains with branches. Hydrogen atoms and other atoms such as nitrogen and oxygen can be attached to these chains. In this way carbon can combine with other elements to make all the compounds we need in our body, such as proteins.

Biologists think that life could not exist without carbon. Silicon, which is next to carbon in the periodic table, has similar properties to carbon. This is why some science fiction writers have imagined silicon-based life evolving elsewhere in the universe. But the chemistry isn't right. Silicon–silicon bonds are not as strong as carbon–carbon bonds. Would silicon-based life breathe out silicon dioxide (sand) instead of carbon dioxide?

SKILL

Writing formulas

In Inquiry 5 you used simple diagrams to represent nut and bolt combinations. Instead of drawing a short bolt with two square nuts on it you drew ⊢□□ to save time. However there is an even quicker way to write this. Suppose you represent a short bolt by the symbol B and a square nut by the symbol S. Then instead of ⊢□□ you can write BSS or BS_2 or S_2B, where S_2 means 'two square nuts'.

In chemistry we write chemical **formulas** in a similar way, using symbols for the elements and numbers. For example, the formula for oxygen is O_2. This tells you that each molecule of oxygen contains two atoms of oxygen joined together.

The formula for water is H_2O, which you say as 'H two O'. This tells you that each molecule of water contains two atoms of hydrogen (symbol H) and one atom of oxygen (symbol O). In other words, the hydrogen and oxygen are in the ratio 2:1. If a drop of water contains a million molecules of water, then it contains a million atoms of oxygen and two million atoms of hydrogen. The symbol H_2O can be used to represent a molecule of water or the compound water.

Hydrogen peroxide has the formula H_2O_2. It contains the same elements as water, but in hydrogen peroxide there are two oxygen atoms instead of one. Its properties are completely different from those of water.

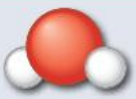
INQUIRY 7

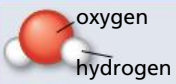
Molecular models

Atoms and molecules are too small to see, but we can use models to represent them.

In the models the atoms are represented by coloured balls of different sizes. Different colours represent different atoms. In some models the balls are joined by sticks to form molecules. There are no such sticks connecting atoms—the sticks merely represent the bonds between the atoms. When you use these models you will notice that the bonds between atoms are at definite angles. In other models the atoms fit together at the correct angles and sticks are not needed.

Draw up a table like the one below. Build a model of each molecule and fill in the table as shown for water. Draw a diagram of each molecule, labelling the different atoms. Then say whether a substance containing molecules like this would be an element or a compound.

Molecule	Formula
	O_2
	H_2O symbol for hydrogen symbol for oxygen This number shows that there are two atoms of hydrogen in each molecule. No number, so this represents one atom of oxygen.
	H_2O_2

Molecule	Formula	Names of elements	Number of atoms of each element	Total number of atoms in one molecule	Drawing of model	Element or compound?
water	H_2O	hydrogen oxygen	2 1	3		compound
hydrogen	H_2					
hydrogen peroxide	H_2O_2					
ammonia	NH_3					
methane	CH_4					
carbon dioxide	CO_2					
ethane	C_2H_6					

Note: Molecules normally contain more than one type of atom. However, some elements contain molecules whose atoms are all the same, e.g. O_2, H_2 and buckyballs.

Over to you

1 Copy and complete these sentences.

a All matter is made of invisible particles called _____.

c A pure substance that *cannot* be broken down into simpler substances is called an _____.

b There are _____ different elements that occur naturally.

d The shorthand way to write the name of an element is to use its _____.

e A pure substance that can be broken down into simpler substances is called a _____. An example is _____.

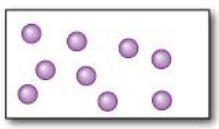
f A group of atoms joined together is called a _____.

g A molecule can be represented by a chemical _____.

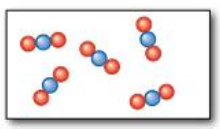
h The formula for _____ is H_2O. This means that a _____ of water contains _____ hydrogen atoms and one _____ atom.

2 Say whether each diagram represents an element, a compound or a mixture. Each circle represents an atom. Explain your answer.

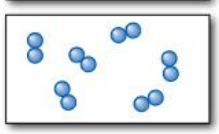
a



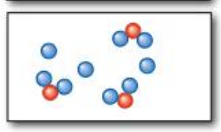
c



b



d



3 Magnesium oxide is formed when magnesium burns in oxygen gas. Name the elements and compound in this reaction.

4 What is the difference between

a an atom and a molecule?

b a molecule and a compound?

5 Classify the following substances as elements, compounds or mixtures:

carbon dioxide	platinum
concrete	protein
hydrogen peroxide	rust
iron	silicon

6 Which of the following represent elements and which represent compounds?

C_{60}	Cl	H_2	O_3
CH_4	Fe	HNO_3	SO_2

7 Which element is present in all of the following compounds?

HCl HNO_3 H_2SO_4 CH_3COOH

8 Copy and complete the following table. The first row has been done for you.

Compound	Formula	Names of elements	Number of atoms of each element	Total number of atoms in one molecule
carbon monoxide	CO	carbon oxygen	1 1	2
carbon dioxide	CO_2			
ammonia	NH_3			
sulfur dioxide	SO_2			
hydrogen peroxide	H_2O_2			
chlorofluoro-carbon (CFC)	CCl_3F			
propane	C_3H_8			
acetone	CH_3COCH_3			

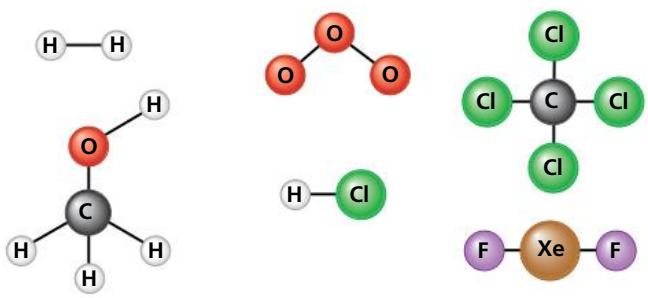
9 Write the formula for each of the following molecules.

a Sulfur dioxide contains one sulfur atom and two oxygen atoms.

b Butane contains four carbon atoms and ten hydrogen atoms.

c Glycerol contains three carbon atoms, eight hydrogen atoms and three oxygen atoms.

10 a Which of the following represent elements and which represent compounds?



b Write the formula for each of the molecules. (Hint: For large molecules you usually write the symbol for the atom in the middle first.)

11 Why are there many more compounds than there are elements?

3.3 Making and breaking compounds

INVESTIGATION

1 Iron filings and sulfur

Aim

To change a mixture of two elements into a compound.

Risk assessment and planning

Because burning sulfur produces poisonous fumes, Part B should be done in a fume cupboard.

Your teacher will discuss this with you.

Read the investigation carefully. Describe to your partner what you have to do in Part A. Your partner will then describe what has to be done in Part B.

- What other safety precautions will be necessary?
- Discuss how you will dispose of leftover chemicals.
- Design a data table in which to record your observations.

Apparatus

- tripod and heatproof mat
- powdered sulfur
- iron filings
- spatula
- bar magnet
- 3 small test tubes
- metal tongs
- *dilute hydrochloric acid (2 M)*
- aluminium foil
- pipeclay triangle
- mortar and pestle
- hand lens
- Bunsen burner
- crucible and lid



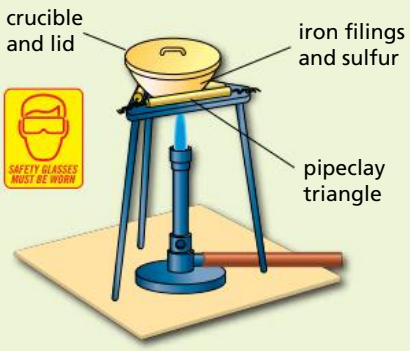
Method

Part A: Making a mixture

1. Put a small amount of iron filings into a test tube. Use a hand lens to look closely at the iron filings. What happens when you bring a magnet up to the side of the test tube?
   - ✻ Record your observations and inferences.
2. Add a small amount of hydrochloric acid to the iron filings.
   - ✻ Record your observations and inferences.
3. Repeat Steps 1 and 2 using sulfur instead of iron filings.
4. Mix two spatulas of sulfur with a spatula of iron filings in a test tube. Use a hand lens to examine the mixture.
   - ✻ Can you see separate bits of iron and sulfur?
5. Can you separate the iron filings from the sulfur using a magnet as in Step 1?
6. Can you separate the iron filings and sulfur by adding some of the mixture to water in a test tube? Try it.

Part B: Making a compound

1. Line the crucible with aluminium foil and put the mixture of iron filings and sulfur in it. (The aluminium foil stops the hot mixture sticking to the crucible.)
2. **In a fume cupboard**, put the crucible in a pipeclay triangle on a tripod as shown. Heat the mixture for a few minutes, lifting the lid of the crucible with tongs occasionally to observe any changes. Continue heating until the mixture glows red. You can now stop heating. The reaction has finished. Allow the crucible to cool.



3. Remove the substance from the crucible and use a mortar and pestle to grind it up.
4. Carry out the following tests on the substance.
   - **a** Examine it with a hand lens. Can you see any iron filings or bits of sulfur?
   - **b** Can you separate any iron using a magnet?
   - **c** What happens when you add hydrochloric acid to some of the substance? **CAUTION: The gas produced has a foul odour.**
   - **d** Can you separate any sulfur by adding some of the substance to water?

Results

1. Did the properties of the mixture of iron filings and sulfur change when you heated it? Explain.
2. Did a chemical reaction occur? How do you know?
3. Did the reaction give off heat or did it need heat to make it go?

Conclusion

1. Use the results to explain the difference between a mixture and a compound.
2. The new substance you have made is called iron sulfide. What are the elements in it? Write a word equation to show how it was formed.

Making compounds

A compound is formed when two or more elements react together. In a compound the elements are not just mixed. A chemical reaction has to occur to cause the atoms in the elements to join together in a definite pattern. For example, in the model on page 56, one cricket ball was glued to one golf ball. The glue represents the chemical bond formed in the chemical reaction.

A mixture of elements is like a pile of different kinds of bricks not joined together. A compound is like a house in which all the bricks are cemented together. This is why the properties of a compound are quite different from the properties of the elements it is made of. Here are three examples of elements combining to form compounds.

1 In Investigation 1 you saw that iron and sulfur react to form iron sulfide.

iron + sulfur → iron sulfide

2 Sodium is a soft silvery-white metal. It reacts readily with many other elements. For example, if you leave it on the laboratory bench it may burst into flames as it reacts with the oxygen in the air. This is why it has to be stored in kerosene. Chlorine is a greenish-yellow poisonous gas with a choking, irritating smell. Amazingly, when you mix sodium and chlorine, a compound is formed with properties that are totally different from those of sodium or chlorine. It is called sodium chloride or table salt, which we add to our food.



sodium + chlorine → sodium chloride

3 If you bring a lighted taper to the mouth of a test tube of hydrogen, the hydrogen reacts explosively with the oxygen in the air to form water.

hydrogen + oxygen → water



The Hindenburg airship was filled with hydrogen gas. On its first flight in 1937 hydrogen leaked out and a spark set off an explosive reaction with the oxygen in the air. Of the 92 passengers and crew, 36 were killed.

Rearranging atoms

John Dalton inferred that when elements combine to form compounds, the different atoms in them join to form molecules. For example, when carbon burns in air, each carbon atom joins with one oxygen molecule to form a molecule of carbon dioxide. Hence carbon dioxide is a compound made up of carbon and oxygen.



carbon + oxygen → carbon dioxide

$$C + O_2 \rightarrow CO_2$$

In the reaction, the bond between the oxygen atoms in the oxygen molecule breaks. The two oxygen atoms then join with the carbon atom to form a carbon dioxide molecule. Notice in the equation above that there are two atoms of oxygen and one atom of carbon on both sides of the equation. No atoms suddenly appear and no atoms disappear. They are simply rearranged, according to the law of **conservation of matter**.

Of course there are millions of carbon atoms in a piece of carbon, and millions of oxygen molecules in a sample of oxygen gas, so when they react they will form millions of carbon dioxide molecules.

INVESTIGATION

2 Decomposing water

Aim

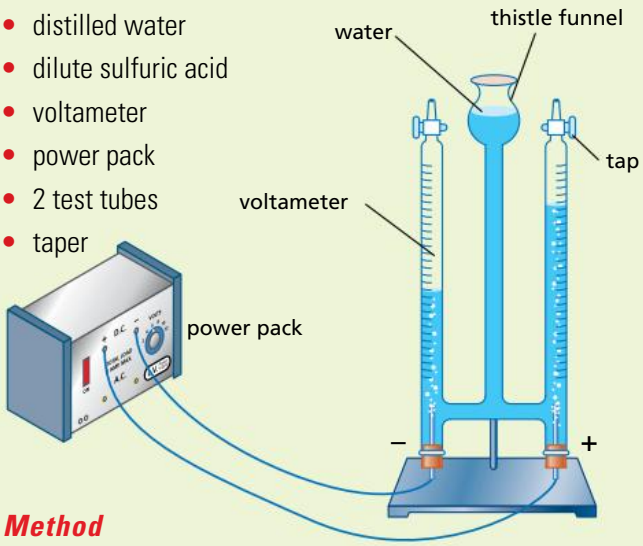
To decompose (break up) water into its elements by passing electricity through it.

Risk assessment and planning

Read through the investigation. Your school may have only one voltameter (vol-TAM-e-ter), so your teacher may demonstrate this experiment.

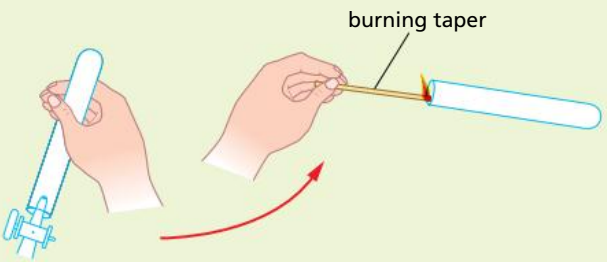
Apparatus

- distilled water
- dilute sulfuric acid
- voltameter
- power pack
- 2 test tubes
- taper



Method

1. Set up the voltameter as shown.
2. Open the taps and add water containing a few millilitres of sulfuric acid to the thistle funnel in the middle. (The acid makes the water conduct electricity more easily.) When the side tubes are full, close the taps.
3. Connect the power pack to the voltameter. Set it on 6 volts DC and turn it on.
4. Pass electricity through the voltameter for about 15 minutes.
   ✻ Note the volume of gas in each tube.
5. Put a test tube over the tube with the most gas in it. Then open the tap to collect the gas.
   Light a taper, tilt the test tube up, and put the burning taper near its mouth as shown.



   ✻ What happens? What was the gas in the test tube?
6. Now collect a test tube of gas from the other voltameter tube. Light the taper again, but this time blow it out just before you put it in the tube.
   ✻ What happens? What was the gas in this tube?

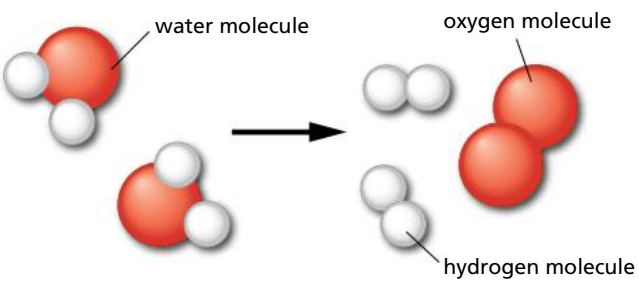
Conclusion

1. What are the two elements in water? How do you know?
2. Write a word equation for the decomposition of water.
3. Write an inference to explain why you got twice as much hydrogen as oxygen.

Decomposing water

If you heat water it simply changes its form to become steam. To decompose it you have to pass electricity through it as you did in Investigation 2. The electricity causes the bonds in the water molecules to break. Two hydrogen atoms break off each water molecule and then combine to form a hydrogen molecule. The remaining oxygen atoms from each water molecule then pair up to form an oxygen molecule, as shown.

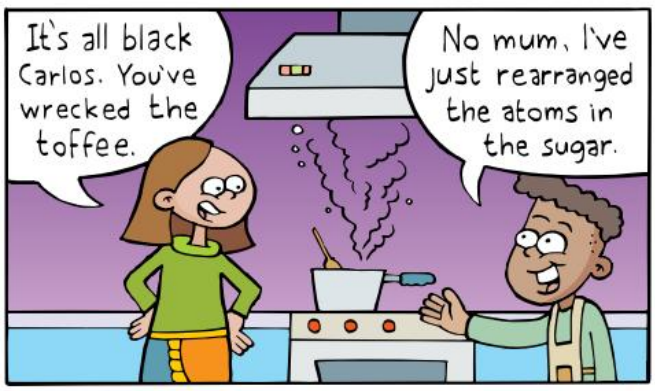
You will notice that this reaction obeys the law of conservation of matter. There are two oxygen atoms and four hydrogen atoms on each side of the equation. Also, water contains two hydrogen atoms for each oxygen atom, so you end up with two molecules of hydrogen and only one molecule of oxygen. This is why you collected twice as much hydrogen as oxygen in Investigation 2. They were in the ratio 2 : 1, as indicated by the formula H_2O.



Breaking compounds

Decomposing water is an example of breaking down a compound into simpler substances by using a chemical reaction. Heating sugar is another example. When it is heated, sugar gives off water, leaving you with the element carbon, which is black. Sugar molecules are quite large and contain carbon, hydrogen and oxygen atoms. During the reaction these molecules break apart and you end up with carbon atoms and water molecules.

sugar → carbon + water



We also use breakdown reactions to obtain the metals we use. Metals such as copper and iron are not usually found in the Earth's crust as elements, but rather as compounds called ores. It is thought that ancient peoples discovered how to break down copper ores into copper by a process called smelting. The powdered ore was mixed with charcoal and heated to a high temperature by a blast of air. The molten copper that formed could be made into useful objects.

Some compounds are very difficult to break into their elements. For example alumina is aluminium oxide and scientists thought it was an element because they couldn't break it down. It wasn't until 1825 that the Danish scientist Hans Oersted was able to split it into its elements aluminium and oxygen.

Over to you

1 State whether each of the following is true or false. Correct those that are false.

- **a** Sodium chloride contains two elements—sodium and chlorine.
- **b** Iron reacts with sulfur to form iron oxide.
- **c** Compounds cannot be broken down into simpler substances.
- **d** The same elements can combine to form many different compounds.
- **e** When you heat water it decomposes into hydrogen and oxygen.

2 What are the tests for hydrogen and oxygen gases?

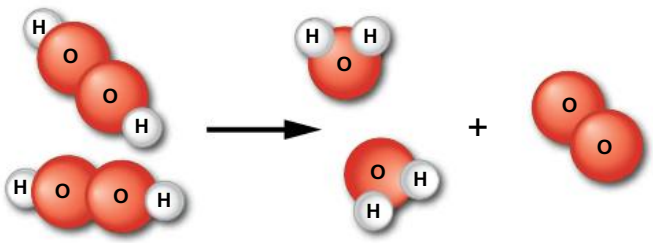
3 **a** What substance is formed when hydrogen and oxygen react together?

- **b** Write a word equation for the reaction.

4 Iron sulfide is a compound of iron and sulfur. How do you know that it is a completely different substance to the two elements from which it is made.

5 Hydrogen peroxide decomposes to give water and oxygen, as in the diagram below.

- **a** What is the formula for hydrogen peroxide?
- **b** How many oxygen atoms are there in the reactants? How many hydrogen atoms are there in the reactants?
- **c** Does this reaction obey the law of conservation of matter? Explain.

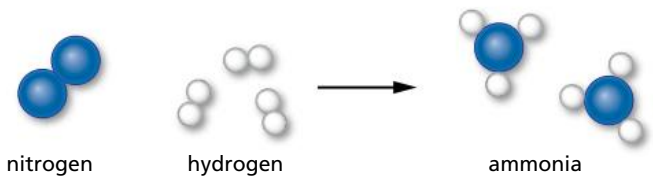


hydrogen peroxide → water + oxygen

6 Sodium and chlorine are very dangerous elements. Sodium chloride (table salt) contains both these elements, but it is safe to eat. Explain.

7 The diagram shows what happens when nitrogen reacts with hydrogen to form ammonia gas.

- **a** Which elements does ammonia contain?
- **b** What is the formula for ammonia?
- **c** Does this reaction obey the law of conservation of matter? Explain.
- **d** If you decomposed ammonia, would the volumes of nitrogen and hydrogen produced be the same? What ratio would they be in? Explain your reasoning.



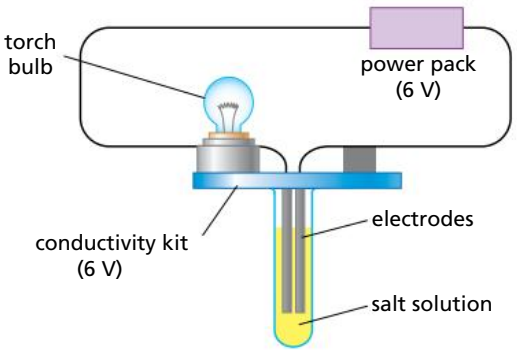
3.4 Ionic compounds

INQUIRY 8 Conductivity

You will need: conductivity kit, power pack, 2 test tubes, distilled water, salt

1 Place about a teaspoon of salt (sodium chloride) in a small test tube.

2 Use the apparatus shown to test whether the salt crystals will conduct an electric current. To do this, dissolve the salt in water and test whether the salt solution conducts electricity.



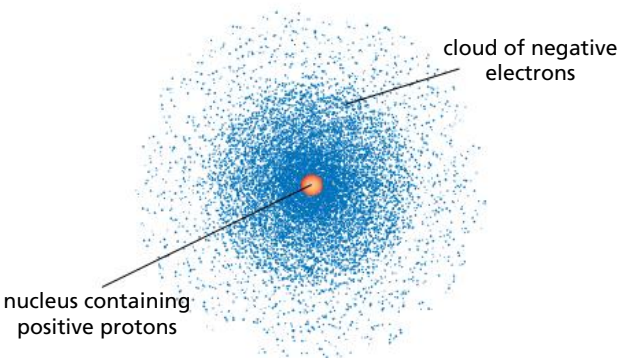
3 Use a second test tube to test whether distilled water conducts electricity.

- Why do you need to do this?

Atoms and ions

Why is it that a salt solution conducts electricity but distilled water does not? To answer this question you need to revise what you already know about atoms.

You have probably learnt that an atom is a sort of ball-shaped cloud with a tiny nucleus at its centre. The nucleus has a positive charge due to the positively charged protons in it. The rest of the atom is mostly empty space containing rapidly moving electrons that are negatively charged. Some of these electrons are close to the nucleus, others are further away. The electrons stay in the atom because they are attracted to the positively charged nucleus.

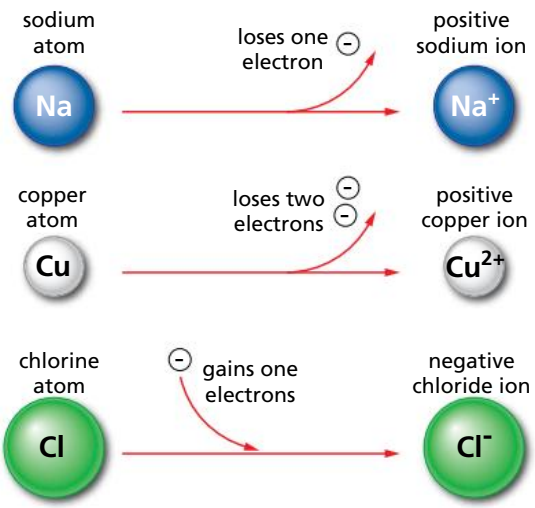


An atom consists of a positive nucleus surrounded by a cloud of negative electrons.

The number of positively charged protons in the nucleus is the same as the number of negatively charged electrons outside the nucleus. The atom is neutral—it has no overall charge. However, some atoms can lose electrons, while others can gain electrons. In either case, the atom is no longer neutral. An atom that has lost or gained electrons is called an **ion** (EYE-on).

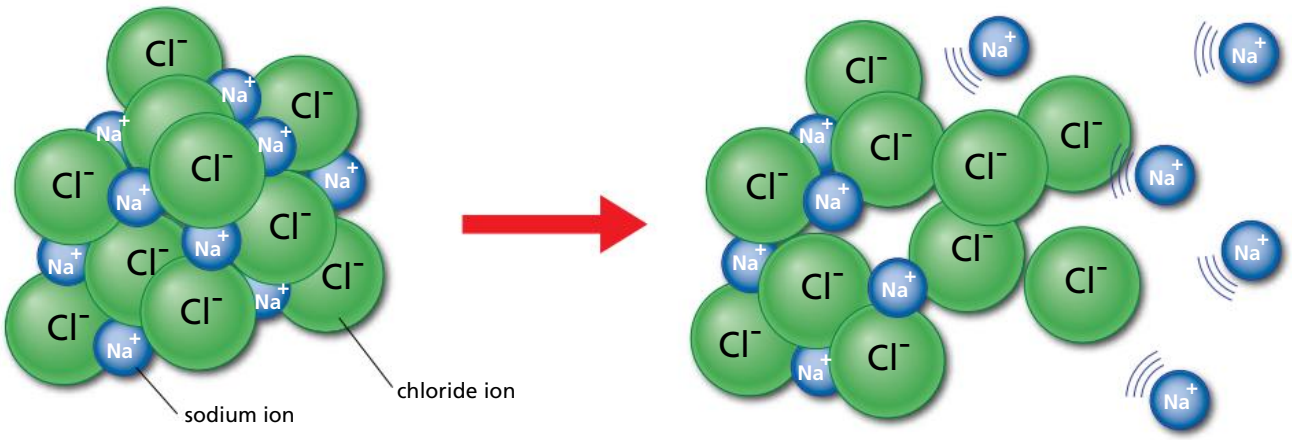
Atoms of metals tend to lose electrons to other atoms. For example, a sodium atom can lose an electron. When this happens the number of positive protons in the atom is one more than the number of negative electrons. The sodium atom then has an overall charge of one positive charge and is represented as Na^+. A copper atom, which can lose two electrons, forms an ion with two positive charges (Cu^{2+}).

In contrast to metals, atoms of non-metals tend to form ions by taking on extra electrons. For example, chlorine atoms gain one electron to form *chloride* ions Cl^- with one negative charge.



Atoms of metals form positive ions by losing electrons. Atoms of non-metals form negative ions by gaining electrons.

When sodium metal reacts with chlorine gas, each sodium atom loses an electron to form a Na^+ ion. This electron is accepted by a chlorine atom to form a Cl^- ion. Opposite charges always attract each other, so the positive sodium ions and the negative chloride ions attract each other, forming the ionic compound sodium chloride.



Part of a crystal of sodium chloride (table salt). When it dissolves in water the sodium ions and chloride ions break apart and can move through the solution.

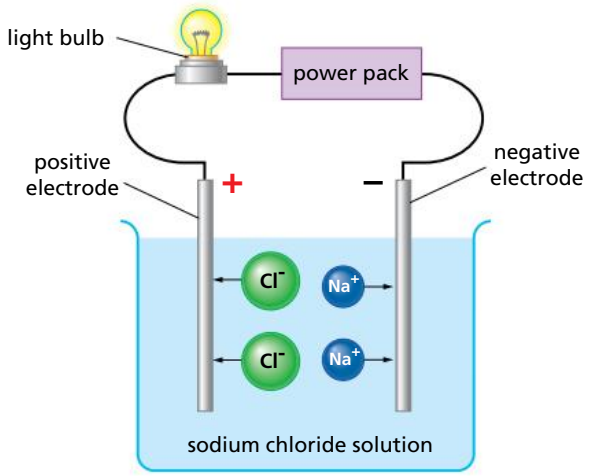
A crystal of sodium chloride contains millions and millions of sodium ions and chloride ions. Each ion attracts the oppositely charged ions around it. It is not possible to identify an individual molecule of sodium chloride because the ions are packed together so tightly in the crystal. If your school has a model of sodium chloride, note how the sodium and chloride ions are arranged.

Ionic compounds dissolving

Sodium chloride is called an ionic compound because it is made up of ions. In solid form it will not conduct an electric current because the ions are held together tightly. However, when you dissolve sodium chloride in water, the sodium ions and the chloride ions break apart and spread throughout the water. You can write an equation to represent what happens:

sodium chloride → Na^+ + Cl^-

If you put electrodes in the sodium chloride solution and pass an electric current through it as in Inquiry 8, the light bulb glows. This means that the solution conducts electricity. The reason for this is that the ions allow electricity to flow. The positive sodium ions are attracted to the negative electrode, and the negative chloride ions are attracted to the positive electrode. Distilled water doesn't conduct electricity because it contains only water molecules which have no charge. However tap water will conduct electricity. This is because it is impure and has dissolved ions in it. (You could try this.)



A sodium chloride solution conducts electricity because the ions in it allow electricity to flow.

Formulas for ionic compounds

When a metal reacts with a non-metal an ionic compound is formed. For example:

sodium + chlorine → sodium chloride (NaCl)

To write the name of the ionic compound you first write the name of the metal, which is the positive ion. You then change the ending on the name of the non-metal, which is the negative ion. For example, chlorine changes to chlor*ide*. To write the formula for sodium chloride you use the symbols for the two elements—NaCl. Here are two more examples:

iron + sulfur → iron sulfide (FeS)

magnesium + oxygen → magnesium oxide (MgO)

INQUIRY 9 Copper ions

Part A

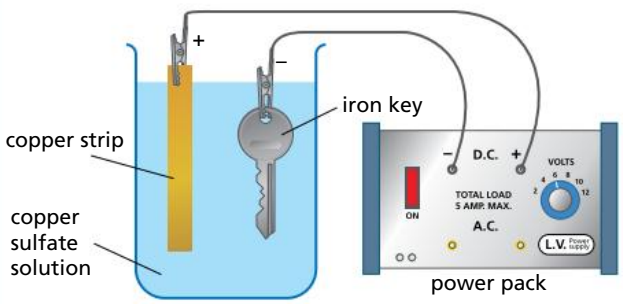
You will need: test tube, small piece of copper, dilute sulfuric acid

Add a small amount of dilute sulfuric acid to a small piece of copper in a test tube. Be careful not to spill any acid as it is corrosive. What happens?

Part B

You will need: copper sulfate solution (1 M), 250 mL beaker, copper strip, old iron key, 2 connecting wires with crocodile clips, power pack, sandpaper

1. Clean the key with sandpaper and wash it in water.
2. Connect up the apparatus as shown. The key must be connected to the negative (black) terminal of the power pack. The copper strip must be connected to the positive (red) terminal. Make sure the key and the strip don't touch.
3. Set the power pack on 6 volts DC and turn it on for about 5 minutes. Then remove the key.
   - Think about what happened in Part A and try to explain what happened in Part B.



Copper is a pinkish metal made up of millions of tiny copper atoms. In Part A of the inquiry you saw that when copper reacts with sulfuric acid, hydrogen gas is produced and a blue solution forms. This solution contains copper sulfate, and it is blue because it contains tiny invisible copper ions. When you pass electricity through this solution in Part B, the copper ions gain electrons and change back to copper metal, which forms a pinkish coating on the key.

Over to you

1. Copy and complete the following sentences.
   - **a** A charged atom is called an _____.
   - **b** Metal atoms lose _____ to form positive ions.
   - **c** Non-metal atoms gain electrons to form _____ ions.
   - **d** Compounds formed from positive and negative ions are called _____ compounds.
2. Substances that contain positive ions always contain negative ions as well. Why?
3. Salt dissolved in water conducts electricity. Sugar dissolved in water doesn't. Write an inference to explain this.
4. 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 air
   - **d** bromine gas reacts with potassium.
5. Name the following compounds.
   - **a** NaCl **c** FeS **e** HgO
   - **b** MgO **d** HCl **f** KI
6. Lead nitrate and potassium iodide do not react unless you dissolve them in water. How can you explain this? (Hint: What happens when ionic compounds dissolve in water?)
7. If a food item contains sodium, would this be sodium atoms or sodium ions? Explain.

PROBLEM SOLVING

Your body needs metals such as iron, zinc, sodium and potassium to function properly. To be carried around your body in your blood these metals must be dissolved as ions. The ionic compound iron sulfate is sometimes added to breakfast cereal. It dissolves in your stomach to produce positive iron ions and negative sulfate ions. Sometimes iron is added to breakfast cereal as fine particles of metal. Your body can't use metallic iron, but the iron reacts with the dilute hydrochloric acid in your stomach to produce iron ions. Your body needs iron ions to help carry the oxygen in your blood.

- In your investigation from page 48, did you find that there is metallic iron in breakfast cereal? Did everyone get the same results? Discuss any differences.
- If there is metallic iron in breakfast cereal, why can't you see it or feel it when you eat breakfast?
- Which type of breakfast cereal contains the most metallic iron? Test this.

THINKING SKILLS

1 Name an element that

a is used to make steel

b is used to make jewellery

c is used to build aeroplanes

d makes up four-fifths of the air

e is used in nuclear reactors

f is sometimes used in thermometers.

2 Hydrogen peroxide is a compound of hydrogen and oxygen. However it is very different from water, and is used in bleaches, antiseptics and rocket fuel. If water and hydrogen peroxide are both made up of hydrogen and oxygen, why are they so different? Write an explanation.



Jet packs which you strap to your back are powered by hydrogen peroxide.

3 A tiny crystal of magnesium chloride contains two billion magnesium atoms and four billion chlorine atoms. Use this information to work out the formula of the compound.

4 Monique heated some blue crystals and two different gases were given off. One was a poisonous brown gas called nitrogen dioxide, the other was oxygen. A black substance was left behind in the test tube.

a Are the blue crystals an element or a compound?

b Which elements can Monique be sure are in the blue crystals?

c Monique heated the black substance with some carbon. Copper was formed. What are all the elements in the blue crystals?

5 Use this table to answer the questions below.

Common compound	Chemical name	Formula
alcohol	ethanol	C_2H_5OH
alumina	aluminium oxide	Al_2O_3
baking soda	sodium hydrogen carbonate	$NaHCO_3$
caustic soda	sodium hydroxide	$NaOH$
hydrochloric acid		HCl
marble or limestone	calcium carbonate	$CaCO_3$
natural gas	methane	CH_4
nitric acid		HNO_3
petrol	octane	C_8H_{18}
rust	iron oxide	Fe_2O_3
sand	silicon dioxide	SiO_2
sulfuric acid		H_2SO_4
table salt	sodium chloride	$NaCl$
cane sugar	sucrose	$C_{12}H_{22}O_{11}$
vinegar	acetic acid	CH_3COOH

a Which elements are present in hydrochloric acid?

b Hydrochloric acid and table salt both contain the same element. What is it?

c How many atoms are there in a molecule of ethanol?

d From which compound do you think aluminium metal would be extracted?

e Which compounds contain the element sodium?

f Which element is present in all acids?

g Which compound do you think would have the biggest molecules? Explain.

6 A scientist has two different compounds containing nitrogen and oxygen. One contains nitrogen and oxygen in the ratio 1 : 1. The other contains nitrogen and oxygen in the ratio 1 : 2.

a Write a formula for each compound.

b Draw the molecules in each compound.

7 Water is a compound made from hydrogen and oxygen. Air is a mixture of nitrogen and oxygen. How would you explain to someone the difference between a mixture and a compound, using water and air as examples?

8 Why do compounds have formulas, but mixtures do not?

Knowing and Understanding

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

1 The _____ table is a way of ordering the elements according to the size of their atoms. Elements with similar _____ are grouped together.

2 All matter can be divided into pure substances and _____. Pure substances are either elements or _____.

3 An element is a pure substance made of only one type of _____. It cannot be broken down into simpler substances by chemical reactions.

4 There are 90 different naturally occurring elements. Three quarters of these are _____ and the rest are non-metals. Each of the elements has its own _____.

5 A compound is a pure substance made up of several different _____ combined together in a fixed _____. It can be broken down into its elements by chemical reactions.

6 _____ can be used to make compounds from elements, and to _____ compounds into elements.

7 Atoms that have lost or gained electrons and therefore carry an electric charge are called _____. Metals tend to _____ electrons to form positively charged ions. Non-metals tend to _____ electrons to form negatively charged ions.

8 The chemical _____ for a compound tells you what elements it contains. It also tells you the ratio of the atoms or ions in it.

atom
break down
chemical reactions
compounds
elements
formula
gain
ions
lose
metals
mixtures
periodic
properties
ratio
symbol

Self-management

1 Draw labelled diagrams to explain the meaning of these words and the differences between them: atom, compound, element, mixture and molecule.

2 Use symbols for the elements from pages 50–51 to make words. For example:

carbon + astatine = CAt

indium + potassium = InK

You may even be able to write a short message in element code. For example:

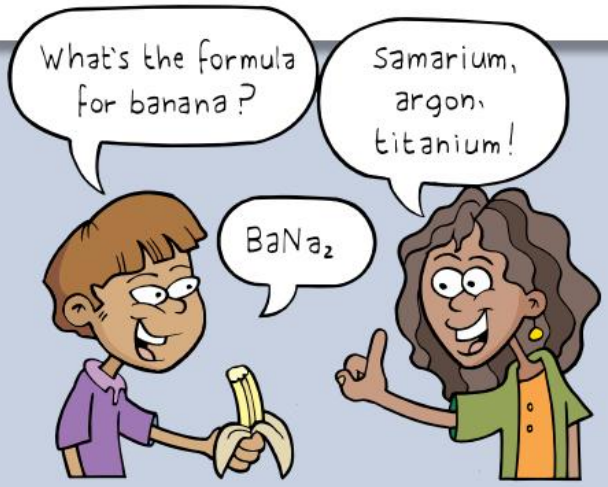
iodine I

lithium + potassium + (europium – uranium) LiKE

yttrium + oxygen + uranium YOU

3 Make up a 'guess the element or compound' card game.

Write a question on one side of a card and the correct answer on the back. For example:



- This element, which is needed to carry oxygen around your body, is found in breakfast cereal. (Iron)
- This compound is used to bleach hair. It has the formula H_2O_2. (Hydrogen peroxide)
- This compound is made by heating iron filings with sulfur. (Iron sulfide)

Checkpoint

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

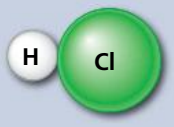
OneStopScience

1 Which one of the following gases is a compound?

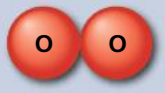
A carbon dioxide
B chlorine
C hydrogen
D nitrogen

2 Look at the models of the four molecules below and write the formula for each of them.

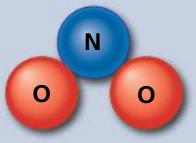
a



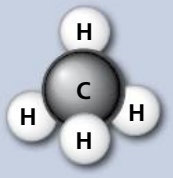
c



b



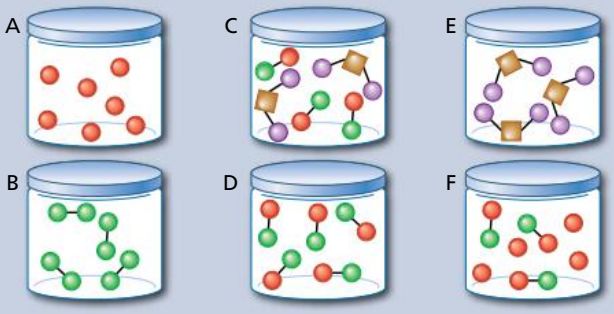
d



3 Nitrogen dioxide is a compound that contains nitrogen and oxygen in the ratio of one atom of nitrogen to two atoms of oxygen. Its formula is

A NO.
B N_2O.
C NO_2.
D N_2O_2.

4 The diagrams below represent containers each holding a different substance. Use them to answer the following questions.



a Which containers hold pure substances?
b Which of these pure substances are elements?
c Substance C is a mixture of two different compounds? Which ones?

5 **a** What is an ion?
b There are two kinds of ions. How are they formed?
c Iodine is a non-metal similar to chlorine. Predict whether iodine tends to lose electrons or gain them. Explain your answer.

6 **a** Use the periodic table on pages 50–51 to decide which of these elements are metals and which are non-metals:
argon, barium, calcium, copper, iron, magnesium, oxygen
b What test could you do that would tell you which are metals and which are non-metals?
c Which three of the metals have similar properties? How do you know?

7 The formula for cane sugar is $C_{12}H_{22}O_{11}$.
a How many different elements are there in sugar?
b How many different types of atoms are there in a sugar molecule?
c What is the total number of atoms in a sugar molecule?

8 Josh knows that substances which contain carbonate ions react with hydrochloric acid to produce carbon dioxide gas. He also knows that calcium compounds give a red colour in a flame, and copper compounds give a bluish-green colour. He tests four compounds and obtains these results.

Compound	Reaction with hydrochloric acid	Flame colour
A	blue solution	bluish-green
B	colourless solution, carbon dioxide gas	red
C	blue solution, carbon dioxide gas	bluish-green
D	colourless solution	red

a Which of the four compounds probably contain calcium?
b One of the four compounds is calcium carbonate (marble chips). Which one?
c Suggest a name for compound C.

9 Kam-Sze has an unknown acid to which she adds the element copper. Hydrogen gas is produced and a blue solution is left in the test tube. She tests the blue solution and finds that it contains only two different ions—copper and chloride. On the basis of these tests Kam-Sze can correctly conclude that the unknown acid contains

A hydrogen.
B chlorine.
C hydrogen and chlorine.
D copper and chlorine.

4



Useful materials

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

Science Understanding

- give examples of how the chemical properties of a substance affect its use
- give examples of how everyday materials such as soap and plastics are made using chemical reactions

Science as a Human Endeavour

- make alcohol, soap and rayon thread without hurting yourself or others

Science Inquiry Skills

- make alcohol, soap and rayon thread without hurting yourself or others
- relate the properties and uses of soaps, plastics and rubber to their chemical structure
- disuss the advantages and disadvantages of plastics and decide whether they can be used sustainably

LITERACY FOCUS

biopolymers
casein
ceramics
detergent
elastic
extrusion
fermentation
fibreglass
injection moulding
monomer
photodegradable plastic
polymer
polymerisation
polythene
structural formula
sustainable
thermoplastics
thermoset
vulcanisation

Focus for learning

You use a range of different materials every day. Each material has properties suited to its use.

For example, car bodies are made from steel. This is because steel is cheap and easy to press into shape. Car engines are usually made from cast iron, which is easily moulded and doesn't rust readily. However, some engines are now made from a magnesium alloy, which is much lighter. The tyres, once made from natural rubber, are now mostly synthetic rubber. It is bouncier than natural rubber and resists punctures. The seats of a car are covered with material woven from synthetic fibres, usually nylon which is cheap and hard-wearing. Most dashboard and interior fittings are made of plastic, which is cheap, light, easy to mould and easy to clean. Windscreens are made of safety glass, which contains a layer of plastic inside it. When the glass is broken it sticks to the plastic and doesn't shatter. Racing car bodies are made from composite materials that include carbon fibres. These materials are very strong and light.

In this chapter you will learn about plastics, rubber, fibres, glass and other materials we use.

PROBLEM SOLVING

Glue goo

Stage 1 Working out the recipe

1 You will need PVA glue (50–50 mixture with water), borax solution (1 teaspoon in half cup of water), a cavity tile and a toothpick.

2 Add 2 drops of PVA glue and 2 drops of borax to one of the dimples in the cavity tile. Use the toothpick to stir the mixture.

3 When the mixture sets to a goo, pick it up and roll it into a ball between your fingers. Investigate its properties. Use what you learn in this chapter to *explain* these properties.

4 Vary the number of drops of PVA and borax you used. Does this change the properties of the goo? How can you explain this? Experiment until you get the goo 'just right'. You could colour it using food colouring.

- Suggest a use for this goo. Give it an interesting name.

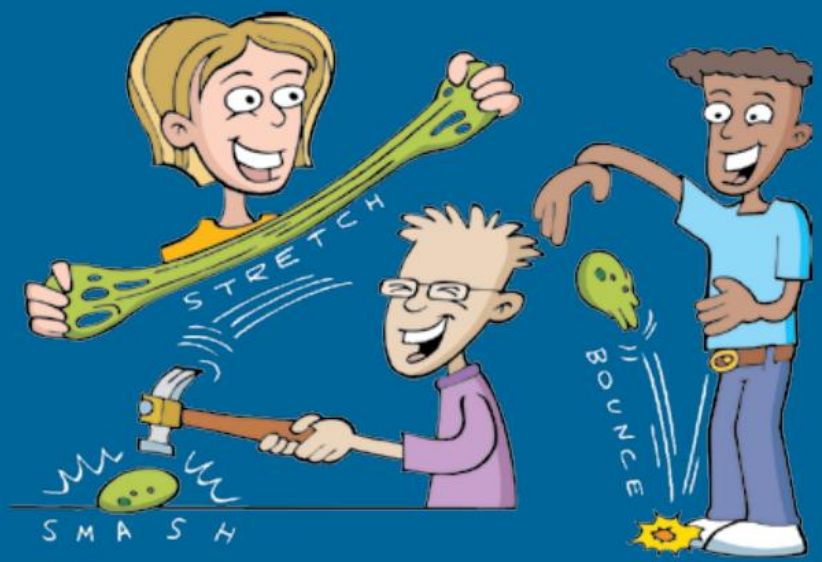
Stage 2 Making the goo

When you have perfected your recipe, try making a much larger piece of goo, about the size of a golf ball. Investigate its properties.

Stage 3 Marketing the goo

Suppose you and your friends have set up a small company to make and market the goo. To do this you will need to answer such questions as:

- What can people do with the goo?
- How will we convince people to buy it?



4.1 Carbon compounds

INVESTIGATION

1 Making alcohol

Aim

To make alcohol, which is a carbon compound, and test its properties.

Risk assessment and planning

- A laboratory coat or apron is essential for the investigations in this chapter.
- Read the investigation carefully before you start, so you know exactly what you will be doing.
- Be careful not to break any of the glassware and, if you do, tell your teacher.
- Alcohol is flammable, so it is safer to use an electric hotplate than a Bunsen burner.

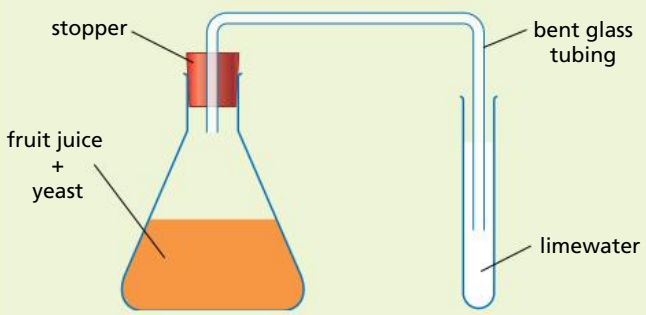
Apparatus

- piece of bent glass tubing fitted into a stopper
- sweet ripe juicy fruit (e.g. grapes or pears)
- two 250 mL flasks
- test tube
- yeast
- limewater
- boiling chips
- small watch glass
- matches
- electric hotplate

Part A: Fermentation

Method

1. Extract 100 mL of juice from the fruit by cutting it up and squeezing it.
2. Make up some yeast according to the instructions on the packet. You will only need a 'pinch' of yeast—about as much as you can hold between your thumb and forefinger.
3. Put the fruit juice in one of the flasks and add the yeast.
4. Put the stopper and glass tubing into the flask as shown, with the end of the tubing in some limewater in a test tube.



5. Leave the apparatus in a warm place (about 30°C) for 2–3 days. Observe what happens during this time, and keep the flask for Part B.

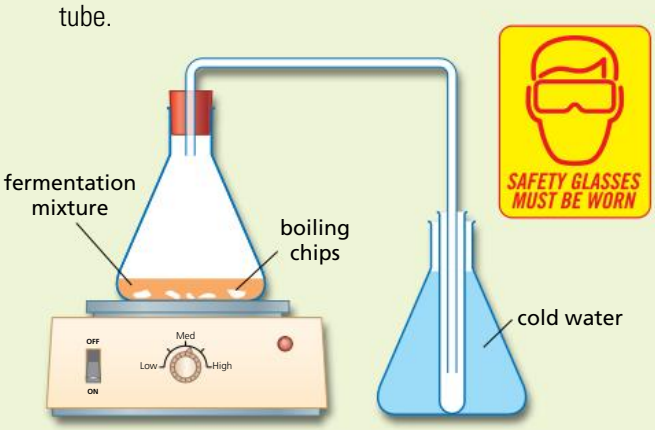
Results

1. Did a chemical reaction occur in the flask? How do you know?
2. What gas was produced? How do you know?
3. Why do you think the flask had to be left in a warm place?

Part B: Distillation

Method

1. After at least 3 days, add some boiling chips to the flask. These prevent 'bumping'—the violent eruption of bubbles from the bottom of the flask during boiling.
2. Put the flask on the hotplate, with the end of the glass tubing in an empty test tube in a flask of cold water, as shown.
3. Heat the mixture strongly but do not boil it. Look for condensation in the glass tubing and collect 5 or 6 drops of alcohol in the the test tube. If you boil the mixture, water as well as alcohol will collect in the test tube.



4. To test the alcohol, put a few drops on a watch glass and use a match to see if it will burn.

Results

1. The alcohol was mixed with water to start with. What happened during the distillation?
2. Suggest why the alcohol collected in the test tube before the water.

SKILL

Making molecular models and drawing structural formulas

The alcohol you made in Investigation 1 is only one of millions of different compounds containing the element carbon. The reason there are so many carbon compounds is because each carbon atom can form four links (bonds) with other atoms to form many different molecules.

1 To get an idea of what these carbon molecules look like you can use a molecular models kit.



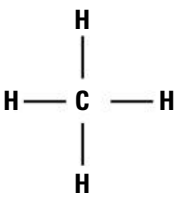
- What do the coloured balls represent?
- What do the connectors represent?
- Which colour represents:
  - **a** carbon?
  - **b** hydrogen?
  - **c** oxygen?
- How many bonds can each of these atoms form?

2 Make a model of methane. It has four hydrogen atoms bonded to a central carbon atom.

- Write the formula for methane.

The methane molecule is three-dimensional, so it is difficult to draw. Instead, a simple two-dimensional *structural formula* can be drawn. Each line represents a chemical bond.

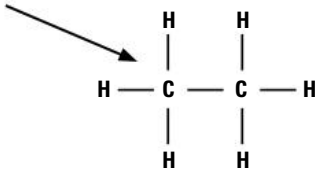




A methane molecule and its structural formula

Carbon atoms can also join with other carbon atoms to form chains of carbon atoms. For example:

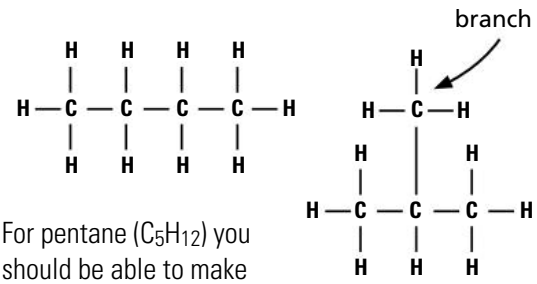
ethane	C_2H_6
propane	C_3H_8
butane	C_4H_{10}
pentane	C_5H_{12}
hexane	C_6H_{14}



These are all hydrocarbons because they contain only hydrogen and carbon. Methane and ethane are found in natural gas. Propane and butane are the gases in bottled gas called LPG (liquefied petroleum gas).

3 Make molecular models of each of the five hydrocarbons above. For each one draw its structural formula, like the one for ethane. For butane (C_4H_{10}) you should be able to make two different molecules —one with a branch, and one without a branch, as shown below.

These two butane molecules are different, even though they both have the formula C_4H_{10}. Note that each carbon atom always forms 4 bonds, and hydrogen always forms only one bond.



For pentane (C_5H_{12}) you should be able to make three different molecules.

- How many different hexane molecules are there?

4 Some molecules are ring-shaped. For example, in cyclohexane (C_6H_{12}) the six carbon atoms are joined in a ring. See if you can make a model of this compound and draw its structural formula.

5 The alcohol you made in Investigation 1 is called ethanol. It has the formula C_2H_5OH. It is written this way because it has an –OH (alcohol) group at one end of the molecule. There are many different types of alcohols, but they all have an –OH group somewhere in their molecule.

Make a model of ethanol and draw its structural formula.

INVESTIGATION

2 Making soap

Aim

To make soap (another carbon compound) and test it.

Risk assessment and planning

Sodium hydroxide (caustic soda) is a strong alkali and is very corrosive, especially when it is hot. So you need to be very careful not to spill it.

- What should be done if sodium hydroxide is spilt on your skin or the bench?
- Suggest why it is safer to use an electric hotplate than a Bunsen burner in this investigation.
- It is not safe to test the soap you make on your skin. Suggest a reason for this.

Apparatus

- electric hotplate (or Bunsen burner equipment)
- 2 small test tubes, with stoppers
- two 250 mL beakers
- 500 mL beaker
- large test tube
- *ethanol*
- margarine
- wash bottle
- vegetable oil (any kind)
- *6 M sodium hydroxide solution*
- sodium chloride (table salt)
- paper towel
- measuring cylinder (10 mL)
- tablespoon



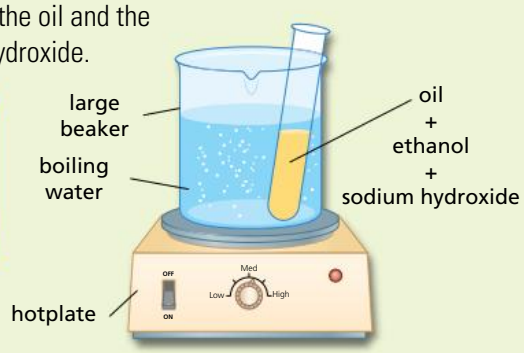


Method

Part A: Making the soap

1 Carefully put 5 mL of vegetable oil, 10 mL of ethanol and 10 mL of sodium hydroxide into a large test tube. The ethanol dissolves the oil and so speeds up the reaction between the oil and the sodium hydroxide.





2 Put the test tube in a boiling water bath for 30 minutes, as shown. Shake the tube gently every few minutes to mix the contents. Eventually the mixture will become a soapy paste.

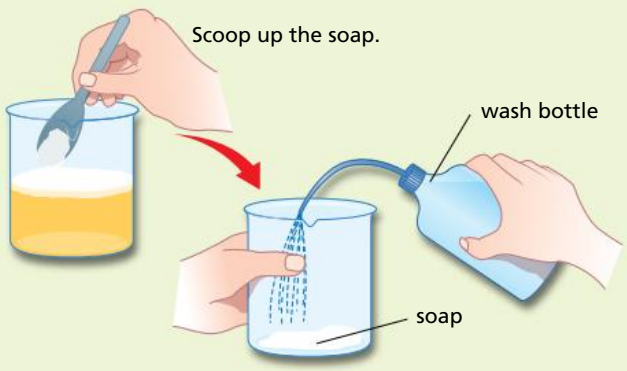
3 Put about 100 mL of boiling water in a 250 mL beaker.

4 Carefully pour the mixture from the test tube into this beaker.

5 Add a tablespoon of sodium chloride to the mixture and stir well. Then leave it to cool. The soap will float to the top.

6 Use a spoon to scoop up the soap and put it into another clean beaker.

7 Rinse the soap a few times with a little water from a wash bottle.



8 Use the spoon to transfer the soap to a piece of paper towel and leave it to dry.

✻ Describe your soap.

Part B: Testing the soap

1 Half fill a test tube with water and add a little of your soap.

2 Stopper the tube and shake it. Does it produce a lather (froth)?

3 Half fill a second test tube with water and add a little margarine. This will be your 'grease'. Stopper and shake. What happens?

4 Now add some soap and shake again. Does the 'grease' disappear?

5 If there is time, design a fair test to compare your soap with commercial soaps.

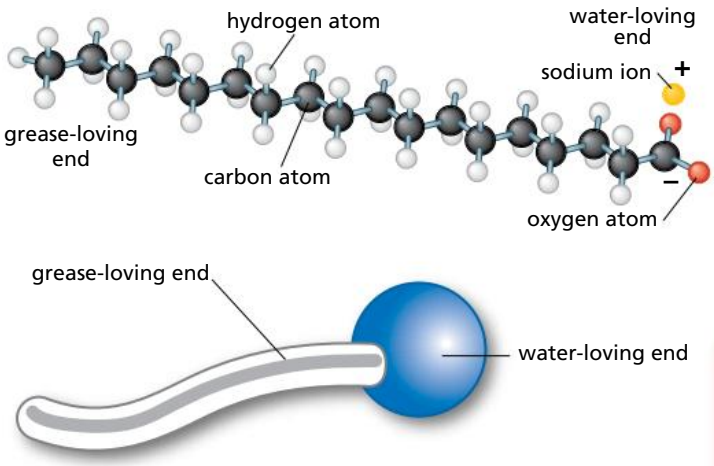
Write your report

1 Write a suitable conclusion for the investigation.

2 What would you need to do if you were running a company and you wanted to market your soap?

How soaps and detergents work

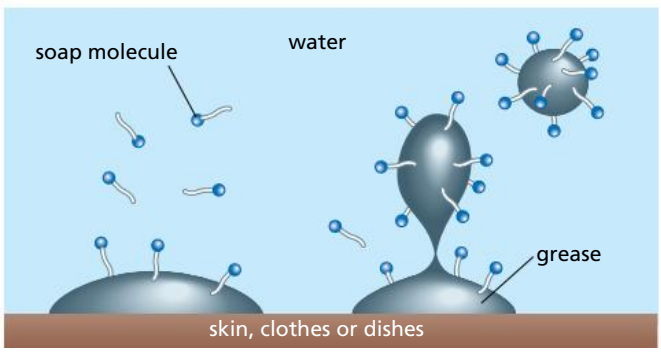
Soap is a carbon compound made of long molecules that contain mainly carbon and hydrogen atoms. This is what a typical soap molecule looks like.



A typical soap molecule (top) and a simplified diagram (bottom)

The 'head' of the soap molecule has a negative charge, and is attracted to water molecules. It is called the *water-loving end*. The hydrocarbon 'tail' is not attracted to water. It is attracted to grease or 'dirt', which is also a hydrocarbon. This end is called the *grease-loving end* or the water-hating end.

The diagram below shows how soap molecules can help to remove grease from your body, clothes or dirty dishes. The grease-loving ends are attracted to the grease and bury themselves in it. The water-loving ends are attracted to the water. The soap molecules pull the grease into tiny round droplets that can float in the water and form an emulsion. (An emulsion is a mixture of tiny droplets of one liquid in another.) The soap helps the grease to form an emulsion in the water. In this way the grease is removed from your skin, the clothes or the dishes, and rinsed away in the water.



Soaps are made from natural fats and oils. Once chemists worked out the structures of soaps, they were able to make synthetic **detergents** to replace soap. These detergents are similar to soap, but their molecular structure is slightly different.

Soaps and detergents work by reducing the *surface tension* of water. In water each molecule is surrounded and attracted by other water molecules. However, at the surface the molecules are attracted only by the molecules below the surface. This creates a tension because the surface molecules are being pulled back into the water. This surface tension is why water seems to have a 'skin' and tends to form round drops on the surface of cloth.

INQUIRY 1 Can water be made wetter?

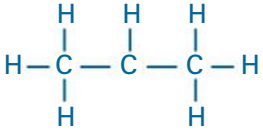
You will need: piece of cloth (e.g. polyester and cotton), dropper, toothpick, liquid detergent

1. Using a dropper, carefully place a drop of water on a piece of cloth.
2. Using a toothpick, add a tiny drop of detergent to the water drop. What happens?
   - Write an inference to *explain* your observation.

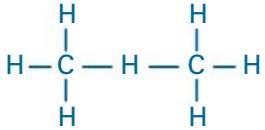
Over to you

1. Which two elements do hydrocarbons contain?
2. Explain why carbon forms so many different compounds.
3. During the process of fermentation in Investgation 1, glucose ($C_6H_{12}O_6$) was broken down by yeast to form ethanol (C_2H_5OH) and carbon dioxide.
   - **a** Which molecules are the largest—those in glucose, ethanol or carbon dioxide?
   - **b** Which elements are in glucose?
   - **c** How many atoms are there in a molecule of glucose?
4. Your younger brother asks you how laundry detergent removes dirt from clothes. How could you explain this to him in simple terms?
5. Both of these structural formulas are incorrect. Use what you learnt on page 73 to say *why* they are wrong.

a



b



4.2 Plastics

Humans have always made use of the carbon compounds in the plant and animal materials around them. For example, we use cotton from cotton plants and wool from sheep. Sometimes new materials were discovered by accident.

Though strictly forbidden by his wife from doing experiments at home, the German chemist Christian Schonbein sometimes disobeyed her when she wasn't around. One day in 1846 he was experimenting in the kitchen when he accidentally spilt a mixture of nitric and sulfuric acids. In a panic, he grabbed his wife's cotton apron and mopped up the mess. He then hung it over the stove to dry before his wife came home. She didn't notice anything until the apron suddenly burst into flames and disappeared. Schonbein had accidentally made a new material called guncotton (cellulose nitrate).

INQUIRY 2 Making plastic from milk

You will need: full-cream milk, vinegar, heating equipment, thermometer, stirrer, two 250 mL beakers, 100 mL measuring cylinder, coarse cloth, rubber band, paper towel, sandpaper

1. Put 100 mL of milk into a beaker and warm it gently until it reaches 50°C.
2. Add 10 mL of vinegar and stir. The milk will curdle to form white lumps of curds (casein) and a yellowish liquid called whey.
3. Use a rubber band to hold the cloth loosely over the second beaker as shown. Strain the curds and whey through it.



4. Carefully take the cloth off the beaker and squeeze it to remove as much liquid as possible.
5. Put the curds on a paper towel, pat them dry and mould them into a shape. Then put the shape in the sun to dry. After a few days you may be able to polish the shape with sandpaper.
6. Experiment to find the best way to make casein glue, by dissolving the wet or dry casein you have made in ammonia or borax solution (use a fume cupboard).

The first synthetic plastic

Casein is a protein that is found in milk. As you will see in Inquiry 2, casein is easily moulded into shapes. That is why it is called a **plastic**. The word plastic comes from the Greek word *plastikos*, which means 'to mould'. Casein is still used to make some buttons and knitting needles. During World War I, casein glue was used to hold aircraft together.

Until the early 1900s all plastics were made from natural materials. In 1904 Leo Baekeland, a Belgian working in the USA, set out to find a synthetic substitute for shellac—a material that was obtained from tiny Indian lac bugs and used mainly for making varnishes and waxes. He mixed two chemicals, phenol and formaldehyde, which produced a dark brown substance that clogged up his test tubes.

After three years his laboratory was filled with pages of failed experiments. Then in 1907 he finally worked out the right recipe to make a shellac-like liquid. If he heated this liquid further it turned into a sticky goo that could be moulded. It was the first synthetic plastic, and he called it *bakelite*, from his own name. It soon became known as the 'material of a thousand uses', and everything from saucepan handles to electrical fittings was made from it.

Polymers

Eventually scientists worked out why materials like cotton, casein and bakelite had such special properties. They inferred that such materials contained **polymers**—very long molecules containing thousands of atoms. To make a polymer small molecules called *monomers* are joined up. This process is called **polymerisation** (pol-IM-er-eyes-AY-shun). This is like linking together a string of paperclips. *Mono* means 'single', *poly* means 'many' and *mer* means 'units', so monomer means 'single units' and polymer means 'many units'.

INQUIRY 3 Paperclip models

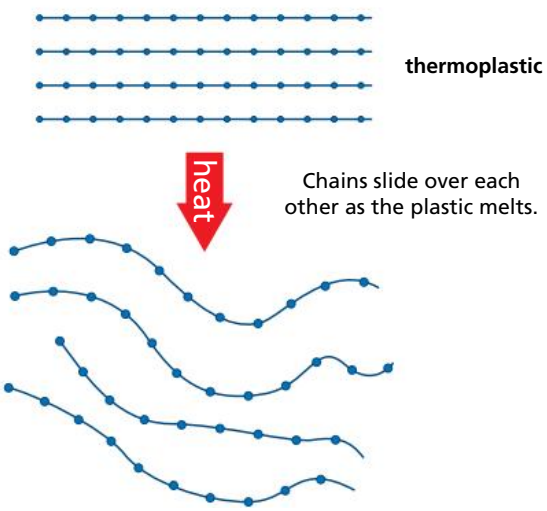
You will need: a box of paperclips

1. Make a single chain of paperclips to represent an unbranched polymer chain. These unbranched chains pack together closely to form strong, rigid polymers such as nylon and high-density polythene (HDPE).
2. Attach paperclips here and there along the chain to form a branched chain. Branched chains like this can't pack together as closely as unbranched chains. They form flexible plastics such as polypropylene (PP) and low density polythene (LDPE).
3. Make at least three branched chains and lay them out next to each other. Now connect some of the branches from one chain to the branches of another chain. You can make as many cross-links as you like. Thermosets such as bakelite and resins are cross-linked like this. They are more rigid and stronger than thermoplastics.

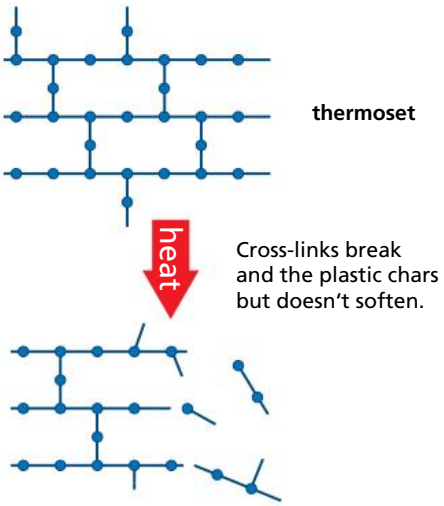
- Draw and label the models you make.

In some polymers, such as polythene and the cellulose in cotton, each monomer is the same. The polymer is like a string of identical beads. In other polymers, such as bakelite and nylon, there are two different monomers and the polymer is like a string of two alternately coloured beads.

Most plastics (for example, polythene and nylon) soften and melt when heated. They are called **thermoplastics**. The polymer molecules form long parallel chains that can slide over each other, allowing the plastic to bend and stretch. When the plastic is melted, it can flow to fill whatever mould it is placed in.



Bakelite is an example of a thermosetting plastic, or **thermoset** (sometimes called a resin). Once made, it cannot be remoulded. The polymer molecules have strong cross-linking bonds, locking them into a giant three-dimensional structure. Individual polymer chains can't be moved without breaking the whole structure. This makes thermoset plastics hard, brittle (will shatter if dropped) and rigid (cannot be bent). When heated, thermosets char (burn at the edges) but do not soften. Because of this they need to be manufactured and moulded at the same time. This is what happens with instant glues such as Araldite where you mix two different chemicals.

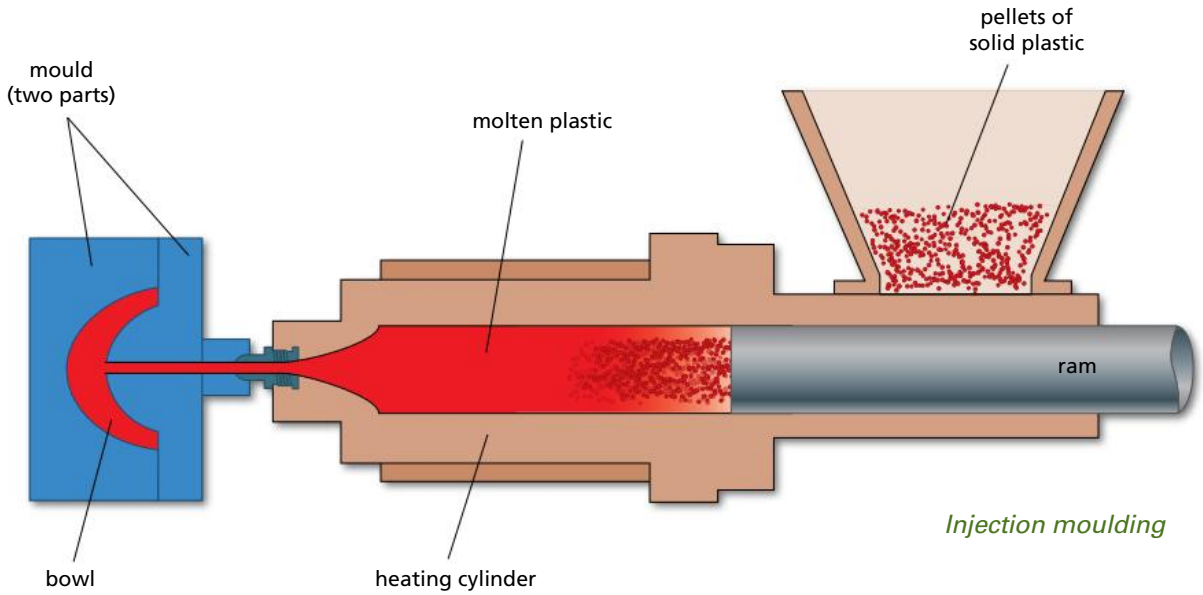


Many gloss paints contain a polymer dissolved in a solvent. In the can the polymer chains are tangled up, so the paint is thick. When the paint is brushed onto a surface, the molecules partly untangle, and the paint flows more easily. As the paint dries the solvent evaporates and the polymer reacts with oxygen in the air. This causes cross-links to form between the polymer chains, and the paint sets hard.

Shaping plastics

Thermoplastics can be shaped in a number of different ways. Each method involves heating the plastic so that it becomes soft, then shaping it and cooling it.

The *injection moulding* machine on the next page works like a grease-gun. The plastic is melted and then squirted (injected) into a mould. As it cools it hardens in the shape of the mould. Moulds are costly to make, so the process is only economical for producing large numbers of articles such as bowls, cups or refrigerator linings, one at a time as shown on the next page.



Injection moulding

Plastic rods, tubes and thin sheets can be made by a continuous process called *extrusion*. For example, if you removed the mould from the equipment above, you could form a solid plastic rod.

INQUIRY 4 Shaping plastics

You will need: metal spoon, 5 cent coin, silicone car wax, polythene or other thermoplastic, Bunsen burner

1. Cover the inside of the spoon and both sides of the coin with silicone car wax.
2. Cut the plastic into small pieces and heat them gently in the spoon until they soften. (Don't melt the plastic.)
3. Carefully push the coin into the softened plastic.
4. Cool the spoon and plastic under a tap, then remove the plastic from the spoon and the coin from the plastic. Be careful, it may still be hot.

Advantages and disadvantages of plastics

Plastics are made from chemicals obtained from oil and coal, and their use has increased in recent years. They have the following advantages over natural materials such as wood, metal and glass:

- Do not rot or corrode in air or water
- Can be used as **insulators** as they do not conduct heat or electricity
- Relatively cheap and can be moulded into any shape
- Easily coloured during manufacture
- Lighter than wood, metal or glass
- Can be made very strong
- Have an attractive finish
- Most are not affected by acids or alkalis.

On the other hand, plastics have some disadvantages:

- Do not rot so are difficult to dispose of
- Some types catch fire easily
- When burnt they often give off harmful gases. (This is especially dangerous when foam furniture burns.)
- Cheap to produce and so are often thrown away
- Often don't look as good as natural materials
- Their manufacture uses up non-renewable resources (oil and coal)
- Once released into the environment they can harm wildlife.



This plastic can holder has been caught around the goanna's neck.

Reduce, reuse, recycle

Our plastic waste problem can be improved by following these three Rs:

- **Reduce** the amount of rubbish you produce. For example, take your own bag instead of accepting plastic bags when shopping.
- **Reuse** waste items. For example, use empty ice cream containers to store things.
- **Recycle** waste materials. Councils collect plastics, as well as paper and glass for recycling. In 2008, 18.5% of plastic waste was recycled. For example, PETE (1) soft drink bottles and HDPE (2) bottles are recycled to make new bottles. Even plastic banknotes, which are made of polypropylene, are recycled to make compost bins.

Biodegradable plastics

If you throw a plastic bottle beside the road it doesn't rot away like an apple core or a piece of paper. Even if it is put in the bin, taken to the dump and buried, it still doesn't rot away. We say that plastics are not **biodegradable**. They are not broken down and used as food by bacteria and fungi in the soil or in water.

Scientists have been trying to make biodegradable plastics. Some years ago they developed a *photo-degradable* plastic that broke down in sunlight. However the plastic broke down very slowly. Scientists have also managed to make a plastic that dissolves in water, but it has limited uses. For example, the laundry bags used in hospitals are made from dissolving plastic. Dirty laundry is sealed in the bag and put in the washing machine. The bag then dissolves and the clothes can be washed without touching them.

Polystyrene packing foam is being replaced by foam made from corn or wheat starch. This forms a suspension in water and is biodegradable. The added advantage is that the wheat or corn is a renewable resource, unlike polystyrene which is made from oil—a non-renewable resource.

In recent years scientists have developed *biopolymers*—biodegradable polymers. Polythene, the most widely used plastic, has polymer chains with about 100 000 carbon atoms. Some bacteria can digest polythene but they can attack only at the ends of the long molecules. So it takes a very long time to break down the plastic. It's a bit like chewing away at the end of a very long rope—it takes a long time to get to the other end! Scientists have found that when corn starch is inserted into the long polythene molecules, bacteria quickly digest the parts that are made of starch. This breaks the molecule in many places, exposing new ends to the bacteria and speeding up the breakdown process.

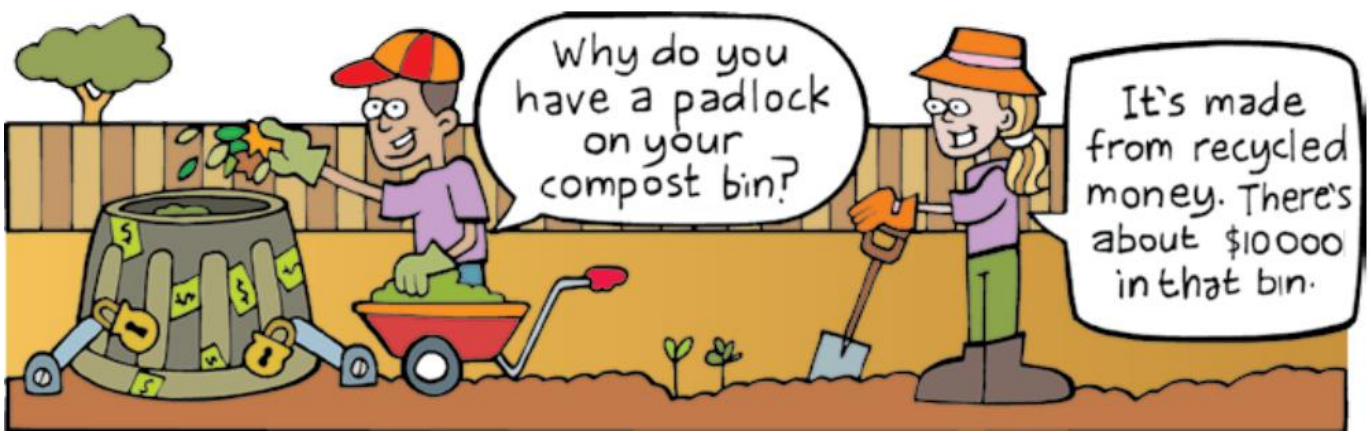
INQUIRY 5 Sustainable plastics?

Probably the biggest disadvantage of plastics is that their manufacture uses up oil and coal, which are non-renewable resources. Form a group and discuss this question:

- Can our use of plastics be **sustainable**? How?

Our use of a resource such as plastics is sustainable only if we can continue using the resource for a very long time without using it up and without damaging the environment.

An internet search under sustainable plastics may give you some ideas.



Another biopolymer is PHB, a natural polyester made by certain bacteria. It breaks down in the soil in about 9 months. But there is a price to pay, as PHB is about 15 times more expensive than polythene at present. Scientists are also experimenting with the idea of using genetic engineering to transfer the genes of the bacteria that produce PHB into plants. If they are successful in doing this, in the future we may be able to grow biopolymers as a renewable farm crop.



This Plantic plastic tray is made from corn starch and degrades rapidly in water.

Over to you

1 Look around the room.
- **a** Identify four objects made of plastic.
- **b** Why is each object made of that particular type of plastic?
- **c** What material do you think each article would have been made of before we had plastics?
- **d** What are the advantages of making the objects from plastic?

2 Explain the differences between thermoplastics and thermosets. Suggest which type of plastic would be best for making
- **a** light fittings
- **b** coatings for handles of screwdrivers
- **c** saucepan handles
- **d** rulers.

In each case give reasons for your choice.

INQUIRY **6** **Starch packing foam**



You will need: starch packing foam 'peanuts'

1 Use your senses (incuding taste) to make as many observations of a starch packing foam peanut as possible. You may be able to compare it with a polystyrene foam peanut.
- How do you think the starch packing foam peanuts were made?

2 Add the starch peanuts to some water. What happens to the peanuts and what happens to the water?

3 If you have time, investigate whether hot water affects starch peanuts more than cold water does. You could also investigate ways of recovering the starch from the suspension.

3 What are cross-links and why do they make a plastic more rigid?

4 Thermoplastics can be recycled but thermosets cannot. Why is this?

5 Suggest a simple test to tell the difference between a thermoplastic and a thermoset.

6 Look at the list of the advantages and disadvantages of plastics on page 78.
- **a** Which of the advantages do you think are the most important? Explain.
- **b** Which of the disadvantages are most important?

7
- **a** Why does the recycling of plastics make such good sense?
- **b** Suggest why only 18.5% of plastics waste is recycled at present.

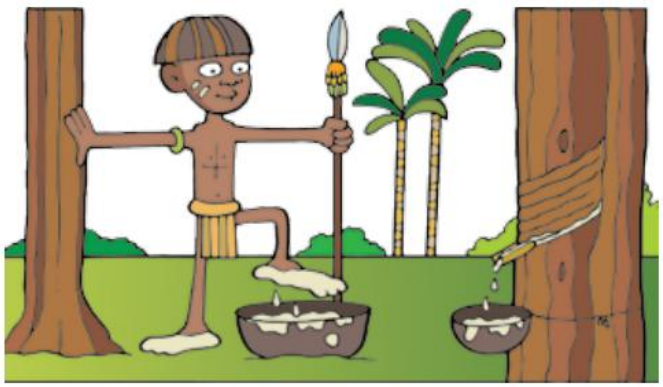
8 What is a biopolymer?

9 How could a plastic-coated dish drainer be made?

10 When bakelite first forms it is soft, but it hardens over a day or so. Infer what causes this hardening.

4.3 Rubber

When the Spanish explorer Christopher Columbus visited the West Indies in 1492 he saw the Indian children playing with bouncing balls made from the gum of a tree. Later explorers found that the South American Indians made waterproof 'shoes' by dipping their feet in gum and allowing it to dry. This gum was the sap (latex) of the rubber tree.



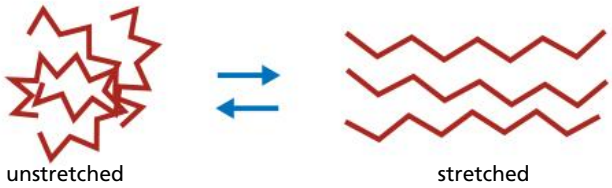
INQUIRY 7 Rubber latex

You will need: safety glasses, natural rubber latex, vinegar, small beaker, stirrer

1. Put about 10 mL of rubber latex in the beaker. Add about 1 mL of vinegar, stirring all the time.
2. Quickly remove the rubber sticking to the stirrer, wash the rubber under a tap and squeeze it into a ball. Be careful the vinegar doesn't squirt into your eyes. Do not pour any waste down the sink.
3. Test how well the ball bounces.
4. To make a rubber band, dip your finger into rubber latex. Leave the latex on your finger until it dries and becomes colourless.
5. Break a hole in the rubber on the tip of your finger, then gently roll the rubber down to form a rubber band.
6. Investigate the effect of water at various temperatures on the rubber ball and the rubber band you made.

Explaining rubber

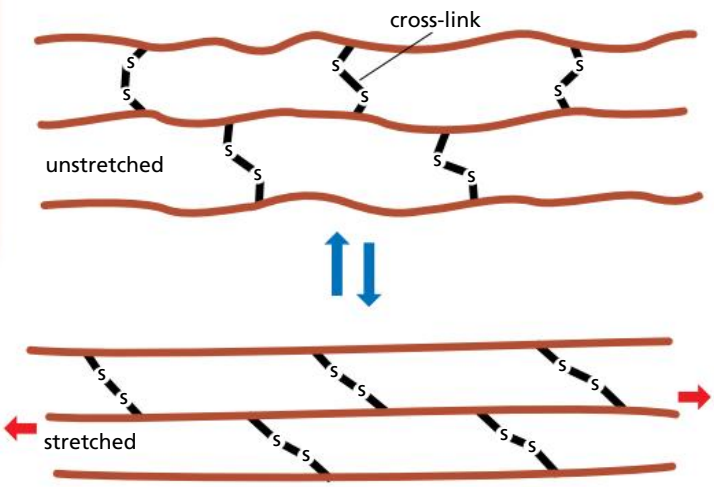
Rubber is a polymer and consists of long, highly kinked molecules as shown top right. These molecules are more tangled than the molecules of other polymers. They are like a bowl of cooked spaghetti. When you stretch a piece of rubber, the molecules in it are pulled out straight and untangle. Then, when you release the rubber, the molecules spring back and tangle up again. Rubber is said to be **elastic** because it returns to its original shape and size after stretching.



The trouble with raw rubber is that it becomes soft and sticky when it is hot, but hard and brittle when it is cold. The American inventor Charles Goodyear set out to solve this problem by mixing other substances with it. After five years of failure, he began experimenting with sulfur.

The story is that in 1839 he wandered into the local store to show off his latest rubber—sulfur gum. When people laughed at him he waved his sticky gum in the air, and it flew out of his hand and landed on a hot stove. When he scraped it off the stove he found that the gum hadn't melted, as he expected, but only charred. Goodyear immediately understood the significance of this accident—he had made the rubber less elastic. He then worked out the best temperature and time for heating, as well as the amounts of rubber and sulfur to use. He patented a process he called **vulcanisation**, after Vulcan the Roman god of fire.

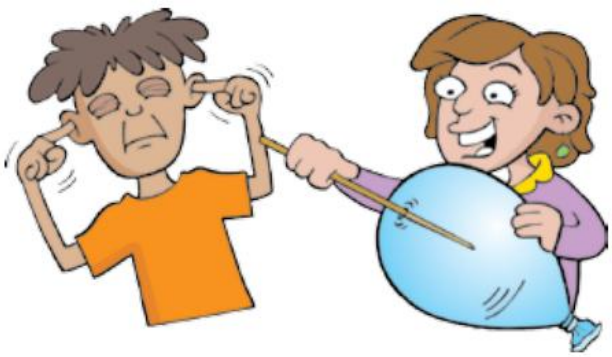
The sulfur reacts with the rubber to form cross-links between the polymer chains. When you stretch the rubber these cross-links stop the rubber from stretching too far. When you release the rubber the cross-links pull the polymer chains back to their original positions.



INQUIRY 8 Balloon kebab

You will need: wooden barbecue skewer, several white balloons, cooking oil

1. Blow up a balloon to half its normal size, no longer than the skewer. Tie the end.
2. Look closely at the balloon. It was made by dipping a mould into rubber latex and then heating it for a while.
   - Why is the balloon a darker colour around the nipple end and around the knot?
3. Dip the tip of the skewer into some cooking oil and rub the tip with your fingers to lubricate it.
4. Using a gentle twisting motion, insert the skewer into the nipple end of the balloon, the end opposite the knot. Were you able to do this without bursting the balloon? Continue pushing and twisting the skewer until it comes out the other side of the balloon close to the knot.
5. Slowly pull the skewer out. Can you feel the air escaping through the tiny holes that are left? What happens when you quickly jab the skewer into the side of the balloon?



6. You could investigate what happens if you use a fully inflated balloon or a balloon filled with water. You may also like to see how many skewers you can put through a balloon without bursting it. The record is seven!
7. Using what you have learnt about the molecular structure of rubber, try to *explain* your results.

Recycling car tyres

Since World War II, many different synthetic rubbers have been developed, and some of these are better than natural rubber. For example, a synthetic rubber that is bouncier than natural rubber was developed for use in car tyres. Puncture-resistant rubber has also been developed.



The big problem is that vulcanised rubber does not melt on heating and therefore cannot be recycled. Australia produces about 18 million used tyres each year, and most of these are dumped, used as landfill or stockpiled. This is a major environmental problem, so ways of reusing and recycling these tyres are being investigated. For example, the tyres can be shredded to make crumbed rubber that can be used as a soft bouncy paving material for children's playgrounds. It can also be mixed with hot bitumen and used on our roads.

Scientists are also investigating thermoplastic rubbers. In these the polymer consists of a block of thermoplastic, followed by a longer block of rubber, and then another short block of thermoplastic. The thermoplastic blocks act as cross-links, tying the rubber blocks together. When the material is heated, the thermoplastic blocks fall apart. The rubber can then be moulded and recycled. However, a thermoplastic rubber suitable for car tyres has not yet been developed.

Over to you

1. Why is rubber so elastic (stretchy)?
2. Vulcanised rubber softens at a much higher temperature than unvulcanised rubber. Why?
3. Suggest how rubber gloves are made.
4. Suggest another use for recycled crumbed rubber (one not mentioned in the text).
5. To avoid bursting the balloon in Inquiry 8 you needed to push the skewer in slowly rather than jab it in. How can you explain this in terms of the rubber molecules in the balloon?
6. Goodyear said his discovery of vulcanisation was not an accident. He said the hot stove incident would only mean something to someone 'whose mind was prepared to draw an inference'. What do you think he meant by this?

4.4 Fibres

INVESTIGATION

3 Making fibres

Aim

To make and form nylon fibres.

Risk assessment and planning

- In Part A the chemicals used to make nylon are hazardous and must be handled only by the teacher. A fume cupboard is recommended.
- In Part B it is important not to melt the pantihose. What do you think is the reason for this?

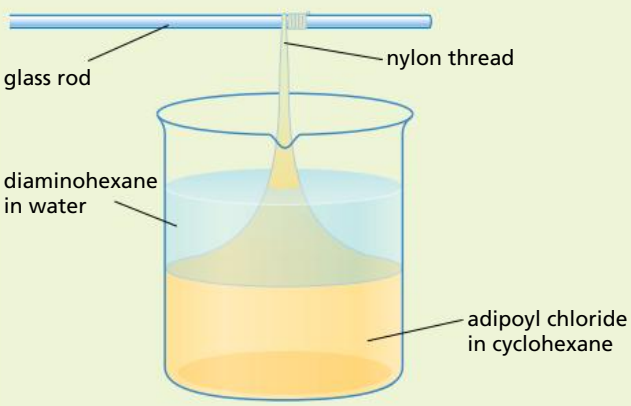
Part A: Nylon rope trick (teacher demonstration)

Apparatus

- anhydrous sodium carbonate
- 1,6-diaminohexane
- adipoyl chloride (or sebacoyl chloride)
- cyclohexane
- two 250 mL beakers
- glass stirring rod
- tweezers

Method

1. Dissolve 5 g of anhydrous sodium carbonate and 2.2 g of diaminohexane in 50 mL of water in a beaker.
2. Dissolve 2 mL of adipoyl chloride in 50 mL of cyclohexane in a second beaker.
3. Carefully pour the diaminohexane solution down the side of the second beaker so that it forms a layer on top of the cyclohexane solution.
4. A skin forms at the boundary between the two solutions. Lift the skin out with a pair of tweezers and wind the nylon thread onto a glass rod as shown.

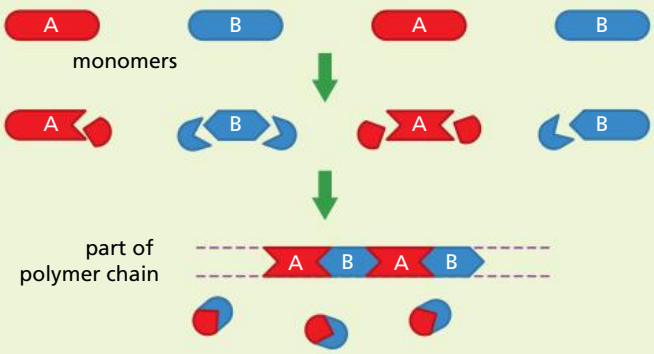


Results

1. The nylon thread is not very useful. Suggest a reason for this.
2. What do you think would have happened if the two solutions had been thoroughly mixed?

How nylon is made

Nylon is a synthetic polymer made by mixing two different monomers that both have reactive ends. During polymerisation the monomers join together as shown and a small molecule—hydrochloric acid—is split off. The sodium carbonate added to the mixture is to neutralise this hydrochloric acid.



Part B: Pantihose fibres

Apparatus

- old pantihose or piece of nylon
- tin lid
- Bunsen burner equipment
- piece of wire (about 10 cm)



Method

1. Cut the pantihose into small pieces and put them into the tin lid.
2. On the Bunsen burner, carefully heat the nylon until it *begins* to melt, then turn off the burner.
3. Push the end of the wire into the soft nylon and pull out a fibre. Do this as many times as you can.
4. When the nylon fibres have cooled, test their strength by stretching them with your fingers.

Conclusion

Do you think nylon pantihose could be recycled by this method? Explain.

Copying the spider

To form nylon into fibres, plastics engineers have copied how spiders spin their webs. Spiders have special glands that secrete silk proteins, which are natural fibres. The spider pushes this silk through organs called *spinnerets* at the rear of its abdomen. It can control the thickness of the silk thread and the speed at which it is pushed out (extruded). It pulls out the silk threads with its hind legs.

When nylon is made, the nylon is softened by heating and squeezed through holes in a metal plate called a spinneret, named after the spider organ.



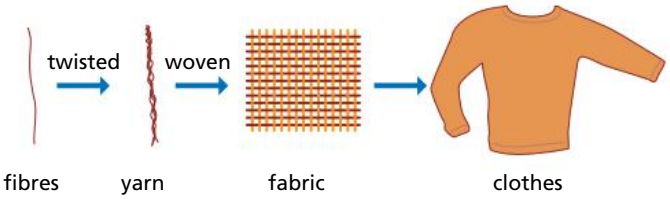
A spider spins a silk web through its spinnerets. Synthetic fibres are made in a similar way.

Fibres to clothes

Fibres are thin filaments of material. They may be natural, like wool, cotton, silk (from silkworms), linen (from flax) or hair. Or they may be synthetic, like nylon, polyester, acrylic, lycra and Kevlar. Some fibres are short; for example, wool fibres are only about 13 cm long. Others are long, for example a silk filament can be up to 3 km long! The molecules in a fibre are aligned along its length. The ends of the molecules are weak spots, so the longer the molecules are, the stronger the fibre will be.

To be useful, fibres need to be joined together in some way. The most common way to do this is to twist them together to form a thread or *yarn*. To make fabric, the yarn is woven by interlacing two sets of threads, one set vertical and the other horizontal.

Sometimes single filaments called *monofilaments* are used, rather than twisting them together to form yarn. For example, fishing lines are made from monofilaments of nylon and are very strong.



All fibres have different properties. For example, cotton absorbs moisture and allows sweat to evaporate. It is therefore comfortable to wear on hot days. Synthetic polyester does not wear out as easily as cotton, but it does not absorb moisture. This makes it sticky and uncomfortable on hot days. By blending cotton and polyester fibres, you have the properties of both fibres. For example, 65% polyester and 35% cotton is a common blend. Clothes made from this are hard-wearing, comfortable in summer and drip-dry (non-iron).

INQUIRY 9 Fibres under the microscope

You will need: small pieces of various fabrics, microscopes (binocular and monocular), microscope slides and cover slips, tweezers

1. Use a binocular microscope or a hand lens to examine small pieces of the various fabrics. Examine the different weaving patterns. If possible, draw them.
2. Remove an individual thread from one of the fabrics. Put it on a microscope slide and use tweezers to tease the fibres apart.
3. Place a cover slip over the fibres and examine them under the monocular microscope. (If you have forgotten how to use a microscope, check with your teacher.) Draw the fibres.
4. Repeat for the other fabrics.



5. Once you have studied the various fibres, try to identify an unknown fabric.

INVESTIGATION

4 Making rayon thread

Aim

To make rayon thread from tissue paper.

Risk assessment and planning

Read the investigation carefully and discuss how you can minimise any hazards.

Apparatus

- piece of white tissue about 12 cm square
- 50% ammonia solution
- copper carbonate
- *dilute sulfuric acid (2 M)*
- small syringe
- stirring rod
- three 250 mL beakers
- paper towel
- tweezers

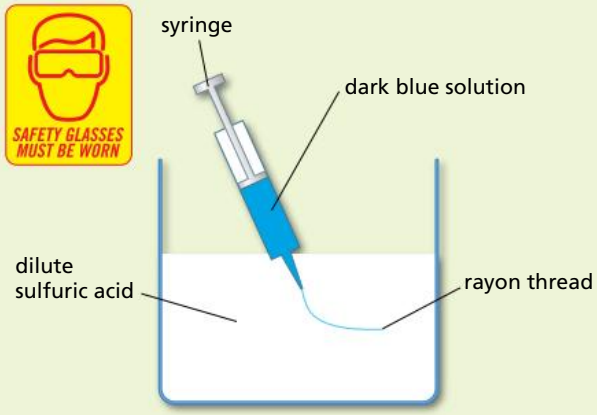


Method

1 Tear up the tissue into very small pieces and put it in one of the beakers.

2 Add about half a teaspoon of copper carbonate and 30 mL of ammonia solution. If possible do this in a fume cupboard, because ammonia fumes irritate the eyes and nose.

3 Stir until the paper dissolves to form a thick, dark blue solution (5–10 minutes). It is important that any lumps of paper dissolve, so that they don't block the syringe in the next step.



4 Put 50 mL of dilute sulfuric acid in a second beaker.

5 Draw up some of the dark blue solution in the syringe. Put the tip of the syringe under the surface of the acid in the beaker and slowly squirt the dark blue solution into it.

6 Carefully remove the thread from the acid by using tweezers. Wash the thread in cold water to remove the acid, then dry it on a paper towel.

✻ Describe the properties of the rayon thread.

Conclusion

Summarise the process of making rayon thread.

Discussion

1 Were you happy with the rayon thread you made?

2 Suggest ways of improving your method.

Over to you

1 What is the difference between a natural fibre and a synthetic fibre? List three examples of each.

2 Explain in your own words how synthetic fibres such as nylon are manufactured.

3 Explain the difference between a fibre and a fabric.

4 Which properties would be particularly important in choosing a fibre for each of the following uses?

- **a** abseiling rope
- **b** laboratory apron
- **c** non-iron shirt or blouse
- **d** swimming togs
- **e** underwear

5 Why are clothes often made from a blend of two or more different fibres?

6 How are the molecules arranged in fibres? Draw a diagram.

7 Suggest why pure silk is such an expensive fibre.

8 Suggest why the silk in a spider's web is so strong.

9 Most synthetic fibres are thermoplastics. Why must a cool iron be used on clothes made from synthetic fibres?

10 When a fibre is stretched it becomes thinner. Write an inference to explain why this usually increases the strength of the fibre.

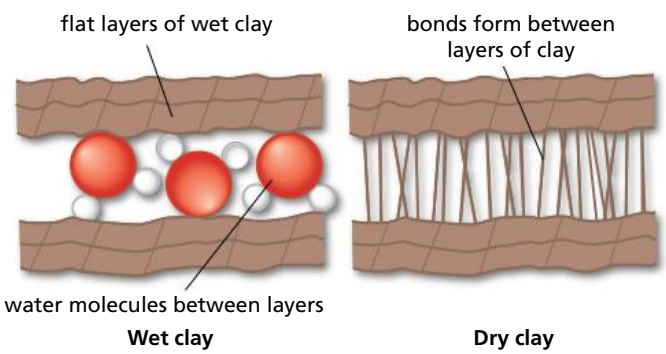
4.5 Materials—old and new



Deborah Halpern's sculpture *Ophelia* at Southgate in Melbourne is covered in brightly coloured ceramic tiles. NASA's space shuttles are covered with ceramic tiles that protect them from the high temperatures that occur during re-entry into the Earth's atmosphere. Ceramics such as pottery have been used since prehistoric times and examples more than 6000 years old have been found.

Ceramics are hard and rigid, and resist wear and tear. They are resistant to heat and chemicals, and are good insulators of heat and electricity. They are relatively light compared to metals. Some common uses are floor and wall tiles, toilet bowls, cooking dishes and electrical insulators on power lines.

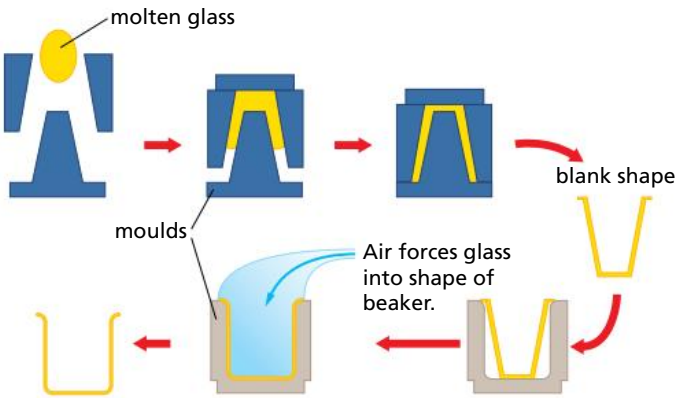
Most ceramics are made from clays. These clays are made up of polymer molecules containing silicon and oxygen, linked together in separate flat layers, like sheets of chicken wire piled one on top of the other. When the clay is wet, water molecules get between the layers and allow them to slide over one another, as shown. This is why clay is soft and slippery. As the clay dries, the water evaporates and the clay shrinks. The layers get closer together and cannot move over each other so easily. As a result the clay loses its slippery feel and gets harder. When the clay is fired by heating in an oven it gets even harder. This is because cross-links form between the layers, giving the clay a hard three-dimensional structure as shown. The process cannot be reversed.



In 1974 the CSIRO Division of Materials Science in Melbourne developed a new ceramic called PSZ (partially stabilised zirconia). It is made from mineral sands. It is so strong that if you hit it with a hammer, the only thing likely to break is the hammer. Also, it does not wear and resists very high temperatures. For this reason it is beginning to be used to make lighter, more efficient car engines, replacement joints for people suffering from arthritis, and scissors that will never need sharpening.

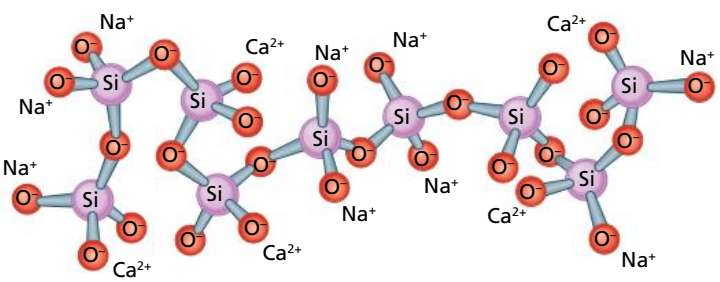
Glass

Glass has properties similar to those of ceramics. Glass is made by mixing sand (silicon dioxide), limestone (calcium carbonate) and soda ash (sodium carbonate), then heating them in a furnace. While the glass is molten it can be poured into various shapes. For example, the diagram below shows how a beaker can be made by moulding and blowing air into the moulded shape.



Glass consists of long chains of silicon and oxygen as shown. These have a negative charge. Positive metal ions such as sodium Na^+ and calcium Ca^{2+} are spread along the chain, making the whole molecule neutral.

As the molten glass cools, the long polymer chains don't have time to line up in a pattern as in a solid. Instead, the molecules are randomly arranged as in a liquid. This is why glass is said to be a supercooled liquid.



SCIENTISTS AT WORK

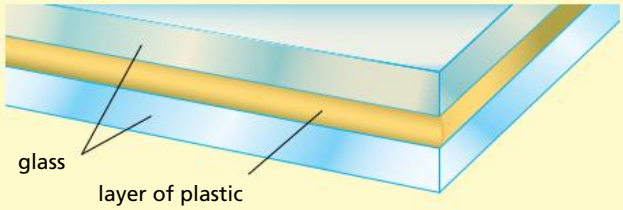
Safety glass

You have already seen how luck played a part in the discovery of guncotton and the vulcanisation of rubber. Luck also played a part in the discovery of safety glass, now used in car windscreens.

Edouard Benedictus was a French painter, composer, writer and chemist. One day in 1903 he climbed a ladder to get some chemicals from a shelf and accidentally knocked a glass flask to the floor. He heard the glass shatter but, when he looked down, to his astonishment the broken pieces of the flask still hung together. Benedictus examined the flask and found that there was a thin plastic film on the inside to which the broken pieces were stuck. He realised that this film had been left behind by the evaporation of a liquid called collodion (a thick gluelike plastic made from guncotton). Benedictus made a note of the accident on a label stuck to the flask, but thought no more about it at the time.



Not long after this accident, Benedictus read about a young girl who had been badly cut by a broken windscreen in a car accident in Paris. Cars were just replacing horse-drawn buggies and they often got out of control. A few weeks later he was reading the newspaper while eating his dinner when he read of another person injured by a broken windscreen. As he recorded in his diary: 'Suddenly there appeared before my eyes an image of the broken flask. I leapt up, dashed to my laboratory, and concentrated on the practical possibilities of my idea'. For 24 hours straight he experimented with coating glass with liquid plastic, then shattering it. 'By the following evening', he wrote, 'I had produced my first piece of Triplex (safety glass)—full of promise for the future'. He called it Triplex because it was made of three sheets of material—two sheets of glass with a layer of plastic between them. The three sheets of transparent material were bonded together by heat.



Benedictus' safety glass

Benedictus patented his Triplex in 1909, but car makers didn't use it because it was too expensive to make. They thought that driving safety was largely in the hands of the driver, not the manufacturers. In 1914 World War I broke out and safety glass was widely used for lenses of gas masks. Following its success under the extreme conditions of war, the glass was then used as windscreens for cars, and has been ever since.

As sometimes happens in science, an Englishman called John Wood invented safety glass at about the same time as Benedictus. The only difference was that he used a natural resin from trees to stick the two pieces of glass together. In fact he patented his safety glass in 1905, four years before Benedictus patented Triplex.

Level 1 Knowledge

1 Where did Edouard Benedictus live?
2 Why did he call his invention Triplex?
3 How was safety glass used in World War I?

Level 2 Understanding

4 The flask that Benedictus dropped didn't break into pieces. Why not?
5 What made Benedictus decide to make safety glass?
6 What do you think Benedictus meant when he said his invention was 'full of promise for the future'?

Level 3 Applying your knowledge

7 John Wood patented safety glass before Benedictus did, but Benedictus is usually given the credit for it. Suggest a reason for this.
8 Collodion was once used to heal wounds. Suggest how it might have worked.

INQUIRY 10 Making safety glass

You will need: small beaker, stirring rod, small pieces of polystyrene foam, 2 microscope slides, acetone

Because of the acetone fumes, this activity should be done in a fume cupboard or as a teacher demonstration.

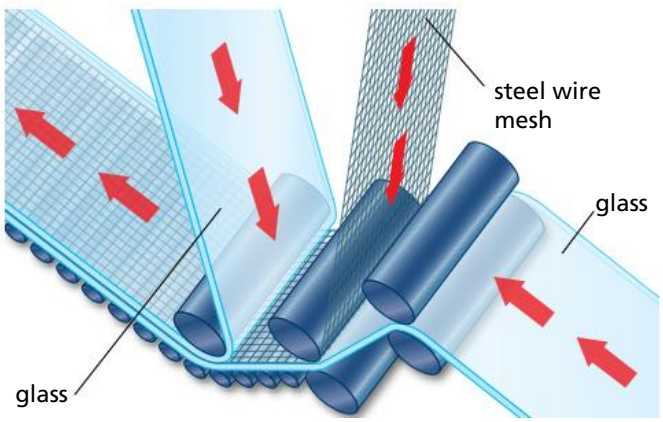




1. Put about 5 mL of acetone into a beaker.
2. Dissolve pieces of polystyrene foam in the acetone to make a thick glue.
3. Use the stirring rod to spread some of this glue onto a microscope slide.
4. Press the second slide firmly down onto the glued slide.
5. After an hour or so your teacher will demonstrate what happens when your safety glass is struck by a hammer or other heavy object.

Composite materials

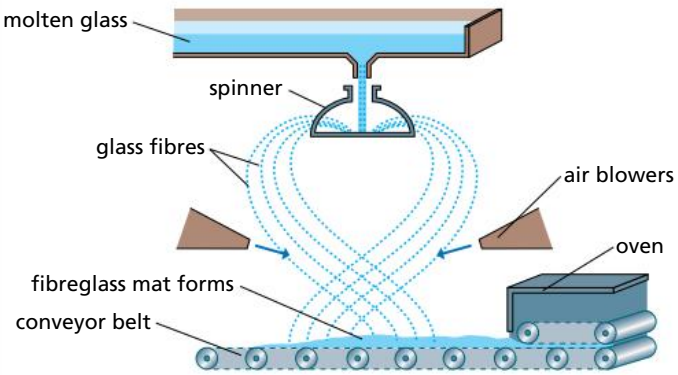
A composite material contains two or more types of material combined together to make a 'new' material with different properties. For example, the safety glass used in car windscreens contains a layer of plastic sandwiched between layers of glass. This process is called lamination. It makes the glass stronger and prevents glass fragments from injuring people in an accident. A layer of steel mesh can also be sandwiched between two plates of glass to make it even tougher. This is done by a rolling process while the glass is still soft. Such toughened glass is used in the outside windows of buildings.



Reinforced concrete is another example of a composite material. Concrete alone is too brittle for the construction of buildings and bridges. However, by pouring the concrete over rods of steel, it can be made much stronger.

Fibreglass

If molten glass is thrown out through holes in a rotating metal spinner as shown, glass fibres are formed. These can be used to make fire-resistant fabrics or insulating material.



The glass fibres can also be mixed with polyester resin to make fibreglass. The resin is made by mixing two monomers and it sets to the shape of the mould. The polyester by itself is brittle and of low strength, but when glass fibres are mixed with it the resulting composite material is strong and tough. It is an ideal material for boat hulls, surfboards, sailboards, swimming pool linings, car bodies, roofing and furniture.



A sailboard moulded from fibreglass

Carbon and Kevlar fibres

Carbon fibres are made by the controlled heating of polymers containing long carbon chains. The result is a very thin and very strong fibre of pure carbon. If the carbon fibre is heated even further, crystals of graphite form within the fibre. These crystals line up in the same direction, making the fibre even stronger. Carbon and graphite fibres are used to reinforce plastics. The composite materials made this way are very stiff and about four times as strong as high-tensile steel.

Carbon-fibre squash and tennis racquets are first made of an alloy with a low melting point. This is then dipped into a mixture of carbon fibres in a plastic that sets very hard. When heated further, the alloy inside melts away, leaving the very strong carbon-fibre racquet. Plastics reinforced with carbon fibres are also used in the manufacture of Formula One racing car bodies and aircraft.

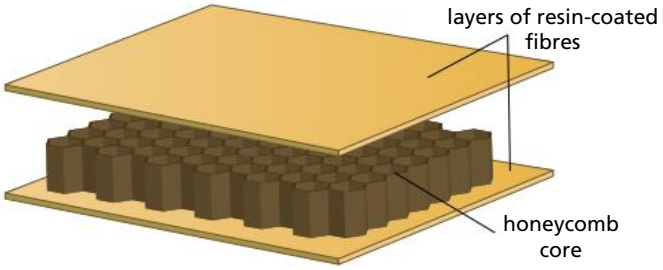


Kevlar is a modern synthetic polymer. Fibres made from it are even stronger than carbon fibres. They are used as reinforcement in car tyres, and can be woven into a fabric for use in yacht sails and bulletproof vests.

Sandwich composites

A sandwich construction is used to make surfboards. A core of polystyrene foam or lightweight wood is coated on both sides with fibreglass. A surfboard made in this way is stiff but light. Sometimes carbon fibres are added down the centre of the board for extra strength.

Honeycomb sandwich structures are widely used to build aircraft. Such structures have greater strength and stiffness for a given weight than light metals such as aluminium and titanium. The outside layers of the sandwich are made of resin-coated fibres. The honeycomb structure in the middle is often made of aluminium foil or a special paper soaked in Kevlar fibres and resin.



A honeycomb sandwich construction

Over to you

1 **a** What are the raw materials for the manufacture of glass?
b What elements are found in glass?

2 How is glass modified to make it safe for use in:
a shower screens?
b car windscreens?

3 **a** What is fibreglass?
b How is it made?
c How is it used to make surfboards?

4 **a** What are composite materials?
b What is their advantage over other materials?

5 Use the diagram on page 86 to explain how glass beakers are made.

6 Knowing the structure of clay, explain why it is slippery when it is wet.

7 Why are sandwich composites used to make surfboards?

8 Large sailing yachts usually have carbon-fibre masts. Suggest reasons for this.

9 How can the properties of ceramics be explained in terms of the strong bonds between the atoms in them?

PROBLEM SOLVING

Have you made glue goo (page 71)? The PVA glue (polyvinyl acetate) is a polymer. When the borax reacts with the PVA it forms cross-links between the polymer chains. Did you find that the more borax you added the harder the goo became?

- What properties does the glue goo have?
- Were you able to make it successfully on a larger scale?
- What name did you give it?
- What are your plans for marketing it? Which group of people will you target with your advertising?

THINKING SKILLS

1 Look at the three different pegs below.

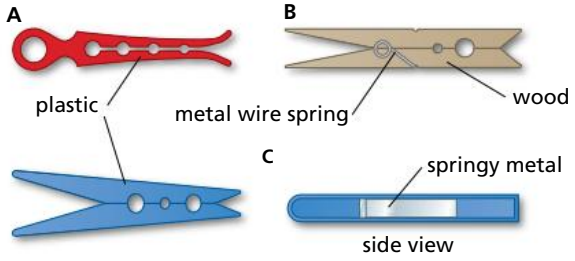
a How many parts does each of the pegs have.

b Suggest how peg A would be made?

c How would peg C be made?

d Which peg do you think would be the cheapest to manufacture? Explain your reasoning.

e Which peg do you think would be the best? Explain.



2 **a** In what order are the hydrocarbons listed in the table below?

Hydrocarbon	Boiling point (°C)
butane (C_4H_{10})	0
decane ($C_{10}H_{22}$)	174
ethane (C_2H_6)	-89
hexane (C_6H_{14})	69
octane (C_8H_{18})	126

b Suppose you wanted to see if there was a pattern in the boiling points. How would you list the hydrocarbons?

c Reorganise the table according to your answer in Part b.

d Which hydrocarbons are gases at room temperature (20°C)?

e Butane stored in steel bottles is used as fuel by campers. Suggest why it is dangerous to use these bottles in very cold weather.

f Plot the boiling point data on a graph. Use this graph to predict the boiling points of methane (CH_4) and pentane (C_5H_{12}).

3 **a** Suggest some suitable uses for photodegradable polymers.

b Suggest some situations where their use would be unsuitable.

c What would happen to a photodegradable polymer when it is dumped and buried?

4 Describe how a fibreglass wall panel might be made.

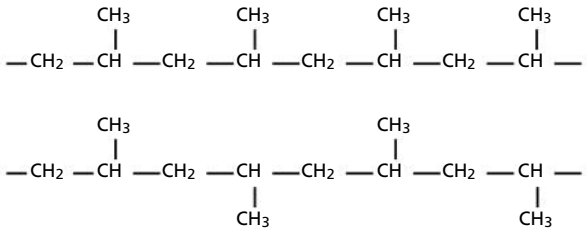
5 Dissolving plastic is used for hospital laundry bags. Suggest other uses for this plastic.



6 'We should ban the use of disposable plastic containers and only allow the returnable type.' Discuss or debate this in a group.

7 To make coloured glass, various metal ions are added. Where would these metal ions fit into the glass structure on page 86?

8 Polypropylene molecules can have different structures, as shown.



a What is the difference between the two structures?

b Which plastic would be denser? Why?

c Which structure do you think would be preferred for fibre formation? Explain the reasons for your choice.

9 Imagine that all the objects made from plastics suddenly disappeared. How would your life be changed? Write an imaginative piece describing this new world. It might be a good idea to talk to someone over the age of 70 about life before plastics.

10 Test a variety of plastics to see whether they

a sink or float in water.

b are affected by various chemicals.

11 Design and perform an experiment to compare the ability of natural and synthetic fibres to absorb water.

Knowing and Understanding

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

1 The properties of a material determine how we use it. These properties can be explained in terms of the molecular _____ of the material.

2 The large number of carbon compounds can be explained by the ability of carbon atoms to form chemical bonds to _____ other atoms.

3 Soaps and _____ both contain long molecules with a water-loving end and a _____-loving end.

4 Polymers are very large molecules made by joining together many small molecules called _____. Some polymers occur naturally, while others are _____.

5 Thermoplastics _____ when heated, but _____ do not, due to cross-links between the polymer chains.

6 Rubber is a polymer that is _____. It may be natural or synthetic. In the process of _____ cross-links are formed between the polymer chains.

7 Some fibres are natural, e.g. _____ and wool, while others are synthetic, e.g. nylon and _____.

8 A _____ material consists of several different materials combined together. It combines the _____ of the materials in it.

composite
cotton
detergents
elastic
four
grease
melt
monomers
polyester
properties
structure
synthetic
thermosets
vulcanisation

Self-management

Match the nine descriptions in the list below with the 10 words on the right. Put the number of the word under the appropriate letter in the magic square. There will be one word you don't use. If you have all the answers right, the sums of the numbers across, down and diagonally will all be the same.

A The process in which sugar is broken down by yeast to form alcohol and carbon dioxide

B A natural polymer formed by adding vinegar to milk

C Many units linked together

D Able to be broken down and used as foods by bacteria and fungi in soil and water

E These hold together the polymer chains in a rubber and make it tougher and less stretchy

F Pantihose are usually made from this synthetic fibre

G Made from clay and used to make tiles

H A composite of glass fibres and resin, used to make surfboards

I A very strong fibre used to make tennis racquets, racing car bodies and aircraft

Use this magic square as a model to design your own magic square using another 10 words from the chapter.

Magic square

A	**B**	**C**
D	**E**	**F**
G	**H**	**I**

1 safety glasses
2 casein
3 carbon
4 biodegradable
5 ceramics
6 cross-links
7 polymer
8 nylon
9 fermentation
10 fibreglass

Checkpoint

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

OneStopScience

1 Soap can remove grease from your hands because

A its molecules are long carbon chains.

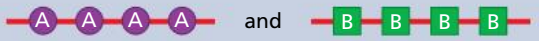
B it is made from grease.

C it dissolves easily in water.

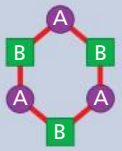
D its molecules have a water-loving end and a grease-loving end.

2 Nylon is a polymer made by the reaction between two chemicals A and B. Which one of the following best represents a nylon molecule?

A 

B 

C 

D 

3 For each of the items below, list two properties of the plastic that make it suitable for making that particular object.

a the case of an electric drill

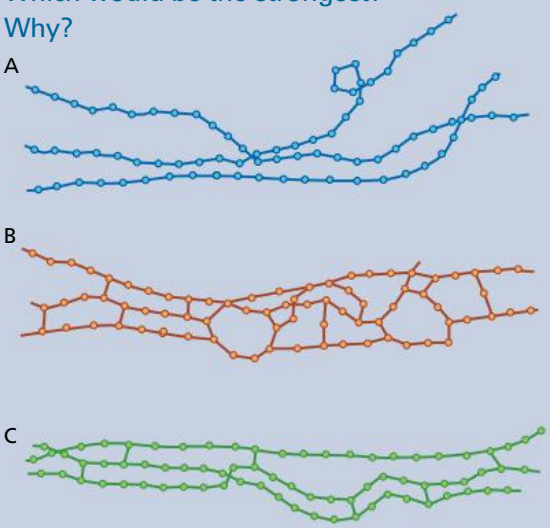
b packaging foam

c plastic cups

4 The diagrams below show the polymer chains of three different plastics.

a Which plastic would you expect to melt most readily? Why?

b Which would be the strongest? Why?



5 Give three advantages and three disadvantages of plastics compared with materials such as wood or metal.

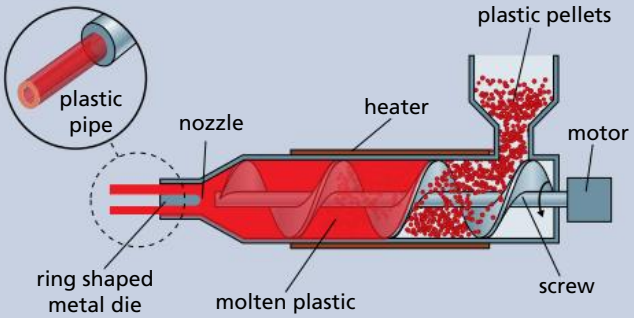
6 A younger person asks you to explain the difference between a monomer and a polymer. Use the idea of a train to help your explanation.

7 Describe how you think foam rubber could be made from rubber latex. (See Inquiry 7, page 81.)

8 What properties of ceramics make them suitable for use on the outside of space vehicles and rockets?

9 The diagram below shows how plastics are shaped by the process of extrusion.

a Use the diagram to explain how this process works.



b Which one of the following products could not be manufactured by this method?

A drainpipes

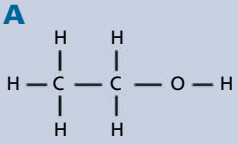
B milk bottles

C plastic film

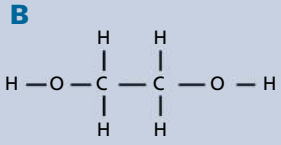
D roof guttering

10 a Which three elements are present in all three substances represented below by their structural formulas?

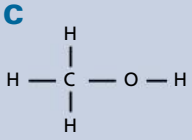
A



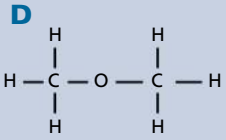
B



C



D



b Which two of the above substances have the same *molecular* formula?

5



Cells—units of life

PROBLEM SOLVING

Skin cancer

Your task is to find out about skin cancer and put forward a sun-safe policy for your school based on what you find.

You will need to:

a Describe what skin cancer is and explain what goes wrong with your body cells to cause skin cancer.

b Investigate ways to prevent skin cancer.

c Suggest 10 sun-safety rules that all students must follow, and ways to make your school grounds sun-safe.

d Advertise sun safety around the school.

Start by reading this chapter. Extra research will also be needed.



Focus for learning

Have you ever grazed your knee and watched your skin repair the graze? It is an amazing process, but how does it happen? What is your body made of, and how is new skin produced to repair your knee? This chapter is all about the small units or building blocks called **cells** that make up your body.

Imagine that cells are like Lego blocks, which can be joined together to make things. Lego blocks make different models, whereas cells make living things. Just like Lego blocks, cells can link with other cells and so become connected. However, there are some important differences between Lego blocks and cells. Lego blocks are large, non-living and the same basic shape. Most cells are very small and can only be seen with a microscope. They are alive and come in many different shapes and sizes. Some cells also reproduce to make new cells, but Lego blocks obviously cannot.

Living things can be made up of one cell (*unicellular*) or many cells (*multicellular*). The paramecium pictured on the previous page is an example of a unicellular organism. You are a multicellular organism made up of millions of cells. In multicellular organisms there are many different cells, each with its own job to do.

So why study cells? Cells can help explain how your body works and provide an insight into many common diseases. Cancer is one example.

The most common cancer in Australia is skin cancer. Statistics show that two out of every three Australians will develop skin cancer at some time in their life. Look around you. Two thirds of your classmates could develop skin cancer. Every time you go out in the sun you are at risk of causing damage to the cells in your skin. A tan is the skin's way of protecting itself against the sun. The browner you get, the more damage is occurring.

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

Science Understanding

- correctly use a microscope to examine a variety of cells and single-celled organisms
- describe and distinguish between plant and animal cells
- identify structures within cells and describe their function
- explain how cells are grouped to form tissues, which work together to form organs and systems
- use a diagram to show how cells divide, and apply this knowledge to explain how cancer spreads in the body

Science as a Human Endeavour

- form an opinion on whether stem cells from embryos should be used in medical research

LITERACY FOCUS

benign
cell division
cells
circulatory system
cytoplasm
diffusion
embryo
excretory system
magnification
malignant
mitochondria
muscle fibres
organ
respiratory system
specialised cells
stem cells
stomata
system
tissue
tumour

5.1 Microscopes

An average cell is between 0.01 and 0.1 mm across. If you could grow a cell 200 times bigger than normal, it would still only be the size of a pin head. To see cells you need to use a microscope.

SKILL

Using a microscope

Aim

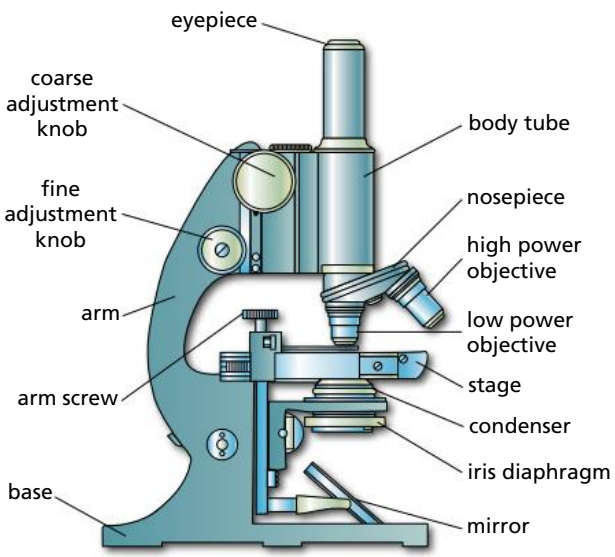
To use different microscopes correctly.

Risk assessment and planning

1 Read the investigation and draw two data tables to record the parts of the microscope. See the table on the next page.

2 Explain why the following rules are necessary.

- Always carry a microscope with two hands—one hand holding the arm and the other supporting the base.
- Place the microscope securely on the bench away from direct sunlight.
- Only use lens-cleaning tissue to clean dirty lenses. Never use your fingers or paper towel.
- Look at the microscope side-on to wind the body tube to its lowest point, then focus by winding the body tube upwards. This way the glass slide cannot be broken.



A monocular microscope

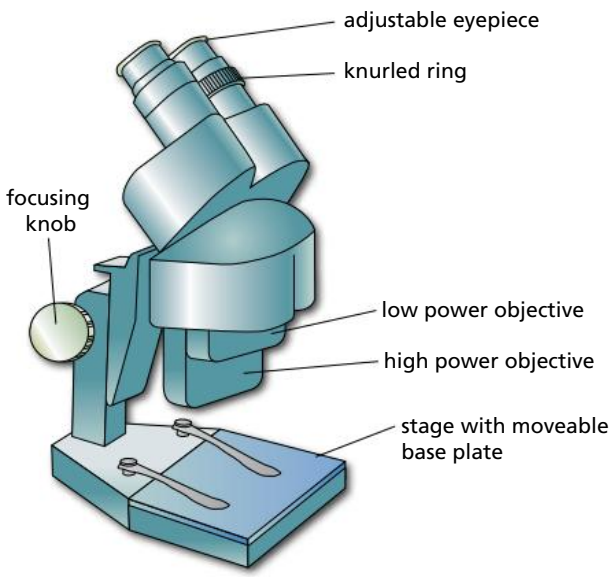
Apparatus

- different types of microscopes as pictured
- microscope lamp
- lens-cleaning tissue
- prepared slides
- microscope slides
- cover slips
- non-permanent black pen
- magazine, newspaper and tissue
- thin plastic ruler with millimetres marked on it
- dropping bottle of water

Method

Part A: Microscope parts

1 Collect each microscope pictured and become familiar with the parts marked on the diagrams.



A binocular microscope

SKILL

Using a microscope

Microscope part	Name	Function
1		A platform where the slide is positioned with clips to hold it in place.
2		Reflects light up through the slide to the eyepiece.
3		The lens that the operator looks through.
4		This concentrates the rays of light and directs them onto the object being viewed.
5		A tube that the eyepiece and nosepiece are attached to.
6		Moves the body tube up or down for focusing; can be coarse or fine.
7		Lenses used to see the detail of the specimen; can be low power or high power.
8		Can be adjusted like a camera shutter to control the light passing through the object and the body tube.
9		Supports and stabilises the microscope.
10		Holds the body tube and can be used as a handle for holding the microscope when carrying.

2 Copy the table above into your notebook and as you examine the monocular microscope enter the following parts in their correct position in the table.

eyepiece, body tube, high and low power objectives, stage, condenser, iris diaphragm, mirror, base, arm, coarse and fine adjustment knobs

3 Check that you have the parts in the correct place in the table.

4 Explain how the binocular or stereo microscope is different from the monocular microscope.

Part B: Magnification and focusing

The total magnification of a microscope is found by multiplying the eyepiece lens magnification by the objective lens magnification. Each lens is labelled with an X which indicates the number of times this lens magnifies. For example, the eyepiece may have a 5X on it and the objective lens may have a 10X on it. The total magnification is 5 multiplied by 10, or 50X, so you are seeing the object 50 times larger than normal.

1 Place a prepared slide onto the stage of the monocular microscope. Follow these steps to set up and focus the microscope.

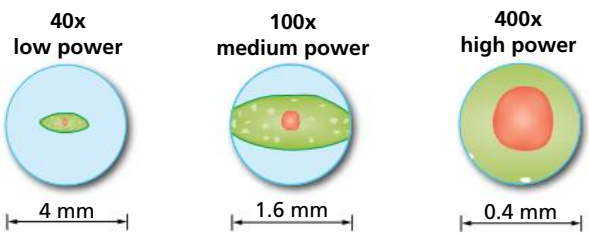
- Turn the objective lens to the lowest possible magnification. What is the total magnification? Record this.
- Look through the eyepiece and angle the mirror so that the field of view, or the area you see as a circle of light, is evenly lit. Use a lamp, not direct sunlight, if there is not enough natural light. If there is too much light, adjust the iris diaphragm.
- Place the prepared slide on the stage under the clips.
- Look at the microscope side-on and use the coarse focus knob to wind the body tube to its lowest point just above the slide.
- Look through the eyepiece and, with the coarse focus knob, wind the body tube upwards away from the slide.
- Once you have the slide in focus, turn the objective lens to high power. If you need to bring the specimen into focus, use only the fine focus knob. What is the total magnification now? Record this.

2 Practise focusing the microscope on high and low power using the different prepared slides available to you.

3 Now try to set up and focus a binocular or stereo microscope. Can you use the prepared slides with the binocular microscope? What sort of things can you examine with this microscope?

Part C: The field of view

When looking into a microscope, the **field of view** changes, depending on the magnification you are using. As the magnification increases the field of view decreases. This means you see less of the specimen you are viewing, but in far more detail.



As the magnification increases the field of view decreases.

SKILL

Using a microscope

1 Set up the monocular microscope on its lowest magnification.

2 Place a thin plastic ruler on the stage and bring it into focus.

3 Measure the diameter of the field of view in millimetres and record it in a table like the one below. Depending on the microscope you use, you may need to alter the magnifications in the table or add more columns. Repeat this for higher magnifications as well.

4 Repeat Steps 1–3 for the binocular microscope.

	Low power	Medium power	High power
Eyepiece lens	5X	5X	5X
Objective lens	10X	15X	20X
Total magnification	50X	75X	100X
Diameter of field of view			

Part D: Moving the slide

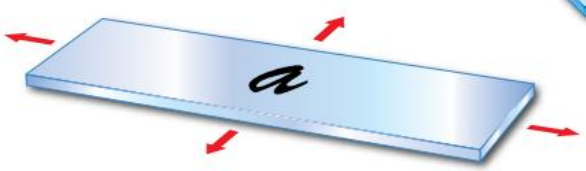
1 On a clean microscope slide draw a small letter **a** (the size of the print on this page). Use a non-permanent marker.

2 As before, set up the monocular microscope on low power and place the slide on the stage.

3 Look into the eyepiece. What do you notice about your letter? Is it upside down? Back-to-front? Can you see all of it? Describe what you see.

4 Now move the slide to your right. Which way does the letter move? Try moving the slide to the left, then up and down. Which way does the letter move for each new position?

5 Repeat these steps for high power and for the binocular microscope. Record your observations.



Part E: Producing a wet-mount

In preparing a **wet-mount** the specimen is placed in a thin layer of water between the slide and the cover slip.

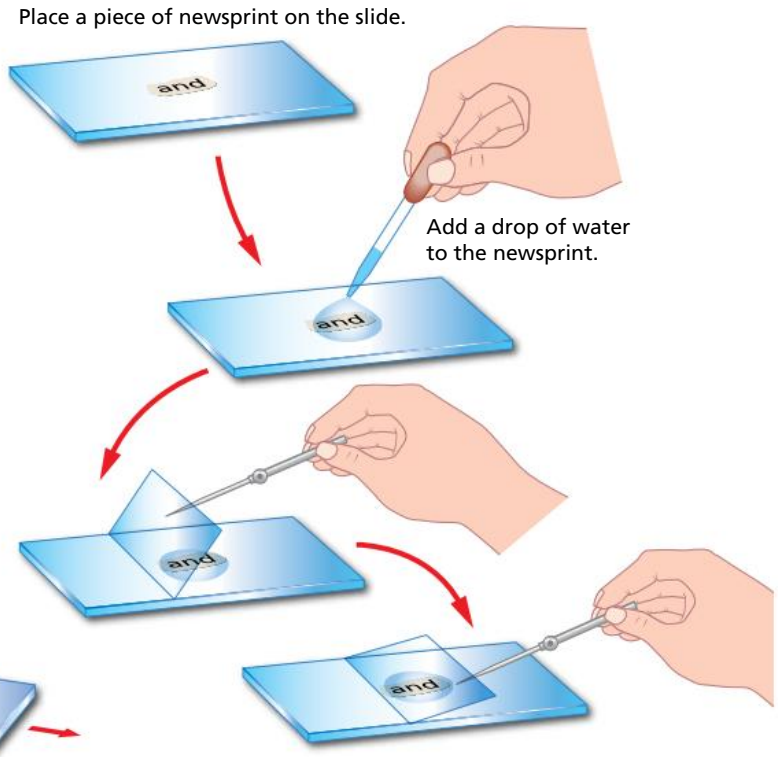
Water can damage the microscope, so make sure the slide is not running with water when it is placed on the stage. Blot up any excess water with a paper towel.
Try not to tilt the microscope in case any excess water runs off the slide onto the stage.

1 Set up the monocular microscope as before.

2 Place a small piece of newsprint onto a slide and secure it in place by adding a drop of water to cover it.

3 Place the cover slip at the edge of the water as pictured and slowly lower the cover slip using a drawing compass. If this is done properly you should avoid air bubbles forming on the slide.

4 Practice may be needed to perfect this skill. Try different objects under the microscope, e.g. magazine print and tissue paper.



Producing a wet mount

SKILL

Using a microscope

Part F: Drawing specimens

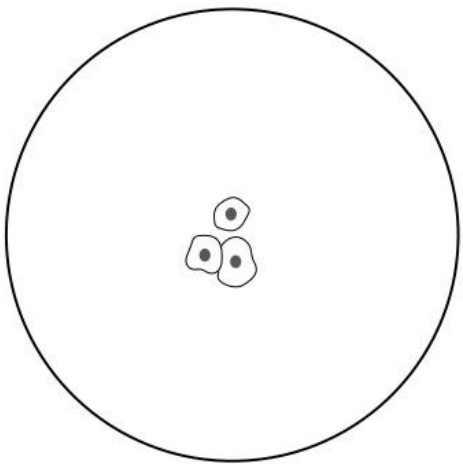
1 Place a prepared slide on the monocular microscope.

2 Put the microscope on low power and focus the image. Now put the microscope on high power and see which is the best view. Draw what you see using the following rules.

- Learn to keep both eyes open. Use one eye for viewing and the other for drawing. This may take some practice.
- Use a lead pencil and blank (unlined) paper.
- Draw the specimen in a circle which represents the field of view, but make it much larger as shown. Show the diameter of the field of view (Part C) and try to draw the specimen to scale.
- Draw the outline of the image and don't shade or colour in the parts. Draw the detail of one or two cells only, not all the cells in view.
- Include the name of the specimen, the date and the total magnification.
- A stain is often used to highlight parts of a cell that cannot easily be seen. A stain is a dye that colours different parts of the cell and makes them more visible. Record any stain used.
- Write a description next to the diagram.

3 Now draw the same object using the binocular microscope. What differences do you notice?

Draw only a few cells in detail.



Date: _____
Object: _____
Description: _____
_____
_____
Stain used (if any): _____
Magnification: _____

Results

The diagrams and observations are the results of this investigation.

Conclusion

For the conclusion, copy and complete the table below. The examples given may need to be changed.

	Parts on this microscope but not on the other	Range of total magnification	Largest field of view	How the specimen is viewed	Description of image seen
Monocular microscope		50X–200X	4 mm	Upside down and back to front	
Binocular microscope	Moveable base plate Knurled ring for focusing				Larger specimens can be viewed, e.g. parts of organisms, but in less detail

SCIENTISTS AT WORK

Invention of the microscope

Cells were not identified until the microscope was invented, because they were too small to be seen. Two people involved in the development of the microscope were Robert Hooke (1635–1703) and Anton van Leeuwenhoek (1632–1723).

Robert Hooke was born on the Isle of Wight, in the English Channel. He was educated by his father and then served as an apprentice to a portrait painter in London. At 13 he entered the Westminster school, then went to Oxford University. Because he had great skill in building equipment and designing experiments, Hooke became an assistant to the chemist Robert Boyle.

Hooke was interested in subjects such as physics, astronomy, chemistry, biology and even architecture and naval studies. He invented many things such as a telescope and a balance spring that made clocks more accurate. He worked out an equation for elasticity known as *Hooke's Law*, and he correctly put forward a theory of combustion (burning). However, Hooke is best known for his work called *Micrographia*, which is a collection of drawings of the different living things he examined using his microscope. His work was a best seller when it was published in 1665.

Hooke made a compound microscope that was the best of its kind at the time. A compound microscope uses more than one lens to magnify an object and was first invented in 1595. With his own version of the microscope Hooke was able to see the details of living things that had never been seen before. He was the first to observe plant cells. When he examined a thin slice of cork (a type of bark) through his microscope he said it looked like a piece of honeycomb, full of little boxes that he called cells, because they reminded him of small rooms (called cells) in a monastery.

Hooke was also the first person to examine fossils with a microscope and to suggest that fossils could help unravel the history of life.

In 1662 Hooke became the Curator of Experiments for the Royal Society of London. Each week he had to demonstrate new experiments and in his demonstrations he often used the compound microscope he had developed.

In 1668 Hooke was asked to confirm the findings of Anton van Leeuwenhoek (LAY-ven-hook), a Dutchman. Leeuwenhoek had discovered tiny animals such as bacteria (disease-causing organisms) by using a different type of microscope he had invented. Leeuwenhoek had learnt how to grind his own lenses and with them he made more than 500 microscopes. These microscopes were very simple, but far more powerful than the compound microscope that Hooke used. They could magnify objects over 200 times. Using these microscopes Leeuwenhoek described the stings of bees, algae such as spirogyra, and animals such as round worms. He also wrote about the plaque (PLARK) between his teeth. He discovered blood cells and observed the sperm of animals.



Van Leeuwenhoek demonstrating his microscope to Queen Catherine of England

Light microscopes

The microscopes made by Hooke and Leeuwenhoek are examples of *optical* or *light* microscopes. A beam of light passes through the object being viewed and lenses are used to magnify the object. The distance between the object and the lens is altered to bring the object into focus. These microscopes are still used, except present-day compound microscopes can magnify up to 1000 times. They can be *monocular*, where one eye is used to view very thin specimens, or *binocular/stereo*, where two eyes are used. As you may have observed in Investigation 1, binocular microscopes allow a larger object to be viewed, but less detail is seen due to the smaller magnification.

Electron microscopes

In the 1930s microscopes were developed which allowed specimens to be magnified up to a million times. They not only show the surface features of an object, but also the structures inside it. However, the images seen through an electron microscope are only black and white.

There are two types of electron microscopes:

- The *transmission electron microscope* (TEM) works like a light microscope except that a beam of electrons is used instead of using light to see through the object in view.
- The *scanning electron microscope* (SEM) sweeps a beam of electrons across the surface of the object in view, stopping at certain points to allow more detailed information about the sample to be gathered.

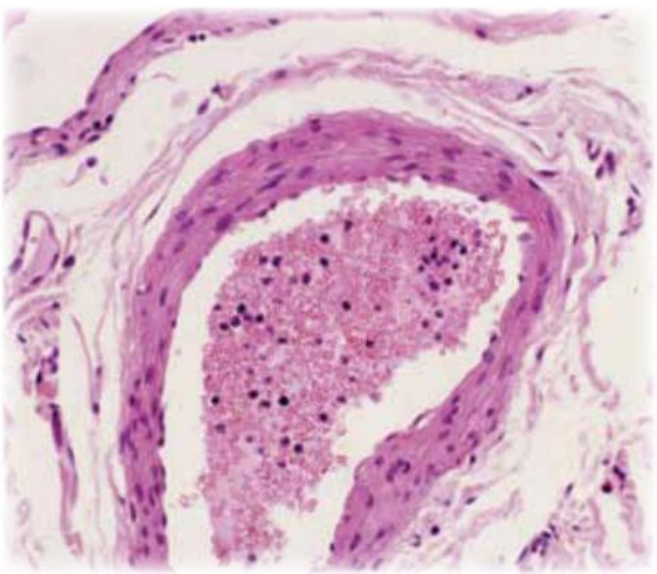
Over to you

1 Which of the following are true and which are false?
   - **a** The total magnification of a microscope is written on the objective lens.
   - **b** Images seen by using an electron microscope are only in black and white.
   - **c** The condenser is like a camera shutter that can be adjusted to alter the light entering the microscope.
   - **d** Larger specimens can be viewed with a binocular microscope.

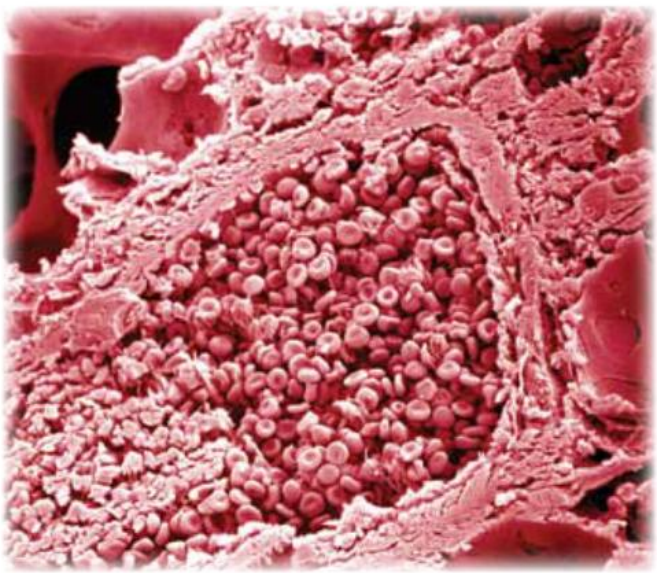
2 What rules must you remember when preparing a wet-mount? Why are these rules important?

3 Describe the main differences between a monocular microscope and a binocular microscope.

4 Look at the picture on page 99 showing Leeuwenhoek using his microscope.
   - **a** What are the similarities and differences between the way Leeuwenhoek used his microscope and the way a monocular microscope is used today?
   - **b** How have developments in microscope technology improved our understanding of the world?



This light microscope view shows a blood vessel with red blood cells inside it.



This scanning electron microscope view shows much more detail, in three dimensions..

5.2 Plant and animal cells

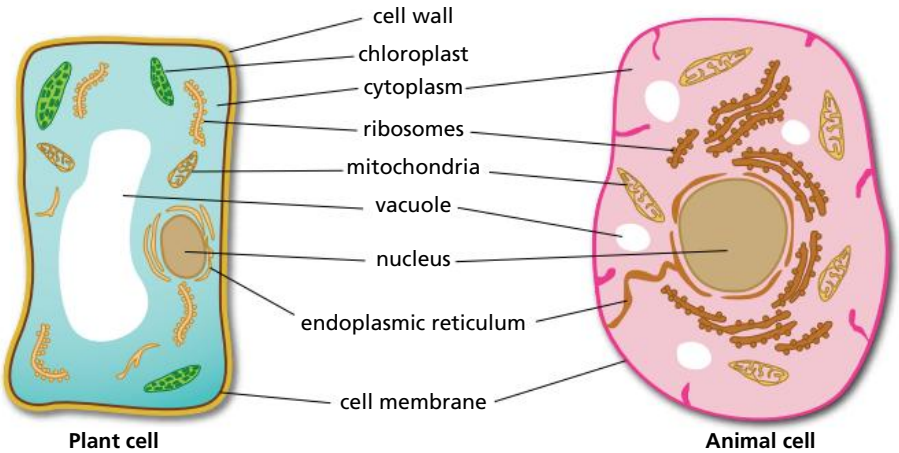
INQUIRY 1 Cell parts

Most cells have the same basic parts, but there are differences.

1 The diagrams below show a plant and an animal cell as seen through an electron microscope. List the parts that are the same in both cells. List the parts that are found in plant cells, but not in animal cells.

2 The table lists and describes what each cell part does.
   a What activities do plant and animal cells carry out that are the same?
   b What activities occur in plant cells but not in animal cells?

3 Construct your own collage, model or mobile of a plant or animal cell, using recycled materials. Label each cell part.



A plant and animal cell as seen through an electron microscope

Cell part	Function
Cell membrane	This is the outer boundary that keeps a cell separate from its environment. It acts like a gatekeeper letting things into and out of the cell. A cell membrane is semi-permeable, which means some things can pass through it but others cannot.
Cell wall	This is a tough rigid structure that surrounds a plant cell. It is made of a substance called cellulose. The cell wall around every plant cell helps the plant stand upright. The cell wall has holes in it so that substances can move in and out of the cell. It is the cell wall that makes many plant cells appear like bricks when viewed under a microscope. The cell membrane lies inside the cell wall of a plant.
Cytoplasm	This is the jelly-like living substance that fills all the area inside a cell except the nucleus.
Nucleus	The nucleus is the brain or control centre of the cell. It controls the chemical reactions that take place within the cell. It is also needed for the cell to reproduce; without a nucleus the cell dies.
Endoplasmic reticulum	The endoplasmic reticulum is a collection of membranes that run throughout the cell. It is believed that materials are moved around a cell via these membranes. Smooth endoplasmic reticulum has no ribosomes attached to it. Rough endoplasmic reticulum has ribosomes scattered across its surface.
Ribosome	Ribosomes are where proteins are made.
Mitochondria	The mitochondria (might-oh-KON-dree-a) (single mitochondrion) make energy for the cell through respiration.
Chloroplast	These are disc-shaped and contain a green substance called chlorophyll, which absorbs the light needed for photosynthesis.
Vacuole	Vacuoles are fluid-filled bags within a cell where excess water, wastes and soluble materials are stored. At the centre of a plant cell is a large permanent vacuole. When full the vacuole pushes against the contents of the cell and provides the plant with support so it can stand upright.
Vesicle	A vesicle is a small temporary vacuole. Vesicles are more often found in animal cells.

INVESTIGATION

1 Examining cells

Aim

To examine different plant and animal cells and use a stain to see the cell detail more clearly.

Risk assessment and planning

1 Review how to use and focus a microscope.
2 Explain how to draw a specimen under the microscope.
3 What precautions are needed to use iodine and methylene blue safely? Discuss this with your teacher.

Apparatus

- monocular microscope
- microscope lamp
- prepared slides
- microscope slides (including cavity slides)
- cover slips
- onion
- knife
- iodine solution in a dropping bottle
- methylene blue in a dropping bottle
- white tile
- tweezers
- elodea
- hay infusion (already prepared for you) or organisms such as paramecium or amoeba from a biological supplier
- dropper
- sticky tape
- dropping bottle of water

Part A: Onion cells

1 Cut and peel an onion to reveal the fine transparent 'skin' between the onion layers. Remove as much of this skin as possible. Try not to fold, roll or crease the onion skin or it will be too thick to view clearly.
2 Make a wet-mount of a small flat piece of onion skin. Secure the onion skin to the microscope slide with a drop of water. Blot up any excess water, then lay a cover slip on top of the onion skin.
3 Set up the microscope and view the onion skin on low power, then high power. Draw the best image you can see.
4 Now stain the onion skin. To do this, make a wet-mount of the onion skin using iodine instead of water. When the iodine has soaked into the skin, blot any excess stain from the slide and place a cover slip on top of it. View and draw as before. Note the differences between the stained and unstained onion skin.
5 Repeat Step 4, this time using methylene blue instead of iodine. What differences do you notice using the different stains?

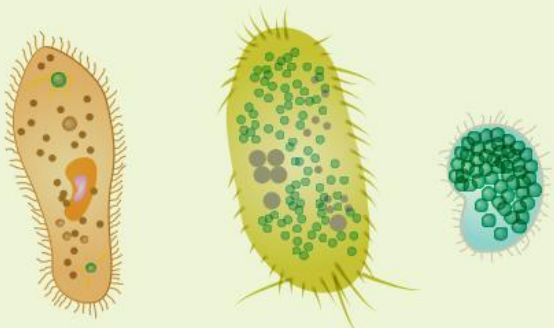
Part B: Elodea and spirogyra

Onions are enlarged roots found underground, so they lack chloroplasts. Elodea and spirogyra are freshwater plants that have chloroplasts which are easily viewed.

1 Pull an elodea leaf off the main stem with tweezers and prepare a wet-mount of the leaf using a drop of water.
2 Set up the microscope and view the elodea as you did the onion skin. Draw the best image you can see. What are the differences between the elodea and the onion skin?
3 Make a wet-mount of some fine threads of spirogyra. View the spirogyra on low and high power and draw the best image you can see. What are the differences between the elodea, the spirogyra and the onion skin?

Part C: Animal cells

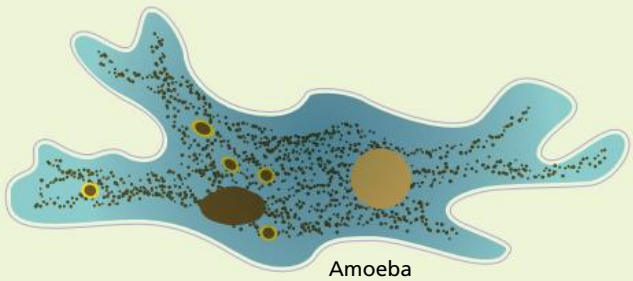
1 Obtain a hay infusion or a solution of unicellular organisms from a biological supplier.
2 Gently shake the solution and place a small amount of the liquid into a cavity slide using a dropper, then cover it with a cover slip.
3 Set up the microscope and view the slide as before. Draw the best image you can see. Some of the animals you may see are shown below and on the next page.



Paramaecium Stylonychia Colpoda

INVESTIGATION

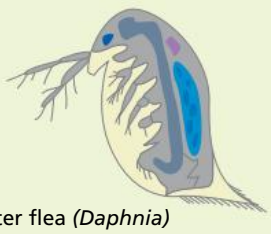
1 Examining cells



Amoeba



Vorticella



Water flea *(Daphnia)*

4 Alternatively, if there are no solutions to examine, view and draw prepared slides of unicellular organisms.

Part D: Skin cells

1 Take a piece of sticky tape and stick it to the back of your hand. After a few minutes quickly remove the sticky tape. Skin cells are constantly lost as you touch objects around you, and the sticky tape should have some of your skin cells on it.

2 Stick the tape to a microscope slide so the skin cells are face down on the slide. There is no need for a cover slip.

3 Set up the microscope and view your skin on low power, then high power. Draw the best image you can see.

Results

The drawings of the cells you have viewed under the microscope form your results, along with the answers to the following questions.

1 What are the similarities between onion skin, elodea and spirogyra cells?

2 Suggest why onion skin cells are different from elodea and spirogyra cells.

3 What are the advantages and disadvantages of staining cells?

4 Do all stains highlight the same parts of a cell? What did you notice with methylene blue and iodine? Explain.

Conclusion

Write your own conclusion for this investigation.

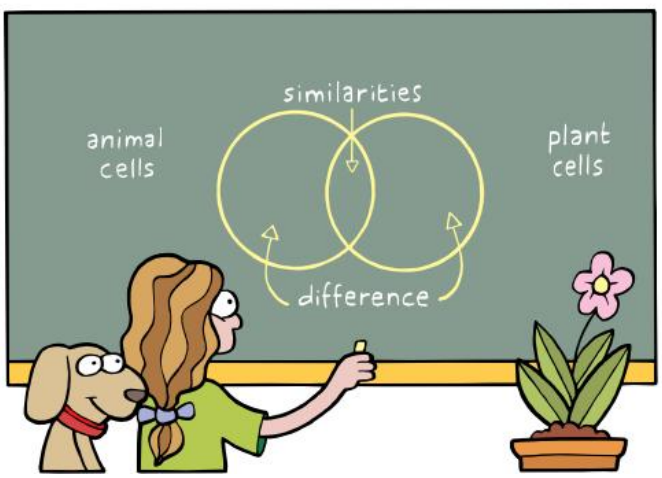
Over to you

1 What activities do plant and animal cells carry out that are the same? Why do plant and animal cells need to carry out these activities?

2 An unknown organism was found on a beach. How could a biologist tell if the organism was a plant or an animal? Explain.

3 What would you expect to find in an elodea cell that would not be in an onion cell? Explain.

4 Draw two overlapping circles. In one circle write down all the ways an animal cell is different from a plant cell. In the other circle write down all the ways a plant cell is different from an animal cell. In the overlapping parts of the circles list the things that plant and animal cells have in common.



5.3 Types of cells

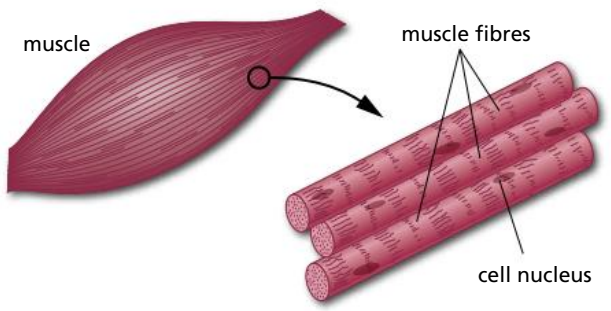
This chapter started by comparing cells to Lego blocks. Lego blocks can be put together to build a wall or a house. Cells join together to make organisms. As you have seen, the inside of a cell is far more complex than a Lego block. Different cells may have parts in common, but they also have different parts or structures because they carry out different jobs. Cells that carry out specific jobs in the body are said to be **specialised.**

In your body there are many specialised cells, such as muscle cells and blood cells. These cells are structurally different from each other and do not do the same job. A young **red blood cell** has a nucleus, but as it matures it loses the nucleus and instead develops haemoglobin—a protein that contains iron and carries oxygen around the body. A red blood cell in the body usually survives only 120 days before it is replaced.



Red blood cells carry oxygen around your body. They are specialised cells.

A muscle cell produces movement in your arms, legs, face, eyes etc. These cells are known as *fibres* and are cylinder-like with many nuclei (plural of nucleus). They are bound together in bundles and are able to draw together or contract. This action pulls on the bones to which the muscle is attached and causes movement.



Tissues, organs and systems

Cells in multicellular organisms cannot work alone. Skeletal muscle cells, for example, join together to form bundles. Groups of cells that have a similar structure and function form a **tissue**.

Plants and animals are made up of many different types of tissue. Some of these can be seen on the next page. In plants, for example, *xylem* tissue is made up of cells that transport water through the plant. *Phloem* tissue is made up of cells that transport the products of photosynthesis around the plant. The surface tissue or *epidermis* is made up of cells that cover the surface of leaves and form a protective cover over the body of the plant.

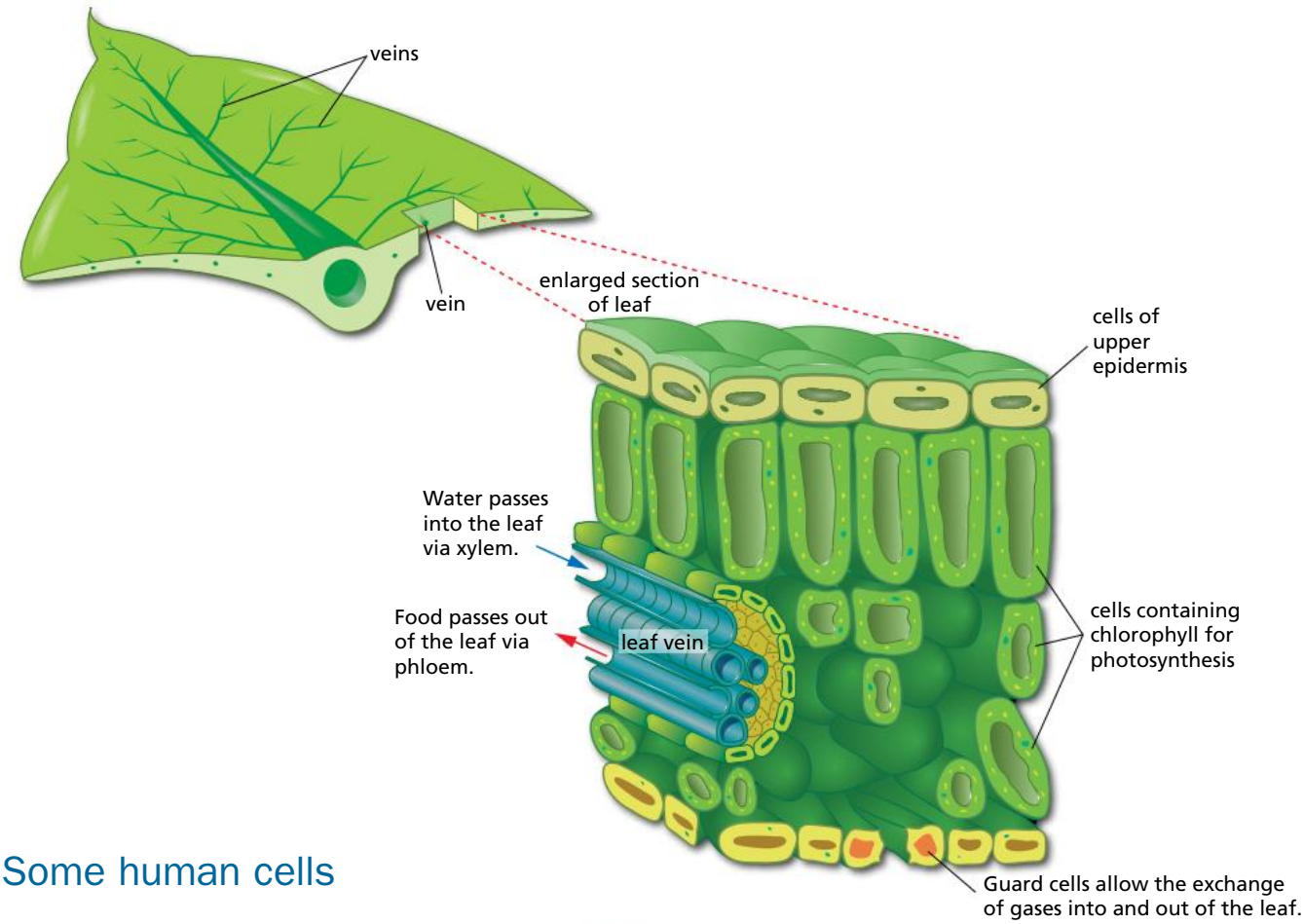
Animals, including humans, also have different types of tissues. For example, the top layer of your skin is made up surface or *epithelial* tissue. *Muscle* tissue has cells that contract to move bones. Cells involved in communicating messages around the body form *nerve* tissue. Individual nerve cells are much bigger than the cells you have observed in this chapter. They can be over a metre long!

Many tissues that work together to carry out a specific task in the body form an **organ.** Plant organs are the root, stem, leaves and reproductive parts such as the flower. There are far more organs in animals. For example, the skin is an organ made up of surface tissue, connective tissue, blood vessels, muscle and nerve tissue. These all work together to protect and enclose the body and help with temperature control.

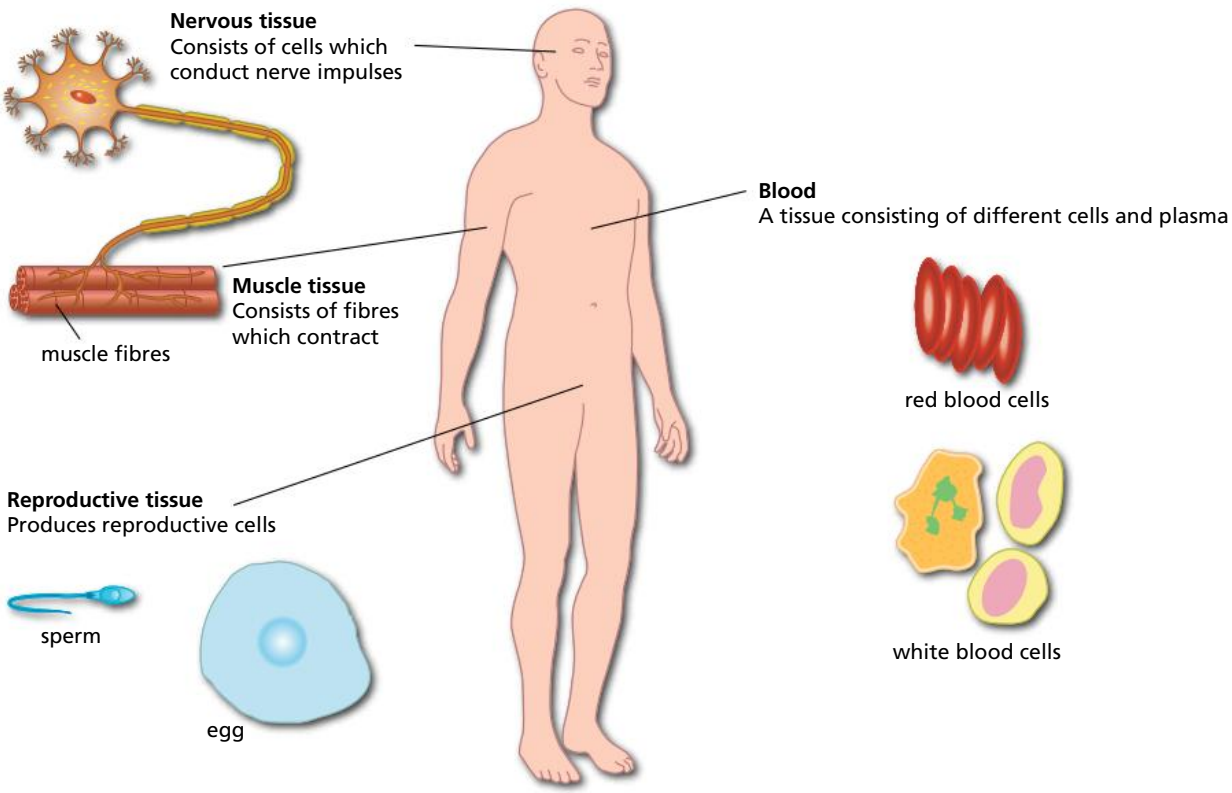
Many organs that work together to complete a specific task form a **system**. For example, the digestive system breaks down the food eaten into particles the body can use. It is made up of organs such as the oesophagus and the stomach, which work together. There are many other systems in the body:

- The *respiratory system* takes in oxygen and removes carbon dioxide.
- The *excretory system* removes wastes.
- The *nervous system* sends messages to the brain about what the body is doing.
- The *skeletal system* provides support.
- The *reproductive system* is for making babies.
- The *circulatory system* carries substances around the body.
- The *muscular system* is for body movement.

Some plant cells



Some human cells



INQUIRY 2 Comparing cells

You can observe differences in cell structure by using a microscope.

- Examine the different tissues that make up a flower, e.g. petals, sepals, stamens, stigmas. Review these parts with your teacher.
- A pollen grain is a single cell. You could look at pollen grains from a variety of flowers and note the differences between them.
- You may like to examine different prepared slides of animal cells to see cell specialisation and note the different tissues in animals.

INQUIRY 3 Building a body

So far you have seen only a small number of the different types of cells that make up an organism.

In groups of five, choose either a flowering plant or a human. Find pictures of cells that make up the tissues, organs and systems of the organism you have chosen. You could use scientific magazines, biology books or the internet. Present the different cells you have found on a poster and show this to the rest of the class.

OR

As a class, choose either a flowering plant or a human and build a body poster, with each student contributing a different picture of a cell to the poster. Display this in the classroom.

Over to you

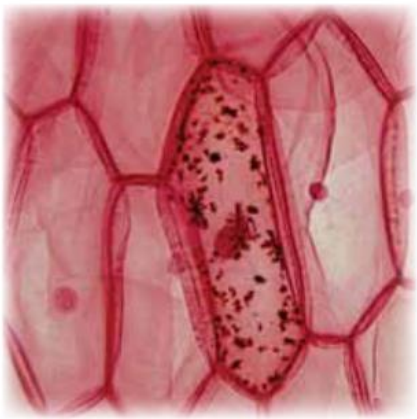
1 **a** What is meant by cell specialisation?
b Why are cells in your body specialised?
c Give three examples of specialised cells and explain their function (job).

2 Use examples to explain the difference between a tissue, an organ and a system.

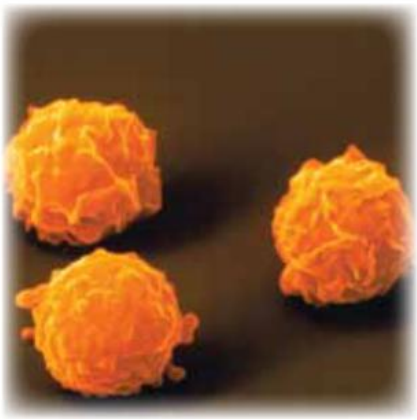
3 Write inferences to explain each of the following observations.
a Red blood cells have lots of haemoglobin and no nucleus.
b Connective tissue in animals, such as the collagen in the skin, is made up of fibres. These fibres are flexible and add strength to the tissue they are in.
c Nerve and muscle tissues are often found together in organisms that can move quickly.
d Bone has a hard, rigid structure with cells located within the spaces of the structure.
e The top layer of epithelial tissue in the skin is made up of cells that are dead and hardened. These cells are constantly lost and replaced.

4 Explain whether you think it would be possible for a multicellular organism to survive without cell specialisation.

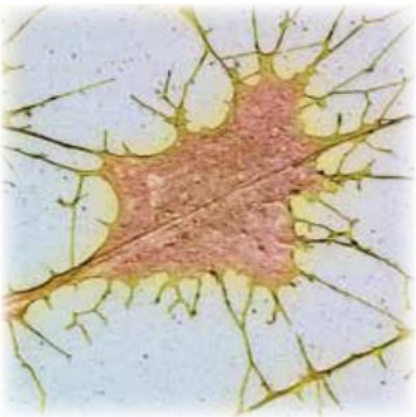
5 Look at the human nerve cell on the previous page. The function of a nerve cell like this is to communicate information from the brain to a muscle. How does the structure of this cell help with this function?



Onion skin cells



Stem cells in bone marrow



Human nerve cells

5.4 Cell processes

Let's review what we have learnt so far about cells.

- Living things are made up of cells. Some organisms are unicellular (made up of one cell) like the organisms you examined in Investigation 2, Part C. Other organisms are multicellular (made up of many cells) like humans and flowering plants.
- All cells have parts in common; for example, most have a nucleus.
- Cells in multicellular organisms are specialised. Each different type of cell has a different structure and function.
- In multicellular organisms, cells form tissues, which form organs, which form systems.

Making energy

An organism that is made up of a single cell is active all the time. Nutrients or food materials are taken into the cell and wastes are removed. Gases such as oxygen and carbon dioxide are passing in and out of the cell. Many chemical reactions are occurring, substances are being made and others are being broken down. The cell also needs to reproduce.

All cells need energy to make these things happen, so respiration occurs in the mitochondria.

Respiration

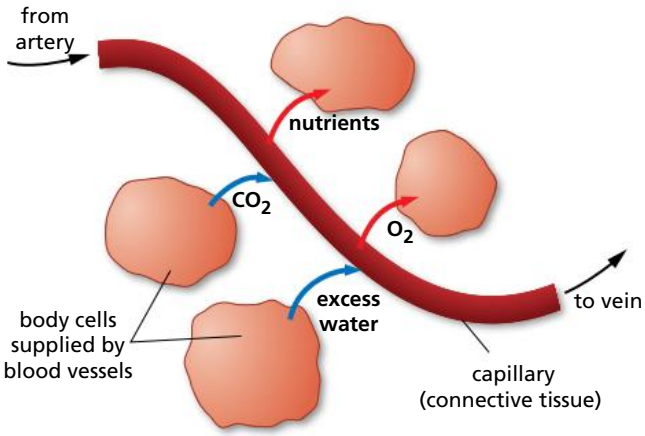
food (glucose) + oxygen → carbon dioxide + water + ENERGY

Diffusion

In previous study you may have discovered that a gas spreads or *diffuses* across a room. The gas molecules move from areas of high concentration to areas of low concentration until there is an equal spread of gas throughout the room. Substances move into and out of cells in a similar way, by passing through the cell membrane. Food and oxygen diffuse into the cell, and wastes such as excess water diffuse out of the cell.

This diffusion process works perfectly if you are a very small unicellular organism, but what happens when you are an organism made up of many cells?

A multicellular organism is too large for all the cells in its body to rely on diffusion of substances from the outside. The process is not fast enough to support every cell, so tissues, organs and systems are needed to quickly bring the substances required to every cell. For example, in animals a network of tiny blood vessels called capillaries brings food and oxygen to every cell. These substances then diffuse from the blood into the cell. Wastes such as carbon dioxide diffuse from the cell into the blood and are taken away. This network of capillaries is connected to larger blood vessels called arteries and veins. This network of tubes in the body provides all cells with what they need to function.



Processes inside plants

Flowering plants also have a network of tubes running through their bodies to supply their cells with what they need.

Respiration is not the only chemical reaction that occurs in plant cells. Photosynthesis occurs too. It is the process by which a plant is able to make its own food using the energy from the sun. This takes place in the chloroplasts in leaf cells.

Photosynthesis

carbon dioxide + water + ENERGY (from sun) → glucose + oxygen

The section of the leaf on page 105 shows how cells are arranged to form leaf tissue. Cells that carry out photosynthesis are positioned near **stomata** or pores that allow gases such as carbon dioxide to move into and out of the leaf. Carbon dioxide passes through the stomata and diffuses into the leaf cells. Water is carried to the leaf cells through xylem tissue. Phloem tissue then takes the products of photosynthesis from the cells to where it is needed. The cells in multicellular organisms are arranged in a way that ensures that each cell gets what it needs to function.

INVESTIGATION

2 The size of cells

Aim

To test the following hypothesis:

The size of a cell affects how quickly substances diffuse into its centre.

You will cut starch agar into different-sized cubes to represent cells, and see how fast iodine moves into them by diffusion.

Risk assessment and planning

1 Read this investigation. When iodine reacts with the starch in the agar a blue-black colour is formed. Predict how long it will take the iodine to diffuse into each cube and turn it black.

2 How can iodine and cutting instruments be safely used? Discuss these with your teacher.

3 Copy this table to record your results.

Length of sides of cube (cm)	Movement of iodine	
	After 5 minutes (mm)	After 10 minutes (mm)
0.5		
1		
2		
4		

Apparatus

- iodine solution
- 500 mL beaker
- starch agar
- stopwatch
- ruler
- knife or sharp blade
- cutting board
- blunt plastic forceps

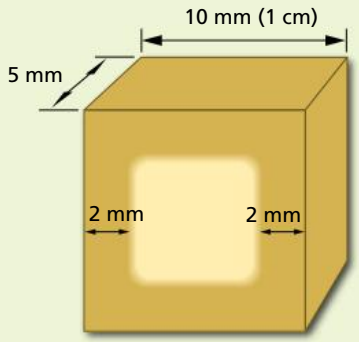
Method

1 Cut the starch agar into cubes to the sizes indicated in the table above. You will need two cubes of each size. Be as accurate as you can.

2 Place the cubes in a beaker and cover them with iodine.

3 *After five minutes* use blunt plastic forceps to remove one cube of each size from the iodine and place them on the cutting board.

4 Cut each cube in half and measure how far the iodine has moved into the cube in mm, as shown below. Record your measurements in the data table.



5 Remove the remaining cubes *after 10 minutes* and repeat Step 4.

Results

1 Were your predictions correct? Explain.

2 What was the variable you were testing? What other variables may have affected the results of this experiment? Do you think these variables were properly controlled? Explain.

3 Would the shape of the starch agar make a difference to the results? For example, would iodine diffuse into a round-shaped piece faster than into a cube-shaped piece about the same size? Explain your prediction and test it.

Conclusion

Write a summary to explain what you found out about cells and diffusion and state whether the hypothesis was correct.

Over to you

1 Explain how a unicellular organism or a single cell in a multicellular organism is carrying out activities all the time.

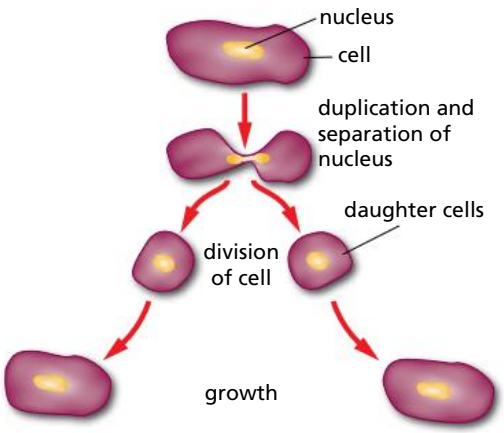
2 Explain how perfume spreads through a room from an open bottle by diffusion. How is this process different for cells?

3 Why is respiration essential to cells?

4 Why are cells in multicellular organisms arranged in tissues, organs and systems? Does a unicellular organism need these structures? Explain.

5.5 Cell division

Some cells of multicellular organisms such as humans reproduce by **cell division**, in which a single cell splits into two. The nucleus of a cell contains all the information needed for the cell to function. Before the cell can divide, the material in the nucleus is copied and separates. A cell membrane then grows down the centre of the cell spitting the cytoplasm and the nuclear material to produce two *daughter* cells. In a plant cell, the cell wall also grows down the centre of the cell to divide it.



Growth and repair

Every person grows from an egg cell into an **embryo**, then a baby, a child and an adult through the process of cell division. During this process, cells become specialised to perform different jobs.

In an adult, cell division occurs only to repair and replace cells. For example, the cells of the liver and pancreas regularly reproduce themselves to replace worn-out cells. Similarly new skin cells replace dead skin cells rubbed away as the result of contact with surfaces. However, not all cells can reproduce themselves.

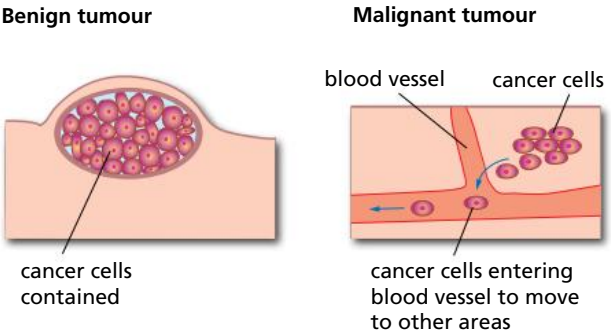
Stem cells are unspecialised cells that can divide when needed to produce new cells. For example, red blood cells only live for about 120 days and must be replaced. They are made from stem cells in the bone marrow inside bones. Stem cells of this kind can even migrate to other areas of the body to produce types of blood cells that are different to those made in the bone marrow, for example white blood cells.

Cells such as muscle and nerve cells that are damaged or die through injury are not replaced. In a muscle, connective tissue or scar tissue patches up the damage, but it never functions as well as the original muscle cells.

Cancer

Cell division is a controlled process. The body produces a signal that switches cell division on and off. For example, if the skin is damaged, cells in the damaged area are 'switched on' and divide to produce new tissue. Once enough tissue has been made, cell division is 'switched off' again.

Cancer occurs because some cells do not switch off in response to these signals, so a *tumour* develops. This is a mass of cells that can stop the body working properly, and can spread to other body parts. A tumour can be non-cancerous (*benign*: be-NINE), or it can be cancerous (*malignant*). In benign tumours the cancer cells are contained and do not spread. In malignant tumours the cells can spread to the rest of the body if not treated, and can grow and stop body functions somewhere else.



Causes of cancer

There is not one single cause of cancer because there are many different types of cells in the body that can be affected in different ways. However the following can contribute to the formation of cancers:

- ultraviolet (UV) radiation from the sun
- tobacco smoke
- chemicals and pollutants
- some viruses.

Over to you

1. What is cell division and why does it occur?
2. What are stem cells?
3. What is the difference between a benign and a malignant tumour?
4. Write a list of clothing and other items that students need to bring to the school swimming carnival to protect themselves from the sun. Explain why these items are needed.

INVESTIGATION

3 Sun protection

Skin cancer is largely preventable. Whenever the UV level is 3 and above (usually in the middle of the day) you need to *Slip* on protective clothing, *Slop* on 30+ broad spectrum sunscreen, *Slap* on a broad-brimmed hat, *Seek* shade and *Slide* on sunglasses.

Your task here is to design an experiment to find out which materials are best to use to protect your skin from the sun. Here are some ideas:

- Does dark coloured clothing provide better protection from the sun than lighter colours?
- Which fabric offers the most sun protection and is the lightest and coolest to wear?
- Which type of shade cloth is the best to use for shade sails in playgrounds or on patios?
- Which hat style/material provides the best protection from the sun?
- Which type of sunscreen offers the best protection or is the most water-resistant?
- Which type of sunglasses offers the most protection from the sun?
- Can you design a bicycle helmet cover that is practical and offers the most sun protection?
- Can you design a windproof shade that is light and easy to carry and can be put up quickly?

Hints: Use a UV light and UV meter to measure the amount of UV penetrating through different materials. Think of ways to test your ideas that do not require your skin to be overexposed to UV radiation.

PROBLEM SOLVING

Having cancer does not mean you are going to die. For example, skin cancer can be easily identified, and 95% of cases are cured if treated early. So any spot on your skin that does not go away within a few weeks or comes back again, or any mole or freckle that changes in any way, should be checked by a doctor without delay. Here are some spots to look out for on your skin:

Melanoma

- Appears as a new spot or an existing spot that changes colour, size or shape.
- Has an uneven, smudgy outline and will be an irregular mix of colours.



Nodular melanoma

- Many are red or pink and some are brown or black.
- They are firm to touch and dome-shaped.
- After a while they begin to bleed and crust.



Basal cell carcinoma

- Red, pale or pearly in colour, appears as a lump or dry, scaly area.
- May ulcerate or fail to heal completely.



Squamous cell carcinoma

- A thickened, red scaly spot that may bleed easily, crust or ulcerate.
- More likely to occur in people over 50.



You should now be able to describe what skin cancer is and explain what causes skin cancer. Investigation 3 should give you ideas on how to prevent skin cancer and some suggestions for making your school sun-safe. For example, what type of shade cloth could you use around the school? What type of hat should students wear? What type of sunscreen should be made available? Complete your task now.

The stem cell debate

Stem cells are unspecialised cells that can change into any one of over 200 different types of cells in the body. They can also divide and make accurate copies of themselves. Scientists have been examining ways to use stem cells to help people whose cells don't work as they should. For example, the cells in heart muscle and nerves cannot be repaired or replaced when they are damaged. Using stem cells, it could be possible to repair heart muscle in a person who has suffered a heart attack.

Curing disease

Stem cells could also be used to grow replacement organs, instead of using transplants. They could also be used to cure diseases such as diabetes. For example, a person who has type 1 diabetes is unable to produce insulin, a substance that keeps the level of sugar in the blood constant. Too much or too little sugar in the blood can cause death. Type 1 diabetes sufferers must check their blood sugar levels daily, and inject themselves with insulin to keep their blood sugar level constant. Also diabetes can lead to nerve damage, kidney failure and blindness. Stem cells could be used to make insulin-producing cells, which could remove the need for insulin injections in a diabetes sufferer.

Scientists have made stem cells into insulin-producing cells and injected these into diabetic mice. They have also made new blood cells and nerve cells. When these new cells were transplanted into newborn mice, the cells functioned correctly. This shows that it is possible to repair damaged nerve cells. However, for this to happen, scientists must be able to collect stem cells, make these cells change into the type of cell needed, and then get the patient's body to accept the new cells.

Finding stem cells

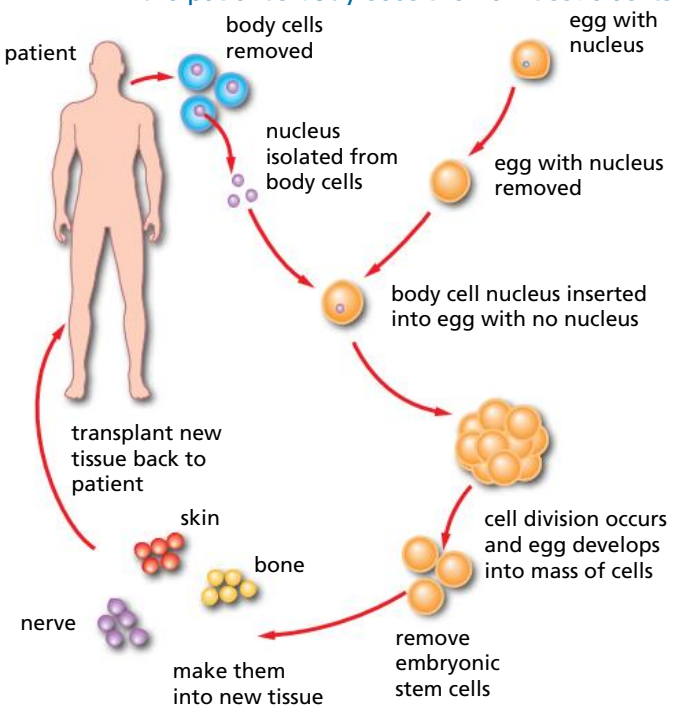
Where do scientists get stem cells? Bone marrow is one place, but these stem cells have already started to become the cells they will replace. However stem cells in human embryos have not yet started to develop, so they are much better to use. To date scientists have taken stem cells from aborted pregnancies or from embryos left over from IVF procedures.

The problem is whether is it ethically correct to use embryos. *Ethics* are the principles or values that we hold. How we act, respond and judge right and wrong are based on these values or ethics. For example, you are taught not to kill another living thing because it is ethically wrong to do so. So, if the embryo is destroyed when the stem cells are taken, is this right?

Therapeutic cloning

The problem with transplanting new tissue is that it is often rejected. Transplant patients have to be given drugs to stop their body seeing the new tissue as 'foreign' and rejecting it. However, these drugs can cause kidney failure and cancer.

Tissue rejection could be avoided by growing stem cells with the patient's own genetic material inside them. This is called therapeutic cloning. Tissue rejection is therefore less likely, because the patient's body sees the new tissue as its own.



The Issues

With any scientific development such as this, there will always be people who are for it or against it. Let's examine some of the issues in the use of embryonic stem cells.

Negative issues

- Religious groups and right-to-life groups are against using and destroying embryos because they believe that, even though they are unborn, the embryos have a right to life.
- There is a fear that if a tissue can be made, then a complete person could be made. Could humans be grown in the laboratory?
- Commercial groups could produce organs and body parts for sale.

Positive issues

- Stem cells are presently used to treat leukaemia, a disease in which a person's own bone marrow stem cells are not making enough white blood cells. These people are given a bone marrow transplant of millions of new bone marrow cells to correct the problem.
- There are not enough donor organs available for people who need them. Many people die before they can receive an organ. Stem cells could be used to make *new* organs.
- Therapeutic cloning is only making tissue to replaced damaged tissue. It is not making a new organism such as Dolly the sheep.
- The law at present is that there is to be no commercial sale of body parts.

Politicians and governments are being forced to make rules and laws or legislate about the use of embryonic research and therapeutic cloning. Presently therapeutic cloning has been put on hold and any research on embryonic tissue in Australia is restricted.

INQUIRY 4 SWAP ideas

In this activity you will discuss the issues involved in the stem cell debate. You may like to work in groups.

1 Draw up a table with the following headings. The first letters of these headings make the word SWAP.

Strengths	Weaknesses	Action	Possibilities

2 Under the heading Strengths write all the points that you can think of *in favour of* the use of embryonic stem cells.

3 Under the heading Weaknesses write all the points that you can think of *against* the use of embryonic stem cells.

4 Now explain what needs to happen to turn the arguments against the use of stem cells (weaknesses) into strengths. Write these in the Action column.

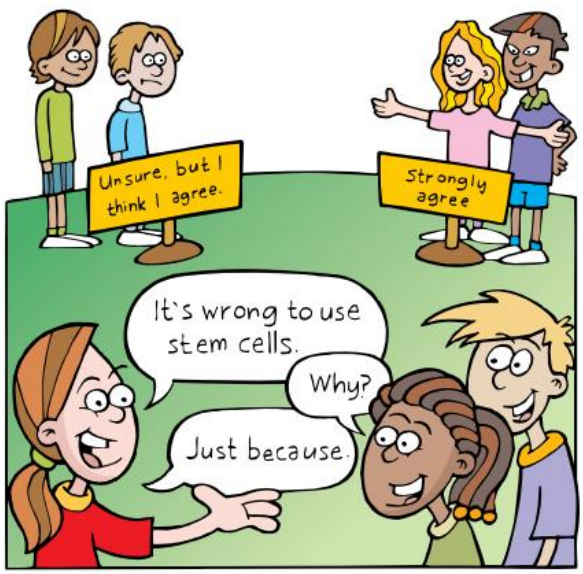
5 Finally explain what the possibilities are for the future in the Possibilities column.

INQUIRY 5 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 embryonic stem cells should be used to make new tissues? Move to the corner that applies to you.



3 Each corner must now try to convince the people in the two unsure corners to join them. The winner of the discussion is the corner with the most students in it. Every student should be given a chance to speak.

Knowing and Understanding

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

1 All living things are made of small building blocks called _____. Organisms can be unicellular or _____.

2 Cells normally divide at a set rate. _____ occurs when cell division is not controlled.

3 In a _____ microscope a beam of light passes through the object being viewed. In an _____ microscope a beam of electrons is used instead of light.

4 Plant and animal cells have many parts in common. Most plant cells have a cell _____ and _____, which animal cells don't have.

5 Cells that carry out specific jobs in the body are said to be _____.

6 Many cells with a similar structure and function form a _____. Many tissues that work together form an _____. A _____ is made up of many organs that work together as a unit.

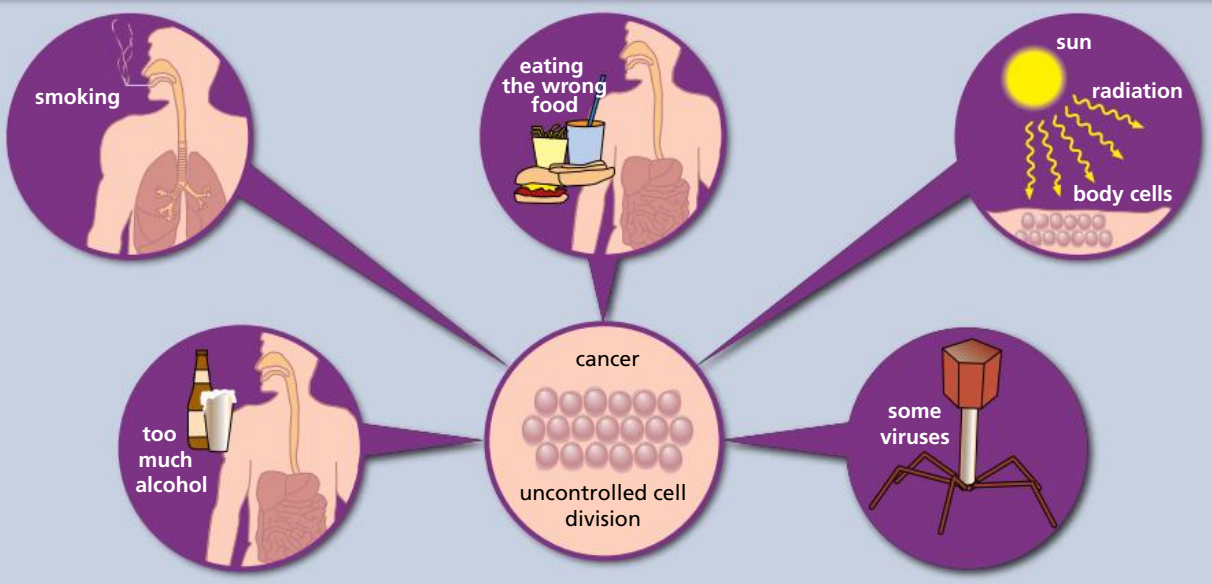
7 Substances move into cells by _____. This limits the size of cells.

8 Cells reproduce by cell _____, splitting the nucleus and the cytoplasm to produce two daughter cells. This process is for the growth and repair of cells. neutrons (no charge).

cancer
cells
chloroplasts
diffusion
division
electron
light
multicellular
organ
specialised
system
tissue
wall

Self-management

Some causes of cancer



Using diagrams for review

This diagram summarises the major causes of cancer by using pictures and a limited number of words. It is possible to use diagrams in this way to summarise the chapter.

1 On a large sheet of paper draw a chapter summary using these headings for each box:

a Cells (centre box) **b** Cancer **c** The microscope **d** Plant and animal cells
e Cell specialisation **f** Cell division **g** Diffusion in cells **h** Tissues, organs and systems

2 Use diagrams to explain what each box is about.

Checkpoint

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

OneStopScience

1 Write meanings for the following words:
cell, diffusion, cell specialisation, embryo, organ, system, cell division

2 Copy and complete the following sentences in your notebook. Use the words you have learnt in this chapter.

a Living things are made up of _____.

b An organism made up of one cell is said to be _____. An organism made up of many cells is said to be _____.

c A monocular microscope has only _____ eyepiece whereas a binocular microscope has _____.

d Robert _____ viewed cork under a microscope and described what he saw as cells.

e Cancer occurs when a cell does not respond to the switching off signals of cell _____.

f The movement of a substance from a region of high concentration to a region of low concentration is called _____.

3 **a** What is the total magnification for the following microscope lens combinations?

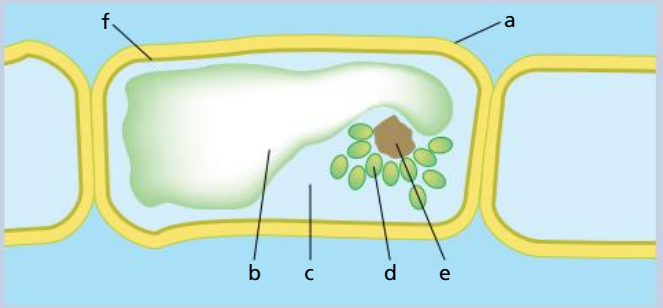
Eyepiece	Objective	Total magnification
5X	10X	
10X	10X	
10X	20X	

b Which of the magnifications in the table above shows low power? Which shows high power?

4 Match the correct microscope part to its function.

Microscope part	Function
iris diaphragm	a platform on which the slide is positioned with clips to hold it in place
body tube	reflects light up through the slide to the eyepiece
stage	a tube to which the eyepiece and nosepiece are attached
mirror	a lens used to see the detail of the specimen; can be low power or high power
objective	like a camera shutter, it can be adjusted to control the light passing through the microscope

5 Marcella had to draw a variety of cells she had been viewing through a microscope. However, when she got home she realised that she had not labelled one of her drawings.



a Copy and label this cell for Marcella.

b Is this is a plant or an animal cell. How do you know?

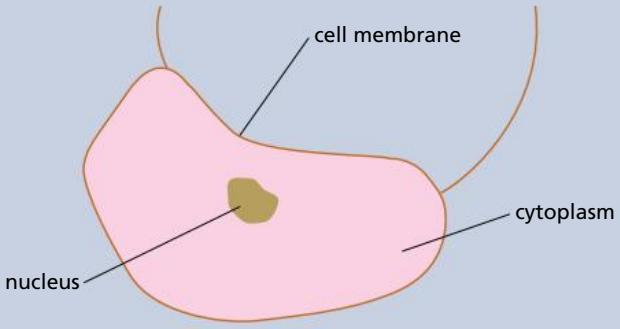
c Are there any parts missing from this diagram? If so list them.

6 What is the difference between a tissue, an organ and a system? Give an example of each.

7 Explain how cells in multicellular organisms obtain the substances they need to function.

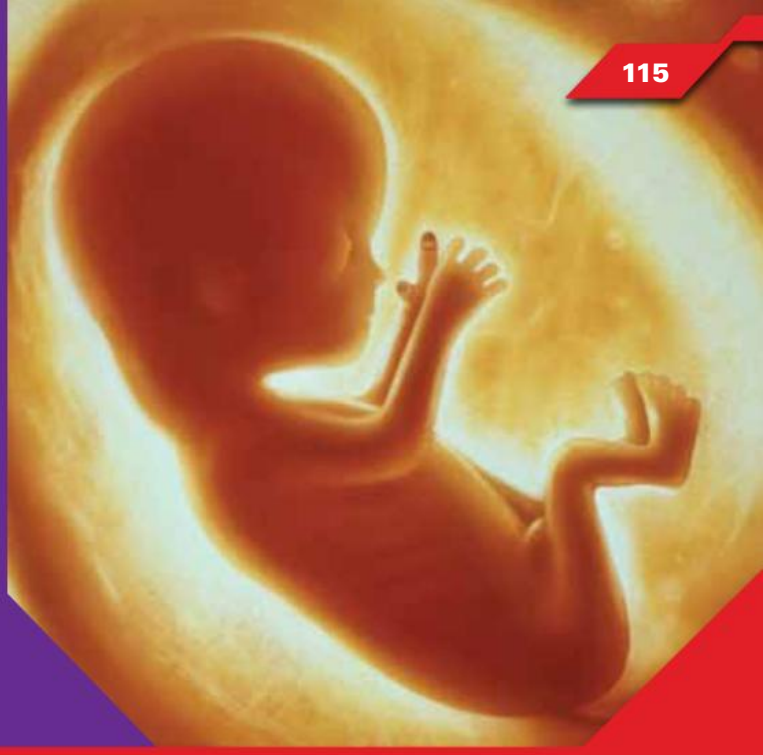
8 Explain why cells are microscopic in size. Use the word 'diffusion' in your answer.

9 **a** Copy the diagram of an animal cell below. On this diagram use arrows to show what substances go into and out of the cell.



b Now draw a plant cell in similar detail. Show what substances go into and out of a plant cell.

6



Plant and animal systems

PROBLEM SOLVING

The human body

1 Your problem is to produce a correct diagram of a human body showing the following systems: digestive, respiratory, excretory and reproductive. You could use your diagram from Inquiry 1 as a rough idea to work from and correct.

2 You can present your human body as a collage, a series of plastic sheets overlaid to make a full body, a series of posters, a pop-up book etc. Try to be creative with your presentation.

3 How do you start? Work through this chapter. You will be given a lot of information on body systems. You can also use the library and internet.

INQUIRY **1** ***The human body***

You can do this activity by yourself or in groups.

You will need: butcher's paper, a model human torso or a diagram of the body

1 Draw a body outline on the butcher's paper. Then draw and label these parts: brain, heart, lungs, stomach, pancreas, bowel (large intestine), small intestine, appendix, kidneys, bladder, skeleton.

2 Compare your diagram of the body with the human torso or the diagrams provided in this chapter. What parts did you get in the correct position? What parts were placed incorrectly? There were 10 parts (excluding the bones). Give yourself a mark out of 10 for the parts you got right!

3 Don't throw out your original diagram because you will need it for the next section.

Focus for learning

Why study plants and animals? Plants capture energy from the sun to provide all life on Earth with food. They produce oxygen and remove carbon dioxide from the air. So plants clean the air for us.

Understanding how your body functions or works helps you to lead a healthy life and to know when things are going wrong. Medical scientists are learning more about the body every day in an attempt to cure diseases and help injured people lead normal lives.

Vaccine for cervical cancer

You may have noticed on the news that a vaccination (injection) for cervical cancer has been developed by scientists at the University of Queensland. Cervical cancer is the second leading cause of cancer among women, with 500 000 cases occurring each year in Australia. (The cervix is the lowest part of the uterus which is at the top of the vagina.) Knowledge of the human body helps you understand why this vaccine is important. Cervical cancer is caused by a virus and this vaccination prevents women getting the virus and developing the disease.

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

Science Understanding

- name the organs that make up human body systems and describe their structure and function
- compare digestive and respiratory systems in different animals
- identify similarities and differences between structures involved in reproduction in plants and animals
- distinguish between asexual and sexual reproduction

Science Inquiry Skills

- design a fair test, identifying variables to be changed, measured and controlled

LITERACY FOCUS

alveoli	**embryo**	**menstruation**	**sexual reproduction**
bronchi	**excretion**	**oesophagus**	**stamen**
chlorophyll	**faeces**	**pistil**	**stomata**
consumers	**fertilisation**	**pollination**	**trachea**
diaphragm	**foetus**	**producers**	**urine**
digestive system	**hypothesis**	**semen**	**variables**

6.1 Materials needed to survive

Respiration

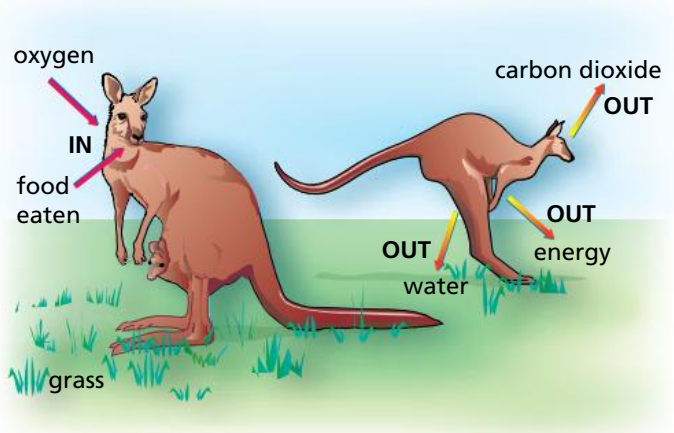
What do you need to survive? If you made a list you would probably write down water and food. You also need to breathe in oxygen and get rid of wastes such as carbon dioxide from your body. You might also say that you need lots of food to give your body **energy** so that you can carry out your daily activities.

Have you ever thought about what happens to the oxygen you breathe in? Or the food you eat? Or the water you drink? Where do these materials go and what are they used for? What does your body do with these materials?

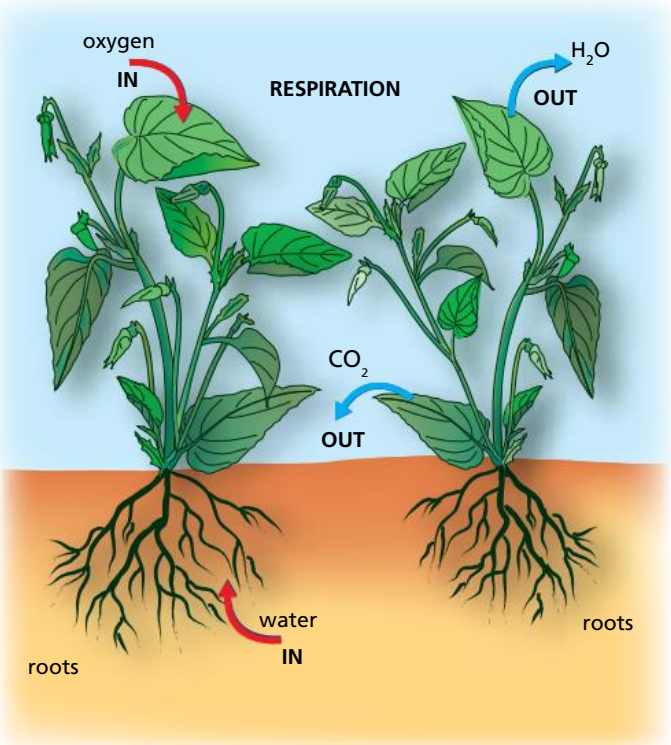
Imagine a toy robot with a battery inside it. The battery provides the energy to produce movement, light and sound in the robot. Your body doesn't have a battery inside it. Instead the food you eat and the oxygen you breathe in are used by your body to provide energy. This is the process of respiration. It is often called 'internal respiration'.

food (glucose) + oxygen
↓
carbon dioxide + water + energy

You need the energy made in respiration so you can walk, run, play, breathe, keep your heart beating and your body alive. You need energy to keep your body temperature constant and for the growth and repair of your cells. These are the smallest units in your body that build together to make you. Energy is also needed for the chemical reactions in your body to take place.



Plants also carry out respiration. They need energy for the repair and growth of new roots, shoots and leaves. Chemical reactions that need energy take place inside a plant. Plants also carry out movements that we do not notice and energy is needed for this. So, just like animals, they combine food with oxygen and give out carbon dioxide and water to provide the energy they need to survive.



It is important to note that respiration also has another meaning, which is 'breathing in and out'. This is sometimes called external respiration so that it is not confused with internal respiration. When we talk about the 'respiratory system' we mean the system involved in external respiration.

INQUIRY 2 Water loss in plants

You can do this activity by yourself or in a group.

You will need: transparent plastic bag, elastic band

1. Go outside and find the leafy end of a branch.
2. Cover the leafy end of the branch with a plastic bag and seal it with the elastic band.
3. Leave the bag over the leaves overnight. What do you predict will happen? Why?
4. What do you notice the next morning? Explain your findings.

Photosynthesis

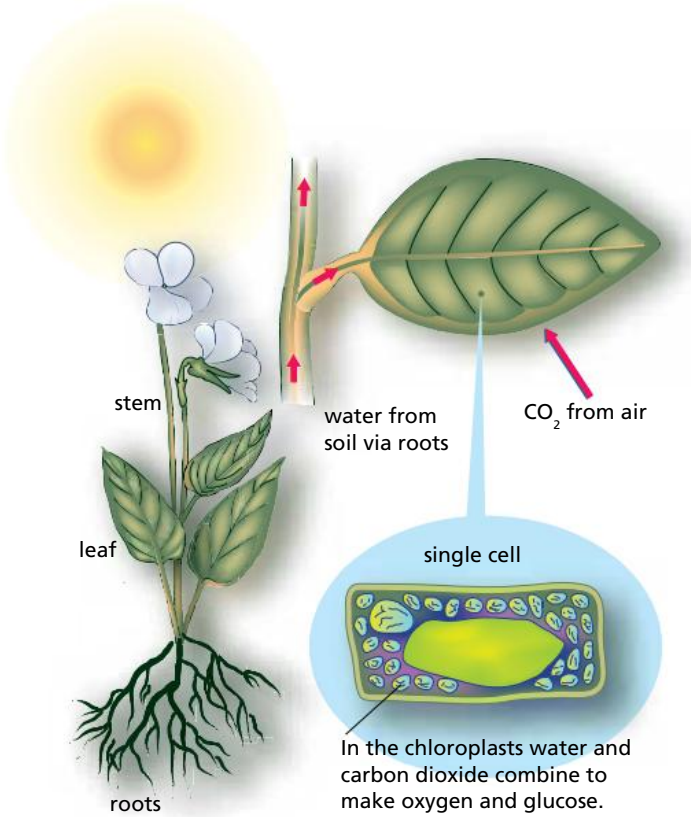
Plants and animals obtain their food differently. Animals are **consumers**. They eat or consume other organisms to get the food they need for respiration. Think of what you have eaten today. You may have eaten meat, fruit and vegetables—all food that comes from other organisms.

The food eaten by animals is broken down into smaller bits that the body is able to use. Some of this food is combined with oxygen during respiration.

Plants are able to make their own food. They are called **producers**. They make or produce food for themselves and other organisms using photosynthesis:

carbon dioxide + water + sunlight → **oxygen + food (glucose)**

They do this in structures called *chloroplasts* found in the leaves. These structures are full of a green material called *chlorophyll* that absorbs sunlight. So the energy from the sun is used to combine carbon dioxide and water to produce oxygen and *glucose* (a simple sugar). The gases that are needed enter and leave the plant via its leaves. Water is taken up from the soil via its roots.



Plants use the food they make in photosynthesis to grow. Some of the food is stored and some is used in respiration to make energy. The oxygen produced during photosynthesis is needed by other organisms to survive.

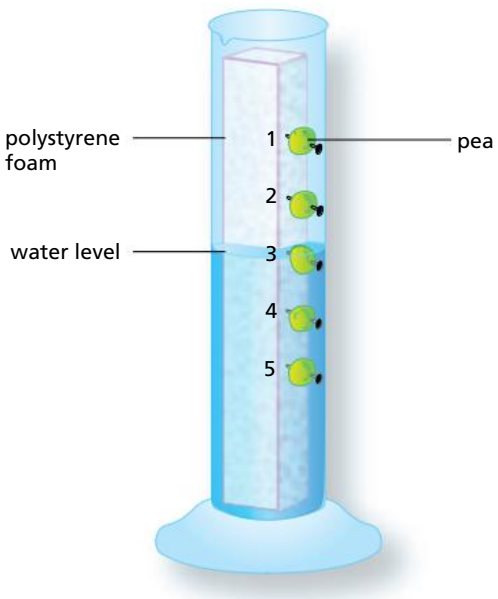
You will notice that photosynthesis makes food, and respiration uses the food to provide energy.

Water, carbon dioxide, oxygen and food are not the only substances needed by plants and animals. There are other nutrients or substances in the foods we eat that organisms need to be healthy. For example, we take nitrogen from proteins, calcium from milk, and iron from red meat. Plants also need nutrients such as nitrogen, sulfur, magnesium, iron and phosphorus. They usually get these substances from the soil through their roots.

INQUIRY 3 Do seeds need water and oxygen?

You will need: measuring cylinder, strip of styrofoam, 10 pins, 5 fresh or dried peas, masking tape, water

1 Set up the apparatus like this with the water level as indicated.



2 Pin the peas down the strip of foam as shown.

3 Observe your peas for a week.

4 Explain your findings.

5 Do seeds need water and oxygen to survive? Explain your answer.

INVESTIGATION

1 Photosynthesis

Aim

To see photosynthesis in action.

Risk assessment and planning

Read through the investigation.

1. *Elodea* is a plant used in fish tanks. Why shouldn't you dispose of *Elodea* down the sink or drain?
2. Predict what you think will happen to the *Elodea* stem in Part A and the potato in Part B. Write your predictions in your notebook and discuss these with your teacher.
3. Why do you think you have to breathe into the water through the straw before starting your observations in Part A?
4. Find out how to use iodine safely.

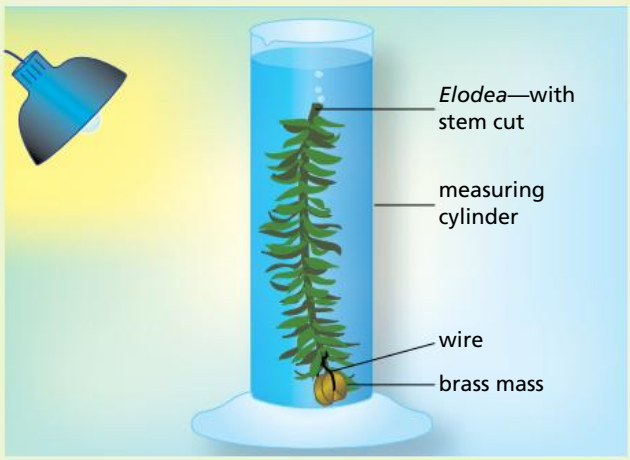
PART A

Apparatus

- measuring cylinder
- a cut piece of *Elodea* stem with leaves attached, anchored with wire to a brass mass
- drinking straw
- a light

Method

1. Set up the apparatus as pictured below.
2. Before you place the water plant in the measuring cylinder, breathe out some carbon dioxide into the water with the straw.
3. Place the water plant in the cylinder near a light or in bright sunshine.
4. Observe the cut end of the stem and record your observations.



PART B

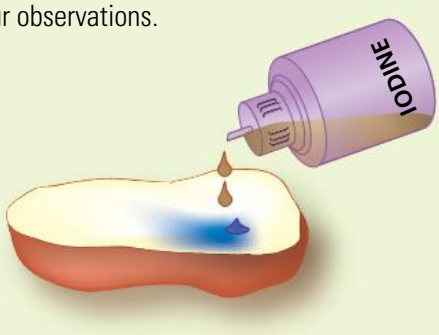
Some of the glucose made in photosynthesis is used to produce energy in respiration. Some of it is used for growth and repair. Anything that isn't used is stored as a substance called *starch* that is made from glucose. This often happens in the roots of the plant as enlarged tubers such as a potato.

Apparatus

- potato
- iodine in a dropping bottle. (Iodine is a chemical that changes from yellow to blue-black when starch is present. Don't get iodine on your hands or clothes as it will stain them.)
- pair of gloves
- knife
- white tile
- starch powder

Method

1. Place a small amount of starch powder on the white tile. Add a drop of iodine to it and note the colour change.
2. Place some iodine on the cut half of the potato.
3. Record your observations.



Results

Answer these questions.

1. Did the *Elodea* carry out photosynthesis? Explain.
2. Was starch present in the potato? How do you know?
3. How did the starch get into the potato in the first place? Draw a diagram explaining this. You will need to start with the sun.

Conclusion

Copy and complete these sentences.

Plants carry out _____ when they are placed in sunlight. As well as sunlight, plants need a supply of _____ and _____ for photosynthesis to occur.

Write your report

Write your report under the usual headings.

SKILL

Designing your own experiment

Imagine you have two plants growing on a window ledge. One is growing well and the other looks quite sick. You might infer that one is getting more water than the other, or maybe more light because of its position.

To test this you need to design an experiment. The amount of water and sunlight are both variables that could change the results of the experiment.

A well-designed experiment tests only one variable and keeps the others the same or constant. Let's say that during your observations you notice that there is sunlight for most of the day where the healthy plant is, but there is little sun where the sick plant is. From this you infer it is the amount of sunlight, not the water, that is affecting the plants. You predict that this will affect future plant growth.

You then make a statement that gives an answer to your observations and can be tested. This statement is a hypothesis; for example:

The amount of sunlight affects plant growth.

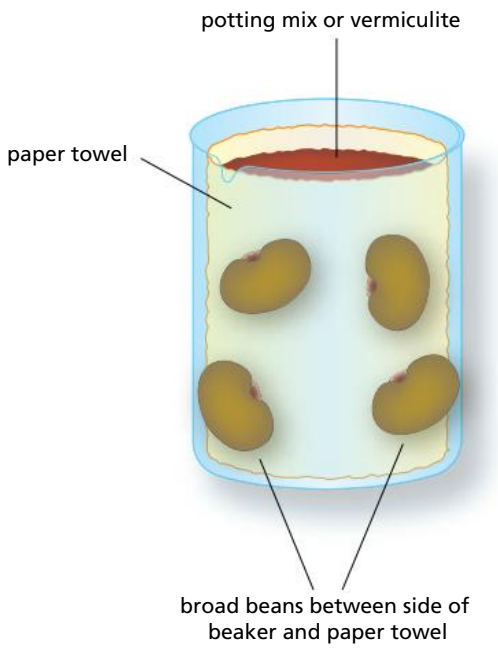
To test your hypothesis you decide to use two new plants in place of the ones you have. To control all the variables you must have the same type of plants, in the same size pots, with the same amount of soil, and the same amount of water. Then the only variable that is altered is the one you are testing, which is the amount of sunlight.

This is what is called a fair test. If you did not control all the variables, you would never know if the sunlight caused the differences in the plants. You must treat both plants in the same way and only alter or test one variable at a time.

INQUIRY 4

Do plants need soil to grow?

You will need: 2 × 500 mL beakers, paper towel, 10 broad bean seeds, packet of vermiculite, potting mix



1. Roll the paper towel into two cylinders and place one cylinder in each beaker so it fits neatly against the glass.
2. Fill the inside of one beaker with potting mix and the other with vermiculite (This is a material that has no nutrients in it.)
3. Place five broad bean seeds in each beaker in between the paper towel and the beaker.
4. Add 50 mL of water to each beaker.
5. Add the same amount of water to each beaker as necessary, but don't over water. If you can see water in the bottom of your beaker you have too much.
6. Make sure the beakers are in the same area with the same conditions.
7. Make a prediction about what you think will happen over time.
8. Observe your beans over a two-week period.

Questions

1. Were your predictions correct?
2. What was the variable you were testing?
3. Which variables did you control?
4. Explain your findings.

INVESTIGATION

2 Design an experiment

Design your own experiment to test one of the following hypotheses:

1. Seeds need good soil drainage to grow.
2. Varying the amount of light or water affects seed growth.
3. Different amounts of nutrients affect the growth of seeds.
4. Varying the temperature or the humidity affects the growth of seeds.
5. The position of seeds in the ground affects how they grow.
6. The shoots from seeds will always grow towards the light.
7. The roots from seeds will always grow downwards because of gravity.

To test some of these hypotheses you could use quick growing radish or bean seeds. Here are some suggestions.

- Give the seeds varying amounts of water and compare their growth.
- Compare the growth of seeds grown in the dark with seeds grown in varying levels of light.
- See if seeds will grow with no drainage holes in the pots they are in.
- Give fertiliser to some seeds and not others. (Fertiliser contains nutrients such as nitrogen and phosphates.)
- Plant broad bean seeds in different positions (e.g. upside down) and see if this affects the way they grow.
- Grow seeds in very warm conditions and compare their growth to seeds in the cold.
- Compare the growth of seeds grown in moist, humid conditions like a greenhouse with seeds in dry air.
- Modify the activities on the earlier pages of this chapter.

Over to you

1. What materials do plants and animals need to survive?
2. **a** What does this equation show?

   food + oxygen → carbon dioxide + water + energy

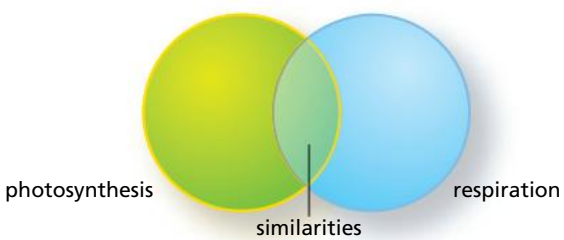
   b Why does the body need to carry out this process?

   c Change the equation around to show photosynthesis.
3. What do plants need energy for? Is this the same as for animals?
4. Why are animals called consumers?
5. Why are plants called producers?
6. Use clues like those below to make the words *photosynthesis* and *respiration*.





7. What do plants do with the food they make in photosynthesis?
8. Draw two circles. In one circle write down all the points you know about photosynthesis. In the other circle write down what you know about respiration. The overlapping parts of the circles are for any points about photosynthesis and respiration that are the same.



6.2 The digestive system

Plants and animals need materials from the environment, and their bodies help them obtain these. For example, we need oxygen from the air, so our lungs bring air into our bodies. We need nutrients, so our stomach breaks down what we eat to give us these.

The body of a plant or an animal is like a machine. Each part has a different job to do, and the parts are linked so that the body can function as a whole. Some parts work together to get a particular job done. For example, when you eat, the food is in bits too big for your body to use. Your mouth, stomach and intestines break down or **digest** the food into smaller, more usable pieces. They form a system called the **digestive system**, one of many body **systems**.

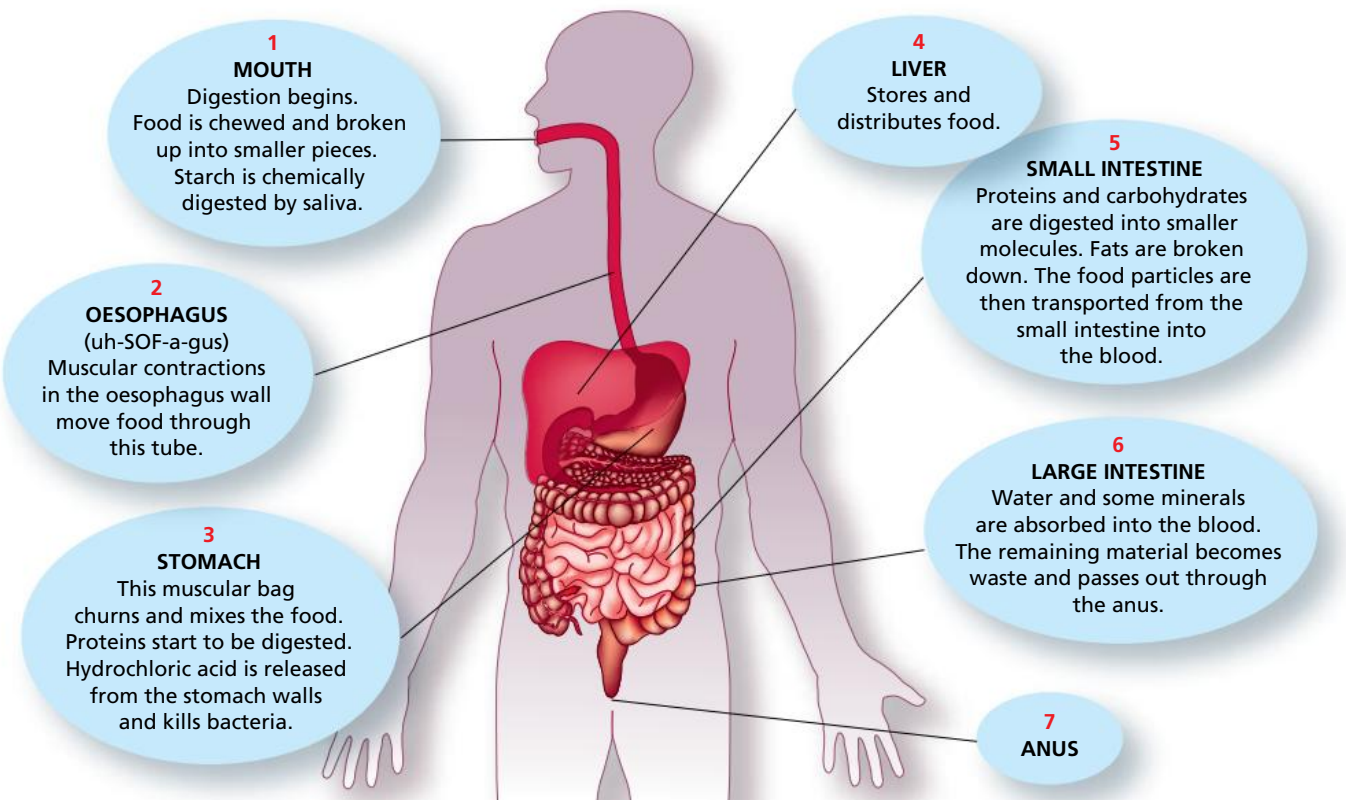
The first stage of digestion is the physical breakdown of large lumps of food into smaller ones. This is done by chewing and by the churning of your stomach. The second stage of digestion is the chemical breakdown of food with the help of enzymes that speed up chemical reactions. These reactions break down the food even further.

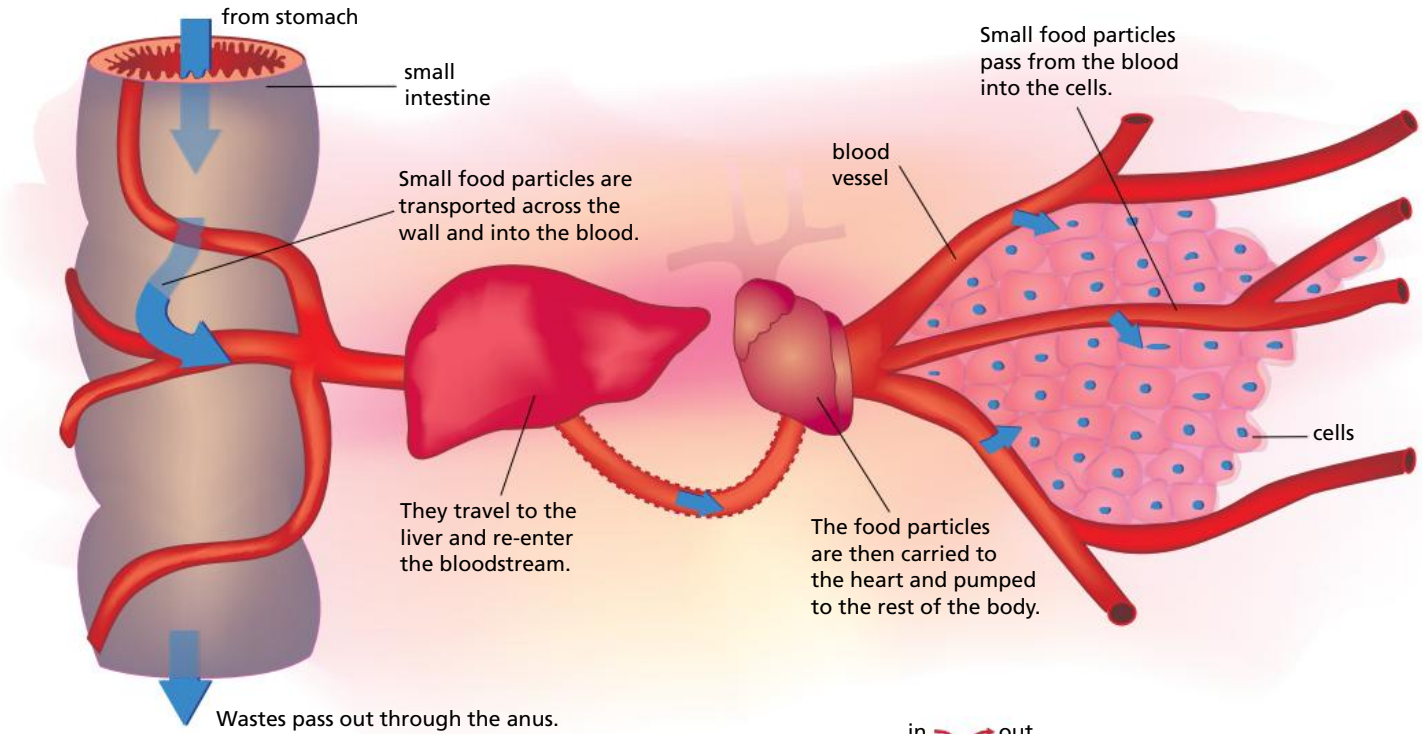
Once you swallow food you don't have to think about where it is going. *Peristalsis* moves the food along by a muscle constricting (shortening) behind the food, pushing it forward. At the same time a muscle in front of the food dilates (widens) to allow the food to move forward. These actions of constriction and dilation pass the food along your digestive system and prevent it from going backwards.

When food reaches your small intestine it is like a thick paste. The starch in food like bread has been broken down to a simple sugar called glucose. Proteins like meat have been broken down to *amino acids*. Any fats are now *fatty acids* and *glycerol*. These nutrients pass through the wall of the small intestine and into your blood.

Your small intestine is covered with tiny finger-like projections (bumps) called *villi* that are filled with blood vessels. The nutrients are carried from the small intestine to the bloodstream via the villi and then to the liver. If there is already enough food in the bloodstream, these nutrients are stored in the liver.

The nutrients in the blood are transported to body cells, the smallest units of your body. It is here that respiration occurs, and the nutrients are used in this process. See the diagram at the top of the next page.





The nutrients enter the bloodstream via the villi and the liver, and are then carried to the rest of the body.

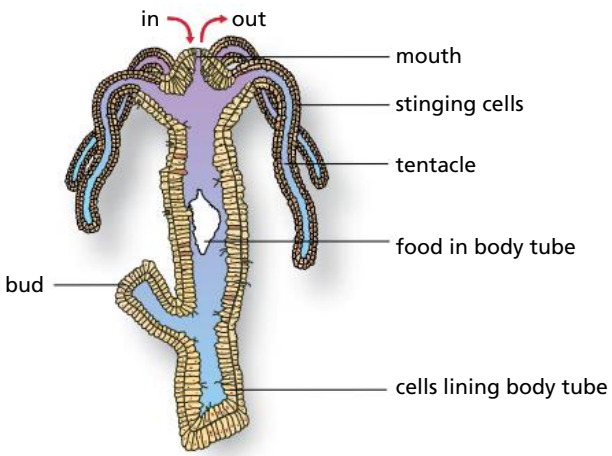
INQUIRY 5 Drinking upside down

You will need: a cup, 5 pegs

1. Find a clear area near a wall where you can do a handstand.
2. With a partner to steady you, do a handstand against the wall so that the wall supports you. (Girls should wear shorts under their skirts or use pegs to tie their skirts around their legs.)
3. Get your partner to help you drink some water upside down. It takes a little bit of practice. What do you notice when you take a sip of water?
4. Explain your observations.

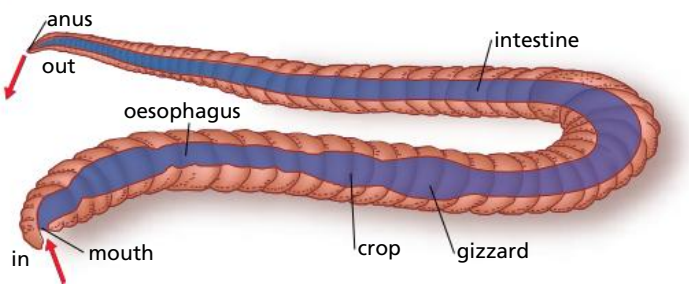
Animal digestive systems

Not all digestive systems are the same. An organism like the hydra stings its food with its tentacles and puts the food into its mouth. It has a hollow tube lined with cells and food passes straight into these cells. Waste products from the cells are passed into the same tube and out through the mouth. So one opening serves as a mouth and an anus!



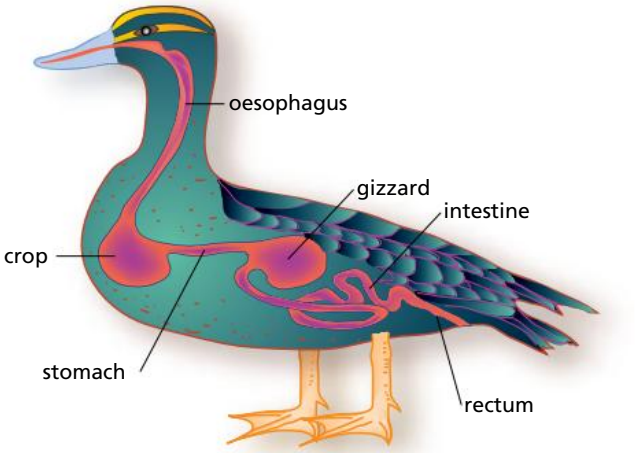
Cross-section of a hydra

In an earthworm, food moves from the **oesophagus** into the crop, where it is stored and digested when needed. After the crop, food moves to the gizzard to be churned up. Then enzymes in the intestine break the food down further and it passes into the body. Wastes are passed out through the anus.



Cross-section of an earthworm

Birds also have a crop. It is used to collect food that is regurgitated or brought back up to feed the young. Hard food is ground with stones and grit in the gizzard. In general, it seems that organisms that don't have teeth have a gizzard.



Plants and digestion

The bodies of plants are not easily divided into systems like the bodies of animals. In flowering plants for example, the major organs are the root, stem, leaf and reproductive organs. Plants do not need a digestive system because they do not need to eat other organisms. They carry out photosynthesis in which sunlight is absorbed by chlorophyll in the leaf. Gases are taken in and out of the body of a plant via the leaves. Water is taken up from the soil via the roots. So systems to do these jobs aren't needed. Carnivorous plants, such as pitcher plants and sundews, have something similar to a digestive system. These plants produce enzymes that can digest trapped insects, allowing their nutrients to be absorbed.

Over to you

1 The following flow diagram shows how food moves through the digestive system. It is incorrect. State why it is incorrect and draw it correctly.

mouth → oesophagus → small intestine → stomach → liver

2 Explain the difference between physical digestion and chemical digestion.

3 In your own words explain how food moves along the digestive system by peristalsis.

4 Name the nutrients that proteins, starch and fats are broken down to in the digestive system.

5 Where is the digestive system linked to the circulatory system or blood stream?

6 What is the role of the liver?

7 Match the following words with their correct meanings: *crop*, *gizzard*, *chlorophyll*, *chloroplast*.

a the part of a plant cell where photosynthesis takes place

b a storage chamber for food

c the green substance in plants that absorbs sunlight

d a place in an organism where physical digestion occurs

8 Which organisms have the following digestive systems?

a a gizzard that comes after the stomach

b no digestive system. These organisms make their own food

c tentacles to sting its food and a hollow body where food passes into cells

9 Compare and contrast the digestive systems of a human and a bird.

10 Use a dictionary to find the meanings of the words: *egestion* and *absorption*. Where do these processes occur in the digestive system?

INQUIRY 6 **Viewing Hydra feeding**

You will need: hand lens, vial of *Hydra* (These can be obtained from biological suppliers. You will need *Hydra* with food, or alternatively obtain *Hydra* and feed them with *Daphnia*.)

Using a hand lens, observe your *Hydra* feeding. Describe what the *Hydra* are doing. How does a *Hydra* feed? Record all your observations.

PROBLEM SOLVING

Have you started your chapter problem?

1 First you need to have a body outline.

2 You can then sketch the organs of the digestive system in the correct places.

3 Put labels on the organs.

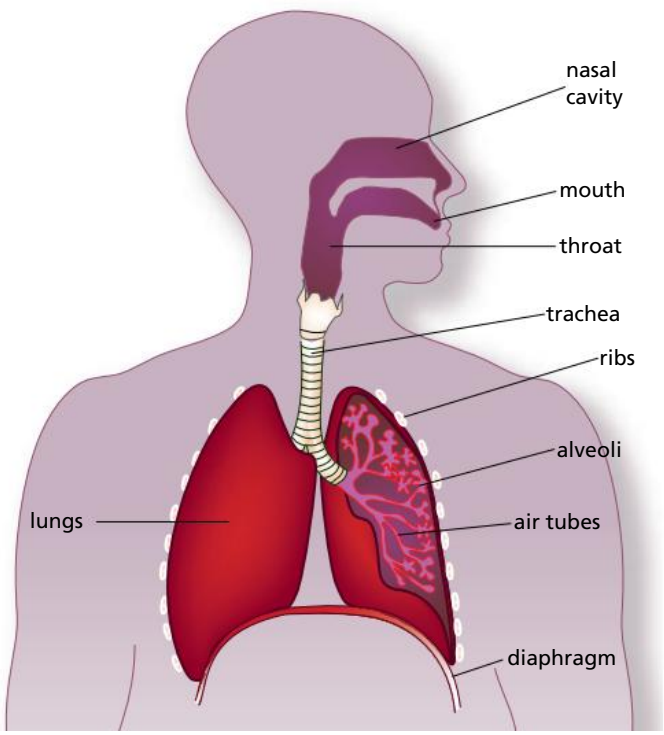
6.3 The respiratory system

Breathing

Breathing is taking in (*inhaling*) and letting out (*exhaling*) air from the lungs. It is the movement of the rib cage and **diaphragm** that make this happen. To inhale, the rib cage is moved up and out by the action of rib muscles. This makes a larger space for air to move into. The diaphragm is a large sheet of muscle that arches underneath the lungs. When it is pulled downwards, air is drawn into the lungs. To exhale, the rib muscles relax and the rib cage falls back to where it started. The diaphragm, which was pulled down during inhalation, arches back into its resting position, pushing air out of the lungs.

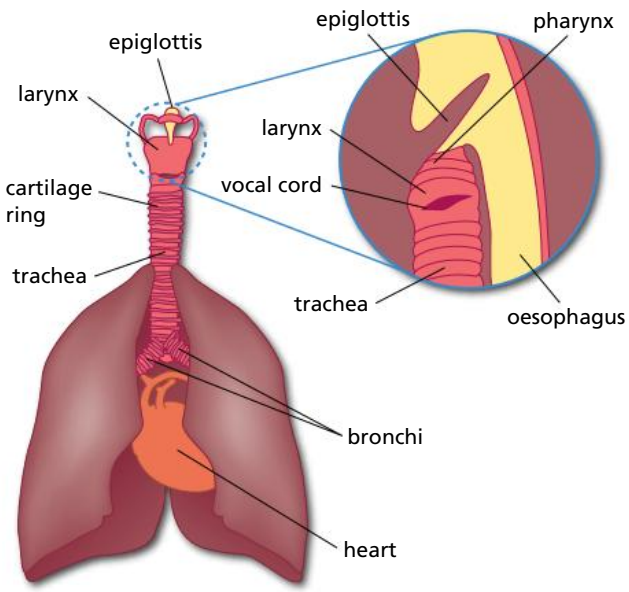
On average four litres of air are drawn into the lungs during breathing, although trained athletes and divers can draw in much more. In one minute you will probably breathe about 16 times. This is called your breathing rate and it is controlled by your brain.

The brain monitors the level of carbon dioxide in the blood. If the level starts to rise, for example during exercise, nerves send messages from the brain to the rib cage and diaphragm to increase the rate of breathing.



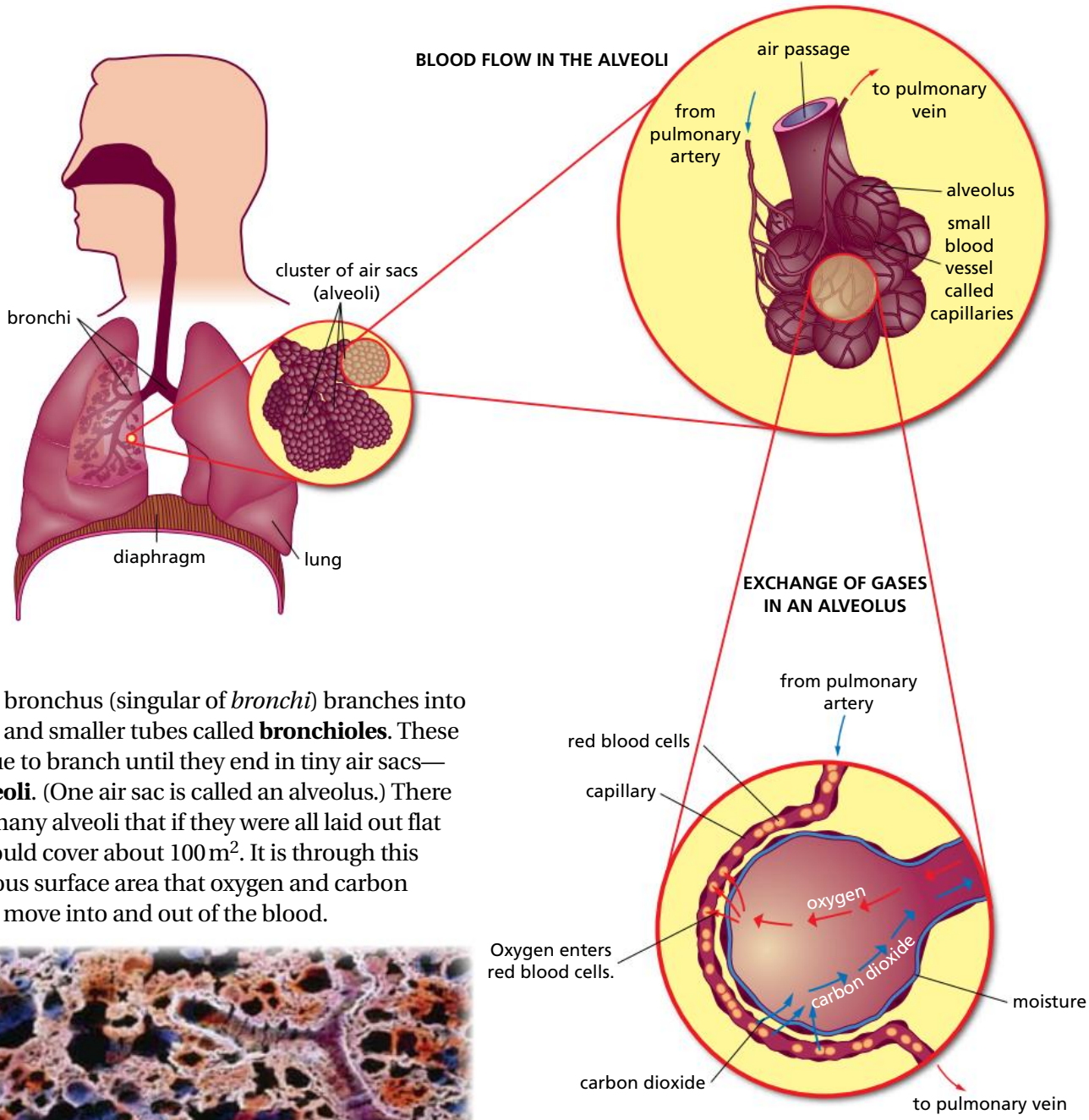
The movement of air

Air enters the body through the nose and the mouth. It is warmed and becomes moist in the nose. Dust and bacteria are trapped in the mucus (sticky fluid) lining the nasal passages. From here air passes into the **pharynx** (PHA-rinks). This is a cavity in the throat that connects the nose and mouth with the oesophagus, the tube leading from the mouth to the stomach. Air doesn't enter the oesophagus and food doesn't enter the lungs because a flap of tissue called the **epiglottis** (EP-ee-GLOT-is) covers the top of the windpipe or **trachea** (TRAY-kee-a) when swallowing. If food does enter the trachea, coughing and choking occur automatically to remove it.

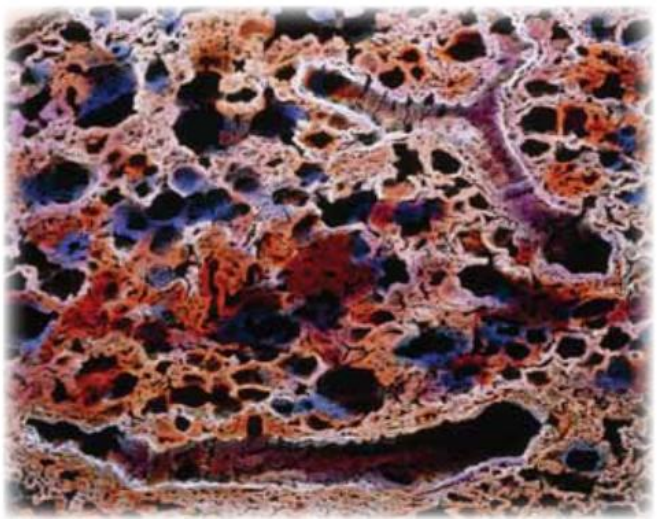


Once the air passes through the pharynx it moves into the **larynx**, which is often called the Adam's apple. It is a chamber surrounded by a firm, flexible material called cartilage, which is the substance found in the end of your nose. In the larynx there are two elastic ridges that are able to vibrate and produce sounds. They are called **vocal cords**. The vocal cords can be relaxed and tightened to produce low and high sounds.

The trachea leads down from the larynx. It is held open by rings of cartilage and looks like a vacuum cleaner tube. It is lined with hair-like extensions called *cilia* that move in waves carrying dust, bacteria and mucus out of the lungs. At the end of the trachea there are two **bronchi** or large tubes leading to each lung.



Each bronchus (singular of *bronchi*) branches into smaller and smaller tubes called **bronchioles**. These continue to branch until they end in tiny air sacs—the **alveoli**. (One air sac is called an alveolus.) There are so many alveoli that if they were all laid out flat they would cover about 100 m^2. It is through this enormous surface area that oxygen and carbon dioxide move into and out of the blood.



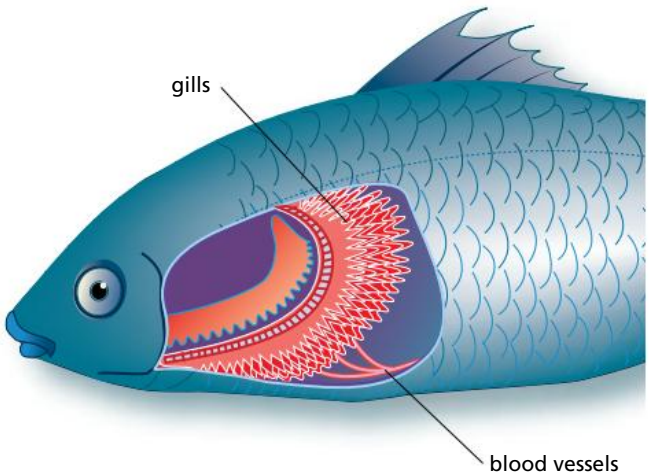
A section of lung

The alveoli

The walls of the alveoli are one cell thick and covered with a fine layer of water. Oxygen dissolves in this water and then moves through the walls of the alveoli, into the blood. Carbon dioxide from respiration is carried by the blood. In the alveoli the carbon dioxide leaves the blood and is exhaled.

Respiratory systems in other organisms

Different organisms have different respiratory and excretory systems. Fish have folded surfaces with many blood vessels called gills instead of lungs. Fish must constantly pump water across their gills to get the oxygen they need. Fast-moving fish swim with their mouths open, moving water across their gills all the time. If they stop swimming they will die.



Instead of lungs, insects have a series of tubes running through their bodies. These tubes branch into smaller ones that carry air straight to the body cells. Because of this, air does not need to be carried in the blood. Air enters these tubes through holes called spiracles on the outside of the insect. The spiracles are opened and closed by muscular movements of the insect's body.

Over to you

1. What happens in your body when you inhale and exhale?
2. Describe the structure of the lungs using these words: trachea, bronchi, alveoli, capillaries.
3. Why is the trachea surrounded by rings of cartilage?
4. Draw a simple diagram to explain how gases move into and out of the alveoli and the blood.
5. During exercise the rate of breathing increases. How does this happen and why is it necessary?
6. Smokers take tar from cigarettes into their lungs. This tar clogs up and blocks the alveoli. Explain how this would affect their lungs during normal breathing, and why smokers are short of breath when they exercise.

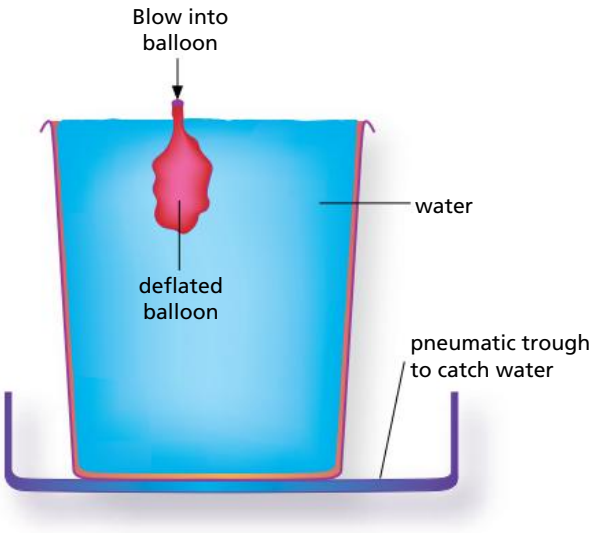
INQUIRY 7 What is your lung capacity?

You will need: bucket, pneumatic trough, balloon, measuring cylinder, stopwatch

Design an experiment to test the following hypothesis:

The fitter you are the more air you can take into your lungs.

Hint: It is possible to measure the volume of air taken into a person's lungs using water displacement.



Was the hypothesis correct? Report on and explain your findings. Discuss whether your design was an accurate way to measure the volume of a person's lungs.

7. If you haven't exercised for a while and then run very fast very quickly, you can wake up the next day with sore rib muscles. Why?
8. People who start to jog and have never done it before soon run out of puff and can't run very far. Yet joggers who exercise regularly can do it so easily. What is the difference?
9. Why does the air you breathe out contain less oxygen and more carbon dioxide than the air you breathe in?
10. Which organisms have the following respiratory systems?
    - **a** Water is constantly pumped through the mouth and across gills to provide this organism with oxygen.
    - **b** Contractions of the body of this organism allow gases into spiracles.

6.4 The excretory system

Excretion in humans

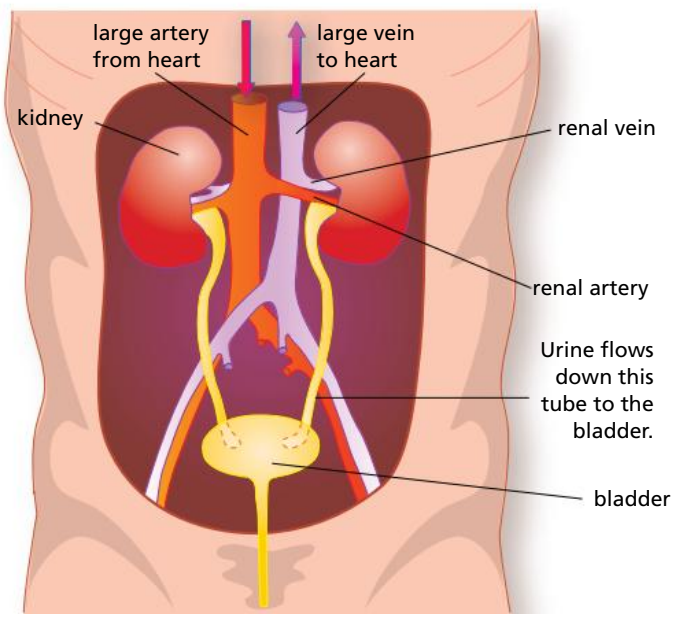
The excretory system removes the excess water and wastes from the body. Removing these wastes is called **excretion** (ex-KREE-shun) and it occurs in the liver and the kidneys.

The liver not only stores and distributes digested food, it also breaks down substances that are harmful or no longer needed by the body. Cell reactions in the liver produce wastes that are removed by the kidneys.

When proteins are broken down in the digestive system to amino acids, they travel to the liver to be stored. They are returned to the blood when needed. The excess amino acids are converted to glucose, glycogen or fat, and this process produces poisonous ammonia. This ammonia then combines with carbon dioxide to make urea that can be safely carried in the blood to the kidneys to be removed.

Water enters the body through the digestive system and it is also produced by our body cells in respiration. If the body has enough water, then any excess is expelled from the kidneys as a waste.

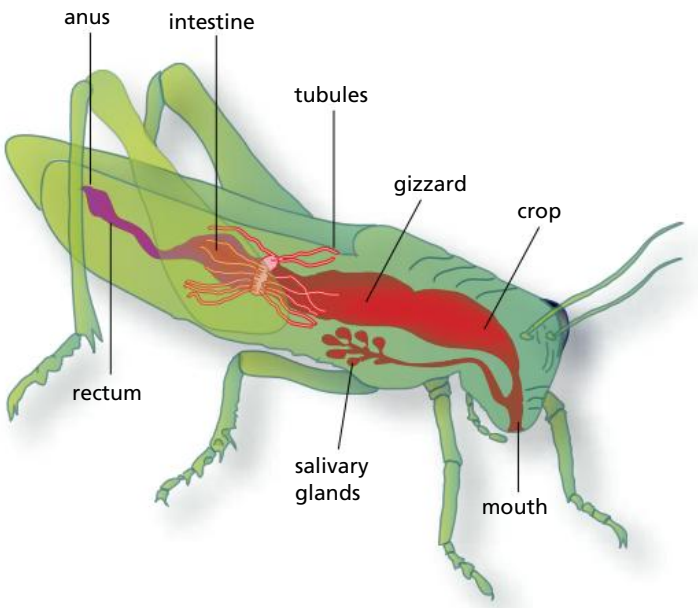
Blood travels to each kidney through the renal artery (*renal* means 'of the kidney'). About one litre of blood passes through the kidneys each minute. The kidneys remove wastes such as urea and excess water from the blood, and these collect in the bladder. They are then expelled as a liquid waste called **urine**.



Other wastes from the body are called **faeces** (FEE–sees). They are the by-products of digestion or leftover material from food (mainly fibre), as well as bacteria and water. The brown colour of faeces is due to a substance produced in the liver when blood is broken down.

Excretion in other organisms

Insects have small tubes or tubules for excretory organs that are linked to the digestive system. These tubules are surrounded by blood in the body spaces of the insect. Fluid from the blood enters these tubules. Water and minerals are taken out of the fluid by the tubules and used by the body. The urine produced then passes through the rest of the digestive system. Urine and faeces both leave the insect through the rectum as a very dry material. Birds have a similar system, so they don't use a lot of water to get rid of their wastes.



The excretory system of a grasshopper

Plants do not have a respiratory or excretory system. Holes in the leaf, called stomata, allow oxygen and carbon dioxide to move in and out of the plant. These gases enter the stomata, move into the spaces between the leaf cells and then into the cells. The stomata can be opened and closed by the plant. Plants get rid of waste products such as water through the stomata. Carbon dioxide and oxygen are released in the same way.

Sweating

The skin also removes wastes, such as water and minerals, from the body as sweat. Its main function, however, is temperature control as explained below.

INQUIRY 8 Cooling by evaporation

You will need: thermometer, methylated spirits, correction fluid, paper tissue, small rubber band, dropper

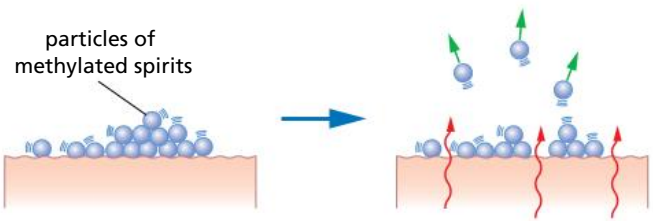
A Put a drop or two of methylated spirits on the back of your hand. What do you notice?

B Put a large blob of correction fluid on a piece of paper. Feel the back of the paper where the correction fluid is. What do you notice?

C Wrap a paper tissue around the bulb of a thermometer and hold it there with a rubber band. Now dip the tissue in cold water, take it out and observe what happens to the temperature.

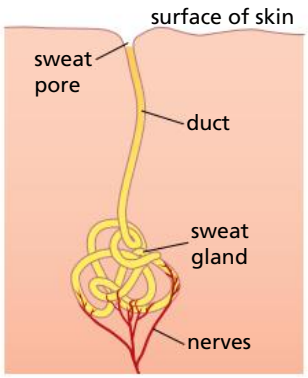
■ The same thing has happened in A, B and C—the temperature decreased. Try to write an inference to explain *why* this happened.

Cooling



In Inquiry 8 when you placed a drop of methylated spirits on the back of your hand, the methylated spirits evaporated. This means the heat from your hand caused the methylated spirits to change from a liquid to a gas. When this happened your hand felt cooler.

Your body uses evaporation to keep you cool. Near the surface of the skin there are many sweat glands. Each gland consists of a coiled tube from which a duct (tube) passes to an opening called a *pore* on the surface of the skin. These glands produce a mixture of salt and body wastes dissolved in water.



Evaporation of this water from the surface of the skin produces a cooling effect. If you are in a breeze or near a fan, the cooling effect is greater, because the evaporated particles are blown away, allowing more evaporation. When you exercise, your body sends a message to the sweat glands via the nerves to produce more sweat to evaporate and cool you down faster.

There are almost 3 million sweat glands all over your body, particularly on the palms of your hands, the soles of your feet, your forehead and under your arms. An adult loses an average of 500–700 mL of water through sweating each day, but can lose as much as 2.5 L/h during vigorous exercise! Males sweat twice as much as females.

Dogs have sweat glands only on their feet. In hot weather they lose heat by panting. They stick out their tongue and water evaporates from it, producing cooling.

Over to you

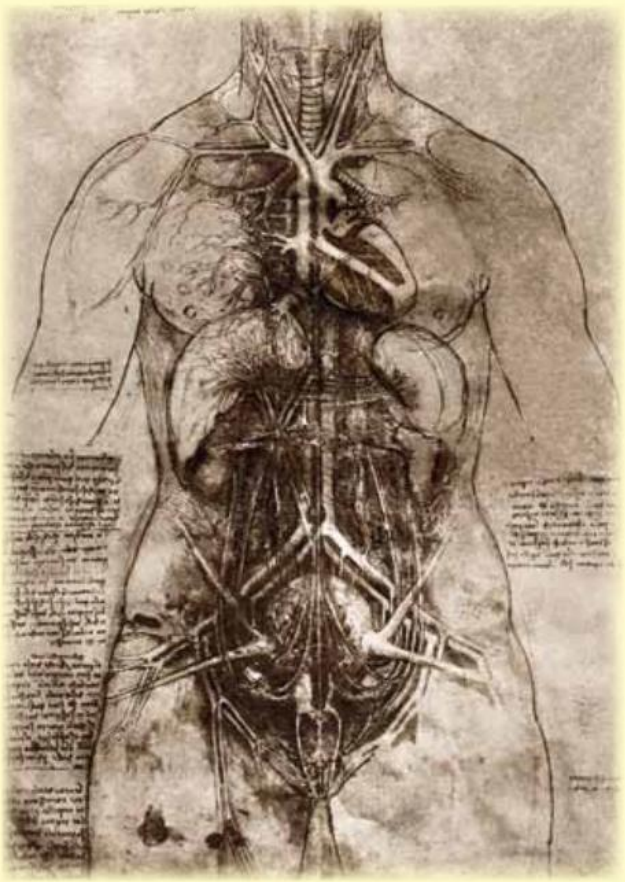
1. How are wastes removed from your body?
2. What does the word *excretion* mean? What substances are excreted from the body?
3. Name the organs of the excretory system.
4. Why is ammonia converted to urea in the body?
5. If you drink a lot of water your urine is almost clear. Little water causes your urine to be very yellow and concentrated. Suggest a reason for this.
6. What is the main function of the skin?
7. What is evaporation? How does evaporation cause cooling on the surface of your skin?
8. If you lick the back of your hand after you have been sweating, it often tastes salty. Give a reason for this.
9. Compare and contrast the respiratory and excretory systems of insects and humans.
10. Urine samples are commonly used to test whether athletes are using drugs. Use the Internet to find out how these tests are performed.

SCIENTISTS AT WORK

Leonardo Da Vinci (1452–1519)

You may have heard of Leonardo Da Vinci since the book *The Da Vinci Code* by Dan Brown hit the bestseller list. Some of his paintings, such as the *Mona Lisa*, *Virgin of the Rocks* and *The Last Supper* held clues that were vital pieces of information in the book. From this you would think that Da Vinci is famous only for his paintings. In fact he was not only a painter, but a sculptor, architect, draftsman, musician, mathematician and scientist.

Da Vinci was considered to be a genius because he invented such things as an armoured tank, a helicopter, a calculator, solar power and the theory of plate tectonics. He even used his studies in anatomy to design a robot. He was so far ahead of his time that many of his inventions could not be built until technology caught up with his thinking. However, he recorded his scientific diagrams, notes and sketches in notebooks that survive to the present day.



Da Vinci's drawing of the organs in a woman's body.

Da Vinci was born near the small town of Vinci, in Tuscany, which is where he gets his name from—Da Vinci means 'of Vinci'. He was well educated and at the age of 14 he was apprenticed to a painter and sculptor called Andrea del Verrocchio. To study the human form, Verrocchio encouraged Da Vinci to learn anatomy. He was given permission to carry out dissections on human corpses at hospitals in Florence, Milan and Rome. He dissected over 30 corpses and made more than 200 drawings. He drew images of the skull, skeleton, brain, lungs, heart, sex organs and even a baby in a uterus. His diagram of the urinary tract is shown below.

Questions

1 What is meant by the sentence 'He was so far ahead of his time that many of his inventions could not be built until technology caught up with his thinking'?

2 Use the internet to investigate some of the body systems that Da Vinci sketched. You could do a search under 'Da Vinci and anatomy'. Alternatively, you could investigate some of the designs he invented such as the parachute, submarine and water turbine. You could also investigate his life and the artworks that he produced. Present a two-minute talk on your findings to the class.



A self-portrait of Da Vinci

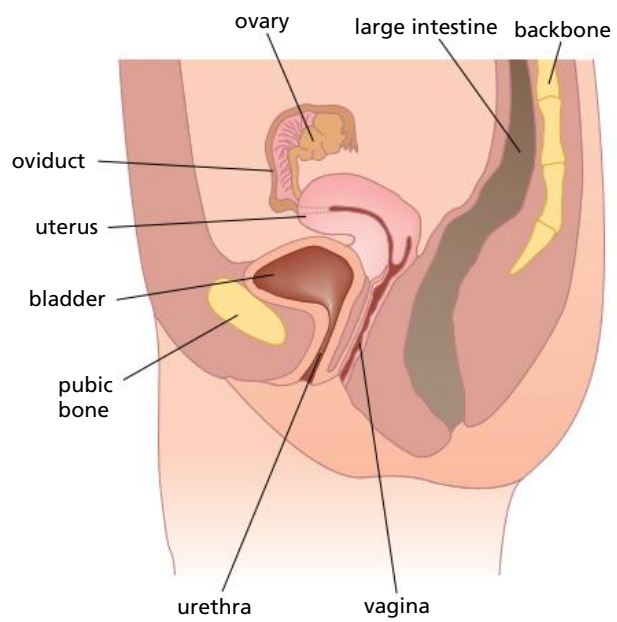
6.5 The reproductive system

The reproductive system is needed to change a human egg into a baby, by the process of **sexual reproduction**.

Female human reproductive system

Egg cells are stored waiting for development in the ovaries of a human female. About 400 000 egg cells are stored in the ovaries but only about 400 will be used. Cells in the ovaries start producing eggs when the female is a foetus inside her mother. At birth, a female has all the eggs she is going to need for her lifetime.

Once a female reaches **puberty**, or sexual maturity, one egg cell finishes its development each month. Each egg cell is contained inside a fluid-filled blister called a *follicle*, which develops and bursts, releasing the egg. This is called **ovulation**. The egg travels towards and through the *fallopian tube* or *oviduct* that links each ovary to the **uterus** or womb. The body prepares the uterus to accept the egg cell if it is *fertilised*—united with a male sperm. The lining of the uterus becomes thicker, softer and enriched with blood. If the egg is not fertilised within two days of ovulation, the lining starts to break down and is shed from the body 14 days later. This is called **menstruation** (MEN-strew-AY-shun), or having a *period*. The full cycle takes 28 days but this can vary from female to female.

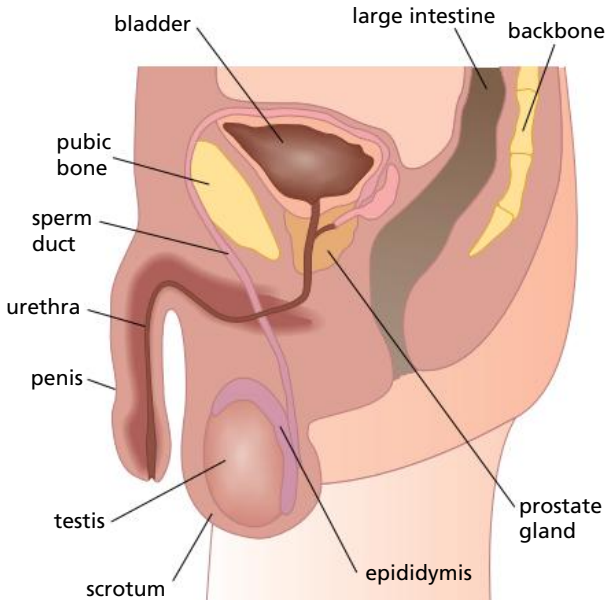


Male human reproductive system

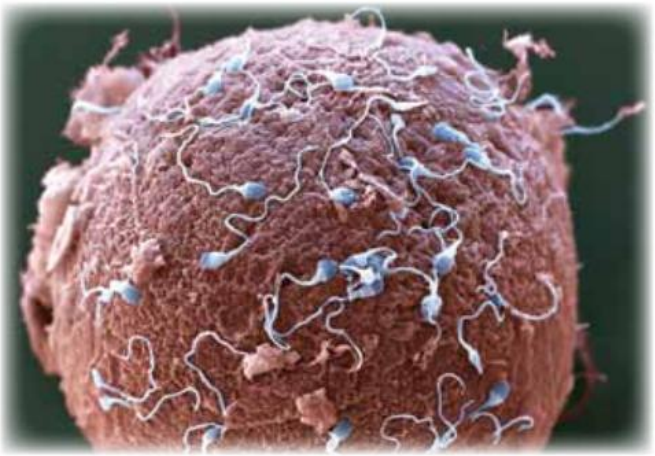
Males produce sperm in the *testicles* (*testes*) and each testicle is contained in a bag of skin called the *scrotum*. The testes hang outside the body because sperm are produced at a temperature 1–2 °C lower than normal body temperature. The testes are made up of coiled tubules. The cells lining these tubules produce sperm, which are stored in the *epididymis* until they are needed. About 100 million sperm cells are made in the testes each day.

For sperm to exit the body, they are mixed with fluid produced by glands in the male reproductive system. This fluid together with sperm is called **semen** (SEE-men). The same tube, called the *urethra*, that carries urine from the bladder out through the *penis* is used to carry semen. The semen is ejaculated (ejected suddenly) from the penis when it is filled with blood and erect. Muscles in the male reproductive system contract to expel the sperm. Urine cannot travel down the tube at the same time as semen.

About 400 million sperm are ejaculated in five millilitres of semen. Hundreds of millions of sperm are ejaculated into the vagina of a female during *sexual intercourse*. However only about 200 sperm will make it to the egg, and only one sperm will fertilise it. Many sperm die in the acidic environment of the vagina, or get stuck in the thickened semen and substances released in the vagina.

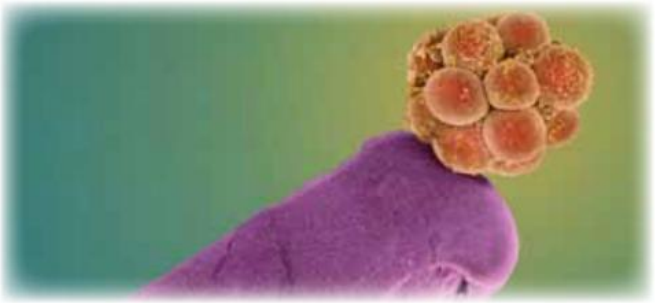


The female's immune system also sends white blood cells to get rid of the invading sperm. Also some sperm go into the wrong oviduct and find no egg to fertilise. It can take up to 40 hours for sperm to make this hazardous journey to reach the egg.



The egg cell is one of the largest cells in the body. Here it is surrounded by sperm trying to fertilise it. Sperm are one of the smallest cells in the body. The image here has been magnified.

If a sperm cell does reach the right oviduct and joins with an egg cell, the membrane of the egg cell changes so that no more sperm can fertilise it. The fertilised egg is now called a *zygote* (ZI-goat) and starts to develop. It divides to produce two cells, and these divide to make four cells. After four days, the zygote is made up of 16 cells. After a further three days it is made up of 64 cells and is called a *blastocyst*. At this stage it attaches itself to the uterus wall and continues to develop. It is now called an *embryo* (EM-bree-oh).



Sixteen-cell ball of human life on the head of a needle

Some of the cells in the embryo become connected with the tissues in the uterus wall, forming a **placenta**. This allows the embryo to receive oxygen and nutrients from the mother and have wastes removed. The embryo is connected to the placenta by an umbilical cord. A fluid-filled sac surrounds the embryo to protect it while inside the mother. After eight weeks, a distinct skeleton, head, arms and legs have formed. The embryo is now called a **foetus** (FEE-tus). Development continues until about 40 weeks from fertilisation, when birth occurs. The single fertilised egg has grown in this time and is now 2 billion times its original mass.



40 weeks

Twins

In the ovary before ovulation, many follicles and eggs start to develop but only one follicle and egg develop fully. The egg is released when the fully developed follicle bursts so that only one child can be produced. However, it is possible for more than one follicle and egg to develop and be released at the same time. If two eggs are released together and then fertilised, *non-identical* or *fraternal* twins occur. The eggs are different so the children do not look exactly the same. However, occasionally twins are produced that look the same as each other. These are called *identical twins*. This occurs when a developing zygote splits and each half becomes attached to the uterus wall and grows separately. The two children produced are the same because they come from the same egg.



Embryo development

When the egg and sperm join together at **fertilisation** growth occurs quite quickly. Many people think that the beginning of pregnancy is when fertilisation occurs. However, doctors say pregnancy starts when the egg implants in the wall of the uterus because very few fertilised eggs make it this far.

Fertilisation to day 10

The fertilised egg develops from a single cell to a zygote and then a blastocyst. The outer cells of the blastocyst start to form the placenta.

Day 10 to day 14

The blastocyst implants in the uterus wall. Blood circulation starts in the embryo. At this stage a home pregnancy test can be used to determine whether the woman is pregnant or not.

Day 14 to 3 weeks

The embryo is about the size of a pencil point and looks like a worm. Its heart begins to beat.

3 to 6 weeks

The embryo is about 5 millimetres long. It has a head and tail. It also has gills, like a fish, which become a throat. It has arms and leg buds, hands and webbed fingers, and eyes.

6 weeks to 3 months

The brain begins to develop and pain sensors develop. However, there is no connection between these and the brain. The embryo has a human face and loses its tail. Fingernails and bones can be seen. Its sex can be determined. It is about 70 millimetres long and weighs about 28 grams. Most abortions are carried out before this stage.

3 months to 6 months

Movement of the foetus can be felt by the mother. It has hair and the lungs develop. The pathways between the brain and the body are formed so the foetus can feel pain and is aware of its surroundings. If it is born at 6 months it has a 14% chance of surviving. It is about 30 centimetres long and weighs about 500 grams.

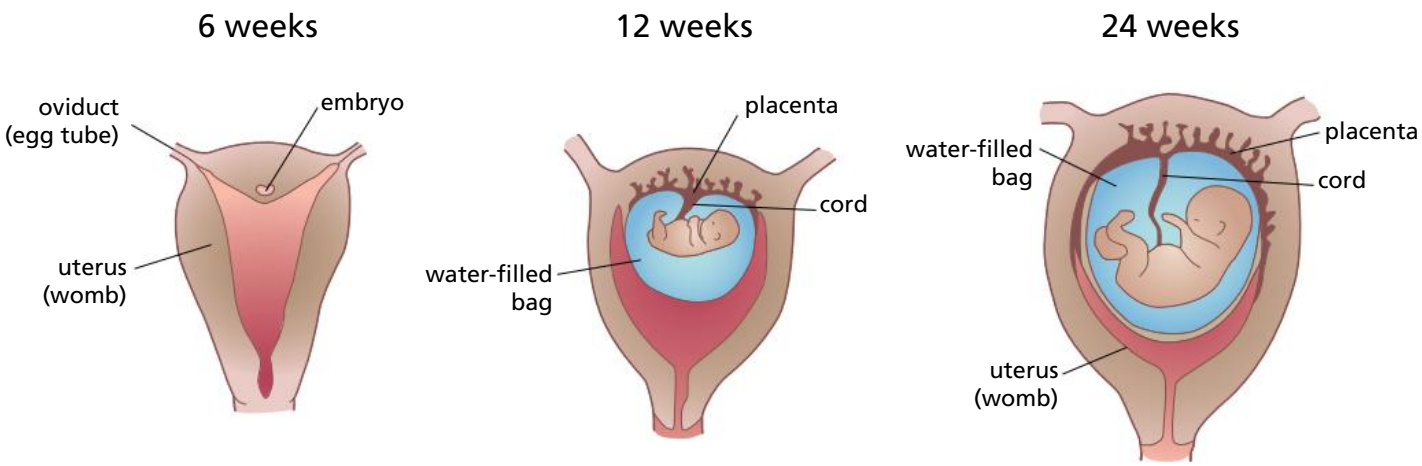
6 months to birth

At 6 months the foetus is almost fully developed. From now on it just grows, and starts to fill the whole space inside the uterus. At birth it is about 50 centimetres long and weighs about 3.5 kilograms.

Teenage pregnancy

As soon as a female starts having a period or commences the menstrual cycle she produces eggs, which can be fertilised. This means that any time she has sex there is a chance of becoming pregnant. The average length of a menstrual cycle is 28 days. It starts on the first day of a female's period, which may last anywhere from three to seven days. Ovulation usually occurs on day 14. However because the human body is not a machine and each female is different, the exact time of ovulation can be hard to predict.

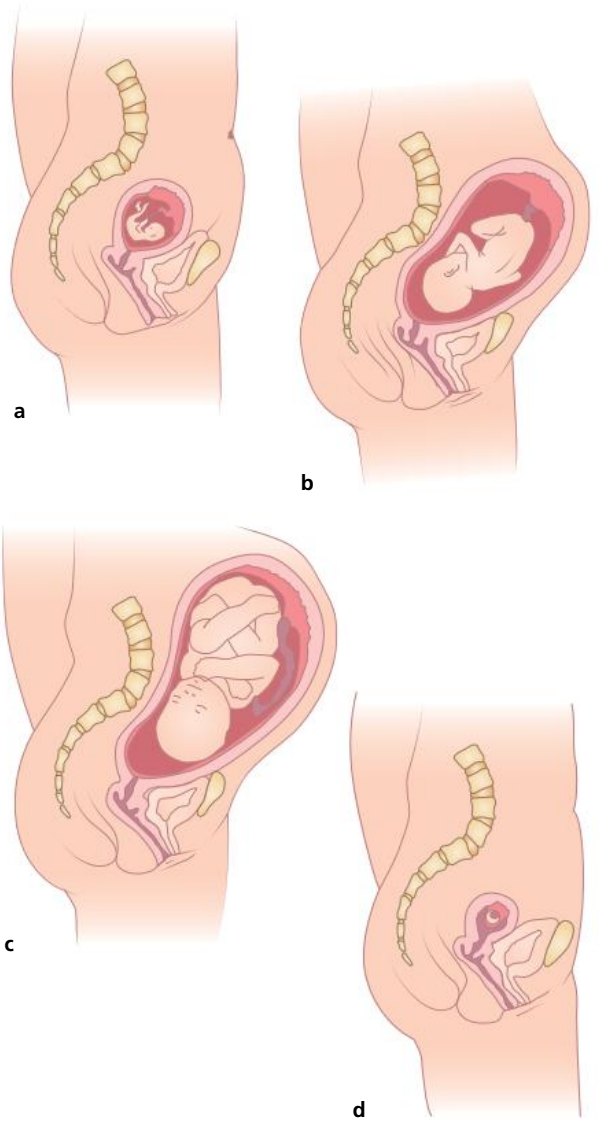
A human egg released from the ovaries can live about 24 to 48 hours. Sperm can live up to five days once inside the female, so there is the possibility of a pregnancy from day 7 to day 20. Therefore contraception should always be used in order to avoid pregnancy. A condom (rubber sheath) should be used because it protects not only against pregnancy but also sexually transmitted viruses like HIV.



INQUIRY 9 Single cell to birth

You will need: models of the male and female reproductive system, video of pregnancy to birth

1. Look at the models of the female and male reproductive systems. On your models, identify the parts labelled in the diagrams on page 131.
2. Watch a video of a pregnancy and birth of a child. Use the information from the video to place the diagrams below in order. Describe in your own words what is happening at each stage of the pregnancy.
3. Your teacher may dissect the reproductive systems of a male and female rat. Compare and contrast these reproductive systems with the human models you have observed.



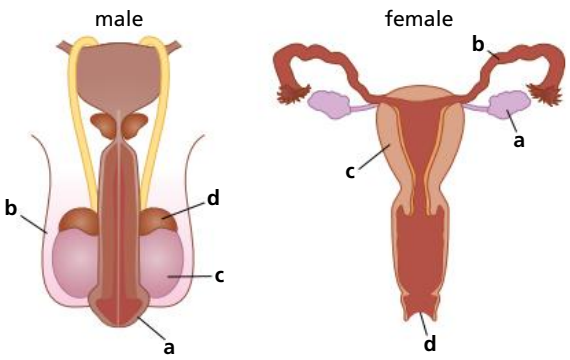
INQUIRY 10 Reproductive cycles

Use the internet to examine the reproductive systems of other organisms. For example, you could examine the different reproductive structures of plants. See page 135 of this text. You could also investigate different life cycles of organisms. For example, rock lobsters produce about 300 000 eggs, yet only five or six survive to reproduce.



Over to you

1. When do a female's ovaries start producing egg cells, and when do these eggs develop?
2. What is the difference between ovulation and fertilisation?
3. Draw a diagram to describe a female's 28-day cycle.
4. Why do the testes hang outside the body of a male?
5. Why do you think that millions of sperm are ejaculated into a woman's reproductive system when only one sperm is needed to fertilise an egg cell?
6. What is the difference between a zygote, a blastocyst, an embryo and a foetus?
7. What is the placenta and why is it needed?
8. Use the diagrams on page 131 to label the diagrams of the female and male reproductive systems shown here from the front.

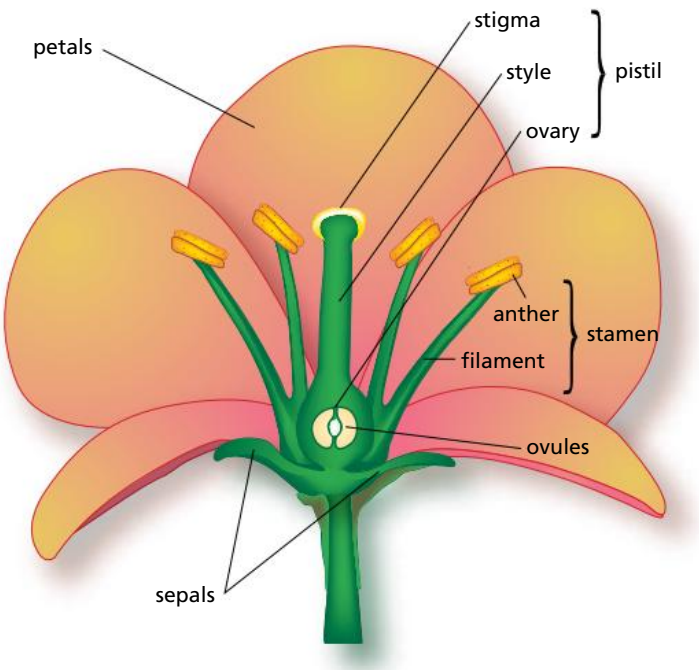


6.6 Plant reproduction

Some plants reproduce by the meeting of male and female sex cells. For example, flowering plants and conifers (plants with pine cones) reproduce in this way.

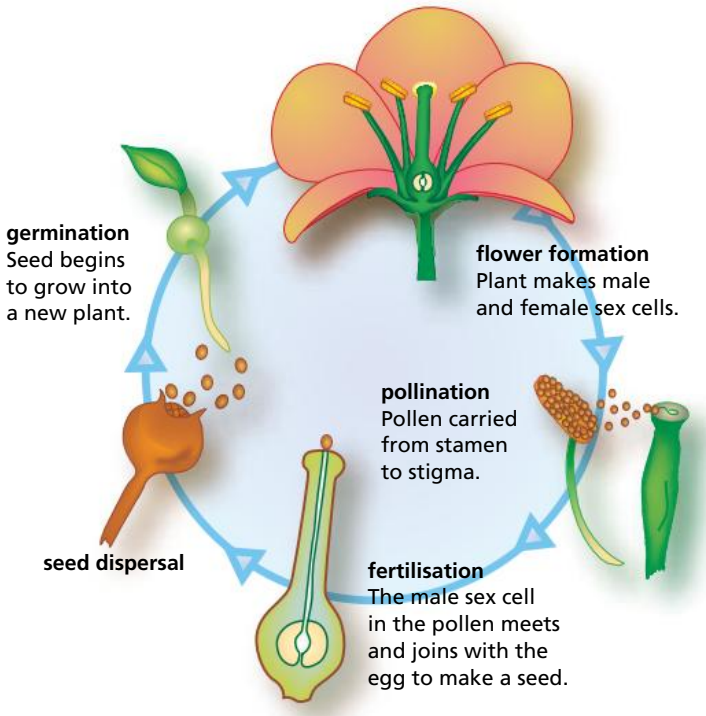
Parts of a flower

The male part of the flower is called the **stamen**. It is made up of the *anther* where the pollen is made, and the *filament*, which holds up the anther. The female part is called the **pistil**. The *stigma* is the sticky tip of the pistil that is used to catch pollen. The stigma is held up by the *style*. At the bottom of the style is the ovary where the **ovules** (egg cells) are found. It is the **ovule** that becomes the seed after fertlisation. The *sepals* are the leaf-like parts that protect and enclose the bud.



Pollen must first travel from the anther to the stigma. This is called **pollination**. The pollen then grows down through the style to meet the egg-cell. When this happens, fertilisation occurs and a seed forms.

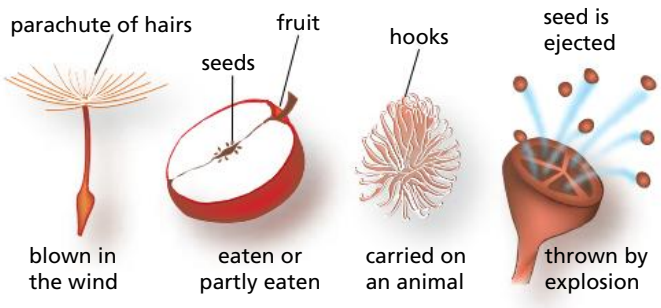
Some plants *self-pollinate*, which means that pollen from the anther of a flower lands on the stigma of the same flower, or another flower on the same plant. However, most plants *cross-pollinate*. This means pollen is released from the anther of one flower and finds its way to the stigma of another flower on a *different* plant. The plants must of course be the same type.



Plants use insects, animals and the wind to carry pollen from one flower to another. Flowers have colourful, bright petals to attract insects to them and nectar or sugar on offer when the insect arrives at the flower. As the insect moves around the flower, it gets pollen on its body. When it travels to another flower the pollen is brushed off on the stigma of that flower.

Plants that are pollinated by the wind have anthers that hang out of the flower to release pollen into the breeze, and feathery stigmas to catch pollen.

Once fertilisation takes place, the ovary becomes the fruit and the ovules become the seeds. The plant must then spread these seeds to help them grow.

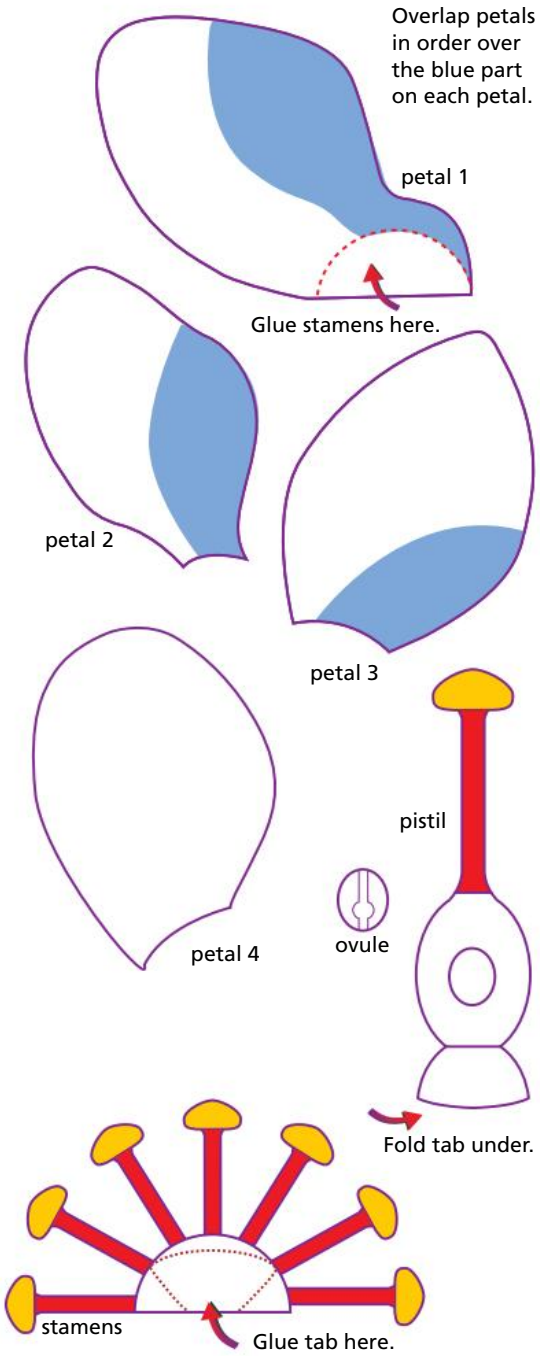


Some plants have seedpods that explode, some are blown in the wind, and some have hooks like burrs that stick to animals so they can be carried away from the plant.

INQUIRY 11 Make your own flower

1 Trace the template of a flower provided here. Enlarge the tracings to the size you would like. The template makes only half a flower, so you will need a second copy to make the other half.

2 Colour your flower parts, cut them out and glue them together. Label each part correctly. You may like to make a stem and leaves to add to your flower.



INQUIRY 12 Dissecting a flower

You will need: cutting board, knife, hand lens, hibiscus flower and leaf, specimens of other flowers and their leaves

Angiosperms are divided into two groups:

a **Monocots** (monocotyledons) have their flower parts in threes and parallel veins in their leaves. There is only one *cotyledon* (COT-el-LEE-don) or first simple leaf that grows from the seed.

b **Dicots** (dicotyledons) have two cotyledons, net-veined leaves and flower parts in fours or fives or multiples of these.

1 Identify the main parts of a flower such as a hibiscus and draw these in your workbook. Using a knife and cutting board, remove the male parts from the flower and draw these. Then remove the female parts. Carefully cut the parts in half. Draw what you see.

2 Examine a range of different flowers. Decide whether the flowers are monocots or dicots. Walk around your school yard or garden and make a list of the monocots and dicots you can find.

4 Grow some seeds from monocots and dicots. Observe the cotyledons as they grow.





Asexual reproduction

Not all organisims reproduce by the meeting of male and female sex cells. Plants can also reproduce by themselves or *asexually*—without the meeting of sperm and egg. Some plants can also grow from a part of a leaf, stem or root.

INVESTIGATION

3 Asexual reproduction

Aim

To investigate asexual reproduction in plants.

Risk assessment and planning

Don't put soil down the sink. Do this investigation outside. Read the instructions on the potting mix packet before handling it.

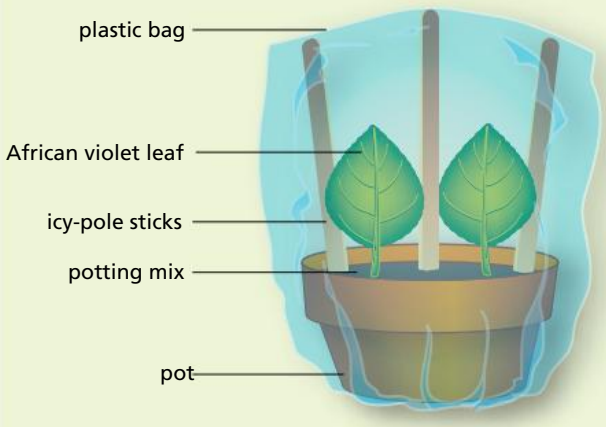
Apparatus

African violet, scissors, potting mix, icy-pole sticks, plastic bag, hormone powder, sphagnum moss, plant pot, pair of gloves

Method

1. Place some sphagnum moss in the bottom of a pot and then fill the pot with potting mix.
2. Using an icy-pole stick make five holes in the potting mix.
3. Cut the leaves off the African violet close to the soil and dip the stalk of each leaf in hormone powder.
4. Place a leaf in each hole, gently pressing the potting mix around the stalk. Water carefully without getting water on the leaves.

   Place the icy-pole sticks in the pot, put a plastic bag over them and tuck the bag under the pot.
6. What do you predict will happen in this experiment? (It may take up to four weeks for you to obtain results.)



Results

Record what happens to the plants.

Conclusion

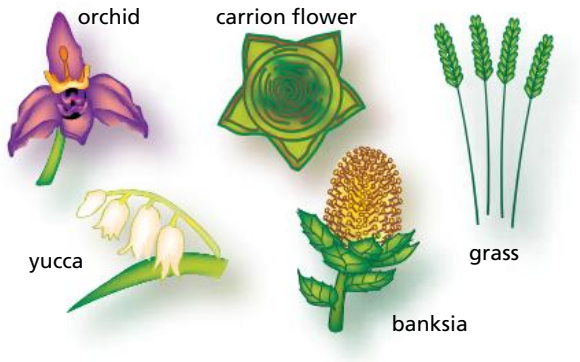
Write your own conclusion.

Write your report

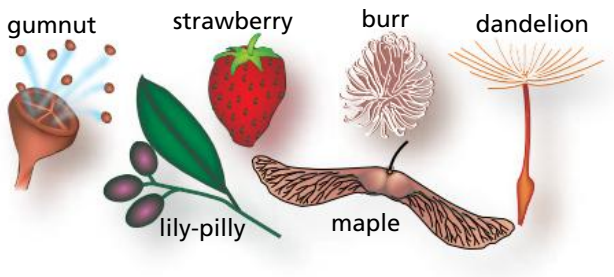
Write up your report in the usual way.

Over to you

1. Which of the following statements are incorrect?
   - **a** The male part of a flower is called a stamen.
   - **b** Angiosperms and ferns both produce seeds.
   - **c** Germination is when the seeds starts to grow.
   - **d** Not all plants reproduce sexually.
   - **e** Pollination and fertilisation are the same.
2. Match each of the following flowers below to one of these pollinators: fly, bee, wasp, wind, moth.
   - **a** An orchid resembles a female wasp.
   - **b** A carrion flower smells like rotting meat.
   - **c** This grass produces a long feathery stalk.
   - **d** The yucca flowers are seen at night.
   - **e** The banksia produces lots of nectar.



3. In conifers or gymnosperms pine cones are produced. The male pine cone releases pollen and the female cone produces the ovules (eggs). How do you think the pollen gets from the male to the female pine cone?
4. Look at the pictures of seeds below. Use them to help you complete the table.



Dispersal method	Examples	Common features
Blown by wind		
Carried by animal		
Eaten		
Thrown by explosion		

THINKING SKILLS

1 Most plants need leaves to take in and release gases, and roots to take up water and anchor the plant to the ground. Design an experiment to show the function of the leaves or the roots. For example

a Place plants with roots and without roots in water. Compare how much water is taken up, or dye the water and see how far the dye travels up the plant with roots and without.

b Keep one plant in the light and one in the dark and use iodine to test if there is food (starch) in the leaves. The leaves of the plant may have to be boiled and softened, then soaked in the iodine overnight for you to see if starch is present.

2 If you measure from the tip of the middle finger on one hand to the tip of the middle finger on the other with your arms stretched out, this is supposed to be the same as your height. If you measure from your wrist to your elbow on either arm, this is supposed to be your foot size. Have a partner measure you and carry out some class measurements to see if these two statements are correct. What variables do you need to control to be able to compare measurements accurately?

3 Urine can be used to measure some aspects of a person's health and diagnose some conditions. If there is more than a trace of glucose or protein in urine, then the kidneys may not be working correctly. These substances are retained by the body. Urinalysis strips indicate the amounts of glucose and protein in urine. Design an experiment using the test strips to show that it does not matter how much sugar or protein you eat over a two-day period, your urine will not show these materials when tested. (Urinalysis strips are available at chemists.)

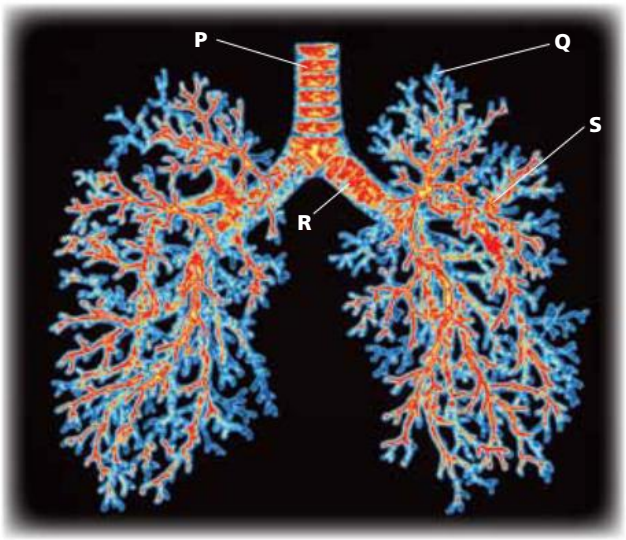
4 Design an experiment to show that the amount of water taken in over a two-day period affects the quantity and colour of urine produced. What variables must you control to get reliable results?

5 The picture below is a representation of the lungs.

a Identify parts P, Q, R and S on the picture.

b What is the function of each part in the lungs that you have identified?

c Describe where you would expect to find capillaries on this picture.



6 Design an experiment to test one of the following hypotheses.

a Lung capacity decreases with smoking.

b Joggers have a better lung capacity than non-joggers.

c Boys have a larger lung capacity than girls.

PROBLEM SOLVING

Now you can complete your human body. How are you going to show all the systems? On separate plastic sheets? As a series of posters? Make sure your diagrams are drawn to scale.

- How does each system fit into the body? Look at the torso in the classroom or in an anatomy book.
- How will you label your diagrams?
- Are you going to use different materials or colours for each system?
- How can you show that the systems are linked?

Knowing and Understanding

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

1 Plants and animals obtain energy in a process called _____. This is where _____ and food are combined to produce _____, _____ and energy.

2 Plants make food in the process called _____.

3 The _____ system is responsible for breaking down large pieces of food so it can be used by our bodies.

4 Air enters the body by the action of the ribcage and _____. Inside the lungs it goes into the _____.

5 A human egg cell and _____ join together to produce a child. This takes place in the _____ system.

6 The _____ system brings gases into the body. Wastes are removed from the body by the _____ system.

7 Flowering plants reproduce with _____. Inside a flower is the male _____ and the female _____. The joining together of ovules and pollen is called _____.

alveoli
carbon dioxide
diaphragm
digestive
excretory
flowers
oxygen
photosynthesis
pistil
pollination
reproductive
respiration
respiratory
sperm
stamen
water

Self-management

Doing better assignments

An important skill is to be able to review your work, especially assignments or projects, to make sure you have covered all that is needed. Students often do not do well on a project because they leave out sections that should be completed. These steps can help you produce better projects.

Look at your completed project from page 115, or any project you have completed.

1 First, make a checklist of all the things you were required to do. This could be a checklist of criteria, questions you had to answer, presentation points etc.

2 Read your work and tick off each point on your checklist if you think you have done it.

3 Get another student to read your work and use the same checklist. Did you both agree? If not, what were the differences? Complete any sections your partner feels you are missing.

4 Re-read your work now and check your spelling. If you are unsure, use a dictionary rather than guess.



Checkpoint

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

OneStopScience

1 State whether the following are true or false.

a The energy needed by body cells is provided by respiration.

b Plants and animals both carry out photosynthesis.

c Carbon dioxide, water and oxygen are the only things needed by organisms to survive.

d Excretion is the muscular movement that moves food along the digestive tract.

e Earthworms and birds both have a crop and a gizzard.

2 Write the equation for respiration.

3 How are the equations for respiration and photosynthesis similar and different?

4 Name the following parts of the human reproductive system

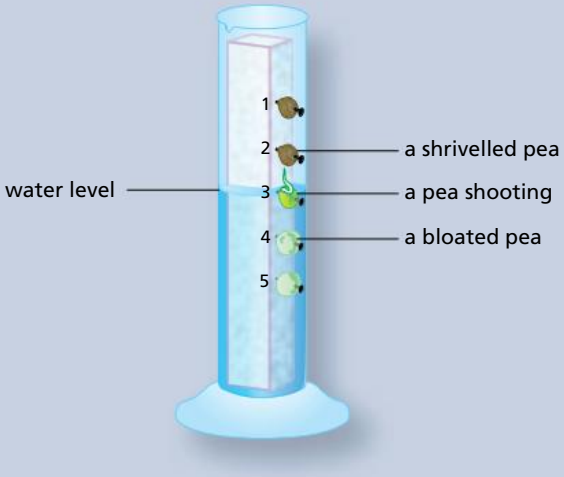
a the place where eggs are made

b the place where an embryo grows

c the place where sperm are stored

d the place where fertilisation occurs.

5 James carried out an experiment to test this hypothesis: Plants need oxygen and water to grow. He set up the following.



James found that only the peas on the water line grew. The ones below the water died and the ones above the water shrivelled up.

Do the results support his hypothesis? Explain.

6 Is it true to say that all life comes from the sun? Explain your answer.

7 A biologist found an unknown organism. She wanted to see if the organism carried out photosynthesis. What signs could she look for that would indicate this?

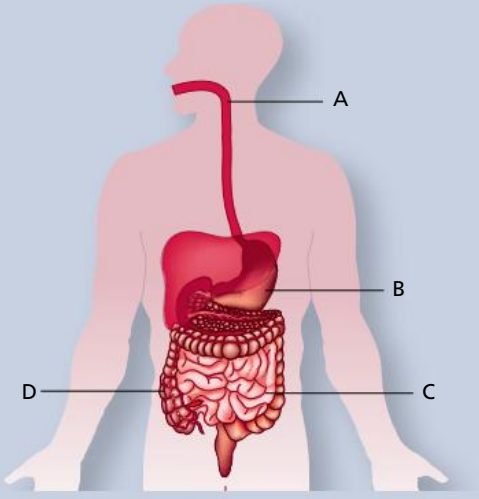
8 What do the following foods become after digestion?

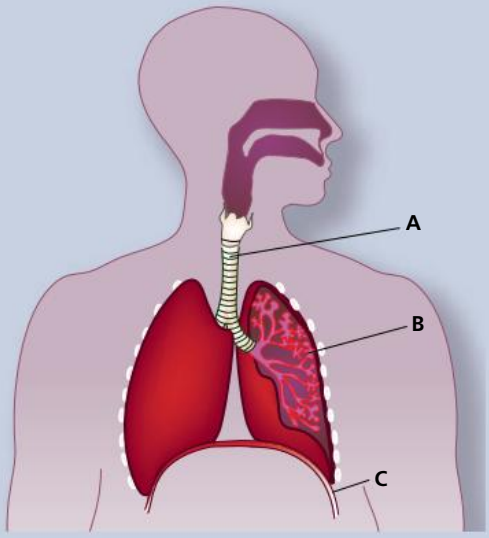
a proteins

b starch

c fats

9 Label the following diagrams:

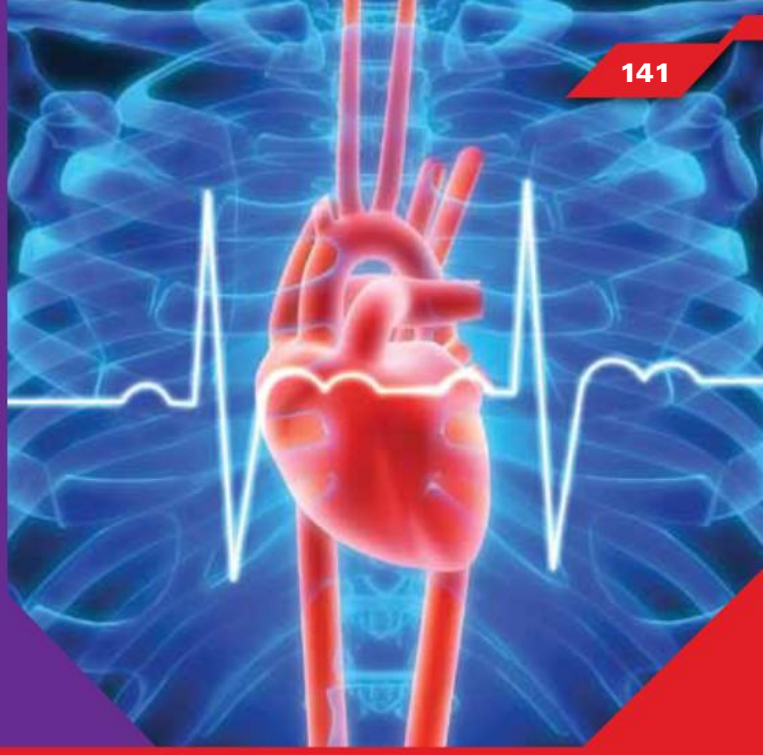




10 Name the parts of the body that carry out excretion and say what they excrete.

11 What are the similarities and differences between the processes of reproduction in plants and animals?

7



Heart and blood

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

Science Understanding

- describe the structure of each organ in the human circulatory system and relate its function to the overall function of the system
- investigate how the circulatory system works, for example by measuring heartbeat and blood flow
- build a model to show how the circulatory system (or part of it) works

Science as a Human Endeavour

- describe the contributions of three Australians to medical research

Science Inquiry Skills

- interpret data in tables and graphs

LITERACY FOCUS

anaemia
antibodies
antigens
aorta
arteries
atria
capillaries
cardiovascular
circulatory system
deoxygenated
haemophilia
leukaemia
lymph vessels
phloem
plasma
platelets
pulmonary artery
red blood cells
reliable
transpiration
veins
vena cava
ventricles
xylem

Focus for learning

Diseases of the heart are one of the biggest cause of death in Australians.

Cardiovascular diseases (diseases of the heart and blood vessels) cause 40% of all deaths, and are the leading cause of death in Australia. One example of this type of disease is *coronary heart disease* or heart attack. A heart attack occurs when the blood supply to the heart is stopped by a blockage in one of the major blood vessels around the heart, causing muscle damage to the heart. This can stop the heart beating.

A stroke is another example of cardiovascular disease. A stroke occurs when a blood vessel leading to the brain becomes blocked. This prevents oxygen getting to the brain cells, causing brain damage. A stroke can result in loss of speech and limb movement, and often causes death. Cardiovascular disease costs our healthcare system around $3.9 billion a year.

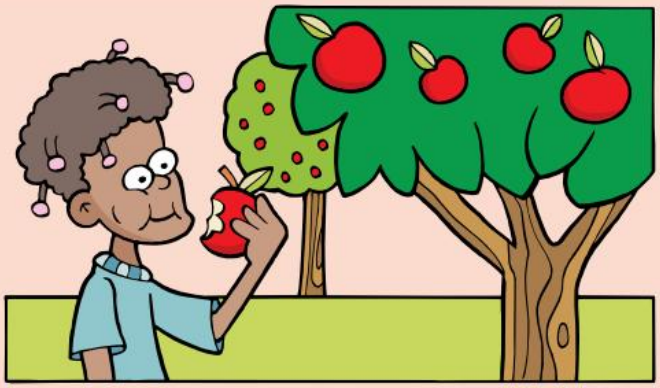
Will you get these diseases? You could, because after the age of 40, there is a one in two chance of having a heart attack for males and a one in three chance for females. For a stroke, this is one in four for men and one in five for women.

To reduce the chance of developing one of these diseases, don't smoke. Smoking is known to cause lung cancer. It can also speed up the hardening and blocking of major blood vessels, making heart attacks and strokes more likely.



Don't smoke.

High blood pressure, being overweight, having a diet high in saturated fat and a lack of physical activity are all risk factors for these diseases. Try to exercise for at least 30 minutes a day. Walking, swimming and cycling are good exercises. Also reduce your intake of foods high in oils and fat.



Eat well.

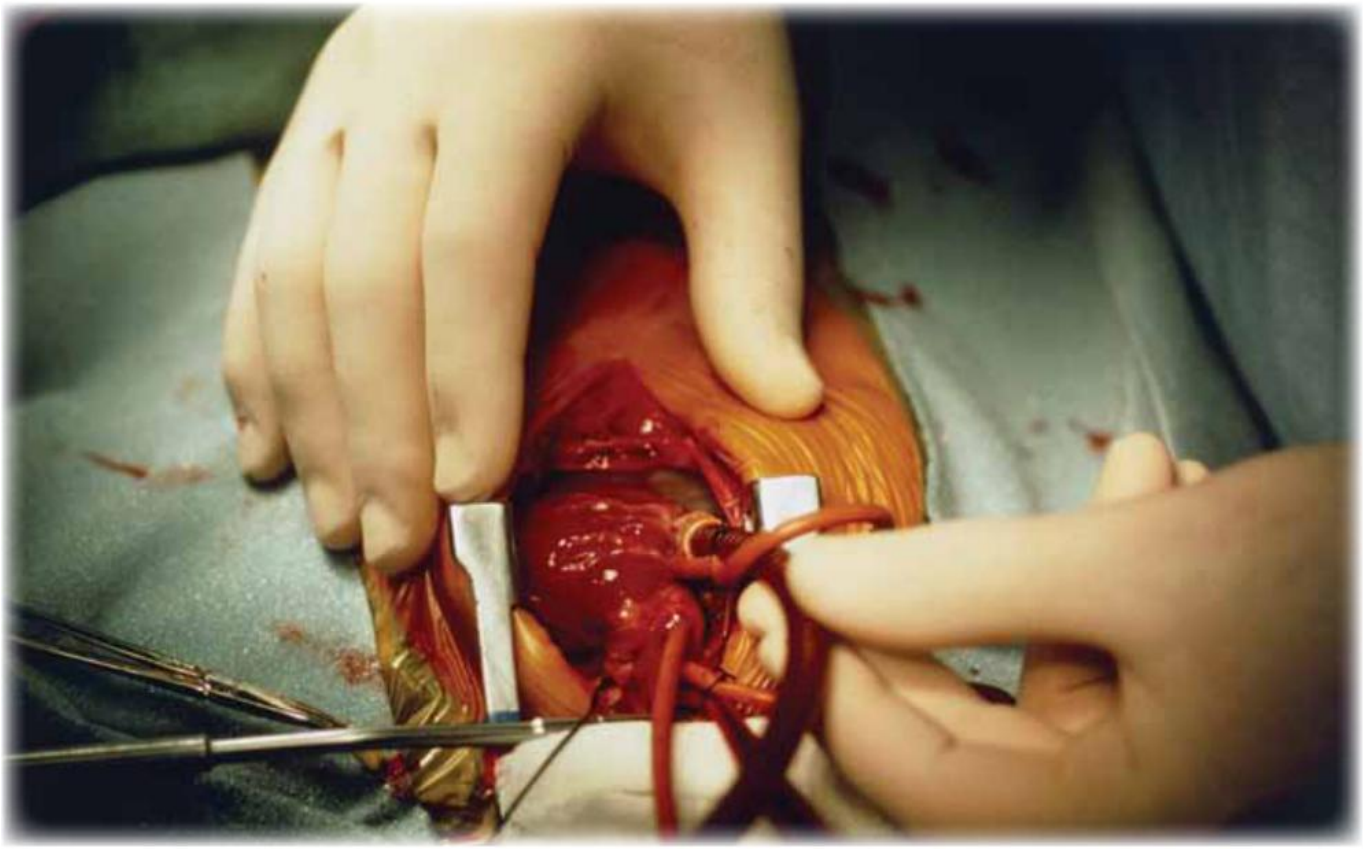


Exercise for at least 30 minutes a day.

Heart transplants

More than 5000 Australians each year wait for heart transplants. New scientific techniques are helping these people, but they often die before a donor heart becomes available. For example a small machine called a VentrAssist has been developed which is able to pump blood out of the heart and around the body. This pump is about one quarter of the size of a human heart and can be placed in the chest. Tubes through the skin connect the device to batteries that need to be recharged after 12 hours. This machine allows the patient to move around. It may give hope to people over 65 who do not qualify for a transplant and give those waiting for a transplant more time.

Stem cells may also be able to help these people. German doctors have used stem cells from a patient's bone marrow to patch his failing heart. The stem cells were injected into a blood vessel near his heart. The cells moved to the area of the heart that wasn't working properly and turned into healthy heart muscle cells, thus repairing some of the damage to the heart.



This heart has been transplanted into a seven-week-old baby boy. The tubes connect it to a heart–lung machine which keeps the baby alive during the operation.

Why study this chapter?

From reading about cardiovascular disease and heart transplants you can see how important it is to know how these body systems function normally. This chapter looks at the **circulatory system**, which is made up of the blood, blood vessels and heart, and carries materials such as oxygen, food and wastes around your body.

PROBLEM SOLVING

Model heart

Your problem in this chapter is in two parts.

1 Build a model out of plasticine showing a part of the circulatory system. For example, you could show:

- how the heart is connected to the body
- how the heart is connected to the lungs
- how blood moves through the heart
- how blood moves through the lungs
- the structure of the blood.

Consider what colours to use to show blood vessels, how to model the sizes of blood vessels and how to label the parts modelled.

2 In no more than one page of writing:

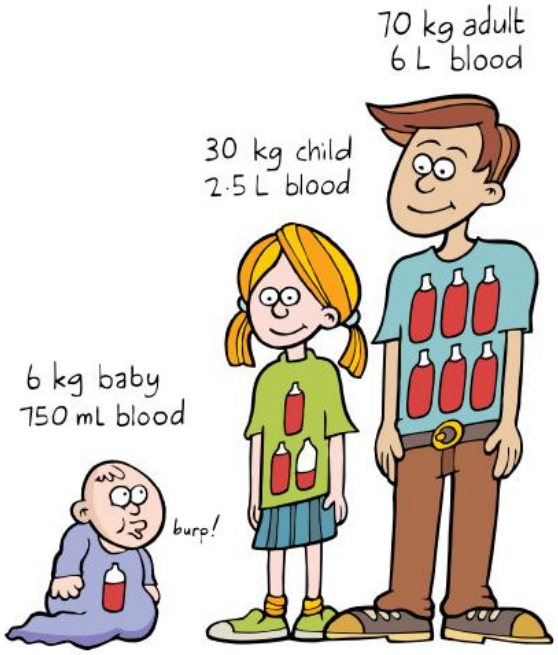
a explain how the modelled body part works

b research one disease that affects the modelled body part and possible technology available to fix it.

To get started, read this chapter. It will provide clues to help with this problem.

7.1 What's in blood?

An adult's body contains about six litres of blood, although this varies with size. Imagine six 1 litre drink bottles and you will see that this is not a huge amount. An infant and a child have even less blood in their bodies. Estimate how much blood you have.



The quantity of blood in the human body

Red blood cells, white blood cells and platelets make up about 40% of blood. The other 60% is made up of plasma. Let's examine each of these parts.

Plasma

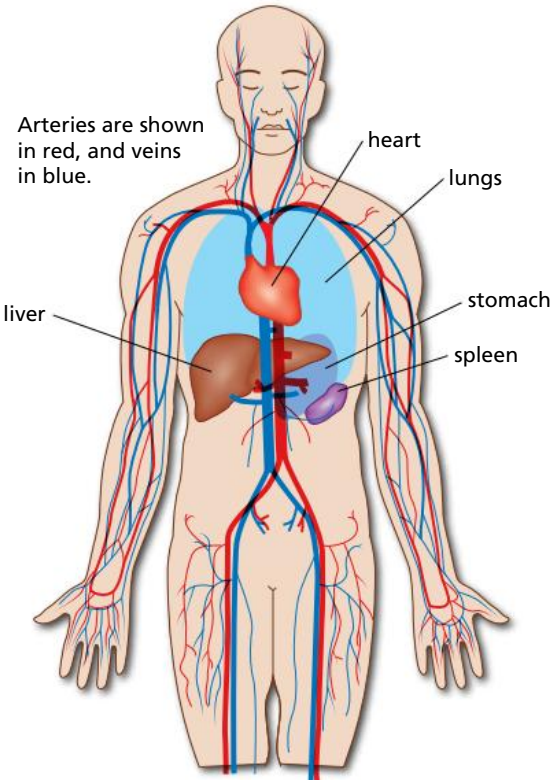
Plasma is the liquid part of the blood. It is made up of about 90% water with many different substances dissolved in it. These substances are carried to and from body cells in the plasma. Plasma contains proteins that help in blood clotting and fighting infections. It also contains substances such as glucose, fats and amino acids, which are carried from the intestine to the liver to be stored, or taken from the liver to where they are needed. The plasma also carries waste products such as urea to the kidneys.

Small amounts of gases such as oxygen, carbon dioxide and nitrogen are dissolved in plasma. There are also substances which are needed to keep cells working properly, such as sodium, calcium, potassium, magnesium and hydrogen carbonate ions. Finally there are hormones or chemical messengers in the plasma, as well as cholesterol (co-LEST-er-ol).

Red blood cells

Red blood cells are disc-shaped cells that start their life with a nucleus (central part) but lose it as they develop. They also lack mitochondria. Instead they have haemoglobin, which is a red-coloured protein that contains iron ions and carries oxygen around the body. It is haemoglobin that gives blood its colour.

There are about 5 million red blood cells per millilitre of blood. Each day about 1% of these are replaced, because they only survive in the body for about 120 days. Red blood cells are made in the red bone marrow of the ribs, pelvis and vertebrae. Dead red blood cells are removed by the liver and spleen. The drawing below shows the circulatory system in relation to these organs.



What red blood cells do

The role of red blood cells is to carry oxygen to other cells in the body. Blood flows through the lungs and it is here that the haemoglobin in the red blood cells combines with oxygen. The red blood cells then circulate through the body to the body cells, where oxygen is released from the haemoglobin.

The job of the red blood cells is not finished here. They also carry carbon dioxide from the cells back to the lungs to be breathed out. Most carbon dioxide is dissolved in the blood rather than combined with haemoglobin.

White blood cells

There are far fewer **white blood cells** than red blood cells in the blood. In fact there is only one white blood cell for every 600 red ones. White blood cells can move from the blood and into body tissues. Fluid from body tissues returns to the circulatory system through special vessels called **lymph** vessels, which link to form the lymphatic system. White blood cells are therefore found in lymph as well as in blood. Some white blood cells are made in the lymphatic system; others are made in the bone marrow and the spleen.

What white blood cells do

The job of white blood cells is to fight disease-causing organisms such as bacteria that enter the body. Some white blood cells *engulf* or flow around and swallow up the bacteria. Others produce substances that make the bacteria harmless. Some white blood cells known as *lymphocytes* (LYMPH-o-sites) produce **antibodies** to fight foreign substances called **antigens**. Antibodies can only fight the particular antigen for which they are made. However the antibodies are like a blueprint (detailed plan) and can be used to make more antibodies to fight the foreign substance. Once the body has made this blueprint, it can fight the foreign substance if it appears again in the body.

You know when white blood cells are working against an infection when pus appears in a cut or a wound. This is a mixture of dead tissue, bacteria and white blood cells.

Platelets

Platelets and plasma proteins are part of the emergency repair team of the body. These substances patch and fix damaged tissue. There are about 400 000 platelets in a millilitre of blood.

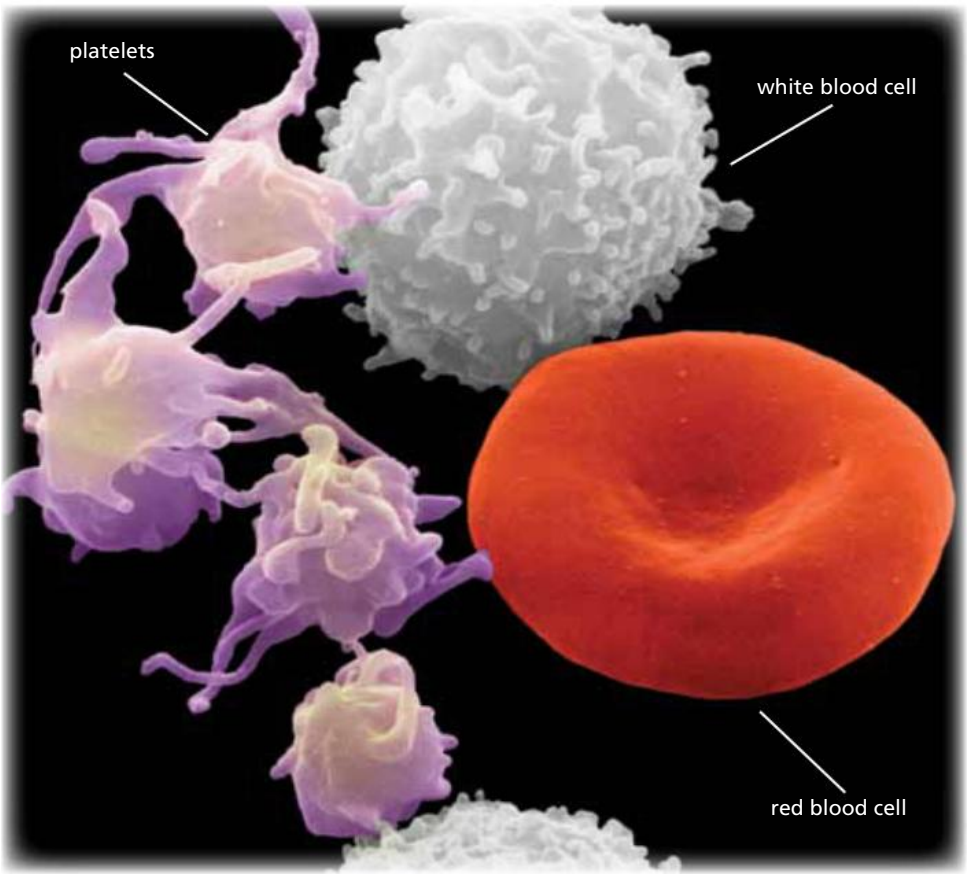
Platelets are small bodies that come from cells in the red bone marrow. They are involved in blood clotting. In areas where tissue is damaged the platelets cause plasma proteins to form a mesh (net) over the damaged area, allowing a clot to form. This is a bit like putting a bandaid on a wound.

Blood diseases

Substances called 'clotting' factors also stop bleeding in the body. People who suffer from the disease *haemophilia* (HEE-mo-FIL-ee-a) lack one of these factors, and so their blood doesn't clot. To prevent bleeding to death internally from a small knock or cut they must have injections of blood with the missing clotting factor in it.

There are other problems that can occur with the blood. For example, *anaemia* (A-NEE-mee-a) occurs when fewer red blood cells than normal are made, so that the body cells receive less oxygen. Lack of iron in the diet can cause anaemia.

Another blood disease is *leukaemia* (loo-KEE-mee-a) in which the bone marrow produces abnormal white blood cells that do not function properly. Leukaemia sufferers need a bone marrow transplant to survive.



INQUIRY 1 Examining blood cells

You will need: a microscope and prepared slides of blood, or a bioviewer (micro-slide-viewer) and prepared slides

Your teacher will show you how to use a microscope. Examine different prepared slides of red and white blood cells. Draw what you see and describe any differences.

If a microscope is unavailable, use a bioviewer to examine prepared slides of blood.



Over to you

1 What is cardiovascular disease? How common is it in Australia?

2 What is the difference between a stroke and a heart attack?

3 After the age of 40, what are the chances of having a heart attack or a stroke for males and females?

4 How can you reduce your chances of having a heart attack or a stroke as you get older?

5 **a** What parts of the body make up the circulatory system?

b Why is it important to study the circulatory system?

6 Copy and complete these sentences using words from this section.

a There are about _____ litres of blood in an adult. It is made up of red and _____ blood cells, platelets and plasma.

b The plasma is the _____ part of the blood, made up of 90% _____.

c Red blood cells have no _____. Instead they have a red oxygen-carrying protein called _____.

d White blood cells can be found in blood, body tissues or _____ vessels. They fight infections and _____ substances in the body.

e Cell bodies called _____ are involved in clotting the blood.

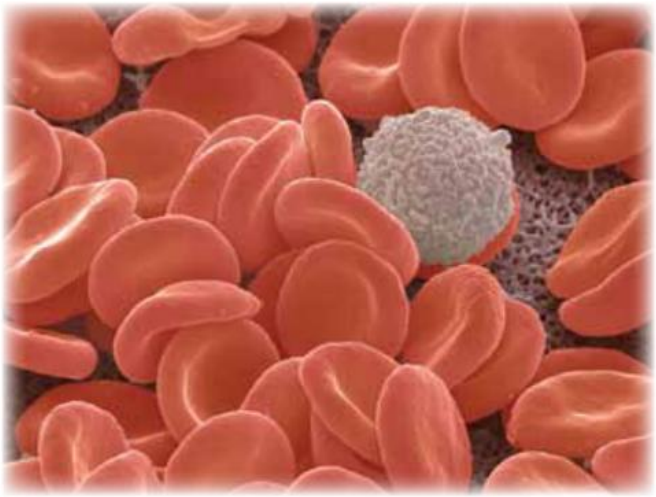
7 When you have a vaccination you are injected with a dead, a modified or a milder version of the disease-causing organism. What part of the blood would react to the vaccination? What would happen? Explain your reasoning.

8 It has been stated that more than 50% of Australians do not have enough iron in their diet. Why is this a problem? Iron is mainly found in red meat. If you don't eat meat, what else could you eat to get iron? (Food nutrition tables may help you.)

9 Why are blood transfusions needed for people who have haemophilia?

10 What is different in the blood of people with leukaemia? What treatment is needed?

11 Which two different types of blood cells can be seen in this photo? How do you know?



PROBLEM SOLVING

What can you use from this section to help you with your problem? You could build a model showing the structure of the blood and what each individual part looks like. What colours will you use for each part? Could you show these parts in a blood vessel? To do this you will need to read more about the different blood vessels that make up the circulatory system in the next section.

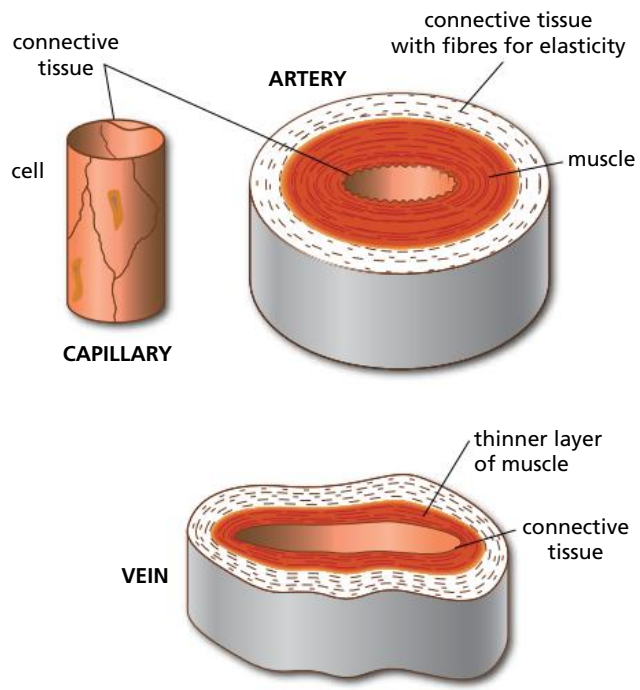
7.2 Blood pressure

There are three types of blood vessels in the body, each with a different job to do.

Arteries

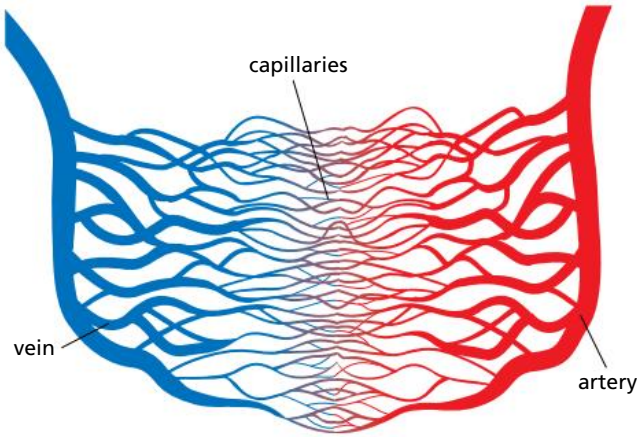
Arteries are the vessels that carry blood away from the heart. When the blood leaves the heart it is forced out under tremendous pressure. The heart must pump strongly enough to force blood through the arteries so that it reaches all the body cells. With each pump of the heart the blood surges into the **aorta**, which is the major artery leaving the heart. This artery then branches into other arteries that carry blood to all parts of the body. The first branches carry blood from the heart to the heart muscle, head, neck and arms, then other branches lead to the stomach, spleen, liver, legs and other body parts.

Arteries are wide, elastic, thick-walled vessels that can withstand the pressure of the blood inside them. Their walls have three different layers. The first one is made of fibres that give the vessels elasticity. Inside this there is a layer of muscle which can act to change the size of the artery. Finally there is an inner layer of connective tissue. The arteries branch into smaller and smaller vessels until they reach a network of fine narrow vessels called **capillaries**.

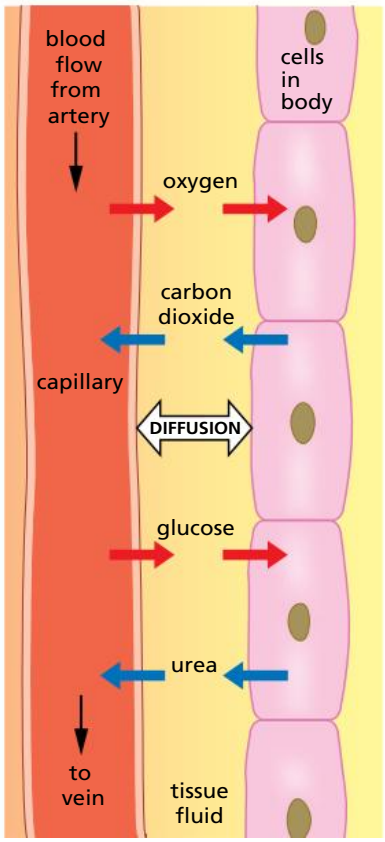


Capillaries

The walls of capillaries are only one cell thick. They are tiny, narrow vessels. Some are so small that red blood cells are squeezed flat as they move through them.



There are capillaries near every cell in the body. It is in the capillaries that the exchange of substances takes place. Substances such as oxygen and dissolved food needed by the cells move across the walls of the capillaries and into the cells. Waste products such as carbon dioxide move from the cells back into the capillaries.

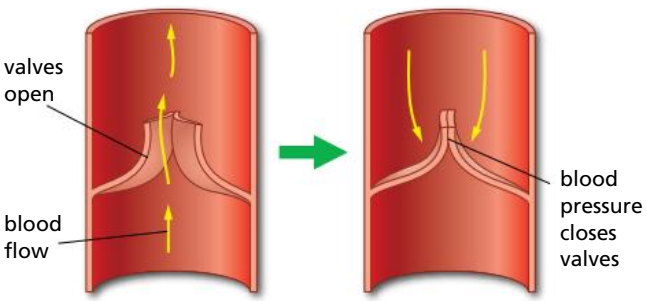


Veins

Capillaries join and unite into larger vessels that come together to form even larger vessels called **veins**. It is the job of veins to carry the blood from the capillaries back to the heart.

The walls of veins are not as rigid as those of arteries and they have a smaller muscle layer and more connective tissue. This is important because veins need to be squashed and squeezed to enable blood to move through them. This occurs when muscles in the body contract, pressing against the walls of the veins and pushing the blood inside them along.

Valves in veins, which are like one-way trapdoors, prevent the blood from flowing in the wrong direction. Blood is allowed to move through a valve towards the heart, but not allowed to move back in the opposite direction.



In this way blood travels from the heart, through arteries, to capillaries and then back to the heart via veins. Not all the blood in the body travels through the heart each time it pumps. Blood that travels to the head may return to the heart faster and be pumped out again. This blood may make many circuits through the heart before blood that makes its way to the legs returns.

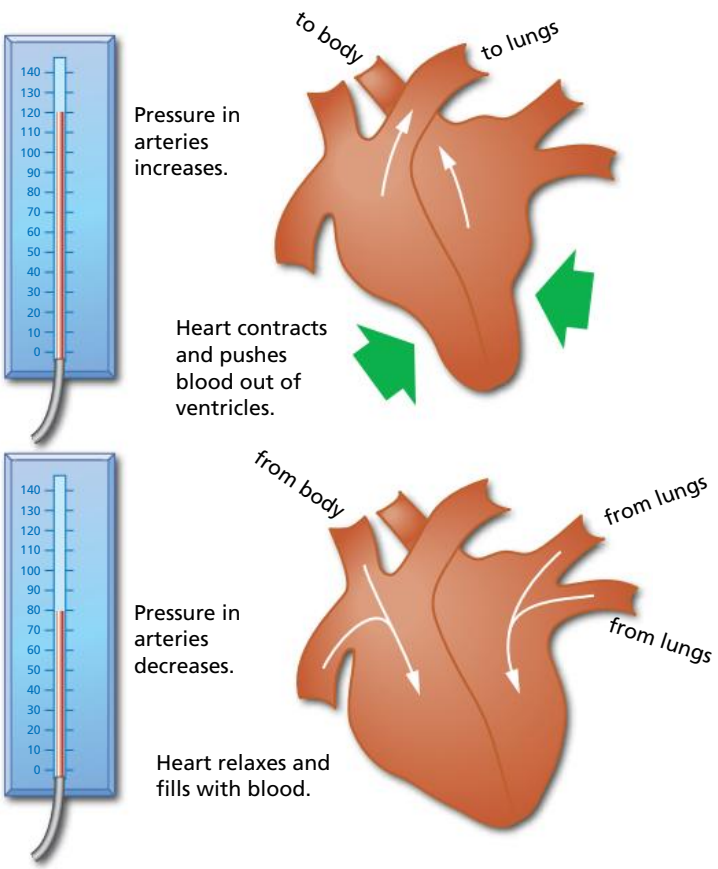
Blood pressure

About 3 million Australians suffer from high blood pressure, and have a greater risk of heart disease because of this. *Blood pressure* is the pressure of blood on the inner walls of the arteries as blood is pumped through them. Blood pressure is measured and recorded as a fraction, e.g. 120/80 or 120 over 80. Both numbers in the fraction are measured in millimetres of mercury. What do these numbers mean?

Blood is forced out of the heart as the heart muscle contracts. This is where the muscle shortens in order to exert a force that can expel blood out of the heart. At this point the pressure in the arteries is at its highest. This is the contraction stage of the heart cycle, and the number on top of the fraction (the 120 in the example) is the blood pressure at this stage. The number on the bottom of the fraction (the 80 in the example) is the pressure during the relaxation phase of the heart cycle when the blood pressure in the arteries drops.

High blood pressure or *hypertension* occurs when the pressure in the arteries is too high. The heart is therefore working harder than it should. A risk factor in developing hypertension is eating foods high in fat, because fatty materials can build up on the inner walls of arteries. This reduces the diameter of the blood vessels, making it harder for blood to flow through them. This in turn limits oxygen flow to the tissues and may cause death if a vessel is blocked completely. The fatty build-up also leads to a loss of elasticity and causes hardening of the arteries.

There are usually no symptoms of high blood pressure (you don't feel anything), so your blood pressure should be checked regularly as you get older. Following the healthy life guidelines on page 142 of this chapter will also help.



INQUIRY

2 Measuring blood pressure

You will need: a blood pressure gauge called a sphygmomanometer (SFIG-mo-ma-NOM-it-er) and a stethoscope. It is suggested that your teacher demonstrates this activity because it involves stopping blood flow to the arm.

1. You will measure your blood pressure, which will be recorded as a fraction. Your teacher will place a rubber cuff around your upper arm and tighten it by pumping it up. This stops blood flow to the artery in the upper arm. When the cuff is slowly deflated, the artery starts to squirt blood with each heartbeat. The sound of this blood flow can be heard using a stethoscope placed below the cuff. Record the value on the pressure gauge just before the first sound is heard. This is the pressure during the contraction phase of the heart cycle.
2. As the cuff is slowly deflated, more and more blood flows through the artery. The sound heard becomes muffled when blood flow through the artery is continuous. Record the value shown on the pressure gauge when the sound becomes muffled. This is the relaxation phase of the heart cycle.
3. Compare blood pressure readings as a class and draw up a graph to present the data. The skill section on the next page will help you.

Blood pressure readings (mm of mercury)	
Normal for daytime	below 135/85
Normal for night time	below 120/75
Normal (average over 24 hours)	below 130/80
High	above 140/90
Very high	above 180/110

INVESTIGATION

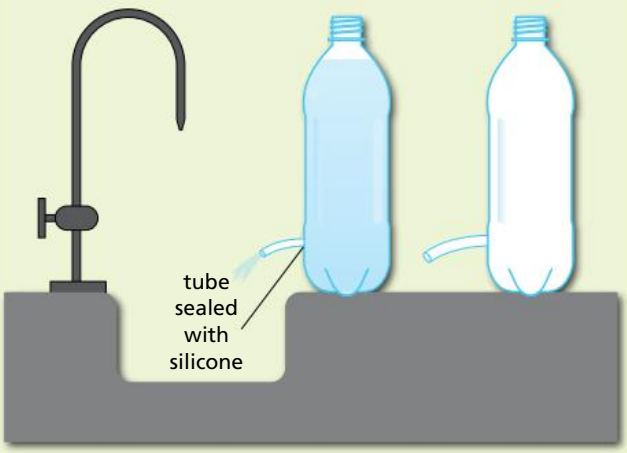
1 Blood pressure model

Aim

One of the contributing factors to high blood pressure is the build-up of fatty deposits in arteries. This can narrow the arteries and in some cases block the vessel completely. Design an experiment to see what the rate of flow of water in a narrow tube is like compared to that in a wider tube, under the same pressure.

Risk assessment and planning

What equipment will you need? Make a list of this. The following diagram may give you some ideas.



Conclusion

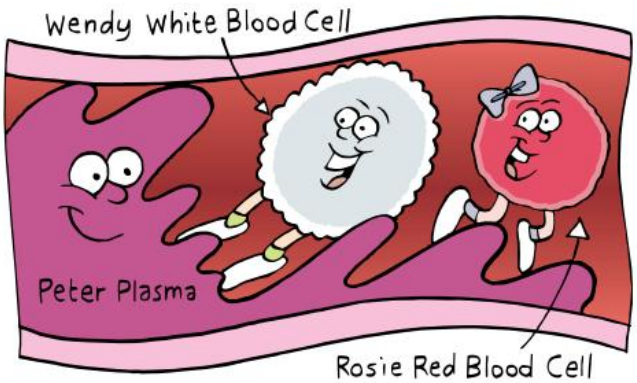
How is the rate of flow of water in a tube affected by the diameter of the tube? What do you think happens to the flow of blood in arteries as fatty deposits build up inside them?

INQUIRY

3 Your bloodstream

Imagine you are your bloodstream. Write a story describing what you are made of, what you look like and what you do. You may like to start with this beginning or invent your own.

You can't see me but I am larger than you can imagine. I am made up of kilometres of pathways. I put out the garbage and I run errands for the 60 billion cells that are my customers. I am so important to them that they would die without me. I am (insert your name here)'s bloodstream.



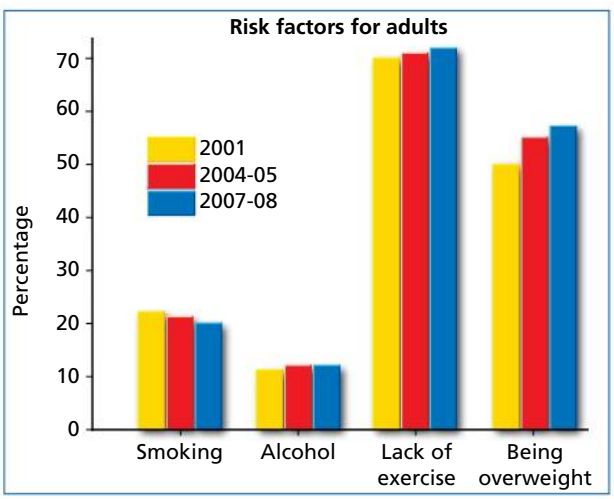
SKILL

Interpreting data

When you are given data to examine or analyse in science, it is often quantitative, using numbers. This type of data can be displayed in a table or as a graph. Whenever you are given data you need to follow these steps.

- **a** First look at where the data came from; that is, is the data *reliable*? If it is untrue or misleading then it is not reliable.
- **b** Who is presenting the data? Do they have a *bias* (prejudice) that could affect the data?
- **c** What is the data about? If it is a graph, what is the title telling you? Make sure you understand exactly what is being presented before attempting to analyse the data.
- **d** If the data is quantitative, what was measured, how were these measurements obtained and what units were used? If the data is graphed, which is the *independent variable*? (Remember this is the variable that is purposely changed in an experiment or set by the tester, and its values appear on the horizontal or x-axis.) Which is the *dependent variable*? (This is the variable that is affected by changes in the *independent variable*, and graphed on the vertical or y-axis.)
- **e** Interpret any scales. For example you may be given a scale that goes up in units of 10 (i.e. 0–10–20–30–40 …) It sometimes helps to use a ruler and pencil to draw lines across the graph showing where these points are.
- **f** Look for any trends or patterns in the data.

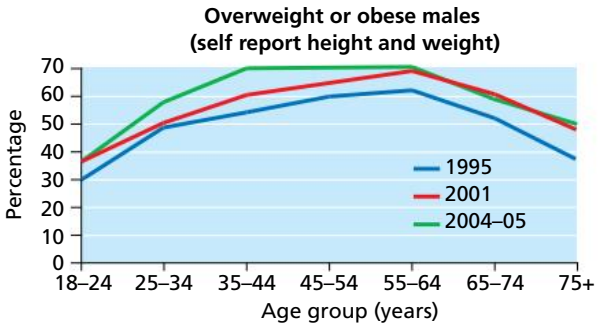
1 The following graph was included in the 2007–08 National Health Survey, which was carried out by the Australian Bureau of Statistics.

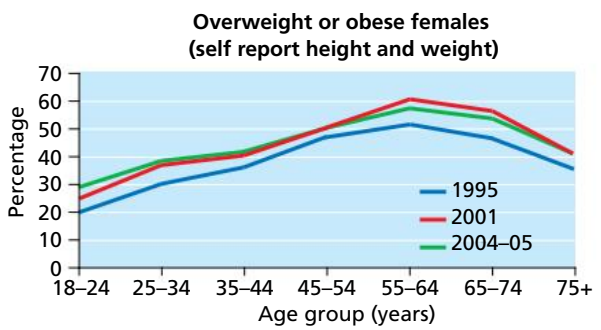


Source: Australian Bureau of Statistics

- **a** Do you think the data for this graph is reliable? Where does this data come from? Why do you think this information is being presented?
- **b** What is the information about?
- **c** What risk factors were examined?
- **d** The x-axis on this graph shows the percentage of the population who carried out the various activities. For example, almost 20% of the population smoked in 2007–08. This means one in five Australians were smokers. Which were the highest and lowest years for each of the risk factors looked at?
- **e** There seems to be a trend or pattern of declining numbers of smokers from 2001 to 2007-08. What other trends can you see?
- **f** Make a prediction about what you think may happen in the light of the data. The four risk factors that were looked at have been linked with an increased chance of developing lung cancer and heart disease. What do you predict will happen to the numbers of people who develop these diseases, based on the information here?
- **g** Imagine you are a spokesperson for National Health. Write a report outlining what lifestyle decisions are needed to remain healthy, in light of your answer to Part f.

2 Examine these graphs before completing the questions on the next page.





Source: Australian Bureau of Statistics

SKILL

Interpreting data

The two graphs on the previous page are also from the 2004–05 National Health Survey. They show the numbers of obese (excessively overweight) people as reported in the survey. Imagine you are a reporter for a newspaper reporting on the numbers of obese Australians. In your report discuss the following.

- **a** Where did the data come from?
- **b** What are the two graphs telling you?
- **c** Explain any patterns or trends that you notice.
- **d** State the possible consequences of these trends for our future health.
- **e** Suggest some lifestyle options to reduce the numbers of obese people.

3 The table below contains data from the Australian Bureau of Statistics.

- **a** What is the table telling you?
- **b** Which disease causes the greatest number of deaths in Australia?
- **c** Explain any patterns or trends that are occurring and the possible consequences of these trends for our future health.
- **d** How could the numbers in this table be reduced?
- **e** Draw separate graphs showing the percentages of total deaths for each year for these four causes: heart disease, trachea and lung cancer, dementia and Alzheimer's disease, diabetes.

Over to you

1 State whether the following are true or false.

- **a** Arteries carry blood away from the heart.
- **b** Veins are more muscular than arteries.
- **c** Capillaries have valves in them.
- **d** Veins are one cell thick.
- **e** Blood moves back to the heart through veins by muscular contraction.

2 Why is high blood pressure dangerous?

3 Look at the drawing below. What blood vessel is it and why do you think so?



4 Why are capillaries one cell thick? Predict some of the problems that could occur for body cells if the capillary walls were thicker.

5 If an adult had a blood pressure reading of 140/90 what would this mean? What steps could they take to change this reading?

6 Why are valves important in veins. Why are there no valves in arteries?

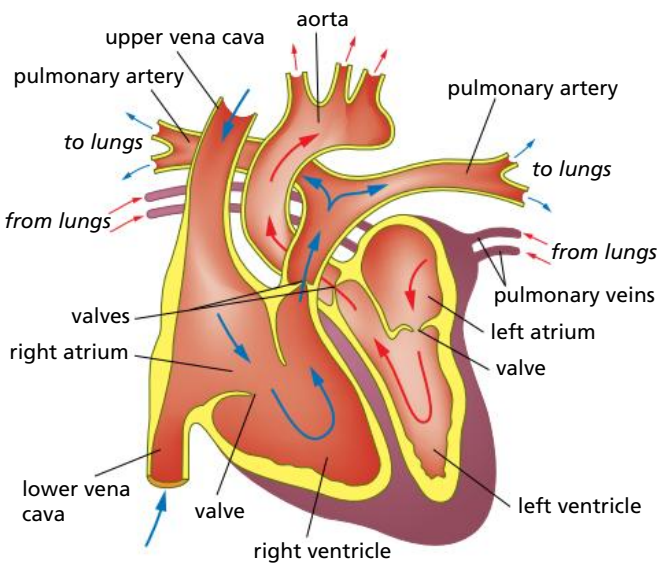
Cause of death	1998		2002		2007	
	No. of persons	% of total deaths	No. of persons	% of total deaths	No. of persons	% of total deaths
Heart diseases	28299	22.2	26063	19.5	22729	16.5
Strokes	12271	9.6	12533	9.4	11491	8.3
Trachea and lung cancer	6742	5.3	7303	5.5	7626	5.5
Dementia and Alzheimer's disease	3244	2.6	4364	3.3	7320	5.3
Respiratory diseases	6134	4.8	6256	4.7	5762	4.2
Colon and rectum cancer	4640	3.6	4649	3.5	4107	3.0
Diabetes	2877	2.3	3329	2.5	3810	2.8
Blood and lymph cancer	3527	2.8	3791	2.8	3603	2.6
Heart failure	3234	2.5	3367	2.5	3444	2.5
Diseases of kidney and urinary system	2618	2.1	2887	2.2	3230	2.3

Source: Australian Bureau of Statistics 2009

7.3 The heart

The human heart is a muscular pump about the size of a clenched fist.

The heart has four chambers—two **atria** (singular atrium) and two **ventricles**. Blood carrying wastes such as carbon dioxide from the cells returns to the heart through veins. This blood is said to be *deoxygenated* (low in oxygen and high in carbon dioxide). Two large veins empty blood directly into the right atrium of the heart. These are the upper **vena cava** bringing blood from the head, neck and arms, and the lower vena cava bringing blood from the rest of the body. The words *vena cava* come from Latin. *Vena* means vein and *cava* means hollow, so *vena cava* means 'hollow vein'.



Right side of the heart

The *right atrium* allows the collected blood to flow into the right ventricle through a valve that snaps shut when the blood has passed through it. This stops blood flowing backwards. The *right ventricle* then contracts, forcing blood out of the heart through another valve into the **pulmonary artery** which branches to carry blood to each lung. The word pulmonary comes from the Latin word for lung. Blood must go to the lungs before it is pumped around the body, so that carbon dioxide can be removed and replaced with oxygen.

In the lungs the pulmonary artery branches into smaller and smaller vessels, eventually leading to the capillaries in the walls of the **alveoli** (see page 126). Carbon dioxide moves out of the blood, through the capillary walls and into the alveoli. Meanwhile oxygen moves into the blood. It is picked up by the haemoglobin in the red blood cells. The blood then leaves the capillaries, moving through larger and larger vessels until it enters a branch of a **pulmonary vein** which empties blood back into the *left atrium* of the heart.

Left side of the heart

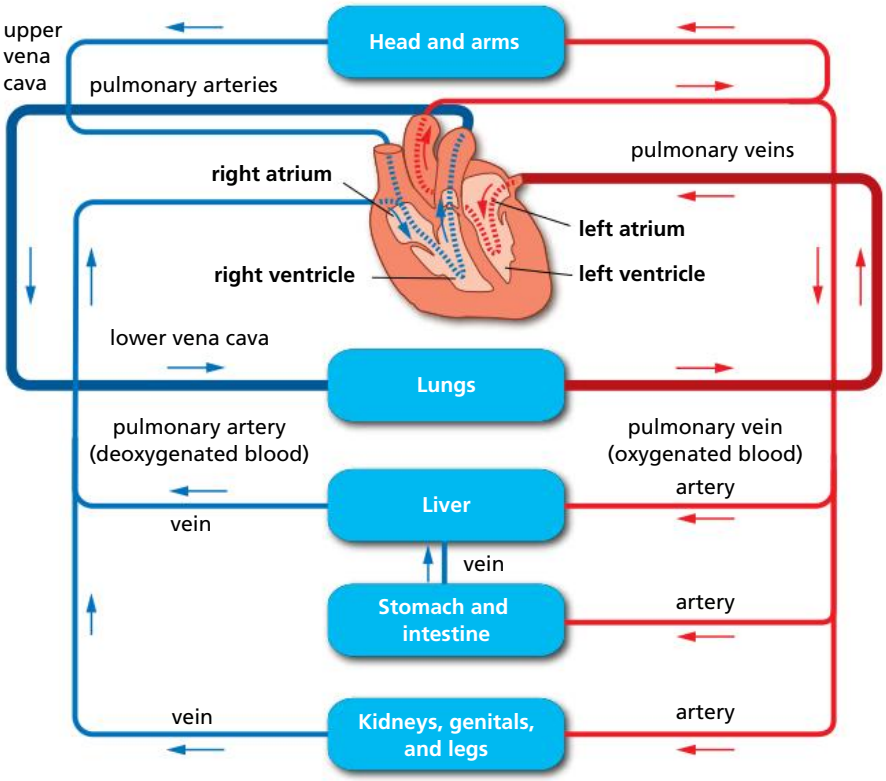
Blood moves from the *left atrium* through a one-way valve to the *left ventricle*. When this ventricle contracts, blood is forced through another valve into the aorta. This artery then branches into smaller arteries to carry oxygen-rich blood or *oxygenated* blood around the body to the body cells.

In general, arteries carry oxygenated blood away from the heart, while veins carry deoxygenated blood towards the heart. The pulmonary artery and the pulmonary vein which take blood to and from the lungs are an exception to this. The heart is part of a continuous circuit of moving blood, as illustrated on the next page.

The heartbeat

The heartbeat that you can hear through a stethoscope (Inquiry 4) is a series of contractions and relaxations of the heart itself. Both ventricles have thick muscular walls to pump blood out of the heart. The left ventricle is thicker than the right as it pumps blood to the body. The right ventricle only pumps blood to the lungs. The first sound in the heartbeat is long and low, and is heard when the valves between the atria and the ventricles close and the ventricles contract. The second sound is shorter and louder. It is the sound of the valves snapping shut between the ventricles and the arteries leaving the heart, and the relaxation of the ventricles. Although there are two sides to the heart, they beat almost together.

There is an area on the wall of the right atrium that starts the heartbeat. It is called the *heart pacemaker* because it keeps up the rhythmic beating of the heart. How fast the heart beats is called the *heart rate*. There are two nerves that can alter the heart rate, one making the heartbeat faster and the other making it slower. A resting heart rate for adults is around 70 beats per minute. During exercise the heart rate and the amount of blood pumped with each beat can be increased to supply the cells with the extra oxygen they need.



The heart is part of a continuous circuit of moving blood. The parts coloured red show the path of oxygenated blood moving away from the heart. The parts coloured blue show deoxygenated blood returning to the heart.

INQUIRY 4

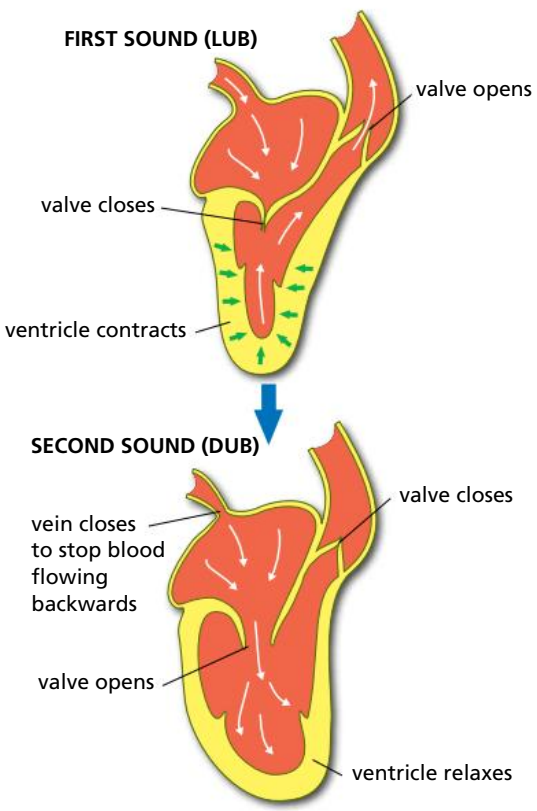
The heartbeat

You will need: stethoscope, tape measure, stop watch

The diagrams on the right show what happens to the heart during a heartbeat.

The sounds that are heard in the stethoscope have already been described.

1. Choose a partner and get them to sit quietly for one minute.
2. Listen to your partner's heartbeat and try to describe what you hear.
3. Use the information on the previous page to describe what is happening to the heart when you hear these sounds.
4. Get your partner to jog lightly on the spot for three minutes.
5. Listen to your partner's heartbeat now. Describe any change from the resting heartbeat.
6. Get your partner to run 20 metres as fast as they can and return.
7. Listen to your partner's heartbeat again and describe any further changes.



INVESTIGATION

2 Heart dissection

Aim

To examine and identify the major parts of a sheep's heart.

Risk assessment and planning

Read through the investigation and discuss these questions with your teacher before starting.

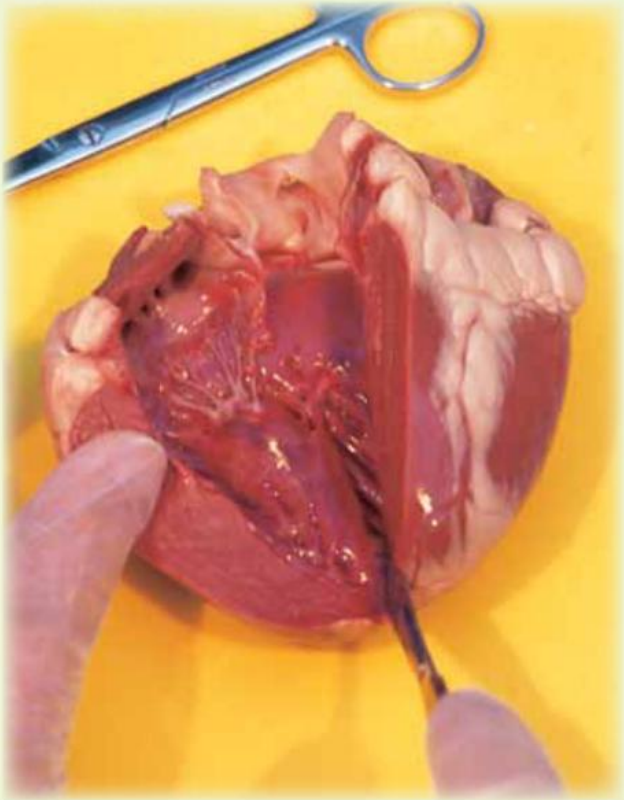
1 What is the value of doing a heart dissection rather than just looking at a picture in a book?
2 What safety precautions are necessary when handling dead organs, to safeguard yourself and others?
3 How should dissected tissue be correctly disposed of?
4 How should the laboratory and any equipment used be cleaned?

Apparatus

- sheep's heart
- newspaper
- plastic bags
- disinfectant
- dissecting equipment
- cutting board
- laboratory coat or apron
- disposable gloves
- ruler
- plastic tubing

Method

1 Lay some newspaper on the bench and place the cutting board on top of the newspaper.
2 Put the sheep's heart on the cutting board.
3 Before you cut the heart examine it on the outside.
   a What does the heart look like? Describe its shape and colour.
   b What does it feel like (through the gloves)?
   c Measure the heart's dimensions and make a sketch of it, including any vessels you can see. (Gently insert plastic tubing into the different vessels leading to and from the heart to see where each blood vessel goes.)
   d How do you know which is the left and right side of the heart?
4 Now cut the heart in half. The photograph top right is how the heart should look after completing this step.



5 Draw the heart as it appears now. Label the atria, the ventricles and the valves.
6 Describe the atria, ventricles, valves and blood vessels, including what they feel like.
7 Examine the walls of the atria and compare them to those of the ventricles. Why are the atria thinner than the ventricles?
8 Are there any differences between the left and right atria? Are there any differences between the left and right ventricles? Suggest reasons for any differences.
9 Draw arrows on your diagram to show how blood moves through the heart.

Results

Present your drawings and descriptions of the heart.

Discussion

1 Was the heart dissection what you expected? Explain.
2 What did you learn from doing a heart dissection that you could not have learnt by reading a book or using a computer?

Conclusion

Write a brief summary about the sheep's heart.

SCIENTISTS AT WORK

Dr Victor Chang (1936–1991)

The Australian of the Century voted at the People's Choice Awards in Sydney in 1999 was the late Dr Victor Chang. He was given this award because of his pioneer work in heart transplants. He established the National Heart Transplant Unit at St Vincent's Hospital, Sydney, in 1984, and worked to raise funds to maintain the unit. His research led to the development of an artificial heart valve and an artificial heart. Almost 300 Australians have received a heart, lung or heart–lung transplant at the unit Chang developed.

Victor Chang was born in Shanghai. He came to Australia in 1953 to go to high school and after doing so, went to Sydney University. He graduated with a Bachelor of Medical Science and then went on to complete a Bachelor of Medicine and Surgery. Dr Chang worked at St Vincent's Hospital in Sydney before going to England to learn more about cardiac (heart) and thoracic (chest) surgery.

The first heart transplant in Australia was performed in 1968 by Dr Harry Windsor. The patient survived only 6 weeks because the heart was rejected. In 1980 an anti-rejection drug was developed and Chang saw that it was possible to perform successful heart transplants. He made a submission to the government to set up a transplant program at St Vincent's and then worked to raise funds to achieve his goal. On 24 February 1984 the first heart transplant under this program was performed at St Vincent's.

Dr Victor Chang's vision did not end there. He travelled and lectured in China, Hong Kong, Singapore, Malaysia and Indonesia, and exchanged surgical knowledge and skills with medical staff in these countries. He won many awards for his outstanding efforts.

Tragically, on 4 July 1991, Dr Chang was fatally shot in Sydney. The unit Chang developed continues the cardiac research and development that he pioneered. Today its transplant program is one of the most successful in the world, with a 90% survival rate for transplant patients after a year and an 85% survival rate after five years.



Dr Victor Chang



Prof Anne Keogh

Professor Anne Keogh

Anne Keogh is a Professor of Medicine and Senior Heart Transplant Cardiologist at St Vincent's Hospital. She is currently researching heart failure and pulmonary hypertension (high blood pressure in the lungs). This disease affects patients of all ages.

At school Professor Keogh studied English, Maths, Science and French. Although she loved music, writing songs, playing the guitar, flute and piano, she decided to go to university to study medicine instead of pursuing a musical career.

In the first two years of the course it was only the encouragement of a friend that kept her going. She took physiology in her third year and became hooked on the way the body worked and how it responded to disease. In training to become a doctor Anne chose cardiology, the study of the heart.

When Professor Keogh started her training in cardiology, Dr Chang had performed his first heart transplant. Professor Keogh wanted to get involved in this exciting new area of medicine. At this time almost 100% of patients with severe heart failure died and transplantation was their only hope. She began to explore the use of new heart failure drugs before the transplant, and drugs to stop rejection after the transplant. Today patients have a 90% chance of surviving.

In 2000, Professor Keogh's work led her to be appointed the President of the International Society of Heart and Lung Transplantation, which was a great honour. She loves her work because heart failure and heart transplant cardiology make a big difference to people suffering from heart disease. She warns that not all areas of medicine are as exciting.

Today Professor Keogh continues her work in heart disease which has brought positive results in an exciting area of medicine.

SCIENTISTS AT WORK

Dr Dan Timms

Dr Dan Timms' father, a plumber, died of heart disease in Prince Charles Hospital in Brisbane in 2007. Dr Timms has a PhD in engineering, and his father's illness made him determined to try to develop an artificial heart to help people like his father suffering from heart disease.

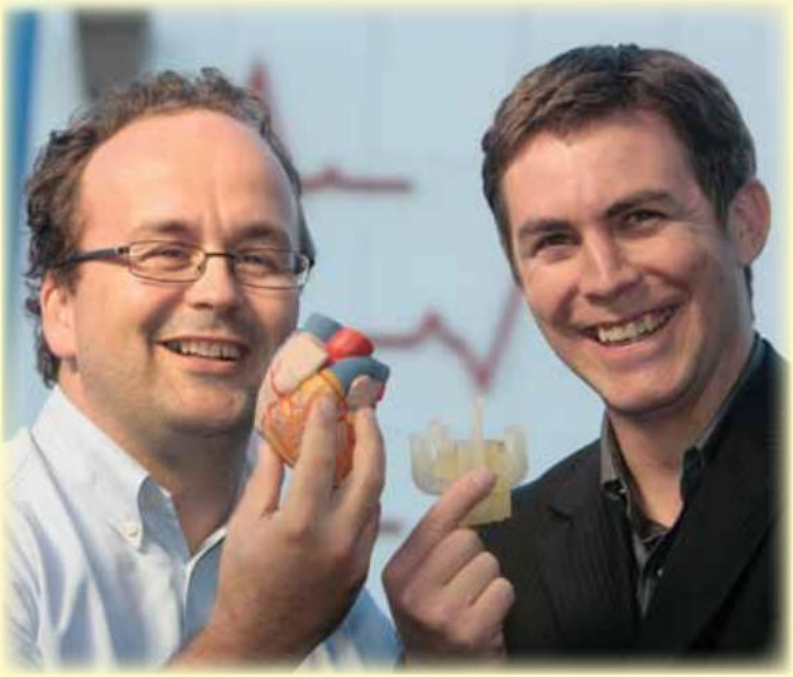
Dr Timms and a team of biomedical engineers, intensive-care specialists, cardiac surgeons and cardiologists worked on an artificial heart project for seven years at Prince Charles Hospital. He perfected the artificial heart's impeller—a twin fan that works a bit like a revolving door. In the right-hand side of the artificial heart one set of spinning blades drags the deoxygenated blood from the body and pumps it to the lungs. The blood then returns to the left-hand side of the heart where a second set of spinning blades pumps the oxygenated blood throughout the body. To reduce friction, the spinning blades are levitated and spun by tiny electromagnets so they do not touch the titanium casing of the artificial heart. The whole device, called *BiVACOR*, is about the size of a human fist, and is small enough to be implanted inside a patient's body. It is expected to cost about $60 000—about a tenth of the cost of present external heart machines.

The Prince Charles team first tested their artificial heart in a mock circulation loop in the laboratory. They then tested it in live sheep. The next step is clinical trials over three years with human patients. This will cost $3 million dollars.

Many patients who need heart transplants die waiting, so Dr Timms' invention has the potential to save thousands of lives a year worldwide. Most of the funding for the BiVACOR project has come from selling strawberry ice creams at the Ekka—the Royal Queensland Show. The government has provided very limited funding, and unless further funding can be obtained this wonderful Australian invention may be lost to an overseas company.

Questions

1. Why did Dr Timms start working on developing an artificial heart?
2. What is engineering? (You may need to research this.) Is the development of the artificial heart science or engineering? Explain your answer.
3. Why did Dr Timms need to work with a team of people?
4. Use the internet to find out the latest news on *BiVACOR*.
5. The Australian Government spends more money on sport than it does on scientific research. Do you think this is right? Why or why not?
6. Copy the diagram of the heart on page 152 and mark the places where tubes would need to be connected to the artificial heart.
7. The impeller blades on the left hand side of the artificial heart are longer than those on the right hand side. Suggest a reason for this.



Dr Dan Timms (right) holds the artificial heart. For comparison Prof John Fraser holds a model of a human heart.

INQUIRY 5 Slowing blood flow

In Inquiry 4 when investigating the effect of exercise on the heartbeat you would have heard changes in the heart rate. In this activity you will see what happens to your body when blood flow slows down.

You will need: a stopwatch

1. Hold one arm by your side in a relaxed position.
2. Open and close your hand as fast as you can. Count each time you open your hand (you might need a partner to help you) and time how long it takes until you feel discomfort in your arm and you want to stop.
3. Rest your arm.
4. Now raise your arm straight above your head. Open and close your hand, timing and counting as before.
5. Describe the differences between the two arm positions.
   - What happens to the blood flow in your raised arm during exercise compared to your arm in the relaxed position by your side?
   - Why does your raised arm get 'tired' faster than your lowered arm?

PROBLEM SOLVING

Remember your problem? You should now be able to explain how the heart and circulatory system work and what makes up blood. There are also some diagrams in the first three sections of this chapter that should give you ideas for your model.

Over to you

1. Cameron was asked to list the sequence in which blood moves through the heart. This is what he listed. Explain what is wrong with this list and write a corrected version.

   left side of heart → capillaries → arteries → cells → capillaries → veins → left side of heart → lungs → right side of heart

2. What are the differences between the following?
   - **a** atrium and ventricle
   - **b** pulmonary artery and pulmonary vein
   - **c** oxygenated and deoxygenated blood
   - **d** heart rate and stroke volume
3. Why is the left ventricle thicker and more muscular than the right ventricle?
4. Atria have thinner walls than ventricles. Why?
5. Why are valves found between the chambers in the heart and in veins throughout the body, but not in arteries?
6. Describe the sounds that can be heard in the heart and what causes these sounds.
7. How is the heart rate of a person running different from their resting heart rate? Why is this change necessary?
8. Imagine you needed a heart transplant. How would you have felt about this if you needed it in 1977? Why? How would this be different if you needed a heart transplant today?
9. Use the library to find out about a woman called Fiona Coote. Who was she and why is she famous?

INQUIRY 6 Heart rap song

Get into groups of four and make your own rap song describing the heart, what it does and how it works. Perform your completed song to the class. Here's an example.

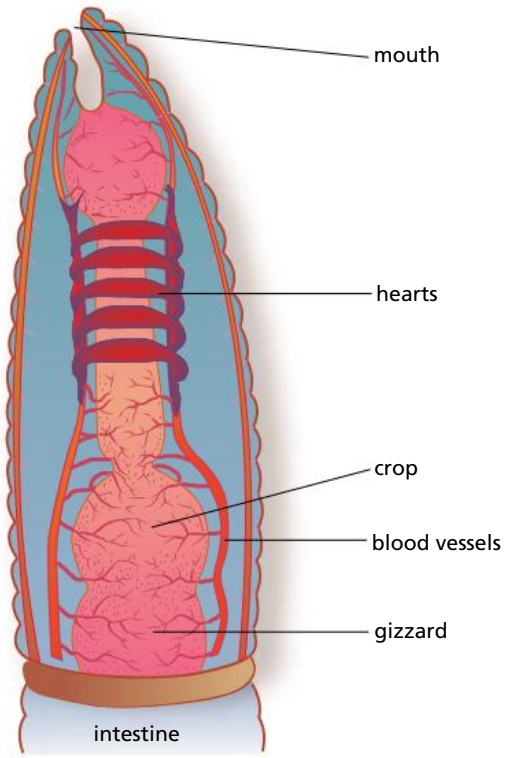
I pump, pump, pump,
all day long.
I'm writing this rap,
yes this is my song.
You can't live without me,
if I stopped you'd be gone.
So I keep on pumping,
yes the beat goes on.

I get blood from the head,
I get blood from the feet.
I'm made of thick muscle,
yes this makes the beat.
Blood enters from the left,
it's forced out the right.
So I keep on pumping,
yes even when it's night.



7.4 Circulatory systems

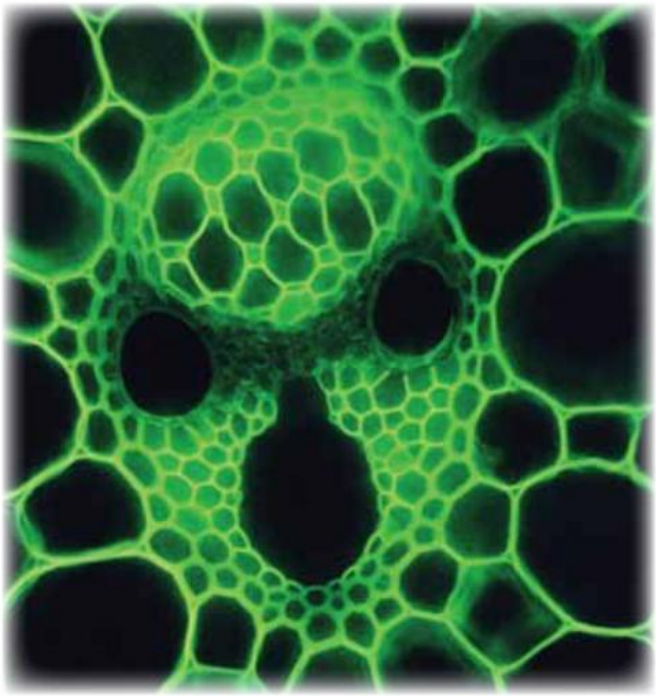
Circulatory systems differ. Humans have only one heart whereas earthworms have 10 hearts—five on each side of their body. Earthworms pump blood by moving their body in and out. Some insects have a main heart with smaller hearts at the base of their legs and wings.



The circulatory systems of an earthworm

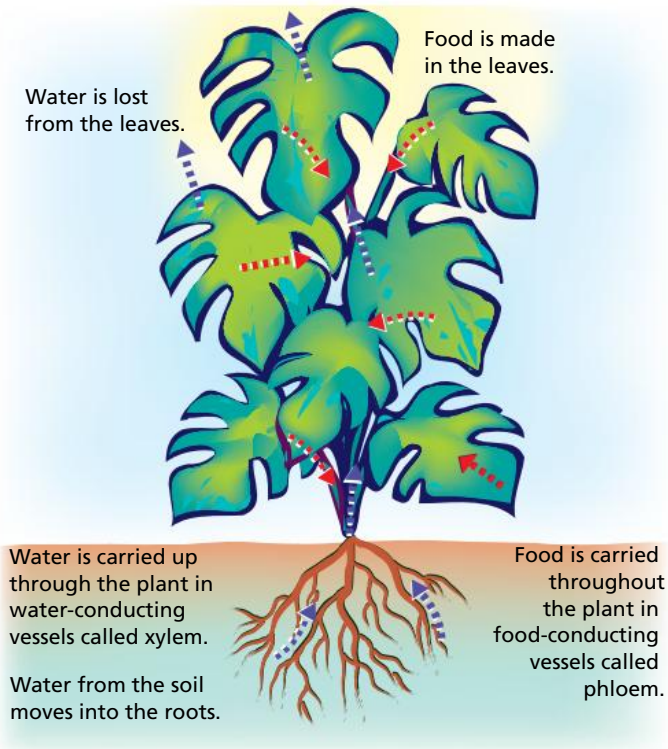
In earthworms, birds, reptiles, fish, mammals and amphibians blood moves in one direction only, through a completely closed circuit of vessels. Snails, oysters, insects, spiders, crabs and crayfish have open circulatory systems. Their blood is not contained in vessels but lies in the body spaces between the organs. Muscular movement and activity forces the blood through the body. The blood does not carry oxygen. It only carries nutrients and wastes.

In many plants, sap (water and minerals) travels from the roots through the plant to the leaves, through tubes called **xylem** (ZI-lem) The xylem do not join to form a circulatory system. Water is lost from the top end of the xylem, at the leaves, through evaporation. This moves the water through the plant. Water loss or evaporation from a leaf's surface is called **transpiration**.



The large black holes are the xylem, and the smaller greenish ones are the phloem.

New materials made by the plant in photosynthesis, such as sugars and amino acids, are moved through tubes in the plant called **phloem** (FLOW-em). The phloem carry these materials from the leaves to the stem and the roots for storage, as well as to the growing parts of the plant. The materials in phloem move when materials are used at either end of these tubes.



INVESTIGATION

3 Water movement in plants

Aim

To investigate water movement in plants.

Risk assessment and planning

Read through the investigation first.

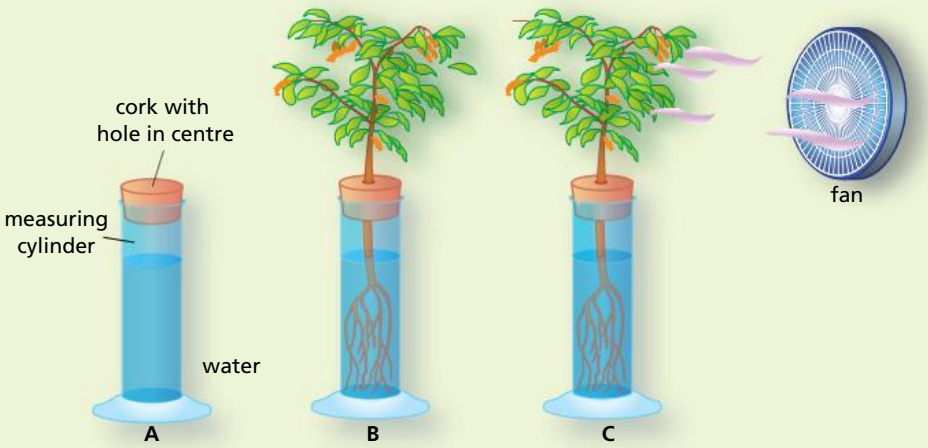
1. How should you handle electrical equipment safely?
2. What do you predict will happen to the level of water in each of the cylinders? Explain.
3. The cylinder without a plant is being used as a control. Why do you think you need a control?

Apparatus

See the diagram below.

Method

1. Set up the apparatus as shown with the same volume of water in each of the three cylinders.
2. Record the volume of water in each cylinder each day for a week.



Results

1. Record your observations under *Results*.
2. Explain what you have observed.

Conclusion

Copy and complete these sentences.

The water in cylinder _____ moved faster through the plant because …

The water in cylinder _____ moved more slowly because …

Write your report

Write your report under the usual headings.

INQUIRY

7 Measuring your pulse

1. Take your partner's pulse as shown.
2. Record the number of beats per minute. (Take the pulse for 30 seconds and multiply this by 2.)
3. Have your partner exercise by jogging on the spot for 3 minutes. Immediately after the exercise take their pulse again, then at minute intervals until their pulse returns to normal. (You will need to count the pulse for 30 seconds, stop for 30 seconds and then take it again.)

Questions

1. Draw a line graph of your data (time in minutes on the x-axis and the number of beats on the y-axis).
2. How does your heart (pulse) respond to changes in activity in your body? Why do you think this happens?
3. A fit person takes less time for their pulse to return to normal after exercise. How fit are you?
4. What variables do you need to control to compare people's pulses?
5. Who is the fittest in the class? (Whose pulse returns to normal the fastest?)



SCIENTISTS AT WORK

William Harvey (1578–1657)

The Greek physician Galen (AD 130–200) was the first to use the pulse to determine a person's health. However little more than this was known about the body for hundreds of years. People thought the sound in the chest was the soul and that blood was made in the liver. The work of William Harvey changed all this.

For most of his life William Harvey dissected and studied organisms. He found the heart was a pump that received and expelled blood, moving it through the body. He discovered valves and saw that they allowed blood to flow in one direction only. He also discovered that the blood in unborn babies does not go through their lungs.

Harvey could not explain the beating of the heart or how blood moved from arteries to veins. Marcello Malpighi, an Italian professor, explained this. He discovered capillaries using a microscope, which was not invented until after Harvey's death.

Harvey used scientific skills, not accepting what he found until it could be tested and re-tested and still shown to be correct. His ideas came from simple observation. He did not have the technology we have today to help him.

In 1628, at the age of 50, Harvey published his discoveries but his ideas were not accepted until 1827. New theories were often harshly criticised. Also people could be imprisoned for their ideas, especially if they disagreed with the teachings of the church which had a powerful control over peoples' lives at the time.



William Harvey lecturing on blood circulation

Over to you

1 Which of the following are true and which are false? Rewrite the ones that are false.
   - **a** Arteries have much thinner walls than veins.
   - **b** Phloem vessels transport food and water to all cells in the plant.
   - **c** Insects have closed circulatory systems.
   - **d** Water loss from a leaf is called photosynthesis.
   - **e** Valves allow blood to flow in one direction only.

2 How can you quicken and slow down your pulse? Explain.

3 Give an example of how body systems are linked.

4 Why do capillaries lie close to cells in your body?

5 Compare and contrast the circulatory systems of
   - **a** an earthworm and a human
   - **b** an insect and a human.

6 Do plants have circulatory systems? Explain.

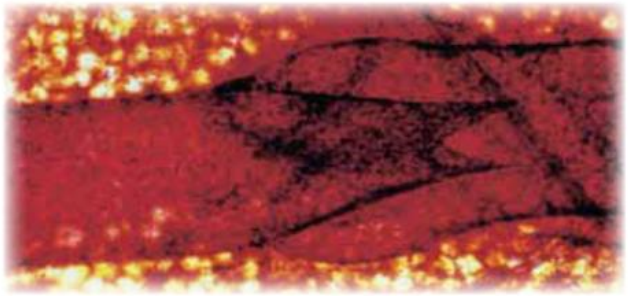
7 How could you tell whether a cut in your arm was bleeding from an artery or a vein? Explain.

8 Why do you think it is not necessary for blood to travel through an unborn baby's lungs?

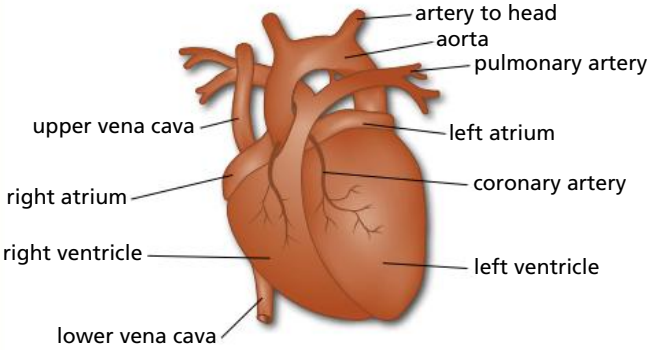
9 How was the spread of scientific ideas influenced by religion and the development of technology? You could use William Harvey as an example or look at the different scientists presented in each chapter. Do you think this is the same today? Explain.

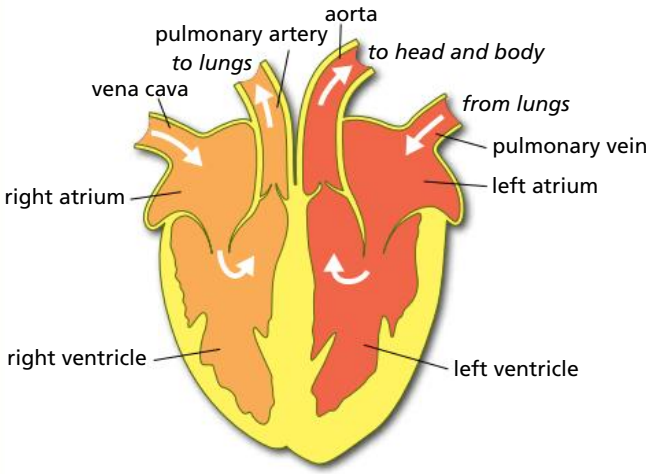
THINKING SKILLS

1 The photograph below shows a valve in a lymph vessel. Why do you think valves in lymph vessels are needed?

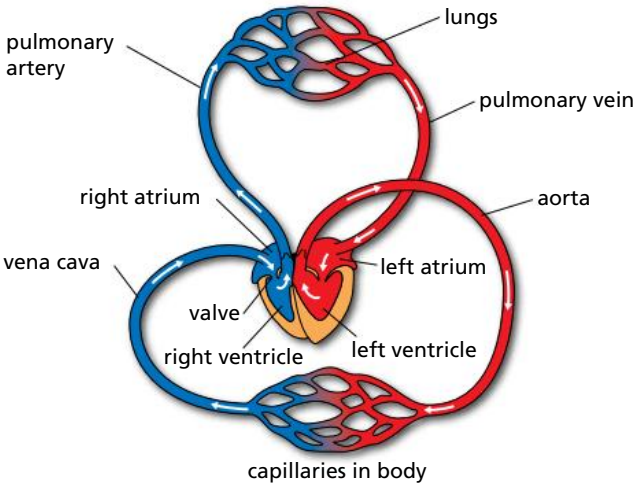


2 There are many different diagrams of the heart. Look at the ones presented here and in the rest of the chapter. Choose which diagram you think is the best and state why you think so.





3 Design your own heart circuit game based on the diagram below to show primary school students how the heart, lungs and circulatory system are connected.



4 People often drink coffee to wake themselves up. They believe it is a stimulant. Design an experiment to see if heart rate increases after drinking coffee. You might also like to see if tea affects the body in the same way.

5 Design an experiment to test one of the following hypotheses.

a Smoking a cigarette increases the heart rate.

b Fit people have a lower resting heart rate than unfit people.

6 Debate or write your own response to one of the following topics.

a Money would be better spent on educating people to avoid heart disease than on heart transplants.

b People should look after their own health rather than rely on doctors to help them when things go wrong.

c Why keep sick people alive when there are healthy people in the world dying of starvation?

d If people have heart disease because they inherited the problem then we should do everything to help them.
If they have these diseases because they chose to smoke or eat badly, then bad luck.

Knowing and Understanding

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

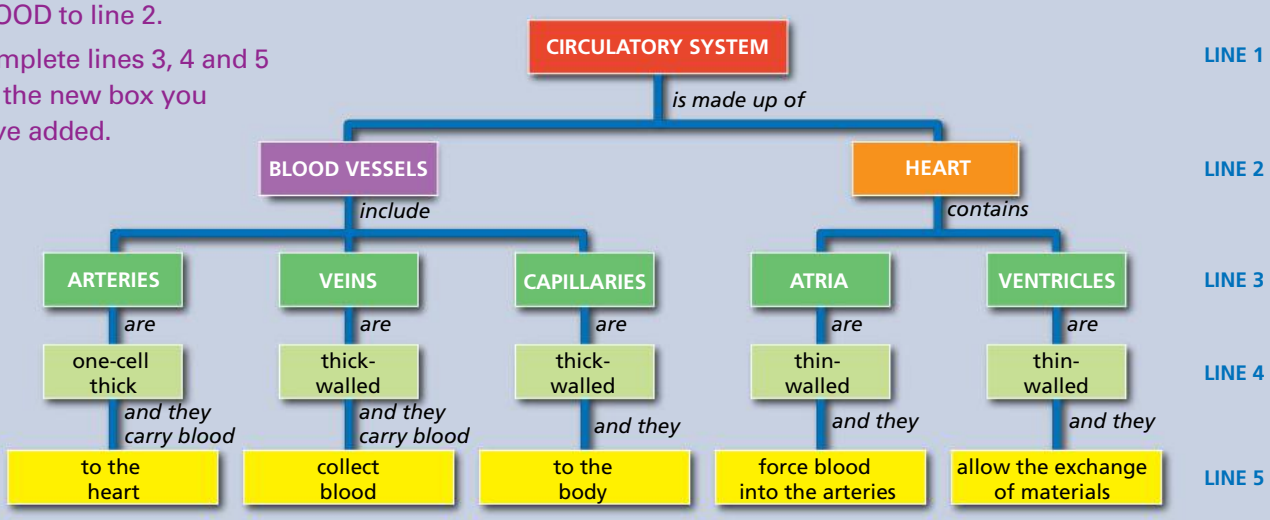
1. Blood is made up of _____ blood cells that carry oxygen around the body, _____ blood cells that fight foreign substances entering the body, _____ that help clot the blood and _____, which is the liquid part.
2. Blood vessels that carry blood away from the heart are called _____. Those that carry blood towards the heart are called _____.
3. The tiny blood vessels that link arteries and veins are called _____. They are one cell thick and allow the exchange of materials between the blood and _____.
4. The heart is a double pump. One side of the heart carries blood returning from the _____ to the heart. The other side carries blood returning from the lungs to the _____.
5. Blood returning from the body is high in _____ and low in oxygen. Blood returning to the heart from the lungs is high in _____
6. The circulatory system and the _____ system are linked so that _____ can be taken in, circulated around the body and removed.
7. Diseases of the _____ system are one of the biggest causes of death in Australians.

arteries
body
capillaries
carbon dioxide
cells
circulatory
gases
heart
oxygen
plasma
platelets
red
respiratory
veins
white

Self-management

Mind map

1. The diagram here shows a mind map about the circulatory system. The boxes in lines 4 and 5 are jumbled up. The linking words are correct. Copy this mind map onto a large sheet of paper and correct the boxes in lines 4 and 5.
2. Now add another box called BLOOD to line 2.
3. Complete lines 3, 4 and 5 for the new box you have added.
4. Draw your own mind map like this one for the respiratory system.
5. Now choose one of the key words from one of the mind maps and write a 'Who am I?' question. For example, *I am a blood vessel with thick elastic walls. I carry oxygenated blood away from the heart. I am an artery.*



Checkpoint

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

OneStopScience

1 State whether the following are true or false.

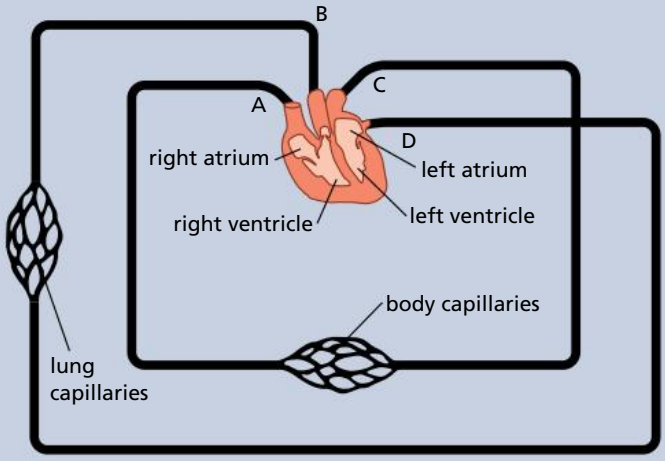
- **a** Arteries carry blood away from the heart.
- **b** Veins are one cell thick.
- **c** Capillaries allow the exchange of materials.
- **d** Red blood cells are needed to fight foreign substances in the body.
- **e** Antibodies are made by the body to fight antigens.

2 What is the difference between

- **a** an artery and a capillary?
- **b** the left and right atria?
- **c** red blood cells and white blood cells?
- **d** the aorta and the pulmonary artery?

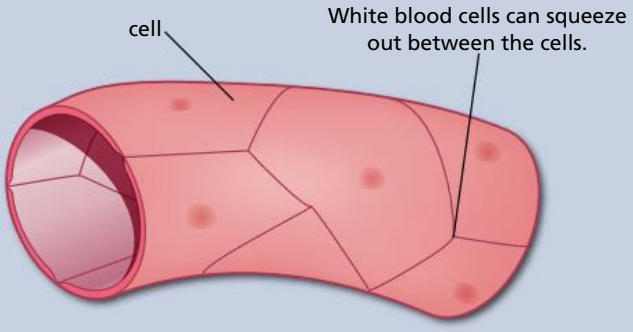
3 The diagram below shows the heart and circulatory system.

- **a** Label the diagram where indicated, with the following: pulmonary artery, aorta, vena cava, pulmonary vein.
- **b** Draw arrows in the blood vessels showing the direction in which the blood moves.
- **c** Indicate where you would find valves.



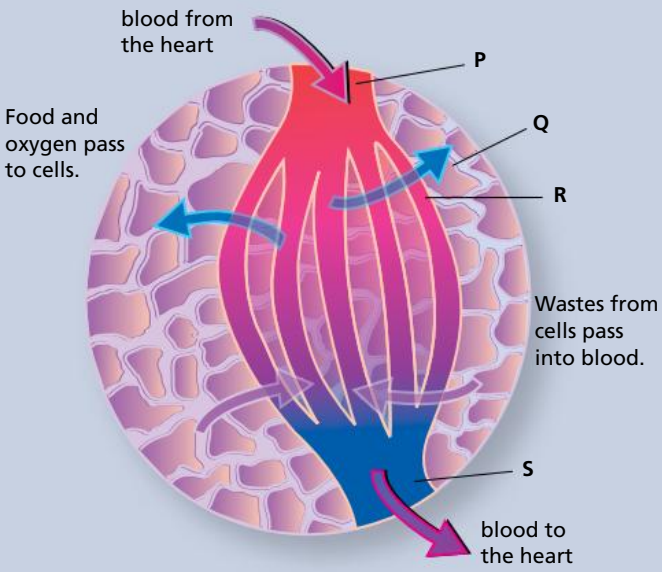
4 The diagram top right shows a blood vessel in the body.

- **a** What type of blood vessel is it? Give reasons for your answer.
- **b** What job would you expect this part of the body to do?



5 The picture below is a representation of a part of the circulatory system.

- **a** Identify parts P, Q, R and S on the picture.
- **b** What is the function of each part in the diagram?
- **c** Describe what the diagram is showing you.

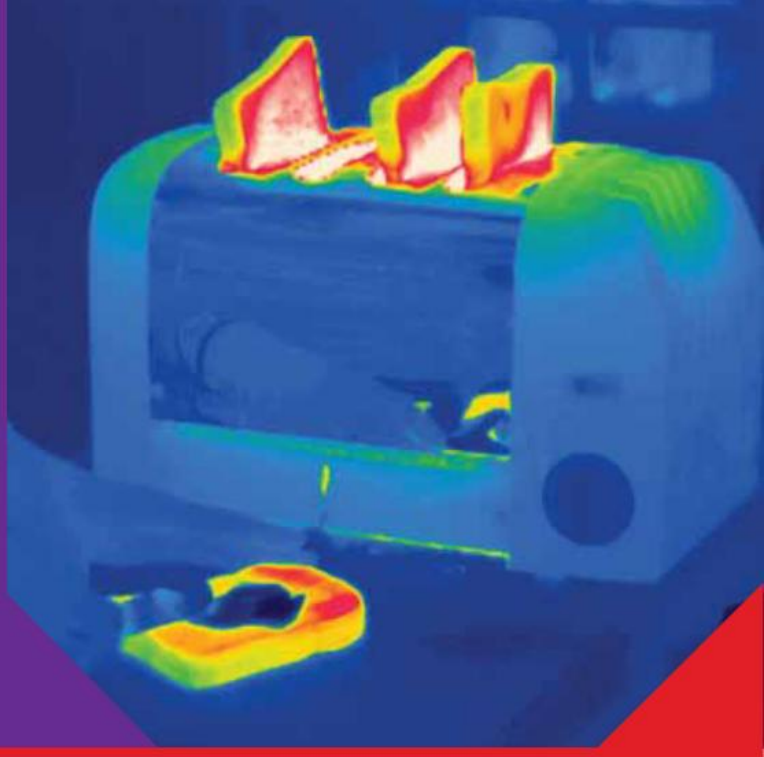


6 **a** List at least four risk factors associated with heart disease.

- **b** How can you reduce these risk factors?

7 Peter went to the doctor and his blood pressure was 135/80. Explain to Peter what these figures mean, and whether his blood pressure is of concern. You may need to refer to the table on page 149.

8

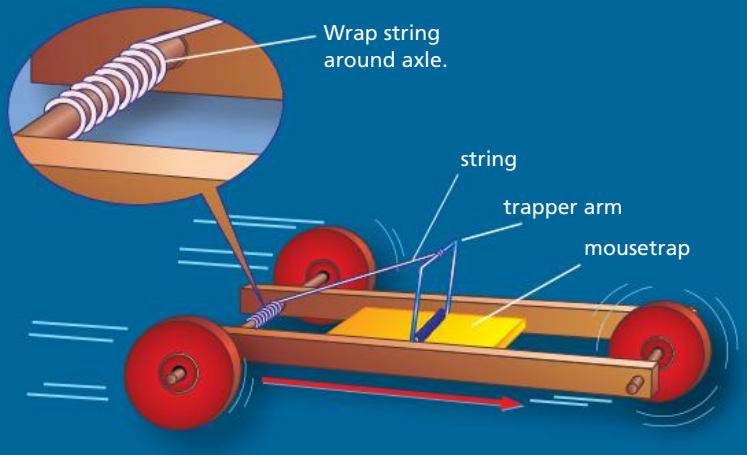


Using energy

PROBLEM SOLVING

Building a mousetrap racer

You can use the spring of a mousetrap to power a model racer. You attach one end of a piece of string to the mousetrap's trapper arm and the other end to the rear axle, as shown below. As you wind the string onto the axle you pull back the trapper arm. Then, when you release the arm, the string is pulled off the axle causing the wheels to rotate.



Your task is to build a mousetrap racer that will go as fast as possible. Really fast ones can go 5 m in less than 2 seconds. Or you could see how far your racer will go. The record is about 100 m.

There are many variables you can alter to make your racer go fast or a long way. Some of these are:

- number of wheels
- type of wheels
- mass of racer
- distance between axles
- the way the string is attached to the rear axle.

By the time you have finished the chapter you will be able to explain how your racer works in terms of energy changes.

Focus for learning

INQUIRY 1 *What is energy?*

We have already used the word *energy* in this book, but what is energy? Are your ideas about energy the same as other people's ideas? A good way to sort out your ideas is by *brainstorming*. To do this you need to follow these six steps.

1. Get into groups of six.
2. Select someone to write down all the ideas thought of by the group.
3. Everyone should try to give at least one idea about energy. The more ideas the better. Here are a few suggestions to get you started.
   - Write a sentence with the word 'energy' in it.
   - Draw something with a lot of energy.
   - What do we use energy for?
   - How do our bodies get the energy they need?
   - What are the different types of energy?
4. Don't discuss the ideas yet, and don't criticise anyone else's idea.
5. After a few minutes of brainstorming, discuss the ideas you have written down. Write or draw them on a large sheet of paper and present them to the class.

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

Science Understanding

- recognise that kinetic energy is the energy possessed by moving bodies
- recognise that potential energy is stored energy, such as gravitational, chemical and elastic energy
- give examples of how heat energy is produced as a by-product of energy transfer, e.g. in a car engine
- use energy chains to show changes between different forms of energy

Science as a Human Endeavour

- discuss the work of Maria Skyllas-Kazacos in developing the vanadium battery

Science Inquiry Skills

- work in a team or by yourself to complete a science project

LITERACY FOCUS

battery
efficiency
elastic potential energy
energy chain
energy converter
fossil fuels
gravitational potential energy
investigate
joules
kinetic energy
law of conservation of energy
non-renewable
nuclear
renewable
research
thermometer
transferred
transformed
uranium
vibration

8.1 Forms of energy

What is energy?

How do you feel when you have lots of energy? How are new batteries different from 'flat' ones? Put them into a CD player or a torch and you can certainly tell the difference. Energy makes things happen.

You can't see energy. You can't weigh it, and it doesn't take up space as matter does. Everything you do needs energy. In fact, everything that happens needs energy. Without it nothing will go. It simply makes things happen when it changes from one form into another.

INQUIRY 2 Hot air rises

You will need: Bunsen burner, scissors, cotton thread, retort stand and clamp

1 Draw a spiral on a sheet of paper and cut it out. Then hang it above a Bunsen burner as shown.

2 Light the burner and adjust it to a small blue flame. You will probably need to adjust the height of the spiral so that it does not burn.



- How do you know energy is involved here? What energy change occurred?

Energy changes can make things move, as you saw in Inquiry 2. The hot air above the burner rose, causing the paper spiral to turn. In this way the heat energy was changed into movement energy.

The energy you get from food enables you to ride a bike. The energy from petrol makes a car move, and energy from rocket fuel can move a spacecraft into space. All objects have energy, and one object can transfer some of its energy to another object. For example, when you hit a golf ball with a club some of the club's energy is transferred to the ball. And when you pour hot water into a cup, some of the energy in the water is transferred to the cup.

Energy changes can do more than make things move. For example heating is caused by some other form of energy, such as the energy stored in gas, changing into heat. That heat can warm our homes and cook our food. Other energy changes produce electricity, light and sound.

There are many different forms (types) of energy. You can classify them into two groups—energy in action and stored energy.

Energy in action

Kinetic energy

Any moving object has **kinetic** (kin-ET-ic) **energy**. When you run you have kinetic energy. A moving train has a large amount of kinetic energy, and in a crash that energy can cause a lot of damage. The kinetic energy of the strong winds in a cyclone can cause enormous damage.



Darwin was destroyed by cyclone Tracy on Christmas Eve 1974. The wind, travelling at up to 200 kilometres per hour, had enormous kinetic energy.

The amount of kinetic energy an object has depends on its speed. The faster the object is moving, the more kinetic energy it has. For example, a car travelling at 100 km/h has much more kinetic energy than one travelling at 60 km/h. As a moving object slows down, it loses kinetic energy. And when it stops it has no kinetic energy at all.

Kinetic energy also depends on the mass of the moving object. The larger the mass, the more kinetic energy the object has. A cyclist and a bus may be travelling at the same speed, but the bus has much more kinetic energy because it has more mass.

Light energy

Burning chemicals, very hot objects and stars all release light energy. It travels through space in waves (as do radio and TV waves, microwaves and ultraviolet waves). It will even travel through a vacuum where there is no air. Light energy from the sun, called *solar energy*, is used by plants in the process of photosynthesis to make food.

Sound energy

Sound is a form of kinetic energy caused by vibrating objects such as a guitar string or the skin of a drum. The bigger the vibrations, the louder the sound. The sound travels from place to place as waves, but it needs a solid, a liquid or a gas to carry it. It won't travel through space where there is no air, because there are no particles to vibrate and carry the sound energy.

Heat energy

Heat energy is energy that an object has because of its temperature. The hotter the object is, the more heat energy it has. Heat energy moves from a hotter object to a colder one. When you put your cold hands around a hot cup of tea, heat energy moves from the cup to your hands, making them warmer.

Electrical energy

Electricity has electrical energy and is widely used because it is easily transmitted by wires to the place where it is needed. It can be changed into other forms of energy by electric lights, computers, hair dryers, TV sets, washing machines, toasters etc.

Stored energy

Stored energy is called **potential energy** because it is not making anything happen, but it has the *potential* to do so. There are four types of stored or potential energy.

Chemical energy

Energy can be stored in chemicals as chemical energy. It is stored in the chemical bonds between atoms. When fuels such as wood and petrol are burnt, this stored energy is released as heat and light. When you switch on a torch the chemical energy stored in the battery is changed to light energy. Food also contains stored energy which can be used by your body.

Nuclear energy

Energy is also stored inside atoms as nuclear energy. It can be released from some atoms, for example uranium atoms, in nuclear power stations. Nuclear energy stored in hydrogen atoms is the source of the sun's energy.

Elastic potential energy

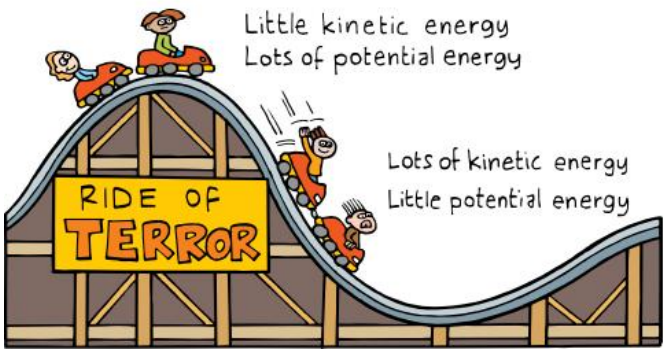
When you jump on a trampoline, what pushes you up into the air? Try to visualise what happens in slow motion. The trampoline has a frame with a flexible mat attached by springs. When you jump on the mat, it is pushed down, stretching the springs and storing energy called **elastic potential energy** in them. As the stretched springs return to their original size and shape, they release their stored energy. The mat is pulled back up, and you are thrown into the air. A wind-up toy also stores elastic potential energy. So does a stretched elastic band. The more it is stretched, the more elastic energy it has.



The elastic potential energy stored in the stretched trampoline springs allows them to throw you into the air when they spring back into place.

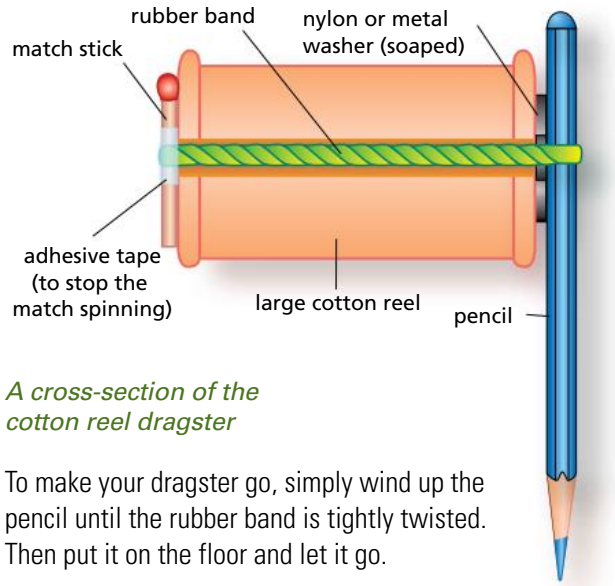
Gravitational potential energy

Gravitational potential energy is the potential energy that an object has because of its height and mass. The higher an object is, the more gravitational potential it has. And the more mass an object has, the more gravitational potential energy it has. When you are at the top of a roller-coaster ride, you have a lot of gravitational potential energy but not much kinetic energy. As you come down again, the gravitational potential energy is converted into kinetic energy, so the cart gets faster and faster. At the bottom of the ride you have much more kinetic energy but much less gravitational potential energy. Energy can be easily changed back and forth between potential and kinetic energy in this way.



INQUIRY 3 Cotton reel dragster

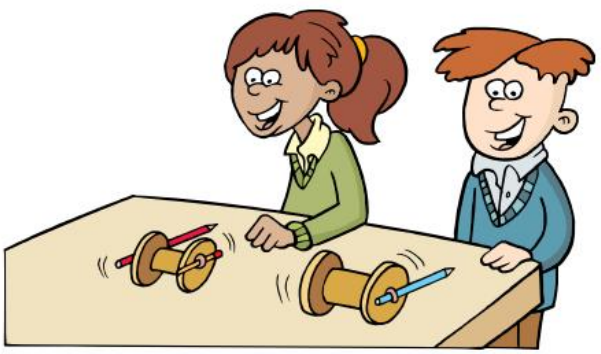
You will need: large cotton reel, rubber band, matchstick, nylon or metal washer, soap, adhesive tape, pencil



A cross-section of the cotton reel dragster

To make your dragster go, simply wind up the pencil until the rubber band is tightly twisted. Then put it on the floor and let it go.

- Which type of energy does the dragster have when you let it go?
- Which type of energy did it have before you let it go?
- Energy is needed to wind up the dragster. Where did this energy come from?



Over to you

1 Copy and complete each of these sentences.
- **a** Energy makes things _____.
- **b** A moving object has _____ energy.
- **c** Energy which is stored is called _____ energy.
- **d** Burning a log of wood changes _____ energy into _____ and _____ energy.
- **e** A large rock rolling downhill is losing _____ energy, but gaining _____ energy.

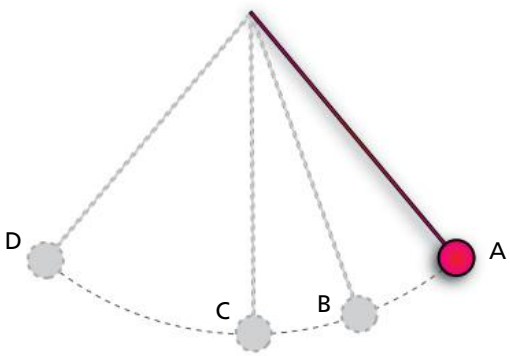
2 What are the four types of stored energy?

3 What form(s) of energy do the following have?
- **a** an apple
- **b** a bent ruler
- **c** a burning log
- **d** a flash of lightning
- **e** a glowing firefly
- **f** a loose rock on top of a hill
- **g** ocean waves
- **h** a piece of chocolate
- **i** a TV set (turned on)
- **j** a warm pizza
- **k** the water in a waterfall
- **l** a wound-up toy

4 Give an example of something that has
- **a** gravitational potential energy due to its high position
- **b** elastic potential energy because it has been stretched
- **c** chemical energy.

In each case explain how the energy can be used to produce movement.

5 The diagram shows a pendulum. It was pulled to point A and released. C is the lowest point of its swing and D is the highest point at the other end of its swing.



- **a** At which point was the pendulum's kinetic energy greatest?
- **b** At which point was its potential energy greatest?
- **c** At which point did the pendulum have kinetic energy and potential energy?

6 In Inquiry 1 on page 165 Emily said that to cause a change you need to supply energy. For example, a kettle boils when you supply heat energy. Give as many examples as you can to illustrate Emily's idea.

7 How do you know if something has energy? Give an example.

8.2 Energy changes

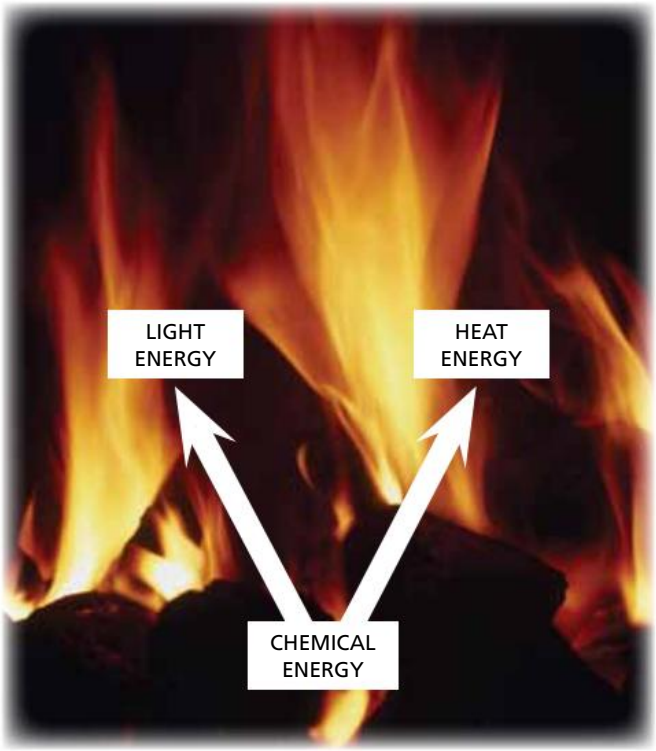
Energy transformations

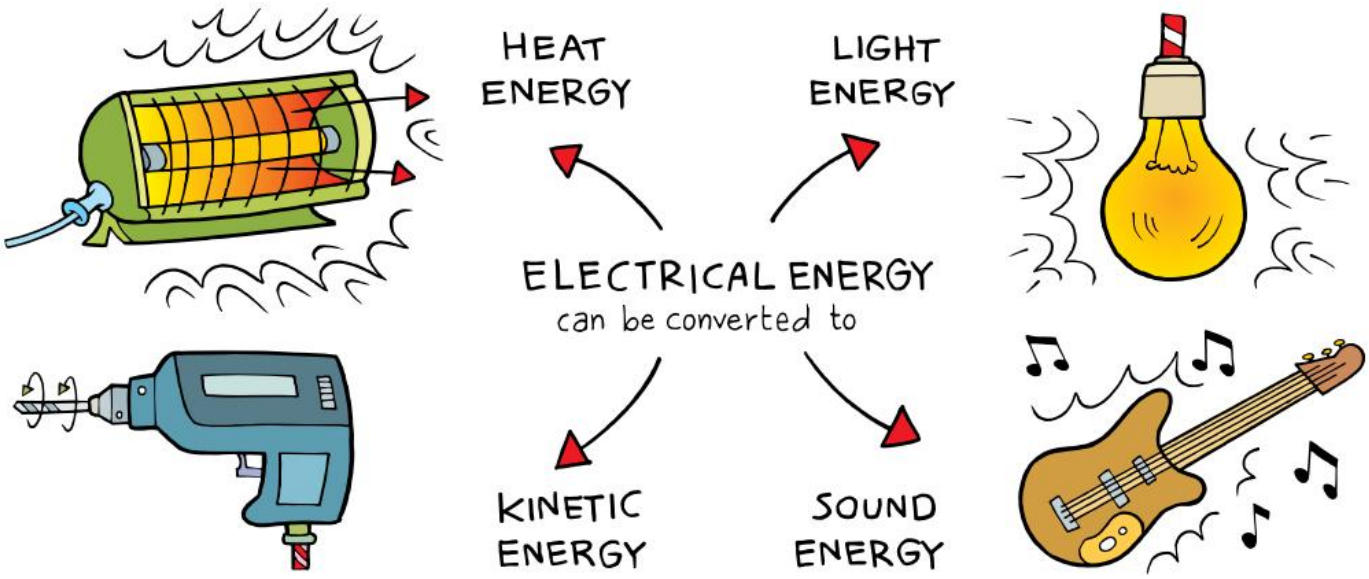
Energy can be *transformed* or *converted* from one form into another. For example, if you rub your hands together they become warm. You have converted the kinetic energy of your moving hands into heat energy. You can describe this change with an arrow, as shown below.



The things you do every day depend upon energy changes. Your body converts the energy stored in food into heat energy to keep you warm and kinetic energy as you move. Electrical energy is very important because you can turn it into many different forms of energy, as shown below. Devices that can convert energy from one form to another are called *energy converters*.

Sometimes more than one form of energy is produced when an energy change occurs. For example, a camp fire converts the chemical energy stored in the wood into light and heat. When you use an electric drill, not all of the electrical energy is converted to the kinetic energy of the drill. Some is lost as sound energy and some as heat energy. This is why the drill is noisy and soon becomes hot.

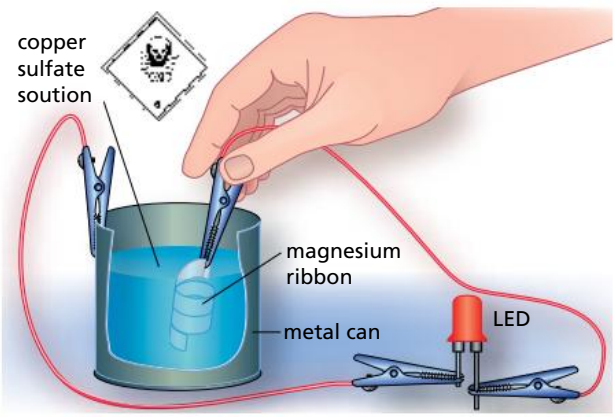




INQUIRY 4 Generating electricity

You will need: piece of magnesium ribbon (about 15 cm), small empty metal can (e.g. baby-food can), low voltage light-emitting diode (LED), 2 connecting wires with alligator clips, steel wool, copper sulfate solution

1. Clean the magnesium ribbon with steel wool until it is shiny. If the can has a coating on the inside, scratch this off in several places.
2. Curl up the magnesium ribbon by winding it around a pencil. Use a connecting wire with alligator clips to connect it to the long leg of the LED, as shown.



3. Three-quarters fill the can with copper sulfate solution.
4. Use the second connecting wire to connect the short leg of the LED to the edge of the can, as shown.
5. Finally, dip the magnesium ribbon into the copper sulfate solution. *Make sure that it doesn't touch the can or the other alligator clip.* Feel the can with your fingers.
   - What energy conversions have occurred?
   - Why did the LED glow only for a short time?

INQUIRY 5 Solar cells

You will need: solar cell kit (consisting of several solar cells connected to an electric motor, preferably fitted with a propeller)

What happens when you connect up the kit and put it in bright sunshine? What happens if you cover all or some of the solar cells?

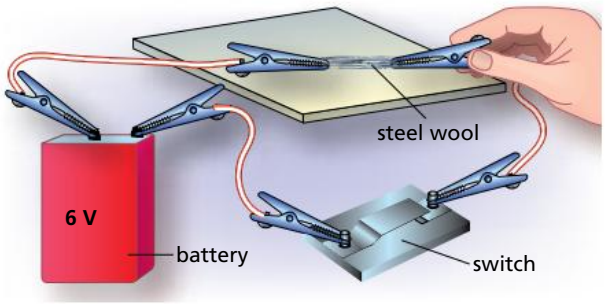
- What energy conversions occur?

INQUIRY 6 Steel wool

You will need: 6 volt battery or power pack, 3 connecting wires with alligator clips, heatproof mat, small piece of steel wool, switch

Use the wires to connect the battery and switch as shown. Put the steel wool on the heatproof mat and connect the wires to it. Close the switch for a few seconds only. Observe what happens.

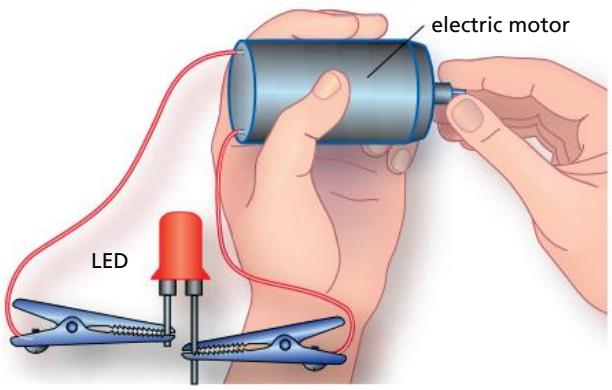
- What energy conversions occur?



INQUIRY 7 Electric motor

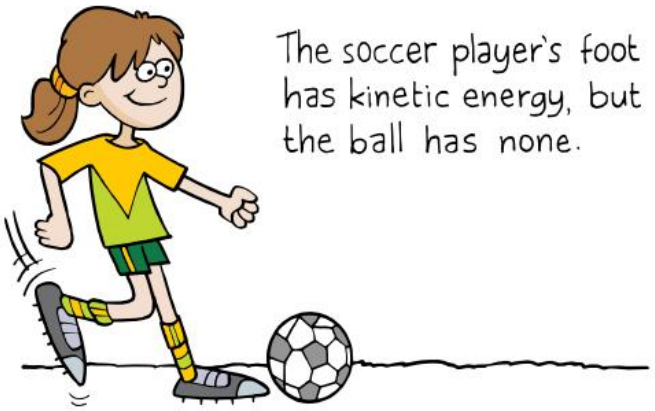
You will need: small electric motor with connecting wires and alligator clips, low voltage light-emitting diode (LED), 1.5 volt battery or power pack

1. Get the motor to work by connecting it to the battery.
2. Get the LED to glow by connecting it to the battery (long leg to the positive terminal).
3. Connect the LED to the motor as shown. Can you get it to glow briefly by giving the shaft of the motor a sharp twist?
   - What energy conversions have occurred in this activity?



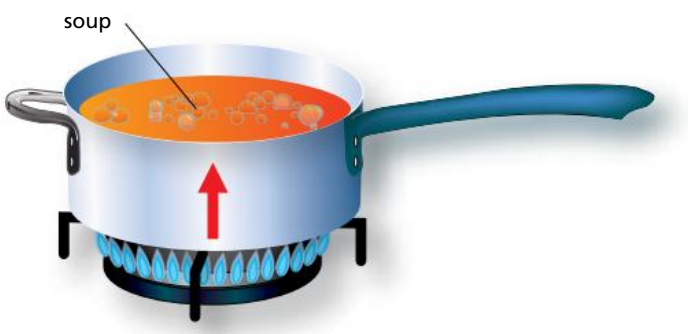
Energy transfers

Energy can be transferred from one object to another without changing its form. For example, when a soccer player kicks a ball, some of the kinetic energy of her moving foot is transferred to the ball, which also moves.





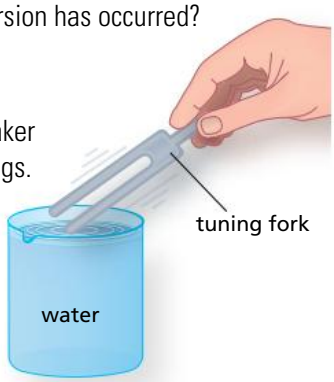
Another everyday energy transfer occurs when you heat soup on a stove. Heat is transferred from the gas flame or the electrical heating element to the soup, making it hot.



INQUIRY 8 Tuning fork

You will need: beaker of water, tuning fork

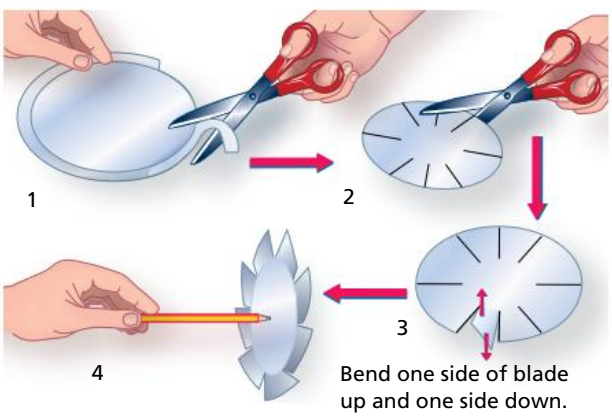
1. Strike the forked end of the tuning fork gently on the heel of your shoe (not on the bench). Hold the fork near your ear. Strike the fork again, but this time look closely at the prongs.
   - What energy conversion has occurred?
2. Strike the fork again, and touch the surface of the water in the beaker with the vibrating prongs.
   - How does this illustrate the transfer of energy?



INQUIRY 9 Wind-wheel

You will need: foil pie plate, scissors, pen or pencil

1. Cut the sides from the foil plate and cut slits as shown. Turn up the same side of each of the sections.



2. Make a small hole in the centre of the wheel and push the point of the pen through the hole.
3. Blow on your wind-wheel to make it turn. If it doesn't turn easily, increase the size of the hole or bend the blades more. You may have the blades facing the wrong way.
   - Explain how energy was transferred to the wind-wheel.

Save your wind-wheel for Inquiry 10.

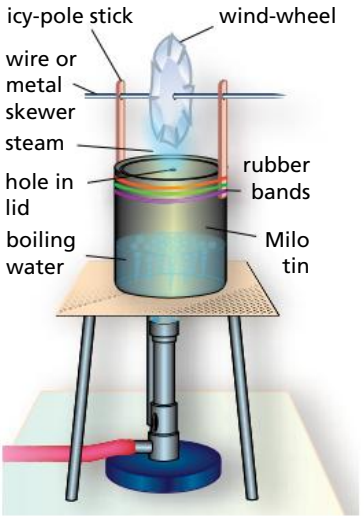
INQUIRY 10 Steam turbine

You will need: equipment pictured

Instead of blowing on your wind-wheel you can use steam. Set up the apparatus below. You may need to modify it a bit.

Don't put your hand near the steam, and don't let the water in the can boil dry.



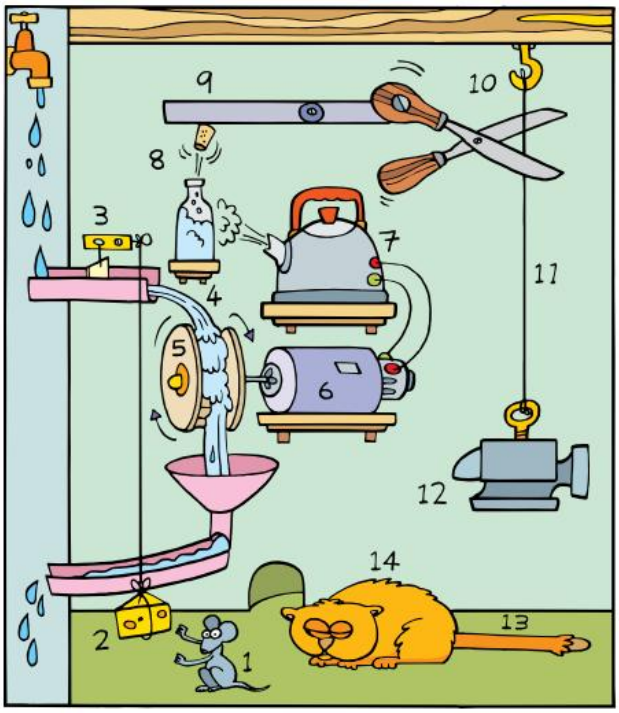


INQUIRY 11 Mousetrap

Study the cartoon mousetrap below.

- List the energy converters.
- Where do energy transfers occur?
- Write an energy chain like the ones on this page to describe all the energy conversions and transfers.

Design your own mousetrap.



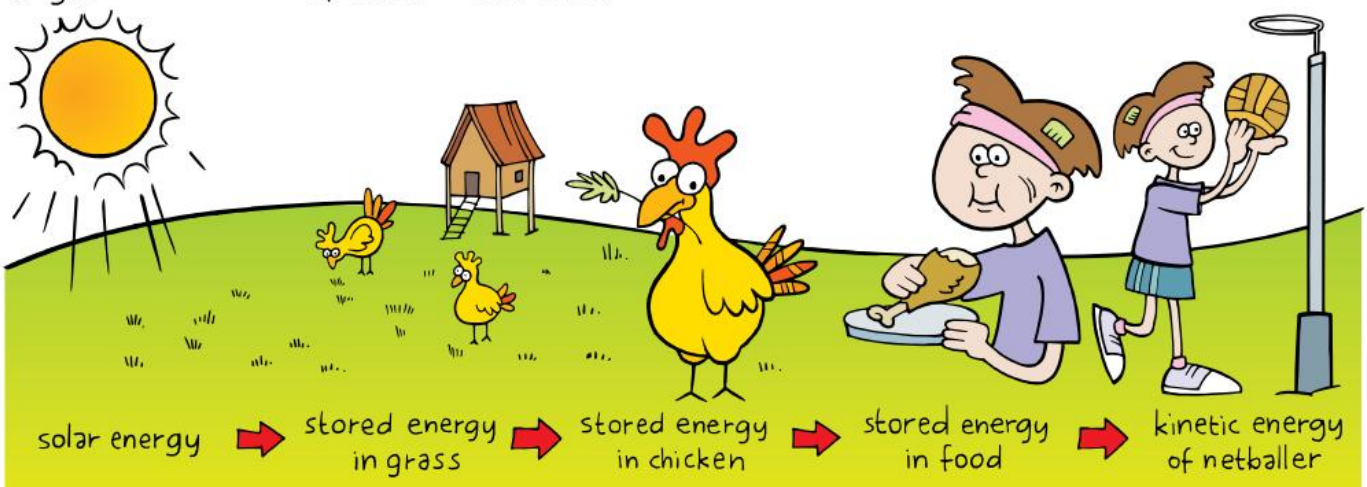
Energy chains

Sometimes one energy change follows another. Theses changes can be transformations or transfers. The series of changes is called an **energy chain**.

Consider what happened with the steam turbine you made in Inquiry 10. As the gas burns in the Bunsen burner, its chemical energy is converted to heat energy. This heat energy is converted to the kinetic energy of the moving steam. This kinetic energy is then transferred to the wind-wheel, causing it to spin.

chemical energy in gas → heat energy → kinetic energy of steam → kinetic energy of wind-wheel

In biology you will learn about food chains. These are also energy chains. In the example below, solar energy is converted to stored energy in the grass. This energy is then transferred to the person who converts it to kinetic energy as she plays netball.



Over to you

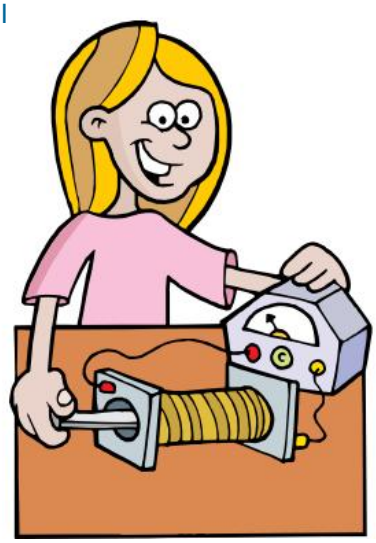
1 Pair up these lists correctly in your notebook.

Object	Main energy conversions
car battery	chemical to heat and light
CD player	electrical to light and sound
electric motor	electrical to sound
gas light	chemical to kinetic
nuclear power station	electrical to kinetic to potential
ski lift going up	chemical to electrical to light
solar cell	electrical to kinetic
torch	nuclear to electrical
truck	chemical to electrical
TV set	light to electrical

2 Copy and complete the table below.

Energy used	Energy converter	Energy produced
.....	chainsaw	.....
.....	electric fan	.....
kinetic	.....	electrical
.....	hydrogen bomb	.....
.....	light bulb	.....
.....	microphone	.....
electrical	.....	heat
.....	slingshot	kinetic
.....	steam engine	.....
kinetic	.....	sound
.....	waterwheel	.....

3 Grace connects a coil of wire to an electrical meter, as shown. When she plunges a bar magnet into the coil the meter shows there is an electric current flowing. When she holds the magnet still, no current flows. Write a sentence or two describing what is happening in terms of energy changes.

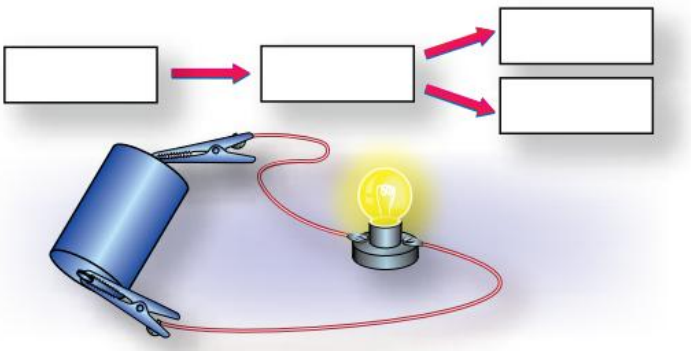


4 Into what forms of energy does your body convert the chemical energy in food?

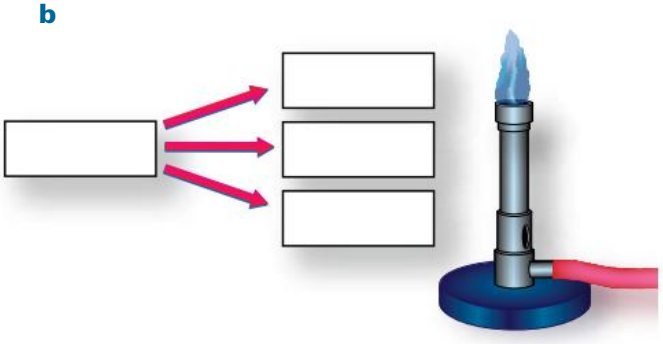
5 What is the difference between an energy transfer and an energy conversion? Give several examples of each.

6 Copy the boxes and complete the two energy chains below.

a



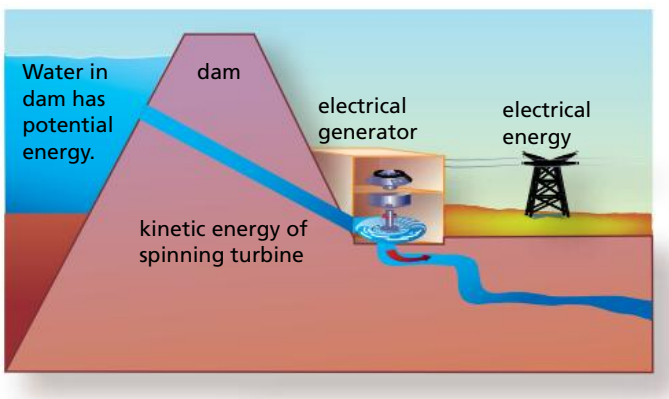
b



7 What energy change takes place in a solar water heater?

8 What is the energy conversion that takes place in a green plant during photosynthesis?

9 The diagram below shows how a hydro-electric power station works. Write an energy chain to show the energy changes that occur.



An electric generator is like an electric motor in reverse (see Inquiry 7). Spinning the shaft generates electricity.

8.3 Energy from food

A car gets its energy from petrol. When the petrol tank is empty the car stops. It has run out of energy. We need energy to keep us alive, to grow and to move. We get this energy from the food we eat. The more we move about the more food we need. Our bodies can change this food into energy that we can use. The triathletes in the photo need to eat a high-energy meal before the race and perhaps eat high-energy snacks and drinks during the race.



The more active we are the more energy we use.

Measuring energy

Energy is measured in **joules**, and the symbol for joule is J. This unit was named after a British scientist called James Joule who did experiments with heat. The amounts of energy in food are quite large so they are measured in *kilojoules* (kJ), where one kilojoule is 1000 joules.

All foods have *energy values*. For example, a 250 mL glass of milk contains 670 kJ of energy. A medium-sized banana contains 380 kJ. The table on the right gives the energy values of some common foods.

On average, a 12-year-old boy needs about 12 000 kJ of energy every day, and a 12-year-old girl needs about 10 500 kJ. Adults need less than this. Different activities require different amounts of energy. For example, walking requires 18 kJ per minute and freestyle swimming requires 125 kJ per minute. See the table on the right.

INQUIRY 12 Brigitte's energy

It is important to start your day with a healthy, nutritious breakfast. Brigitte therefore starts her day with an orange, corn flakes with milk, two boiled eggs, two slices of toast with butter (a large spoonful) and a glass of milk.

- How many kilojoules of energy does this meal give her?
- Suppose Brigitte swims in the 1500 m freestyle at the swimming carnival. She takes 2 minutes. How much energy does she use up during the race?

Food	Energy value (kJ)
Apple	300
Banana	380
Bread or toast (slice)	340
Butter (large spoonful)	460
Chocolate bar (45 g)	1100
Chocolate cake (medium slice)	1200
Cheese, cheddar (30 g)	460
Corn flakes (1 serving)	445
Egg, boiled	300
Egg, fried	400
Milk, full-cream (250 mL)	670
Orange	200
Peanuts, salted (45 g)	1100

Activity	Kilojoules required per minute
Riding a bicycle	29
Climbing stairs	47
Playing football	78
Doing homework	8
Jogging	69
Riding a motorbike	15
Singing	9
Sleeping	6
Standing	8
Swimming, freestyle	125
Swimming, backstroke	156
Walking	18
Washing up	15

INVESTIGATION

1 Energy from food

Aim

To find out how much energy is released when a small piece of food burns.

Risk assessment and planning

1 Read through the experiment, then describe to your partner what you have to do, measure and record.

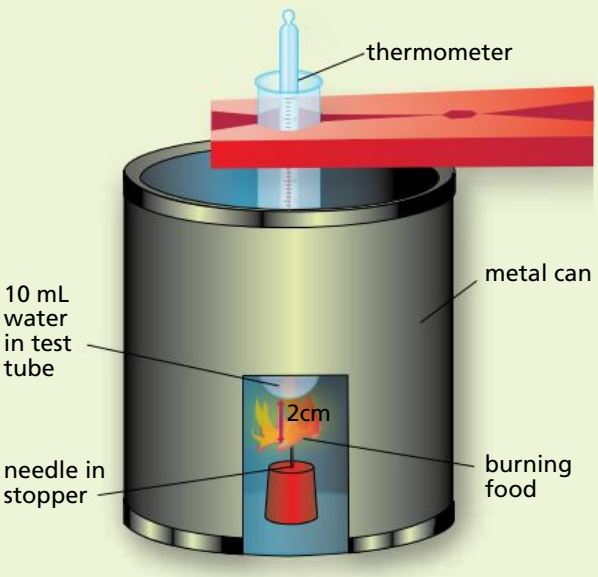
2 What safety precautions will be necessary?

3 What data will you need to record?

Apparatus

- large test tube
- test-tube holder
- small piece of food, e.g. Nutri-Grain or Tiny Teddy
- needle
- stopper
- Bunsen burner
- heatproof mat
- thermometer
- metal can
- measuring cylinder (25 mL)





Method

1 Cut the top and bottom out of a metal can, and also cut a door as shown so that you can see the food burning. Put the can on a heatproof mat.

2 Pour exactly 10 mL of water into the test tube and hold it in the can with a test-tube holder as shown.

✻ Measure and record the starting temperature of the water.

3 Push the blunt end of the needle into the stopper and then stick the sharp end into the piece of food.

4 Slide the stopper and food under the test tube. There should be a space of about 2 cm between the test tube and the food.

5 Get the food to burn in a Bunsen flame and immediately put it back under the test tube.

6 ✻ When the food stops burning, stir the water *gently* with the thermometer, and measure the final temperature.

7 If you have time, repeat the experiment with other foods, e.g. nuts, bread, rice, spaghetti. Note that some people may be allergic to burning peanuts.

✻ Record all your results in your data table.

Results

1 By how many degrees did the temperature of the water increase?

2 It takes 4.2 joules to raise the temperature of 1 mL of water by 1°C. So, to calculate the heat energy gained by 10 mL of water, multiply the temperature rise by 42. Your answer will then be in joules. This is the energy released by the burning food.

3 Which of the foods you tested contained the most energy?

Discussion

This is a new section of your report where you analyse your experiment by answering these questions.

a Were the results what you expected?

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

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

d Were there any problems or errors in the experiment? If so, describe them. For example, in Step 7, were you able to accurately compare the energy released by different foods? Why or why not?

e What could be done to improve the experiment?

Write your report

Use the usual headings, including a conclusion, but this time add a discussion after your results and before your conclusion.

8.4 Energy comes and goes

Where does energy come from?

You use a lot of stored energy without really thinking about where it comes from. You get food from the supermarket, petrol from the service station and gas through pipes. But how did the energy get into these things in the first place?

During photosynthesis green plants store the energy of sunlight in their bodies as chemical energy. Animals that eat these plants use some of this energy and store the rest. So when you eat food that comes from plants and animals you are using stored energy that came originally from the sun.



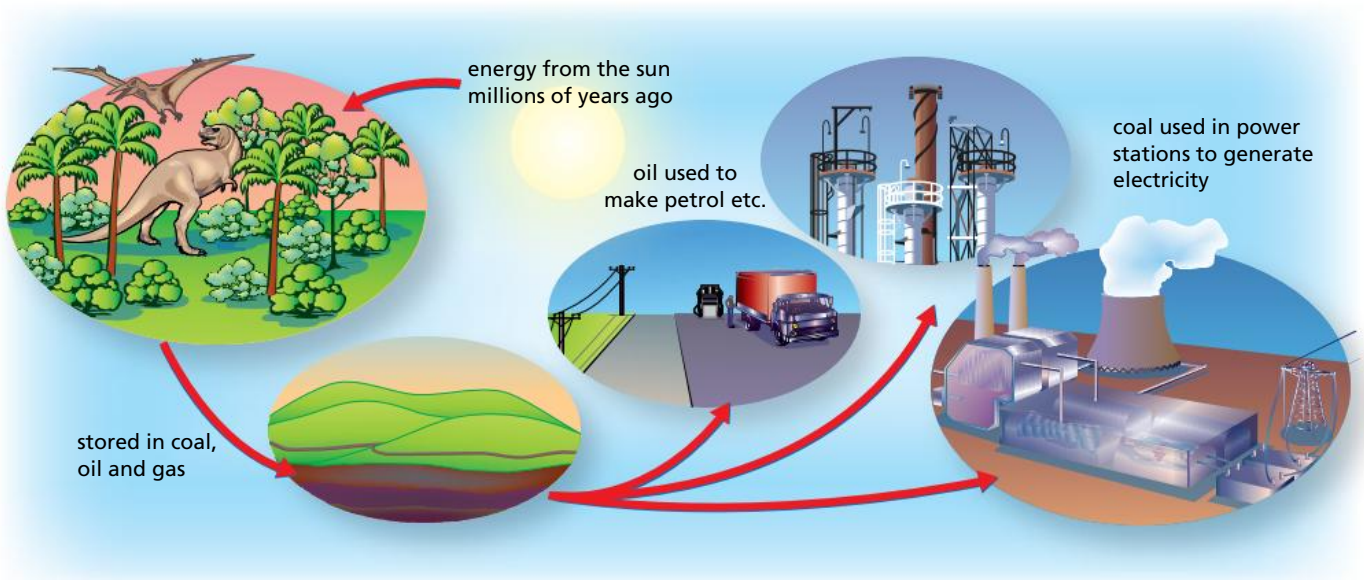
Millions of years ago plants and animals also turned the energy of the sun into stored energy. When they died their bodies were sometimes buried under mud and sand before they decayed. In this way their stored energy was trapped. Slowly the remains of these plants and animals changed to coal, oil and gas. These are called **fossil fuels**. When we burn them we are releasing their stored energy.

If the sun did not shine on the Earth there would be no green plants, and without the plants there would be no animals. Also, if the sun had not shone for millions of years, there would be no fossil fuels. In fact, without the sun there would be no life on Earth.

Renewable and non-renewable

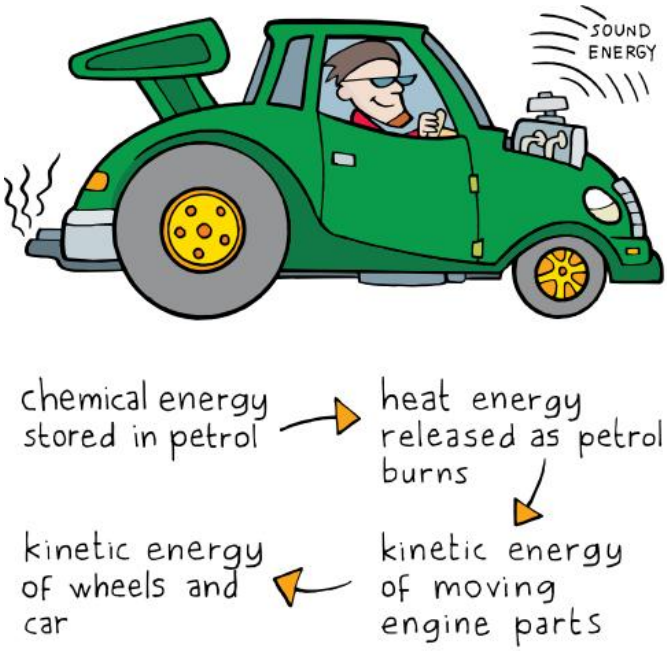
Fossil fuels are our main source of energy, but they are **non-renewable**. They have taken millions of years to form from sunlight falling on the ancient Earth. Yet once we have used them to make petrol or to generate electricity, they are gone forever. This is why we say they are non-renewable. Also, the amount of energy stored in fossil fuels is very small compared with the amount of solar energy reaching the Earth. In fact, it is estimated that there is more energy in the sunlight reaching the Earth in 10 days than in all the fossil fuels on Earth!

Our supplies of fossil fuels are very limited and it makes much better sense to use **renewable** energy sources that can be replaced. We now have the technology to capture the sun's energy directly for our use. For example, panels of solar cells mounted on the roof can supply enough electricity for your house. Hydro-electricity and wind power are other renewable energy sources.



Wasted energy

Look at the energy chain below for a moving car.



Each step in the chain involves some loss of energy. Friction between the moving parts of the engine produces heat. This heat is then transferred to the air around the car. Also, as the engine parts move they produce sound energy that is also transferred to the air. So not all the stored energy in the petrol is used to make the car's wheels turn. In fact, engineers have calculated that if you start with 100 joules of chemical energy, you end up with only 20 joules of kinetic energy. The other 80 joules is wasted as heat and sound and is not useful because it cannot be used again. Note that the *total* amount of energy you end up with is the same as the amount you started with. It has merely changed its form.

All energy converters waste energy—usually as heat. And the longer the energy chain, the more energy that is wasted. The **efficiency** of an energy converter is the percentage of the input energy which is turned into useful energy.

$$\text{Efficiency} = \frac{\text{useful energy}}{\text{input energy}} \times 100$$

For example, the efficiency of a car is about 20%. Because there is always some waste energy, the efficiency of an energy converter is always less than 100%.

Energy never disappears

You have looked at many examples of how energy is transformed and transferred. After thousands of such observations, scientists decided that there is a special rule or *law* that describes energy changes. The law of **conservation of energy** says that energy cannot be made, destroyed or lost—it can only be converted from one form to another. This means that the universe always has the same amount of energy, even though this energy is constantly being converted from one form to another and being transferred from one place to another.

To help you understand the law of conservation of energy, think about a board game such as Monopoly, in which money can be used for buying and selling. The money is transferred between players and the bank, but the total amount is always the same. If at the end of the game all the cash is added up, the total should be the same as at the beginning, although it will be distributed differently. The same applies to energy. It may move around and change its form, but the total amount is always the same.

Over to you

1 When using a hacksaw to cut a piece of metal, the blade and the metal both become hot. Explain in energy terms why this happens.

2 Suppose you wind up a toy duck and let it go.



   a Where did the energy needed to wind up the duck come from?

   b Where has this energy gone when the duck stops moving?

3 To charge a battery you have to supply electrical energy. But you never get as much energy from the battery as you use to charge it. Why is this?

4 A hot water system is 65% efficient. If it is supplied with 3000 joules of electrical energy, how much heat energy does it produce?

5 What is the difference between renewable energy and non-renewable energy? Give several examples of each.

6 Explain in your own words how the energy stored in the petrol you use in your car originally came from the sun.

INVESTIGATION

2 Colliding ball bearings

Aim

To investigate the efficiency of energy transfers between colliding ball bearings.

Risk assessment and planning

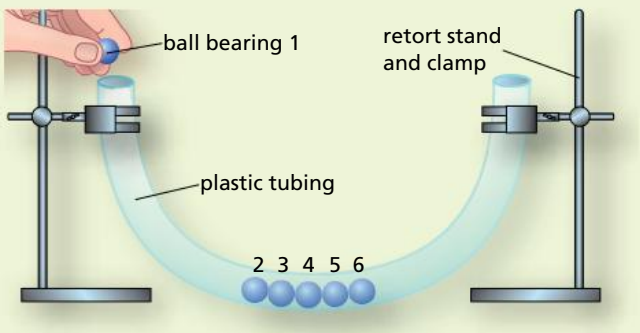
Read through the investigation and do a risk assessment.

Apparatus

- piece of plastic tubing, about 80 cm long
- 6 ball bearings or marbles, to fit inside the tubing
- marking pen
- 2 retort stands and clamps
- metre rule

Method

1 Use the stands and clamps to set up the plastic tubing as shown.



2 Place 5 ball bearings in the tube. Then drop another ball bearing in one end of the tube.

✻ Use what you have learnt in this chapter to explain what happened.

3 Use a metre rule to measure the vertical distance that ball bearing 1 fell before it hit the other ball bearings in the tube.

✻ Record this distance.

4 Remove ball bearing 1 from the tube. Drop it into the tube as before, but this time use the marking pen to mark how far up the tube ball bearing 6 goes. Repeat the measurement several times.

✻ Record your measurements and calculate the average distance.

5 Calculate the efficiency of the colliding ball bearing device as follows:

$$\text{Efficiency} = \frac{\text{distance ball 6 rises}}{\text{distance ball 1 falls}} \times 100$$

✻ Why do you think the efficiency of your device is less than 100%?

✻ Was any energy wasted? If so, what do you think happened to it?

6 Predict what will happen if you drop two ball bearings into the tube together. Try it.

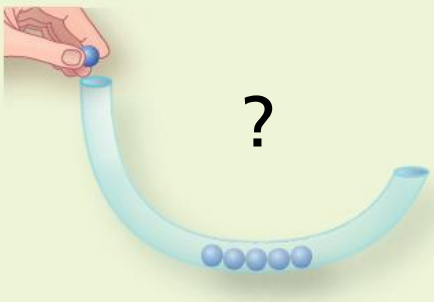
To release two ball bearings together you can pinch the tubing with your fingers. Then, when you are ready, let the tubing go and the ball bearings will fall together.



✻ Was your prediction correct? Explain.

7 What will happen if you drop *three* ball bearings into the tube together? Check your prediction.

8 Suppose you change the position of the plastic tube as shown, then drop in a ball bearing? Will ball bearing 6 come out of the end of the tube?



Clamp the tube in position where you think ball bearing 6 will just stay in the tube after collision. Use your results from Steps 1–5 and make any measurements you think are necessary.

✻ When you have chosen a position, explain why you picked that particular position.

9 Now for the moment of truth. Drop ball bearing 1 into the tube.

Was your prediction correct? If it wasn't, you may need to rethink the problem.

Discussion

Write a discussion using the questions on page 175 as a guide.

Conclusion

Write your own conclusion, summarising what you found out about the colliding ball bearing device.

SCIENTISTS AT WORK

Maria Skyllas-Kazacos

Maria Skyllas (SKY-las) was born in Greece in 1951 and came to Australia with her parents when she was only 2 years old. She went to Fort Street Girls' High School in Sydney. She chose easy subjects but after about a month her maths teacher said 'Maria, you should be doing advanced maths', to which Maria replied 'Oh no, I can't. It's too hard. I'm going to fail!'. But the teacher insisted she do it and she was soon top of the class.

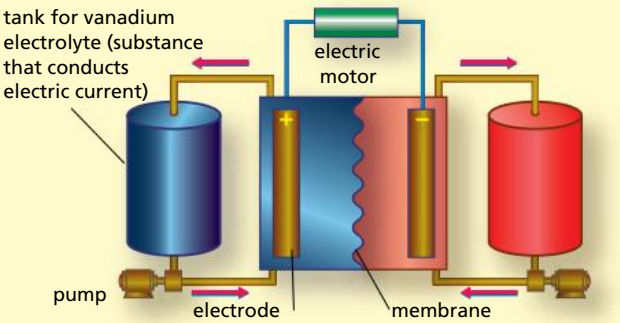


Maria is fourth from the left in the front row.

Maria went to the University of New South Wales to do a degree in industrial chemistry and she had to study hard in order to do well. There were only two or three females in her chemical engineering classes but that didn't worry her as the male students and professors were all very supportive.

In 1976 Maria married Michael Kazacos (ka-ZAR-cos) and she now has three sons. She has managed to combine being a mother with her research at the University of New South Wales. Her third son Anthony arrived just as she was organising a major international conference, but she managed to look after her new baby as well as run the conference.

Maria has always wanted to apply science to real-life problems. Because petrol and diesel-powered vehicles cause so much air pollution, a lot of research is being done on electric vehicles. However, these vehicles are limited because they have to use heavy bulky lead batteries to store electrical energy. Maria was also very interested in renewable energy and was aware that its widespread use was limited by the lack of a suitable energy storage system. So she got together a team to develop a new type of battery. Her husband Michael worked with her too. They had little money for research and had to be very resourceful, using many borrowed or recycled materials and equipment. After only two years of research, Maria and her team developed the vanadium battery. However it took others 15 years of development before the technology was manufactured commercially.



The vanadium battery is up to 90% efficient and can be recharged thousands of times, making it ideal for electric vehicles. You recharge it overnight using off-peak electricity, or you can replace the electrolyte solutions. In the future Maria believes you may be able to have your vanadium battery recharged by replacing the electrolyte—just like filling up the petrol.

Once Maria showed that her new battery would work, the patents were sold by the University of New South Wales to a manufacturer. Vanadium batteries are now being used all around the world for solar and wind energy storage. For example, a large vanadium battery is used to store wind energy for King Island in Bass Strait. And the battery has been used to power a golf buggy.



Questions

1. Why was Maria keen to develop a new type of battery?
2. Why does the vanadium battery need recharging? How can you do this?
3. How did Maria show determination and perseverance in achieving her goals?

8.5 Doing a project

In science you will sometimes be asked to do a project. How do you go about this?

First, you could turn one of the chapter problems into a project. Second, there are many ideas for projects in *Thinking skills*. Third, you could extend one of the Inquiries. For example, you could investigate how energy is changed in electric circuits (see page 170).

If you do a *student research project* like this, you will not simply be following instructions in a book. A project involves you deciding what needs to be done, then doing it, and reporting your results to others.



On a trip to India Christopher Bentley wondered whether chilli in food kept away diseases. So he did a CSIRO CREST project to see what affect various parts of chilli plants have on micro organisms.

INQUIRY 13 Choosing a project

1 Look through this textbook and note down the things that interest you the most and that you would like to know more about. In particular, check the problems, inquiries, and investigations. Which do you think would be suitable for a student research project? Write these down.

2 Most projects start with a question to investigate. Some that students have investigated are:

- Can dogs see colours?
- Do all your fingernails grow at the same rate? Do fingernails grow faster than toenails?
- How can I make a better cleaning device for our fish tank?
- How can I make a device to alert you when it is raining so that you can get the washing off the line?
- How can soil erosion in our area be reduced?
- How can you keep the house cool in summer and warm in winter?
- How can you make the bubbles in a bubble bath last longer?
- What affect does oil have on water plants?
- Which materials make the strongest bricks?
- Is it true that people with low blood pressure are not bitten by mosquitoes as much as people with higher blood pressure?

3 Check these two websites for further ideas to get you started.

Do-it-yourself science

www.csiro.au/resources/DIYScience.html

Science fair projects

www.all-science-fair-projects.com

You could also check BHP Billiton, CSIRO CREST and the Science Teachers' Associations for details of the competitions they run.

4 Consider each of your ideas in turn. You will probably ask yourself questions like these:

- Which project do I like the most? Which is the most interesting?
- Can I get the equipment and materials I need?
- Can I find the information I need to do the project?
- Can I complete the project in the time available?

Talk with teachers and other people about your ideas. Finally, pick the project you think would be best for *you*.

Gathering information

You can gather information in three main ways:

a from libraries, magazines, newspapers, TV programs and the internet (see Inquiry 14).

b by talking to a few people who know a lot about the topic, or by doing surveys of many people. For example, you could use a questionnaire to find out which brands of washing-up liquid people use.

c by doing experiments yourself to try to answer the question under investigation, e.g. Which of these materials is the best insulator?

PROBLEM SOLVING

Have you made a successful mousetrap racer? How far did it go? How fast did it go? What problems did you have to solve? Can you explain how it works in terms of energy changes?

You may want to keep working on it. For example, you could investigate its motion using a datalogger and motion detector. If you make it into a project you may be able to use some of the ideas in this section.

You may be able to enter your racer in a competition. You could check the internet for information on this.

INQUIRY 14 ***Using the internet***

Answer the questions below by investigating the following science websites.

Nova: www.science.org.au/nova

Australia Advances: www.csiro.au/promos/ozadvances

ABC Science: www.abc.net.au/science

New Scientist: www.newscientist.com

Double Helix: www.csiro.au/helix

How Stuff Works: www.howstuffworks.com

1. Which of the general science sites listed above are Australian?
2. Which site would be best for doing research on Australian discoveries in science and technology?
3. The *Nova* site lists topics under six categories. What are they? Check out a topic that sounds interesting, including the Activities page.
4. Investigate the *How Stuff Works* site. They have a wide range of things you might be interested in.
5. What is in the latest issue of *New Scientist* magazine? Pick an article or news item that interests you.
6. On the *Double Helix* site you can work with some of Australia's leading scientists doing real research. Which project(s) are they working on at present?
7. Think of a science topic you might need to research. Then do a search for it in one of these science sites.
8. Check out the *ABC Science* site. Look for possible project ideas.

Surfing tips

Here are some tips to help with your web surfing project research.

- If you get an error message after typing in a web address, first check that you have the address exactly right. If this doesn't work try deleting the last part of the address, back to the first /.
- Searching using key words takes a bit of practice. If you use only one word like *hovercraft* you often get too many sites. When this happens you need to narrow your search by adding a word or two to describe more precisely what you are looking for; for example *how to make a hovercraft* or *hovercraft + balanced forces*.
- When you are researching a topic it is best to use several different sites. The information on one site may be inaccurate or not up to date. Some sites are also biased, that is, they only present one side of the story.
- Instead of doing a general search using a search engine such as *Google*, it is sometimes a good idea to go into a general science site such as one of those on the left and search within it.



Hints on doing your project

1 Plan what equipment and materials you will need for your project. Check what is available at school, what you can get from home and what you can borrow. You don't always need proper laboratory equipment. For example, you could use glass jars instead of beakers, or measuring jugs instead of measuring cylinders.

2 Write a brief outline of what you plan to do. This outline should include:

- the question you are going to investigate
- the equipment and materials you will need and where you can get them
- a list of possible information sources.

Show this to your teacher who will give you helpful suggestions and then give you the okay to go ahead. *Do not attempt the project without your teacher's approval.*

3 Plan your time carefully by dividing the project into stages. An example of a plan for a 5-week project is shown below.

Selecting a topic and preparing plans	1 week
Doing project	2–3 weeks
Evaluating results and preparing report	1–2 weeks
Presenting report	1 day

4 Keep a journal just for your project. This will be very useful when you come to prepare your report. It could include notes you have taken from books, photographs or drawings of your experiments, tables of data, drawings or plans of a model at various stages of construction etc.

5 When doing experiments, you should follow these steps:

- Write down the aim of the experiment. This may be a hypothesis you are testing; for example. *Substances dissolve faster in warm water than in cold water.*
- Make sure any tests you do are fair. To do this you need to test one variable and control all the others.
- Do the experiment, and collect and record data. Computer spreadsheets are useful here.
- Try to duplicate your tests for more accurate results. For example, if you are germinating seeds, set up three or four pots for each test, not just one.

Remember, there are no incorrect answers when doing an experiment—only unexpected ones.

For more information on designing your own experiment see pages 13–14.

6 You will need to make a list of the sources of your information as part of your report, so keep careful notes of any books, magazines and websites you use.

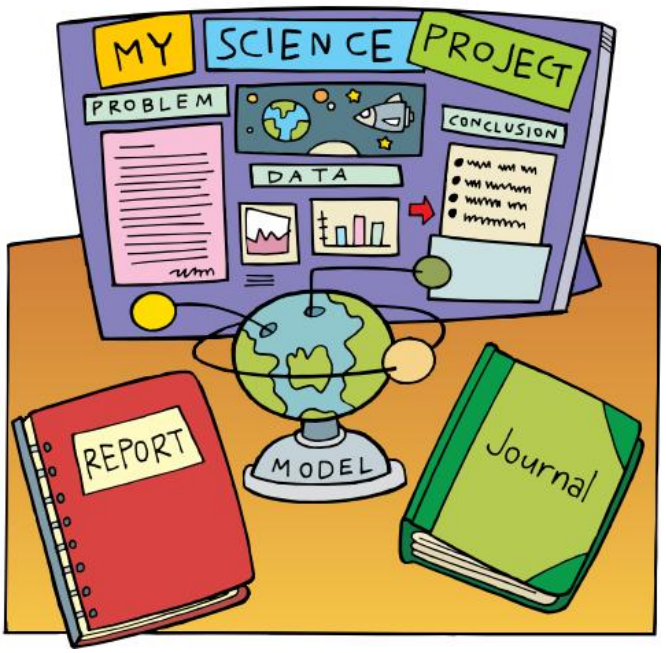
Hints on preparing a report

1 Your report should have the same headings as for an investigation. It should also have a Discussion where you discuss any difficulties, errors and results you cannot explain. Don't forget your Conclusion. Doing the project may be the most important thing for you, but most people will want to know how successful you were in achieving your aim.

2 As well as your written report, you will need to display any device or model you have made. You could also make a display for the library, a short talk using overhead transparencies or a PowerPoint presentation.

You can display a report made of many different parts on large sheets of white card taped together to create a display board as shown below.

3 Ask your teacher about entering your project in a science contest.

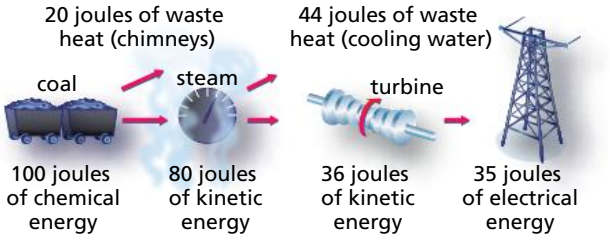


THINKING SKILLS

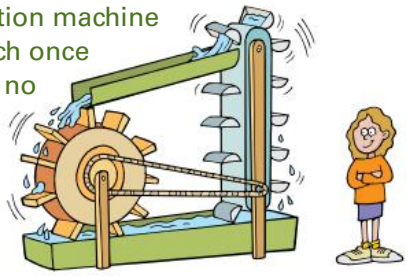
1 A neon street light converts 300 J of electrical energy into 200 J of heat energy and 90 J of light energy.
   a Some energy is missing. Suggest what has happened to it and what it is.
   b What is the efficiency of the light?

2 Peter burnt his finger on a frypan. He immediately put his burnt finger on a piece of ice. Explain how energy was transferred when
   a he burnt his finger
   b he put his finger on the ice.

3 The diagram below shows the energy changes in a coal-burning power station.
   a Draw an energy chain to describe what happens in the power station.
   b A small amount of energy is lost when the kinetic energy of the turbine is converted to electrical energy. Infer how this energy is lost.
   c How many joules of heat are released into the environment for each 100 joules of chemical energy stored in the coal?
   d What is the overall efficiency of the power station?



4 The diagram shows someone's idea of a perpetual motion machine (a device which once started needs no more energy to keep it going). Do you think it will work? Explain your answer.



5 How could you demonstrate that sound is a form of kinetic energy?

6 Two cars collide head-on and come to a stop. What has happened to the kinetic energy that the cars had before the crash?

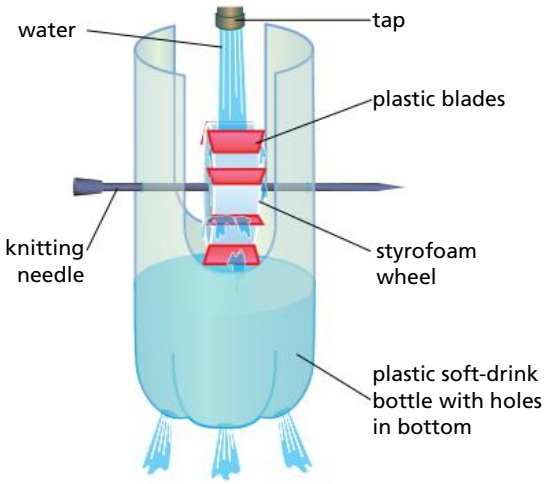
7 Draw a cartoon of an archer about to fire an arrow. Discuss with another student how potential energy is involved, and how this energy will change when the arrow is fired. Write a caption to describe your cartoon in energy terms.

8 In an experiment similar to the one you did in Investigation 1, five different foods were burnt and the increases in water temperature measured. The results are shown below.

Food	Mass of food (g)	Mass of water heated (mL)	Increase in water temperature (°C)
Beans	1.0	20	6
Bread	1.0	20	35
Cashews	0.5	20	47
Oil	0.5	20	73
Pasta	0.5	20	10

   a Calculate the energy released from each food.
   b Calculate the energy *per gram* released from each food. Which has the highest energy value?

9 Make a working model of a waterwheel. One way to do this is shown below.
   a Describe the energy changes that occur in a waterwheel.
   b How could you use your waterwheel to light a LED as in Inquiry 7?



Knowing and Understanding

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

1 _____ makes thing go. It makes things happen, or causes _____. It is measured in joules or _____ (kJ).

2 There are many different _____ of energy; for example, light, heat, sound and _____.

3 _____ energy is the energy an object has because of its movement. Energy that is stored is called _____ energy.

4 Energy can be _____ from one object to another, and it can be _____ from one form to another. A series of energy changes is called an energy _____.

5 When an energy change occurs some energy is always wasted as _____. The law of conservation of energy says that energy cannot be _____ or destroyed.

6 Most forms of energy (including fossil fuels) can be traced back to the _____.

7 _____ energy sources such as solar energy can be replaced as they are used. _____ are non-renewable sources and cannot be replaced when they are used.

chain
changes
converted
electricity
energy
forms
fossil fuels
heat
kilojoules
kinetic
made
potential
renewable
sun
transferred

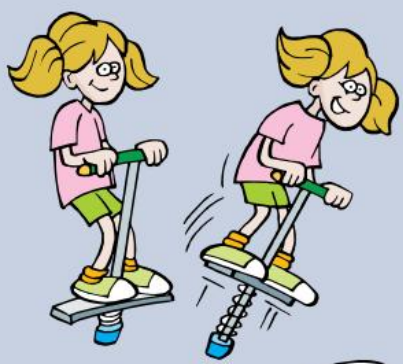
Self-management

A good way to explain scientific ideas is to draw pictures.

1 Apply what you have learnt in this chapter by explaining each of the four situations pictured in terms of energy. Try to talk about:
   - forms of energy
   - energy conversions
   - transfer of energy.

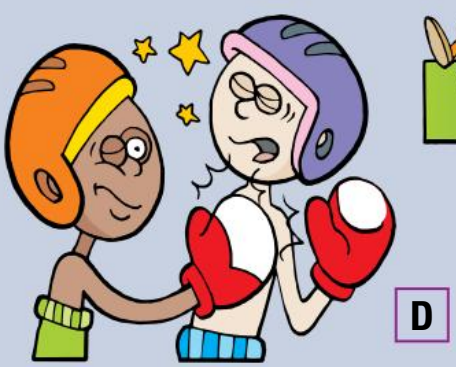
2 Draw your own picture to illustrate energy being
   a transformed from one form to another
   b transferred from one object to another.

3 Think of an energy chain and draw it.









Checkpoint

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

OneStopScience

1 In any energy change some energy is always wasted as

A potential energy

B heat energy

C sound energy

D kinetic energy.

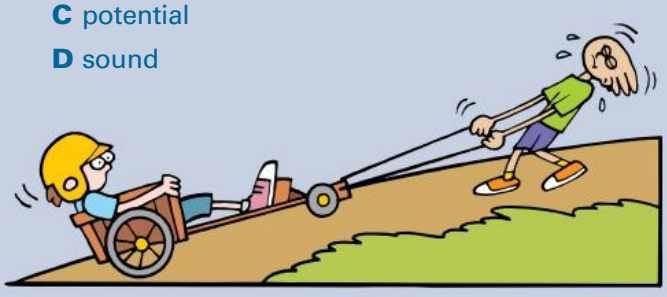
2 As a go-cart is pulled up a hill, which form of energy is gradually increasing?

A chemical

B kinetic

C potential

D sound



3 Which of these requires the most energy?

A riding a bicycle on level ground

B riding a bicycle up a hill

C walking

D doing your homework

4 The same energy conversion occurs in a person running, a car engine and a coal-burning power station. Which is it?

A kinetic → electrical

B heat → chemical

C heat → kinetic

D chemical → kinetic

5 Which of the following is incorrect?

A Energy can be made.

B Energy can be changed from one form to another.

C Energy can exist in more than one form.

D The energy in food came initially from the sun.

6 Which of the following involves a transfer of energy from one object to another, rather than an energy conversion?

A Hot coffee poured into a cup makes the cup hot.

B A hydro-electric power station uses running water to generate electricity.

C The tyres of a moving car become hot.

D Gas is burnt to cook a meal.

7 Classify the following energy sources as renewable or non-renewable: coal, diesel fuel, LPG gas, ocean waves, the sun, uranium fuel, wind, wood.

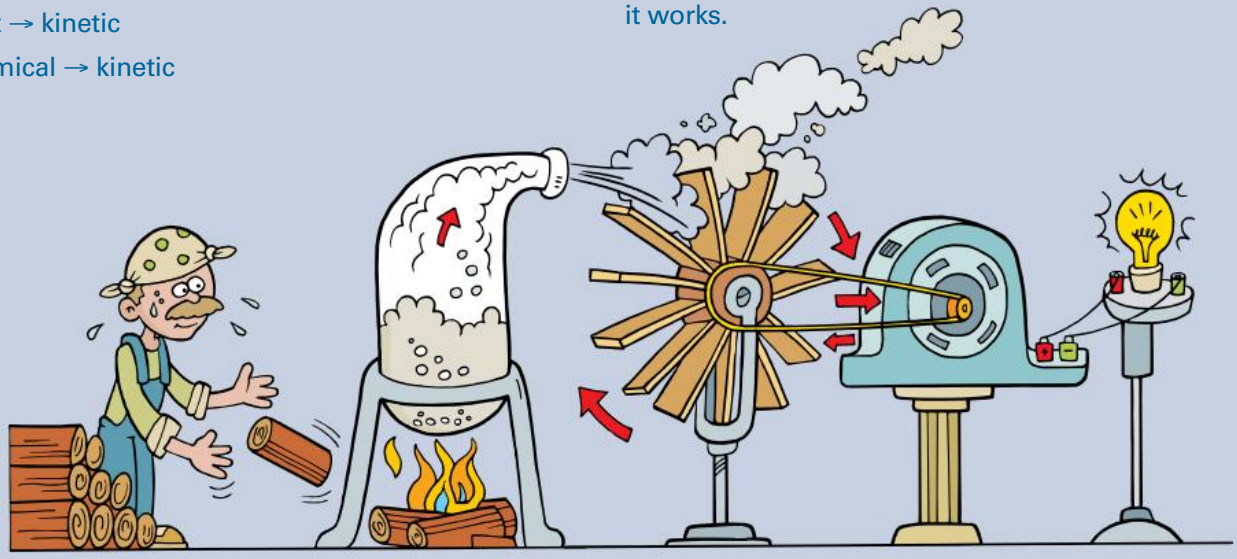
8 For every 100 joules of energy used by an electric light bulb, you get only about 5 joules of light energy.

a What happens to the other 95 joules of energy?

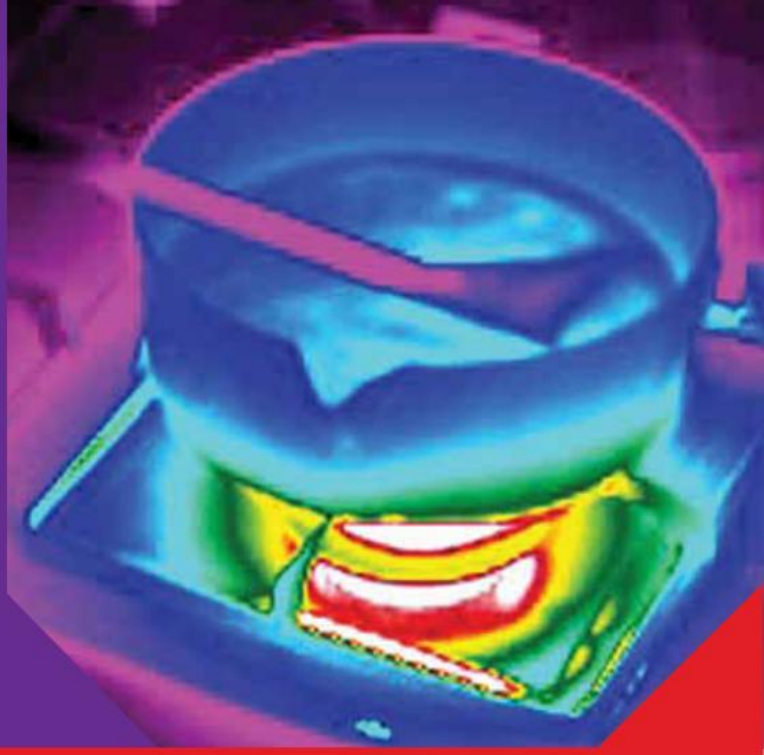
b How efficient is the light bulb?

9 Sam said that electrical energy is made in a hydro-electric power station (page 173 bottom right). In terms of the law of conservation of energy, is Sam correct? Explain.

10 The cartoon below shows a way of generating electricity. Write an energy chain to describe how it works.



9



Heat energy

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

Science Understanding

- investigate heat transfer by conduction, convection and radiation in everyday situations

Science Inquiry Skills

- measure temperature using your skin and thermometers
- work in a group to design, build and test a solar water heater
- build a model house to investigate ways of keeping it warm or cool
- interpret illustrations

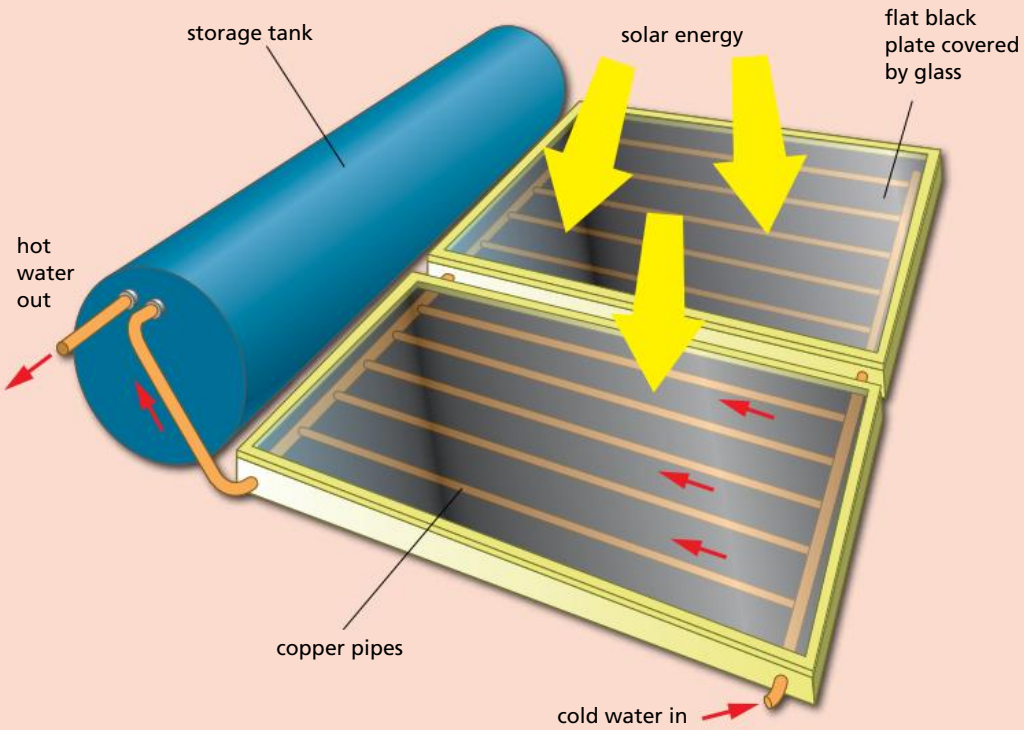
LITERACY FOCUS

Celsius
conduction
conductor
convection
equilibrium
evaporation
heat
hypothermia
infra-red
insulator
microwaves
particle theory
prototype
radiation
temperature
thermometer
thermostat
transmitted
transparent
ultraviolet

Focus for learning

The free hot water from a solar water heater means you save on the cost of gas or electricity and, as most power stations burn coal and produce carbon dioxide, you are also helping to reduce greenhouse gases and minimise global warming.

A solar hot water system works in the same way as a garden hose that has been sitting in the sun all day. It has a black plate called a collector that absorbs solar energy and gets hot, just like the hose in the sun. This collector has insulation underneath and a glass plate on top to trap heat energy inside. The heat absorbed by the collector passes into copper pipes filled with water. This water heats up and flows into a storage tank, ready for use. It is then replaced by cold water and the cycle repeats itself.



PROBLEM SOLVING

Building a solar water heater

Design and build a solar water heater that will raise the temperature of 4 L of cold water by at least 20 °C after standing in the sun for an hour.

Use these steps to complete this task.

1. Search for information in the library and on the internet. Discuss the problem with others. Jot down any good ideas.
2. Draw a plan of your solar water heater. List the equipment needed and where you can get it.
3. Build a *prototype*—your first experimental model.
4. Test the prototype. If it doesn't work very well, what can you do to improve it?
5. If necessary build an improved model and test it.
6. Demonstrate your solar water heater to the rest of the class.
7. Write a full report using the correct headings for an investigation. Don't forget to include a Discussion describing any problems you had and how you solved them. Your solar water heater and report may be good enough to enter into a science contest or CSIRO CREST Award (see page 16).

9.1 Conduction of heat

INQUIRY 1 Hot or cold?

How good are you at telling whether things are hot or cold?

You will need: 3 ice-cream containers (2 L), hot water, ice cubes

1. Touch various objects in the classroom. Do some feel cooler than others? Which ones?
2. Prepare the ice-cream containers—one with cold water containing ice cubes, one with hot water (not too hot to put your hand in) and one with lukewarm water.
3. Put one hand in the hot water and one in the cold and leave them there for at least a minute.
4. Now put both hands into the lukewarm water. What do you notice?



Did you find that metal objects feel cooler than wooden, plastic or cloth objects, even though they are all at the same temperature as the room? Did you find that the hand that had been in the cold water felt warm in the lukewarm water, while the hand that had been in the hot water felt cold? Obviously it is hard to tell exactly how hot or cold something is just by touching it, so we use thermometers. To find out how a thermometer works, try Inquiry 2.

How does a thermometer work?

The first thermometer was invented by Galileo in Italy in 1593. It worked like the one you will use in Inquiry 2. The thermometer we use in the laboratory was invented in 1742 in Sweden by Anders Celsius. It consists of mercury (a silvery liquid) in a long glass tube. As the temperature increases the mercury expands and rises up the tube. As the temperature decreases the mercury contracts and falls back down the tube. Celsius marked the freezing point of pure water as 0 °C and its boiling point as 100 °C. By marking a scale from 0 to 100 he could then measure a range of temperatures.

Celsius called his units of measurement 'degrees Celsius'. Because thermometers are easily broken and mercury is poisonous, the thermometers you use usually contain alcohol plus a red dye, instead of mercury. The alcohol works in the same way as mercury.

The list below shows the range of temperatures in the world around us.

Inside some stars	over 50 000 000 °C
Surface of our sun	approx 6000 °C
Arc welding	approx 3500 °C
Electric light filament	approx 2500 °C
Factory furnace	approx 2200 °C
Bunsen burner	approx 600 °C
Boiling water	100 °C
Melting ice	0 °C
Ice–salt mixture	–20 °C
Liquid air	approx –190 °C
Liquid helium	approx –270 °C

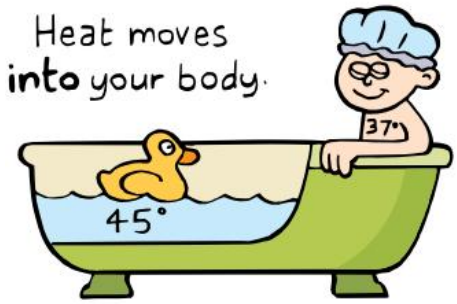
INQUIRY 2 Homemade thermometer

You will need: plastic film canister, plastic straw, Blu-Tack, ice cubes, hot water, piece of wire, food colouring, Bunsen burner, heatproof mat

1. Heat the wire in a Bunsen burner flame and use it to make a hole in the lid of the canister, just large enough to fit the plastic straw.
2. About one-third fill the canister with coloured water, then click on the lid. Some water may move up the straw.
3. Adjust the height of water in the straw to about half way up by partly opening the lid and shutting it again.
4. Mark this as the water level for room temperature. Experiment with cooler and warmer temperatures, e.g. in a fridge or a container of ice-cold water, holding the canister in your hands for a couple of minutes, putting it in hot water.
   - How could you make a scale for your thermometer to measure temperatures accurately? Perhaps you could compare it with a proper thermometer.
   - Can your thermometer measure 0 °C (ice water) and 100 °C (boiling water) accurately?

How heat moves

Imagine sitting in a hot bath. If the temperature of the bath is greater than 37 °C (normal body temperature), heat moves from the hot water into your body—warming you up. If the bath water is cooler than 37°C, heat moves out of your body into the water, making you feel cold.

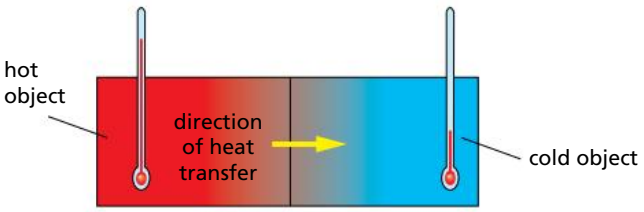


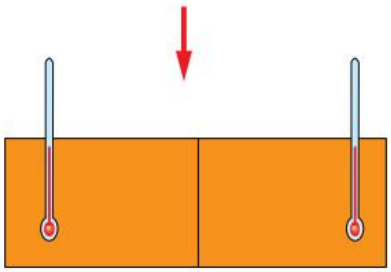


This is what happened in Inquiry 1. When you put your cold hand into lukewarm water, heat moved into your hand. This is why it felt warm. When you put your hot hand into lukewarm water, heat moved out of your hand, making it feel cool. It was the movement of heat that fooled you into thinking that the temperature was different for each hand.

When a hot object comes into contact with a cold object, heat flows from hot to cold until both objects are at the same temperature, that is, they are in a state of balance or **equilibrium** (equil-LIB-ree-um). See the diagram top right. If you put a cold pack on your arm, heat moves from your arm to the cold pack. This flow of heat cools down your arm and warms up the cold pack, until they are both at the same temperature. The larger the temperature difference, the faster the heat moves from hot to cold.

Warm objects lose heat to their surroundings. If you aren't rugged up when you go skiing, heat energy is soon lost from your body to your surroundings and you feel cold. Similarly, cool objects in warm places take in energy from their surroundings. This is why an ice-cream melts so quickly on a hot day.



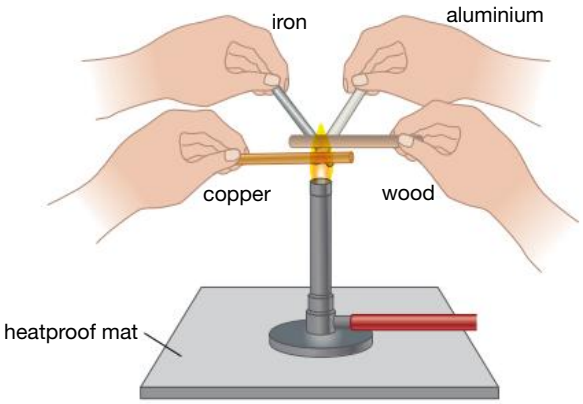


Equilibrium—heat transfer has stopped.

INQUIRY 3 Which conducts best?

You will need: Bunsen burner, rods made of various materials, e.g. copper, iron, wood, glass (If possible they should be the same diameter and the same length.)

Four students hold the ends of the rods in the burner flame as shown. As soon as a rod feels hot or starts to burn, take it out of the flame. *This is not a competition.*



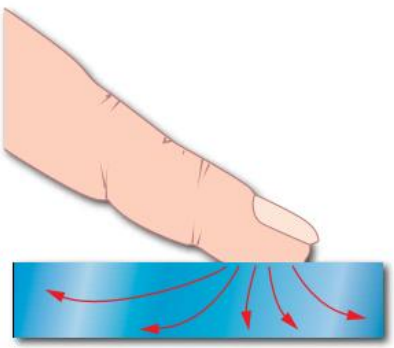
- Which rod gets hot first?
- List the rods in order, from the one that heated up first to the one that took the longest to heat up.

A **conductor** allows heat to move through it; an *insulator* does not.

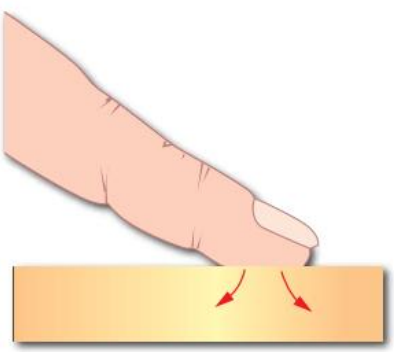
- Which rod materials were conductors?
- Which materials were insulators?

Conductors and insulators

If you hold an ice cube in your hand, heat flows out of your body into the ice cube. This type of heat transfer is called **conduction**. As you found in Inquiry 3, some materials conduct heat better than others. For example, the reason a metal object feels cold is because it conducts the heat away from your body very rapidly. This is why metals are called conductors. The reason that most other materials feel warm is because they don't conduct the heat away from your body. They are called insulators. They stop the flow of heat by conduction. This is why saucepans have plastic handles rather than metal ones, and why eskies (portable coolers) are made of polystyrene foam. Plastic and polystyrene foam are both good insulators.



Metal conducts heat well so it feels cold.



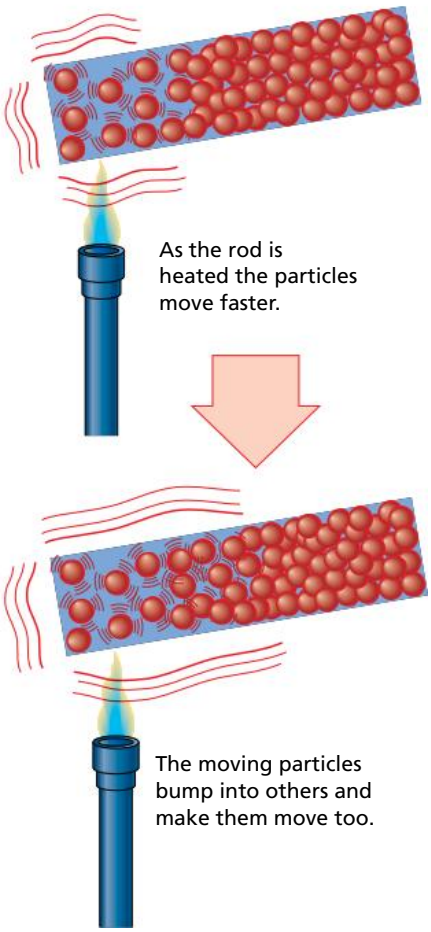
Plastic conducts heat poorly so it feels warm.

Explaining conduction

The particle theory tells us that everything is made of tiny particles. In solids the particles are close together and can hardly move. In liquids the particles are not as close together and can move around a little, sliding over each other. In gases the particles are far apart and move about freely.

When a metal rod is placed in a flame as in Inquiry 3, it soon becomes hot. The heat is transferred along the rod by conduction. The particles in the end of the rod gain energy from the flame. This causes them to vibrate faster and collide more violently with each other. This process continues like a chain reaction from particle to particle along the rod. This is how heat energy is transferred from the hot end of the rod to the cooler end.

Why are metals better conductors than other materials? The reason is that metals are made of atoms that hold their electrons very loosely. Some of these electrons are free to move around, bumping into other atoms and making them vibrate more. Liquids are poor conductors of heat because their particles are slightly further apart than in solids.



Gases are very poor conductors of heat, meaning they are good insulators. Birds fluff up their feathers on cold days to trap air in them. (See the photo on the next page.) Because air is an insulator, it slows down the loss of heat from the bird's skin to the surrounding cooler air. Woollen jumpers, sleeping bags and ceiling insulation batts also work by trapping air.

INVESTIGATION

1 Keeping it cool

Aim

To design an experiment to find out which is the best insulator to keep a drink cold.

Planning hints

A simple way to do this experiment is to cover empty soft drink cans with different insulating materials, fill them with ice-cold water and measure the temperature as the water warms up. As a comparison, you will need to leave one can uncovered. This is your *control*. You will need to work out the details of the experiment. For example:

- Which insulating materials will you use?
- How will you control variables to make it a fair test?
- How often will you measure the temperature?
- Are there any safety precautions you need to take?
- How will you record your results?

Write your report

As you were not given the method, it is important to describe what you did, with diagrams if necessary. A list of the apparatus you used is also needed.

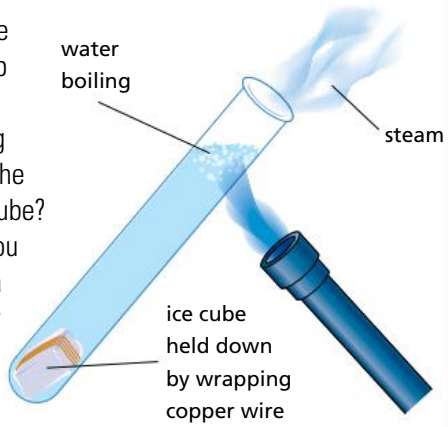
Decide on a way to display your results so others can see quickly what you found out.

When writing a conclusion, make sure you answer the question in the aim. Did other groups come to the same conclusion? Are you confident your conclusion is correct? For example, did you have any difficulties making sure your comparison of insulators was fair?

INQUIRY

4 Does water conduct?

Can you boil the water in the top of a test tube without melting an ice cube in the bottom of the tube? From this, do you think water is a good conductor of heat? Explain.





Birds often fluff up their feathers to keep warm.

Temperature and heat

Temperature and heat are not the same. Temperature tells you how hot or cold something is. It is measured in degrees Celsius (°C), using a thermometer.

Heat is a form of energy which can raise the temperature of an object. The temperature of an object depends on how fast its particles are moving. The higher the temperature the faster they move. Heat energy can be transferred from a hot object to a cooler one. It is measured in joules.

The amount of heat energy in an object depends on the mass of the object, as well as on its temperature. To understand this, think of a spark from a sparkler. The spark is actually a tiny piece of white-hot metal with a temperature as high as 600 °C. Why then doesn't the spark burn you when it lands on your hand? The spark has so little mass it contains very little energy. When this heat energy is transferred to your hand by conduction, the rise in temperature is so small you hardly notice it.

Inquiry 5 on the next page will help you to understand the difference between heat and temperature.

INQUIRY

5 Hot washers

You will need: three 250 ml beakers, 2 thermometers, 6 metal washers (about 3 cm in diameter), 2 pieces of string about 20 cm long, 100 mL measuring cylinder, Bunsen burner equipment, stirring rod

1. Three-quarters fill a beaker with water and use the Bunsen burner to bring it to the boil.
2. Watch the beaker, while someone else measures out 100 mL of water into each of the other two beakers. Measure the temperature of the water in each.
3. Tie 1 metal washer on 1 piece of string and 5 washers on the other piece.
4. Put both pieces of string with the washers attached into the boiling water and leave them there for 5 minutes.



5. After 5 minutes, quickly transfer the string with one washer to one beaker and the string with five washers to the other beaker.
6. Stir gently and measure the highest temperature reached in each beaker.
   - Was the single washer the same temperature as the string of five washers? How do you know?
   - In Step 6, which beaker reached the higher temperature?
   - Which contained more heat—the single washer or the string of five? How do you know?
   - Use your results to explain the difference between temperature and heat.

Over to you

1. Arrange the following temperatures in order from the highest to the lowest: 75 °C, 100 °C, –20 °C, 0 °C.
2. Copy and complete these sentences.
   - **a** _____ is a measure of how hot something is.
   - **b** Temperature is measured with a _____.
   - **c** On the Celsius scale water _____ at 100°C and _____ at 0 °C.
   - **d** Metals are good _____ of heat.
   - **e** Plastics are good _____ because they prevent heat from passing through them.
   - **f** Heat can travel through solids because the _____ in them bump into each other.
   - **g** As an object gets hotter its particles move _____.
3. Why are you more likely to burn your lips drinking from a metal cup than one made from china?
4. You get into a bath containing water at 45°C.
   - **a** What will happen to your body temperature?
   - **b** What will happen to the temperature of the water?
   - **c** Does heat flow from the water into your body or from your body into the water? Explain.
5. You leave the door of your heated house open on a cold night. Does the cold come in or does heat go out? Explain.
6. **a** Which is hotter—a cup of water at 50 °C or a bathtub full of water at 50 °C?
   - **b** Which contains more heat energy?
7. Imagine what it would be like to eat off metal plates. The food would probably be cold before you could eat it. Why?
8. Use the particle theory to explain why conduction of heat occurs in solids but not in gases.
9. Your friend Kate says that the iron in a fence feels hotter than the wooden posts. How could you convince her that the iron and the wood are really at the same temperature, and explain to her *why* the iron feels hotter?
10. Use what you have learnt in this section to explain each of the following.
    - **a** Containers for cooking have plastic handles.
    - **b** Putting a metal skewer into a potato will decrease the time needed to bake it.
    - **c** It is warmer to wear two thin pullovers than one thick one.
    - **d** Drink coolers are made of foam plastic rather than solid plastic.

9.2 Convection of heat

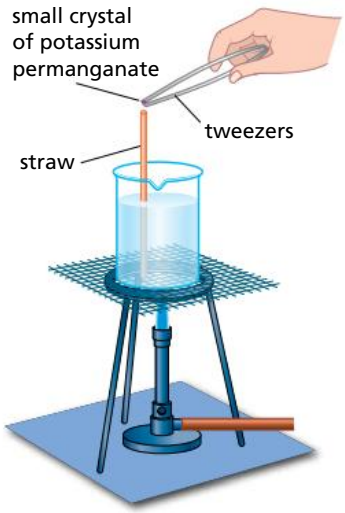
INQUIRY 6 Convection currents

Part A

You will need: 250 mL beaker, Bunsen burner equipment, tweezers, potassium permanganate, plastic straw

1 Fill the beaker with water and put it on the gauze mat and tripod. Let the water sit for a minute or so.

2 Without disturbing the water, put a straw into the beaker. Use tweezers to drop a small crystal of potassium permanganate down the straw.



3 Carefully remove the straw and heat the beaker.

- Draw a diagram to show what happens.

Part B

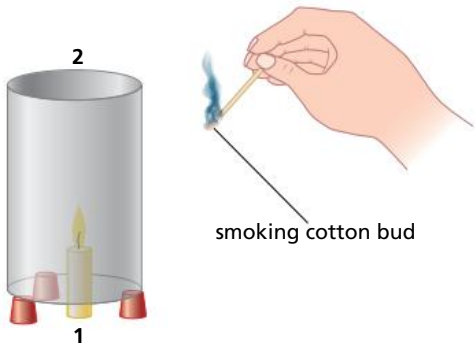
You will need: small can with lid and base removed, short candle, 3 stoppers all the same size, cotton bud soaked in oil or glycerine

1 Set up the can, stoppers and burning candle as shown.

2 Light the cotton bud, let it burn for about 10 seconds then blow it out.

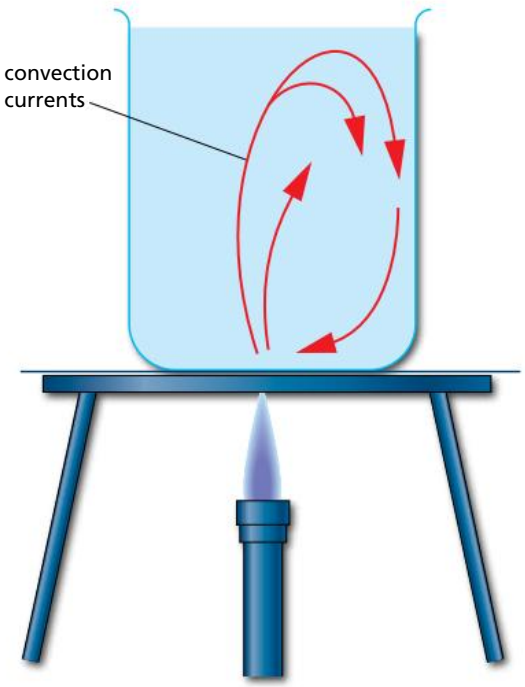
3 Put the smoking cotton bud first in position 1, then in position 2.

- What happened to the smoke when the cotton bud was in position 1? Suggest a reason for this.
- What happened to the smoke when the cotton bud was in position 2? Why?



How convection works

When you turned on the Bunsen burner in Part A, heat was transferred by conduction through the gauze mat and the beaker to the water. The water at the bottom of the beaker expanded as the water molecules began to move faster, knocking into each other and spreading apart slightly. This made the water in this area less dense and as a result it moved upwards, as shown by the purple colour. The water near the top of the beaker was cooler and more dense, so it sank. As a result a roughly circular **convection** current formed. This cycle of hot water rising and cold water taking its place continued until all the water in the beaker was at the same temperature.



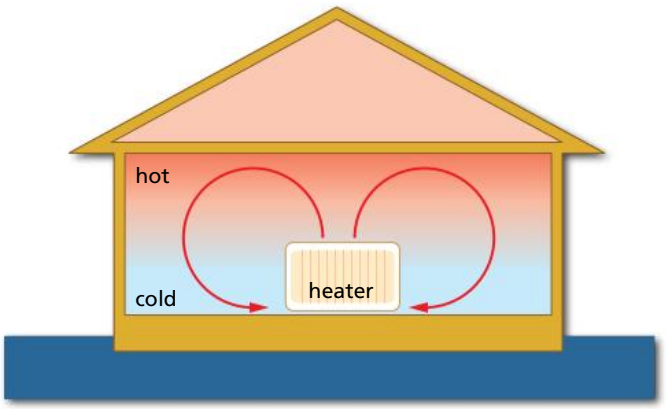
Convection currents also form in air, as you saw in Part B. People often say that 'heat rises', but this is not really true. The heat energy does not rise on its own. The hot air rises and takes the energy with it.

In solids the particles can't move about. Heat causes them to vibrate more and they pass this vibration on by conduction, without leaving their place in the solid. The heat can't be transferred by convection because the particles can't move.

In a liquid or a gas the particles can move from place to place. If part of the liquid or gas becomes warmer than its surroundings it can move upwards by convection, taking heat energy with it.

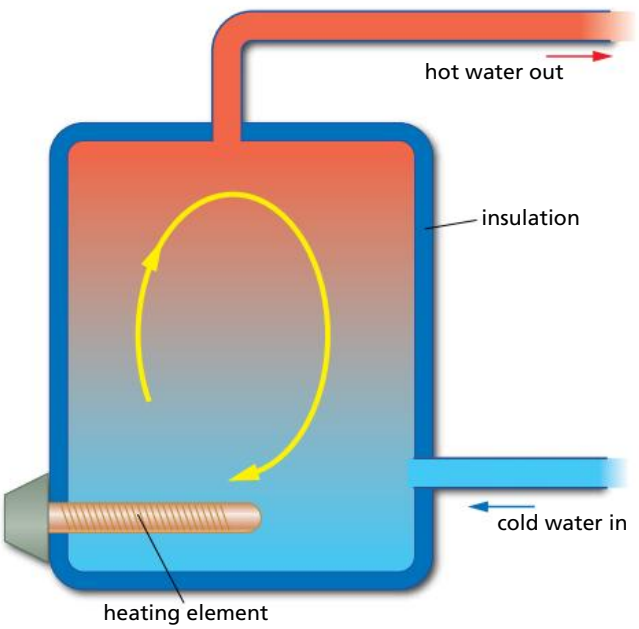
Convection in our homes

There are many examples of convection in our homes. For example, a room heater heats the air around it. This causes the air to expand and it becomes lighter than the surrounding cooler air. The heated air rises and the cooler air replaces it. In this way the convection currents spread heat energy evenly throughout the room. Kitchen ovens work in the same way. The heating element is at the bottom, so the hot air will move up and circulate throughout the oven. This is why these ovens are often called convection ovens.

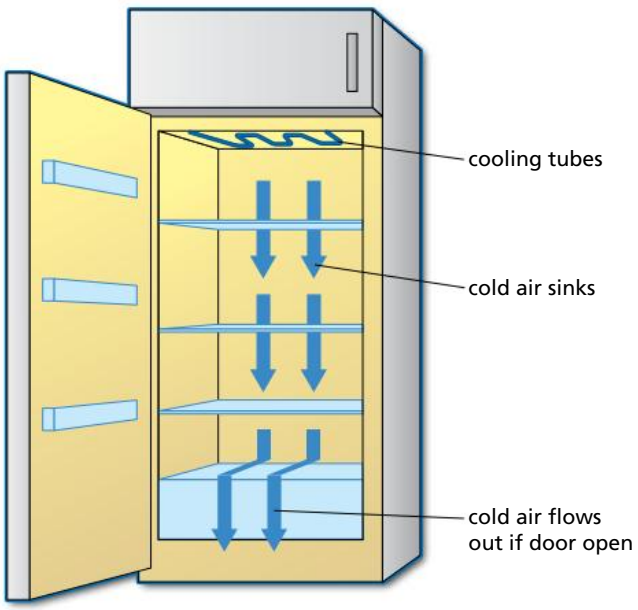


Convection currents spread the heat from a room heater.

A hot water system also works by convection. When you turn on a hot water tap, hot water is taken from the top of the water tank and cold water flows in at the bottom to replace it.

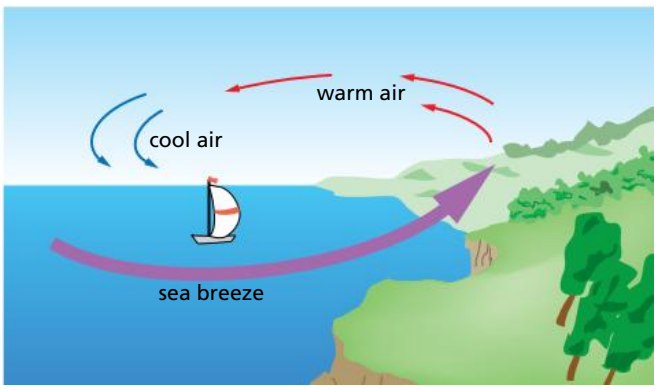


A refrigerator works slightly differently because the cooling element is at the top. Cooled air sinks to the bottom of the fridge while warm air rises and is cooled, setting up convection currents. When you open the door of the fridge, cold air flows out onto the floor and you can feel it on your feet. When this happens the cooling element has to start working again. If you want to save energy, don't leave the fridge door open for too long.



Convection in nature

Convection currents affect weather patterns near the ocean and large lakes. On a hot, sunny day the land warms up more quickly than the water. The air above the land warms up as well and rises, and the cooler air above the water flows in to take its place. This large convection current is called a *sea breeze*. At night the opposite occurs. The land cools down more quickly than the water, so a *land breeze* blows from the land out over the water.



Thermals

Rising convection currents in the atmosphere are called thermals. They generally occur on hot days in the summer. Birds make use of thermals to help them soar and glide. Like birds, gliders and hang-gliders also make use of thermals. By manoeuvring from one thermal to another they can stay in flight for several hours.

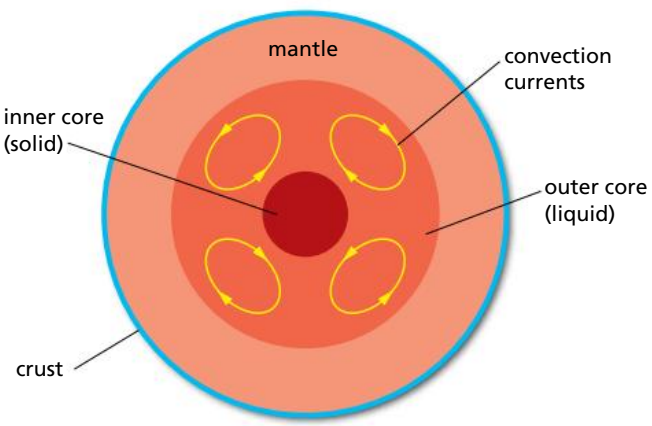


Hang-gliders depend on rising convection currents called thermals.

Earth's magnetic field

Scientists think that convection currents may be responsible for the Earth's magnetic field. They infer that the liquid outer core contains iron (and nickel), which is magnetic. If this material is not all at the same temperature, convection currents will be set up within it. This moving molten iron can conduct an electric current, and scientists think this generates a magnetic field. However at this stage they aren't sure that this is how it happens.

There are also convection currents in the mantle that move very, very slowly, causing volcanoes and earthquakes.



Over to you

1. What is convection? Draw a diagram, using what happens in an electric jug to explain your answer.
2. Suggest why the air in a heated room is usually cooler near the floor than near the ceiling.
3. **a** Where is the cooling element fitted in a refrigerator? Why?
   b What happens to the air inside a fridge when you open the door? Why?
4. Draw a diagram showing how a cup of hot coffee cools by convection.
5. If you are cooking a dish which needs a very high temperature, the recipe may tell you to put it on the top shelf of the oven. Why?
6. Why is it that in solids heat is transferred by conduction, yet in liquids and gases it is transferred by convection?
7. Glider pilots look for thermals. What are they and why are they important for gliders?
8. If you hold a piece of paper a few centimetres above a burning candle it will burn. Yet if you hold the paper a centimetre or so *beside* the flame it doesn't burn. Why is this so?
9. When taking the temperature of water being heated in a beaker, it is important to stir the water before you take the reading. Why?
10. Suppose you are camping and want to boil a billy on a fire. Would you place the billy on the ground and build a fire around it, or would you hang the billy above the fire? Explain your answer.
11. A fire in a room with a chimney is said to keep the air in the room fresh. How would it do this?
12. Explain how a deep-freeze unit in a supermarket keeps its contents frozen even though it has no lid.

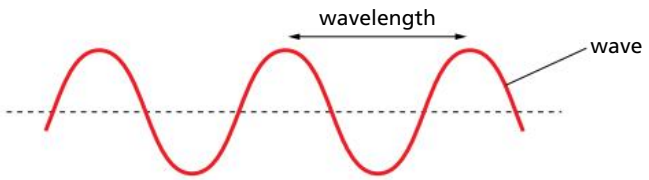


9.3 Heat radiation

When standing in the sunshine you can feel its warmth, but if you move into the shade you feel much cooler. The heat you feel has obviously come from the sun. It can't have got there by conduction or convection, because there is empty space between us and the sun. This means there are almost no particles to transfer the heat energy. There must therefore be a third way of transferring energy, one that doesn't need particles. This method is called **radiation**—the transfer of energy as waves.

Types of radiation

There are many different forms of radiation. All of them occur naturally and can be used in technology. The only difference between them is their *wavelength*.



The waves with the shortest wavelength are gamma rays given off by radioactive substances, for example in a nuclear reactor. The only radiation we can see is light, which has a medium wavelength. Infrared waves or heat waves have just the right wavelength to cause the particles in matter to vibrate and move faster. As a result the substance that has absorbed the radiation becomes warmer. We can't see heat radiation, but because it can make the particles in our skin move faster, we can feel it. Microwaves are similar to heat radiation, but have longer wavelengths. They cause the molecules in food to vibrate faster, causing heating. TV and radio waves have the longest wavelengths.

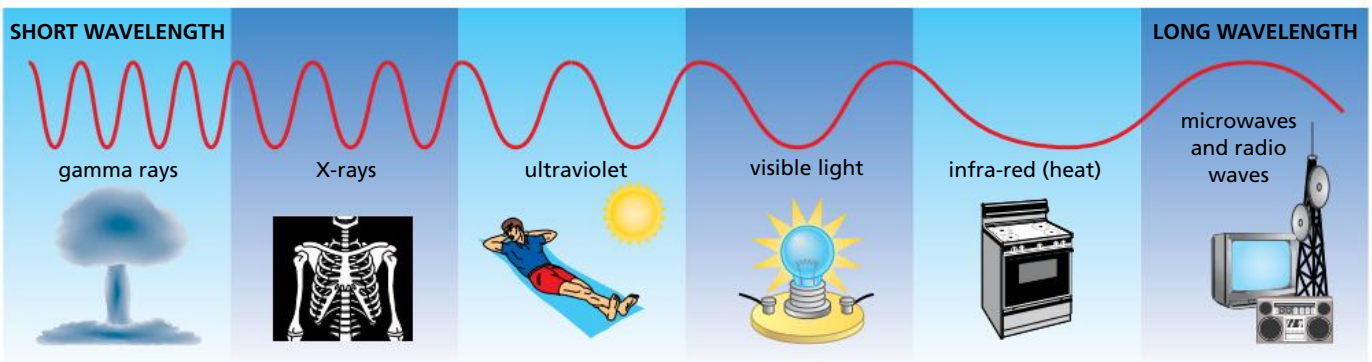
Properties of radiation

Heat radiation is very similar to light but has a different wavelength. Unlike sound waves, which can only move through matter, heat radiation can move through empty space. It can also move through matter, if the matter is transparent like air and glass. Like all radiation, heat radiation travels at the speed of light (300 000 km/s). Like light, it travels in a straight line.

Heat radiation is very important in bushfires. Many people die in bushfires without the flames even touching them. As a bushfire approaches, the heat radiation travels ahead of the flames at the speed of light, scorching vegetation and animals well ahead of the flames. The radiation travels in a straight line, so when a bushfire approaches a solid structure, such as a brick wall, it will block the radiation and give you some protection.



All bodies emit (give off) some heat radiation. The hotter they are the more heat radiation they emit. We cannot see this radiation, but it can be detected by infrared scanners. People are usually warmer than their surroundings. This is why infrared scanners are used at night by air–sea rescue helicopters to help find people who are lost. They are also used to look for survivors in disaster areas.



Transmitted, absorbed or reflected

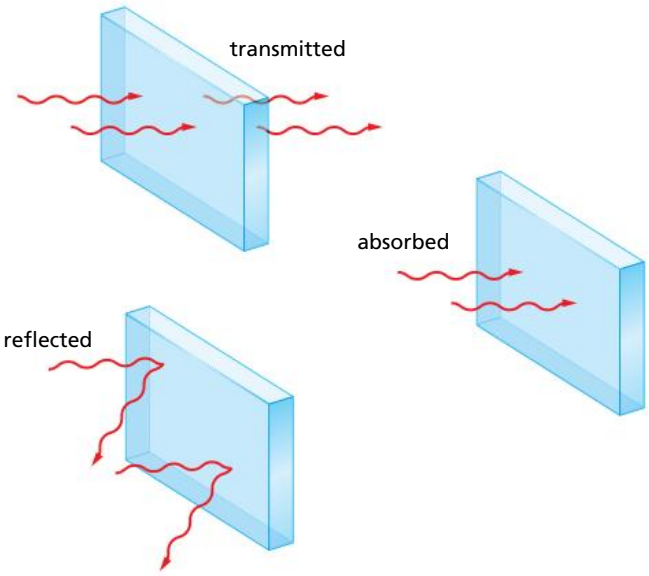
If an object becomes red hot it emits visible light. This is what happens with an electric heater. If the object becomes white hot it gives off even more visible light. This is what happens with the filament of an electric light bulb.

When heat radiation hits the surface of an object it behaves like light. One or more things can happen.

a The heat radiation may be *transmitted*, that is, pass straight through the object. For example, it passes through air and glass. We say these substances are transparent to the radiation.

b The radiation may be *reflected* or bounce off the surface.

c The radiation may be *absorbed* by the surface and changed into heat. If this happens the temperature of the object is raised.



Heat radiation can be transmitted, absorbed or reflected.

Substances such as glass are not completely transparent to heat radiation. Some radiation is absorbed and the temperature of the glass rises. You can test this by putting a piece of glass in sunlight.

The amount of radiation emitted by an object and the amount of radiation absorbed by an object both depend on the surface of the object. You can investigate this for yourself in Investigation 2.

PROBLEM SOLVING

Have you built your solar water heater? Does it work? If not, try to improve it.

INVESTIGATION 2

Investigating radiation

Aim

To design an experiment to find out which types of surfaces:

a absorb the most heat, and

b radiate the most heat.

Planning

1 The experiment is in two parts.

2 A simple way to do the experiment is to use empty soft drink cans. You will need one that is bright and shiny, one that is dull and dark, and one that is white. You can use any other colours you like. You may be able to paint the cans.

3 You can leave the cans empty (i.e. with air in them) or you can fill them with water.

4 For Part A you can simply put the cans in sunlight, or you can use a bar heater, a bright lamp or even a Bunsen burner.

5 How often will you measure the temperatures in the cans? How will you record your results?

6 For each part, decide which is the independent variable in the experiment and which is the dependent variable. Which variables will you need to control and how will you do this?

7 In Part B you will need to reduce the amount of heat lost to the bench by conduction and into the air by convection. How can you do this?

8 Before you start the experiment, predict which cans you think will heat up, or cool down most rapidly. Give reasons for your predictions.

Write your report

Write a report under the usual headings of *Aim*, *Risk assessment*, *Apparatus*, *Method*, *Results*, *Discussion* and *Conclusion*.

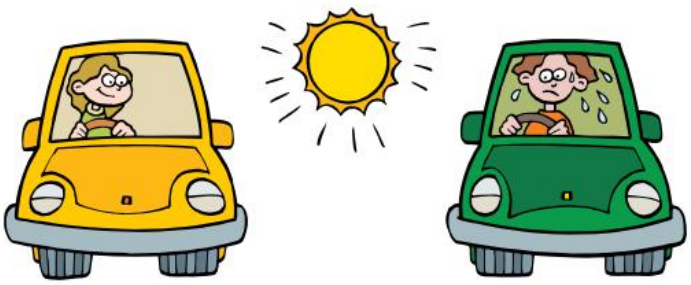
A good way to display your results is to plot temperature against time for each can. You can then draw a smooth curve showing how the can is getting warmer or cooler. For comparison you can draw the curves for several cans on the one graph.

In the discussion say whether your predictions were correct. In the conclusion try to write a generalisation saying how the amount of heat absorbed or radiated depends on the type of surface.

Absorbers and emitters

In Investigation 2 did you find that dull, black surfaces are better absorbers and emitters of heat radiation than white shiny surfaces? Dull black objects warm up more quickly than shiny white objects, which are good reflectors of heat radiation. Dull black objects also cool down more quickly than shiny white objects. There are many everyday applications of this.

On a hot summer day you will notice that the dark-coloured bitumen on the road is much hotter than the light-coloured concrete footpath, because the bitumen absorbs more heat radiation. This is why the panels on the back of a solar water heater are always painted black to absorb as much heat radiation as possible from the sun. This is also why dark-coloured cars get much hotter inside than light-coloured ones when left in the sun.



Light-coloured clothes are cooler than dark-coloured ones because they don't absorb as much heat radiation. This is why clothing for summer outdoor sports such as cricket is often white. Oil storage tanks are painted silver-white so that they don't absorb too much heat from the sun, and satellites are often a shiny gold colour to reflect radiation.

If you want something to stay hot you need a bright shiny surface. This is why kettles are made of shiny metal. However if you want something to cool down quickly, you use a dull black surface. This is why the radiator of a car is black so that it radiates the heat produced by the engine. For the same reason the cooling coils at the back of a fridge are black.

Over to you

1 **a** Why can't heat from the sun reach us by conduction or convection?

b How does heat travel through space?

2 List three properties of radiation.

3 What three things can happen to heat radiation when it hits a surface?

4 Suppose you have two surfaces, one white and the other black.

a Which is the better radiator of heat?

b Which is the better reflector?

c Which is the better absorber?

5 When you walk barefoot on a hot day you can walk easily on grass, not so easily on bare dirt and it is almost impossible to walk more than a few steps on bitumen. How can you explain this?



6 Predict which will melt more quickly in the same conditions—a plain white ice-cream or a chocolate-flavoured one. Explain your prediction, then test it.

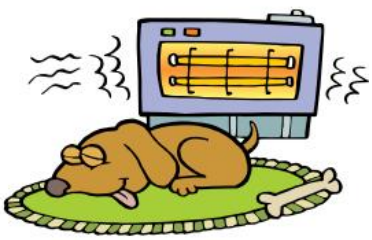
7 Different coloured cars absorb different amounts of heat radiation.

a Rate the following coloured cars in order, from the one that absorbs the most to the one that absorbs the least: black, dark blue, light blue, brown, green, orange, red, silver, white, yellow.

b Which will cool down faster when parked in the shade after being in the sun all day?

If you have time you could design and carry out an experiment to test your predictions.

8 Look at this cartoon. Explain how the dog is keeping warm. In your explanation, use the words *radiation*, *emitted*, *absorbed* and *reflected*.



9 Why is the base of a saucepan best left black, but the sides and the lid should be shiny?

10 In an experiment two metal cans are filled with water at 50 °C. One can is black and the other is shiny silver. After 30 minutes the temperature has dropped to 30 °C in the black can and 38 °C in the silver can. Room temperature is 20 °C.

a Why did both cans decrease in temperature?

b Why did the temperature of one can decrease more than the other can?

c Draw a graph showing how the temperature of the two cans changed in 30 minutes.

d Use your graph to predict what would happen if the experiment was continued for another 30 minutes.

9.4 Not too hot, not too cold



Ella has been training all year for the 1500 metres race, but at the district carnival she has collapsed 100 metres from the finish line. What has happened? Why has her body let her down all of a sudden?

As Ella ran her muscles worked hard and produced waste heat. Because it was such a hot and sunny day her body couldn't get rid of this heat quickly enough. As a result her body temperature rose well above its normal 37 °C. Ella's nervous system responded to this overheating by sending messages to her brain, which shut down her whole body and made her unconscious. Ella is suffering from *heatstroke* and her trainer will need to cool her down quickly.

In this section you will learn about how our body tries to stay at a constant temperature—one that is not too hot and not too cold.

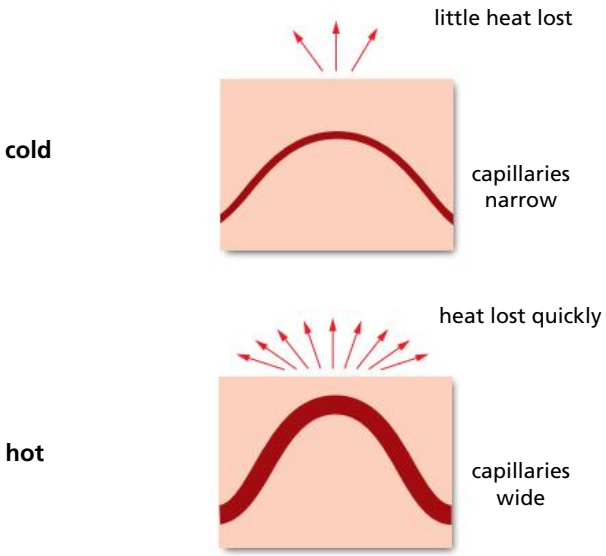
Sweating

As you learnt on page 129, your body has an in-built cooling system. Sweat glands produce sweat, which evaporates from the surface of your skin. This evaporation produces cooling. To replace the water you lose during sweating you need to drink lots of water.



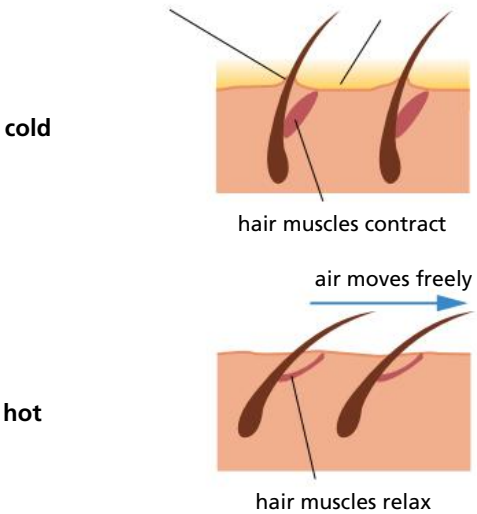
Becoming flushed

After vigorous exercise or on a very hot day your skin becomes flushed. This is also part of your body's cooling system. The capillaries near the surface of the skin become larger, allowing more blood to be pumped through them. The extra blood makes your skin pinker. The blood carries the heat to the surface of the skin where it can be lost by conduction, convection and radiation, cooling your body.



Goose bumps

When you get cold, 'goose bumps' form on your skin. These are caused by tiny muscles attached to the hairs on the skin. When the muscles contract they make the hairs stand up straight. Some air is trapped around these hairs and, because air is an insulator, this cuts down the heat loss from your body a little. If the body cools too much, people generally go to sleep and may die. This is called *hypothermia*.

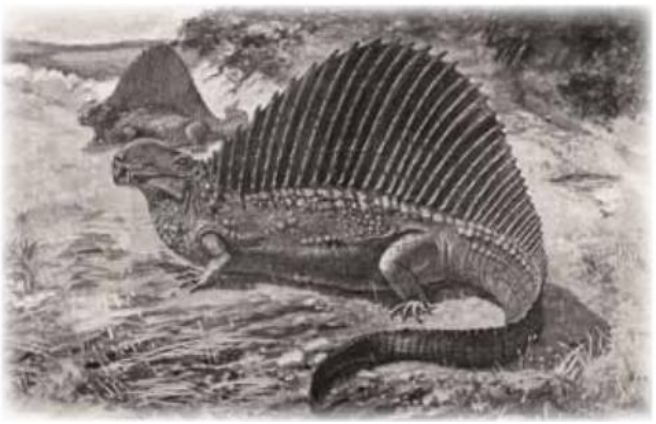


Other adaptations

Animals have many adaptations to enable them to cope with hot and cold conditions. For example, elephants, which usually live where it is hot, wallow in mud. As the water evaporates from the surface of the skin, the elephant is cooled. The elephant can flap its large ears, which are full of blood vessels. As it does this the blood in these vessels loses heat.



A reptile can't keep its body warm as we can. Its temperature rises and falls with the temperature of its surroundings. This is why you often see lizards sunning themselves to absorb heat. Some of the dinosaurs, for example *Dimetrodon*, had large fins on their backs. Scientists infer that these fins helped them to warm up quickly in the morning. If they stood sideways on to the sun, the large area of the fins would absorb heat radiation, raising their body temperature and allowing them to be more active.



INQUIRY 7 Are you a lark or an owl?

Your body temperature varies by about a degree over 24 hours. Some people reach their lowest temperature between midnight and 3 am and their highest temperature at about 8 pm. These people generally like getting up early but feel tired late in the day. They are sometimes called *larks*, after a bird that gets up early. Others reach their lowest temperature between 4 and 7 am, and their highest temperature at about midnight. These people are often sluggish in the morning but feel like doing things late at night. Hence they are called *owls*.

The table below shows Ian's body temperature over two days. Plot this data on graph paper or use a spreadsheet.

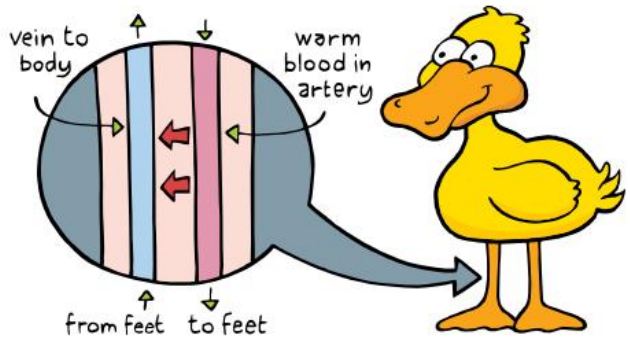
- Do you think Ian is a lark or an owl?
- Ian is considering getting a job as a night filler at Woolworth's, working from 9 am to 1 pm. Use your graph to predict whether Ian would be suited to this job.
- Are you a lark or an owl? How could you find out? You could do some testing.

	Body temperature (°C)	
	Day 1	Day 2
12 midnight	36.9	36.8
2 am	36.2	36.2
4 am	36.3	36.2
6 am	36.4	36.4
8 am	36.8	36.5
10 am	36.8	36.7
12 noon	36.9	36.9
2 pm	37.1	37.1
4 pm	37.3	37.3
6 pm	37.5	37.4
8 pm	37.5	37.5
10 pm	37.4	37.5
12 midnight	36.7	36.9

Surviving the cold

The polar bear has several adaptations that allow it to cope with the extreme cold of the Arctic. It has a thick layer of fur which traps an insulating layer of air. Under its fur the skin is black, like its nose. This is to absorb as much of the sun's heat radiation as possible. Under its skin the polar bear has an insulating layer of fat, called blubber.

Many birds, such as ducks, have an interesting structural adaptation to keep warm when their feet are on ice or in cold water. Blood flows down the duck's leg to its foot in an artery. It then returns up the duck's leg in a vein. The artery and the vein are close together so heat can flow by conduction from the artery to the vein. In this way the heat is kept in the duck's body and very little is lost from its feet. This adaptation is called a *heat exchanger* and similar systems are used in air conditioners, refrigerators and factories to control heat flow.



INVESTIGATION

3 Penguin huddling

Penguins living in very cold regions around the Antarctic often huddle together to keep warm. Using test tubes full of water to represent penguins, design and carry out an experiment to find out whether huddling together helps penguins to retain their body heat. Will you need a control?

Write a full report describing what you did and what you found out.



Over to you

1 Explain in your own words why we:
- **a** sweat
- **b** get goose bumps
- **c** become red in the face after exercise.

2 What is the difference between heatstroke and hypothermia? Use a dictionary if necessary.

3 Use what you have learnt in this section to explain why it is important to drink lots of water when you play sport.

4 You shouldn't wear damp clothes on a cold day. Why?

5 Animals, including humans, have various adaptations to allow them to survive hot and cold climates. Review the difference between structural, functional and behavioural adaptations, then give one example of each from the chapter.

6 Explain in terms of the particle theory why evaporation causes cooling.

7 In Inquiry 8 on page 129, you wrapped a wet tissue around the bulb of a thermometer and observed a drop in temperature. Would it make any difference if you held the thermometer in front of a fan? Would using methylated spirits instead of water cool it faster? Explain your predictions, and test them if you have time.

8 Raising a wet finger allows you to tell which way the wind is blowing. Suggest how this might work.

9 Suggest why thin people tend to feel the cold more than others.

10 In a huddle of emperor penguins the birds constantly change places. Suggest why.

11 Suggest why we shiver when we are cold.

12 The temperature in the body of an Arctic fox is about 35 °C, but the temperature in the bottom of its feet is 0 °C.
- **a** What is the advantage of this?
- **b** Explain what happens to the fox's blood as it flows down its leg and back to its body.

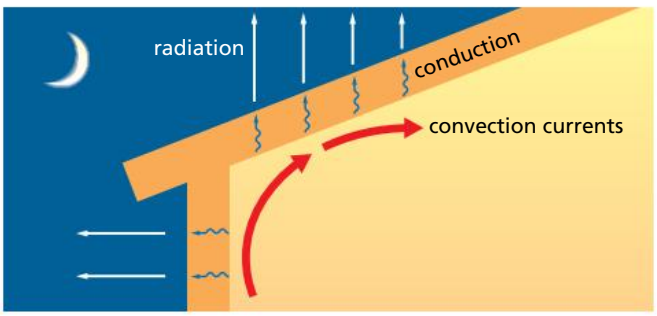


9.5 Controlling heat

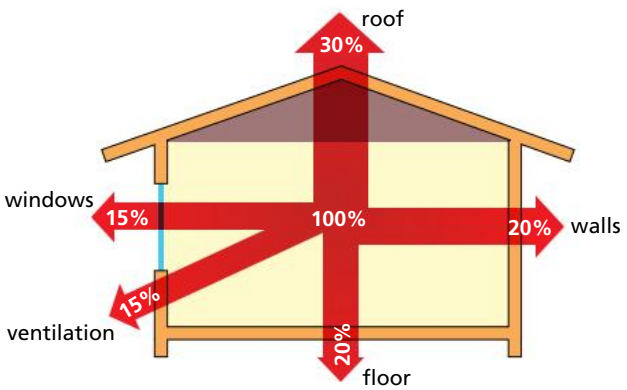
The photograph below was taken with special film which picks up the heat radiation escaping from a house. The white and yellow is where the most heat is being radiated and the green and blue is where the least heat is being radiated.



Convection currents take warm air to ceilings and walls, where the heat is transferred through them by conduction. The heat is then radiated to the outside, as shown.



During winter it will be warmer inside the house than outside, so heat tends to escape. The typical heat loss from an uninsulated brick veneer house is shown below. During summer it is warmer outside than inside, so heat flows *into* the house.



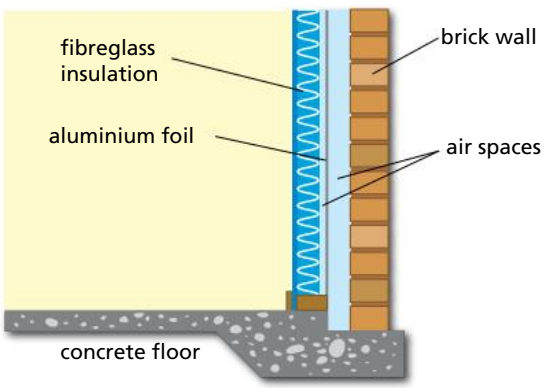
To cut down heat loss through the ceiling and roof you can use insulation. For example, fibreglass batts can reduce heat loss by up to 80%. The fibreglass itself is a good insulator, and so is the air trapped between the fibres.



Installing insulation batts in a ceiling

Insulating walls can reduce heat loss by up to 70%. Brick veneer walls can be insulated as shown. Very little heat can get through the three layers of insulation—the fibreglass, the air and the brick wall. Any heat that is radiated through the air gap is reflected back by the shiny aluminium foil.

Cavity brick walls have two layers of bricks with an insulating air gap between. This air gap cannot be too wide or convection currents will be set up.



Heat loss through windows can be reduced by curtains. Another way is to use double-glazed windows which have two panes of glass with an air gap between them, like an oven door. Concrete floors provide good insulation and heat loss can be further reduced by installing carpet with an underlay.

Cutting down on heat loss saves on energy for heating in winter and energy for cooling in summer. This not only saves money but conserves fossil fuels and reduces greenhouse gas emissions.

INVESTIGATION

4 A model house

Aim

To build a model house and investigate one of the following questions.

- Which is the best insulation for keeping the house warm in winter or cool in summer? Does the thickness of the insulation make any difference? Is it better to insulate the ceiling or the walls, or both?
- How much heat is lost through windows and doors? What difference do curtains make?
- Does the type of roofing material make any difference?
- Does the colour of the house and the roof make any difference?
- A ceiling may be flat or raked. Does the type of ceiling matter?



Planning

1 Choose one of the questions above, or you might be able to think of another question.

2 A simple way to make your model house is to use two shoeboxes—a control and an experimental one.

3 How are you going to create a temperature difference between the inside and the outside of the house?

4 You will need to work out how you are going to measure the temperature inside and outside the house. You may be able to use a datalogger and temperature probes.

5 Before you start, use what you have learnt in this chapter to *predict* what you think will happen.

6 You may need to experiment a bit before you get reliable results.

Write your report

- In the method make sure you describe everything you did, including things that didn't work very well.
- For the discussion refer to page 175 (bottom right).
- In the conclusion make sure you answer the question you were investigating. If you cannot reach a definite conclusion, say so, but explain why.

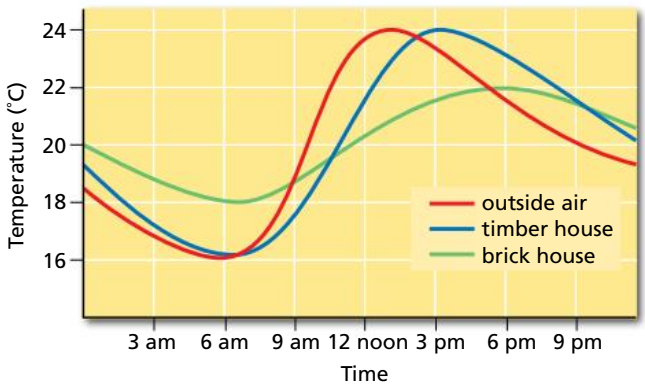
Over to you

1 Which method of heat transfer are you reducing by installing insulation in the walls and ceiling of your house?

2 People often install roof ventilators like the one shown. Use what you have learnt in this chapter to explain how these ventilators cool down a house.



3 The graph below shows the temperatures inside two houses that are the same except that one house is made of bricks and the other is made of timber. The outside temperature is also shown.



a What were the maximum and minimum temperatures—outside and inside the two houses?

b Which house heated up more quickly? Which cooled down more quickly? Suggest reasons for this.

c Which house had a more even temperature throughout the day?

d Which house would be cheaper to keep cool in summer and warm in winter? Explain your answer.

4 Many energy-efficient homes use two types of roof insulation—one layer of insulation on top of the ceiling and a layer of aluminium foil under the tiles on the roof. Explain the function of each layer.

5 Why is a room with a raked ceiling usually warmer in summer and cooler in winter than one with a flat ceiling?

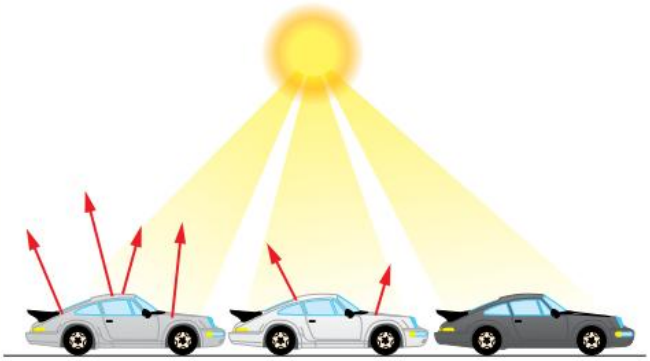
6 Draw a diagram to show how eaves can make a house cooler in summer.

SKILL

Interpreting diagrams

The illustrations in a textbook are just as important as the text itself. You need to be able to interpret the illustrations, or understand what they are showing. The four examples on this page will give you some practice at this. For each example, study the diagram and answer the questions.

Example 1: Radiation



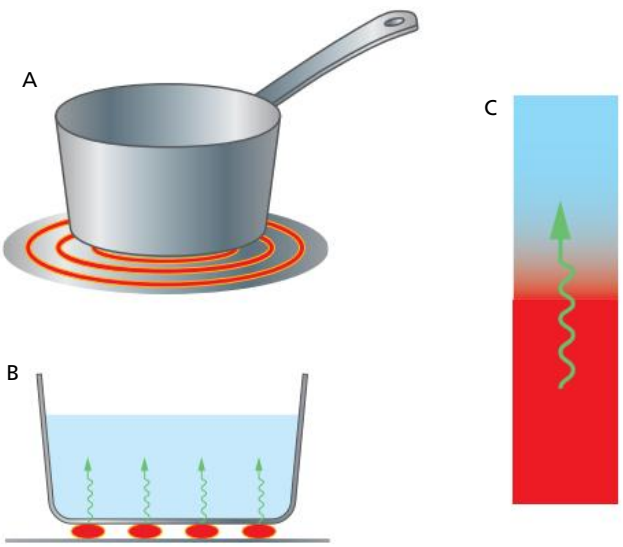
a What do the red arrows represent?

b Why are there no arrows coming from the black car?

c In one sentence, describe what the artist is trying to show.

Example 2: Conduction of heat

There are three parts to the diagram. Parts B and C show what happens in Part A.

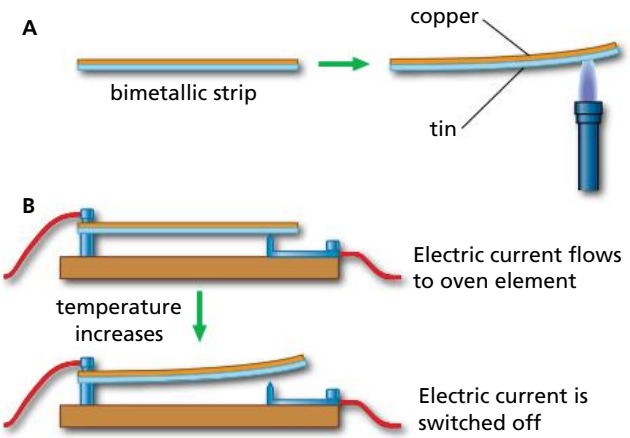


a In Part A of the diagram, what do the red ovals represent?

b What do the green arrows in Part B represent?

c What is Part C showing?

Example 3: Oven thermostat



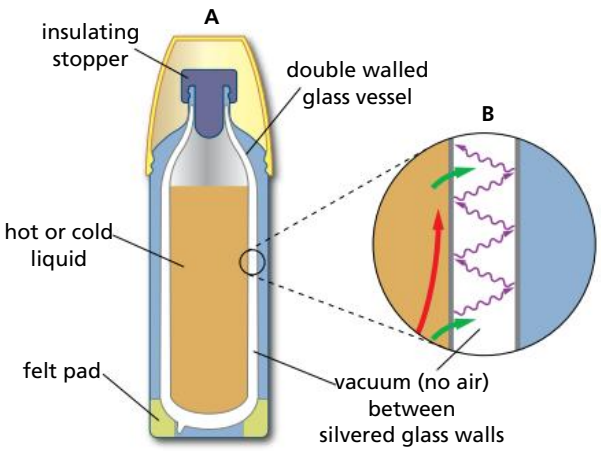
a What has happened in Part A? Why is there an arrow between the two parts of A?

b What has happened in Part B?

c Explain how this thermostat controls the temperature in an oven.

d Why does the bimetallic strip bend when it is heated? (Hint: Metals expand when heated.)

Example 4: Thermos



a Using Part A, write a description of a thermos.

b Why is Part B in a circle connected to Part A?

c What does the brown colour in B represent? What does the white represent?

d There are three different types of arrows in B. Which represent conduction? Which represent convection, and which represent radiation?

e Explain how the thermos keeps the liquid in it hot or cold.

Water bag

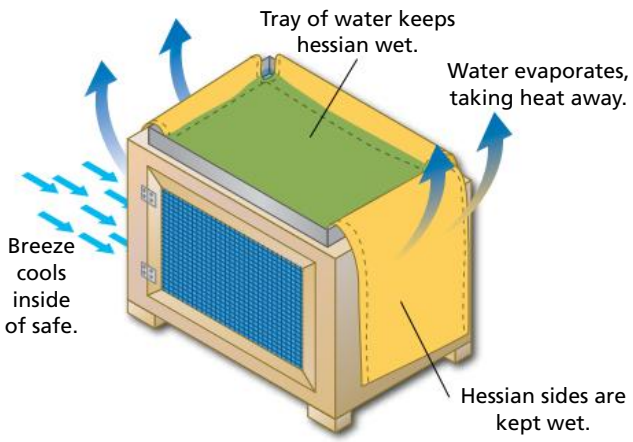
It is said that the explorer Sir Thomas Mitchell saw the Indigenous Australians carrying water in kangaroo skins. The water slowly seeped through the skin, wetting it. The water then evaporated, cooling the water inside the skin. Using this idea, Mitchell made a canvas water bag to carry his own water, and similar bags are still used today.



Coolgardie safe

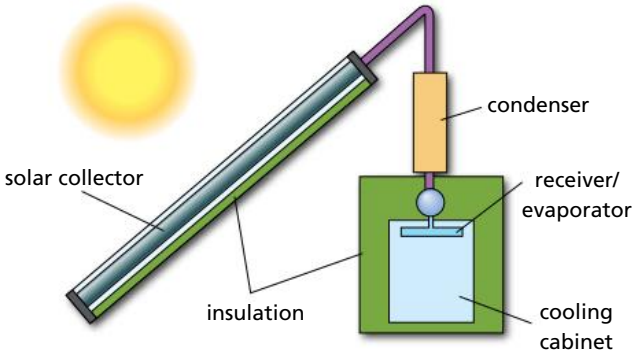
In the 1890s gold rush in the Coolgardie–Kalgoorlie area of Western Australia it was very hot and people had trouble storing food, until the Coolgardie safe was invented.

The safe had a wooden frame and sides made of wire mesh. On top there was a galvanised iron tray that was filled with water. Hessian bags were hung over the sides as shown, with their ends in the tray to soak up the water. When the breeze blew, the water on the wet bag evaporated, causing cooling. This kept the air inside the safe cool, and food could be stored there.



Solar ice maker

Dr Eric Hu, now working at the University of Adelaide, has developed a solar ice maker. It has a solar collector which contains activated charcoal soaked in methanol. During the day the collector absorbs heat from the sun. The methanol evaporates to form a vapour. This vapour moves through the condenser where it cools back to a liquid and collects in the receiver. At night the collector cools and the pressure in the system drops. This lower pressure causes the methanol to evaporate again, cooling the cabinet and producing ice. The methanol then moves back to the collector, where it is adsorbed by the charcoal ready for the next day.



This solar ice maker has a collector with an area of 1 m^2 and can produce 2 kg of ice in 24 hours. Dr Hu believes it could be used to help keep vaccines and other medical supplies cool in developing countries and remote areas. It could also be developed further as solar–powered air conditioning. However, a lot of work and a lot of money will be needed before such devices are ready to be sold commercially.



THINKING SKILLS

1 Why do you need to turn eggs in a frying pan if you want them to cook quickly?

2 Moving objects are said to have kinetic energy. Why then can heat be considered a form of kinetic energy?

3 Draw a diagram to show how a radiator is used to cool the engine of a car by convection currents and radiation.

4 Using what you have learnt in this chapter suggest

a four ways of keeping your house warm in winter

b four ways of keeping your house cool in summer.

5 If air was a good conductor of heat you would feel cold even on a day when the air temperature is 25 °C. Why?

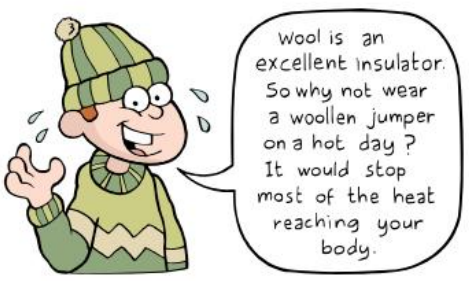
6 You have four different house bricks. Design an experiment to find out which is the best insulator.

7 Design and conduct an experiment to show that a baby loses heat more rapidly than an adult.

8 Suppose you represent the particles in a solid, liquid or a gas by the people in your class. Use this model to show the difference in the way heat travels by conduction and convection.

9 Luka put some ice in a test tube of water and heated the bottom of the tube. The ice melted. Does this show that water conducts heat? Explain.

10 Ben has been thinking about what he has learnt in this chapter about how heat travels. How would you answer him?



11 It is possible to walk over red-hot coals without burning your feet, even though the coals are at 600–800 °C. The secret is that the coals are poor conductors of heat and so are your feet. Provided your foot doesn't stay in contact with the coals for more than one second, not enough heat is transferred to your foot to burn you. (Caution: The coals must be properly prepared, so don't try this yourself.)

Use firewalking to explain the difference between heat and temperature.



A Buddist firewalking festival in Japan

12 A magician at a show has five 20-cent coins, each with a different year marked on it. She puts the coins into a hat and asks someone in the audience to pick out one coin. Then she says, 'Pass the coin around so that everyone can see what year is marked on it. Then put the coin back in the hat and I'll try to pick out the coin you selected.' When they have done this she reaches into the hat and after a little while pulls out the correct coin.

Use what you have learnt in this chapter to explain how the magician does this trick.

13 A piece of paper wrapped tightly once around a copper rod can be held in a Bunsen flame without burning. However, if it is wrapped around a wooden rod it quickly chars. Explain the difference. You could try this yourself.

Knowing and Understanding

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

1 Heat is a form of _____ which can raise the temperature of an object. The temperature of an object depends on how fast its _____ are moving. The higher the temperature the faster they move.

2 Heat can be transferred from one place to another by conduction, convection or radiation. Heat energy flows from places where the temperature is _____ to where it is _____.

3 _____ occurs when heat is transferred by circulating currents in liquids or gases.

4 _____ occurs when heat energy is transferred from particle to particle by vibration. Metals are the best conductors of heat. Poor conductors are called _____.

5 Heat energy can be transferred across empty space as infrared waves called heat _____. When this reaches a surface it can be _____, transmitted or reflected.

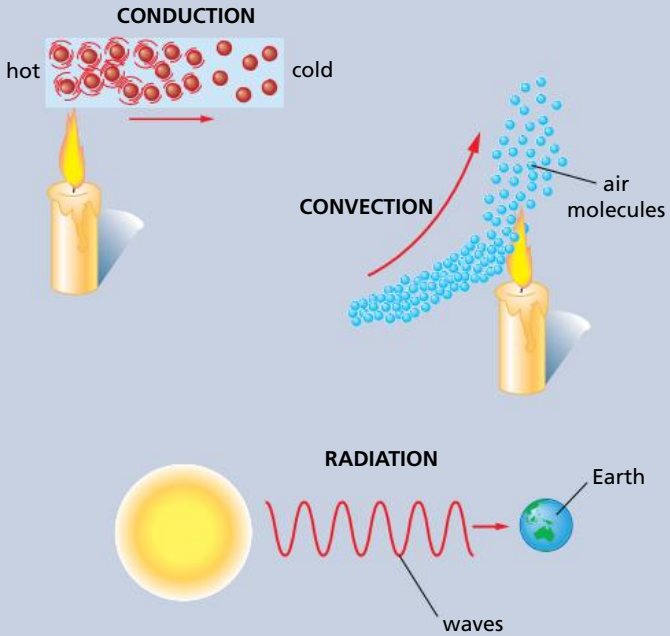
6 Dull _____ surfaces are better absorbers and emitters of heat radiation than shiny white surfaces. Shiny white surfaces tend to _____ heat.

7 Animals, including humans, have _____ to help them survive hot and cold weather. For example, sweat produces cooling as it _____.

absorbed
adaptations
black
conduction
convection
energy
evaporates
high
insulators
low
particles
radiation
reflect

Self-management

1 Look at the diagram showing the three methods of heat transfer. Use these diagrams to describe how heat travels by each method.



2 Copy and complete this table to show how well conduction, convection and radiation occur in solids, liquids, gases and space (where there is virtually no matter). You can use words such as *good* and *poor*.

	Solids	Liquids	Gases	Space
Conduction				
Convection				
Radiation				

PROBLEM SOLVING

You should have finished your chapter task to build a solar water heater. Now you have to use what you have learnt in this chapter to explain how it works. Does it use all three ways of transferring heat—conduction, convection and radiation? You should also explain why you built it the way you did. For example, why did you use a black collector? Why did you use insulation? To help your explanation, it is a good idea to use a diagram.

Checkpoint

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

OneStopScience

1 Hot coffee is poured into a cold mug. In less than a minute the outside of the mug feels hot. This method of heat transfer is

A conduction

B convection

C infra-red rays

D radiation.

2 Which of the following statements are true and which are false? Rewrite the false ones to make them correct.

a As an object becomes hotter its particles move more rapidly.

b Dull black surfaces are good reflectors of heat.

c Heat is measured in degrees Celsius.

d Heat travels from cold objects to hot objects.

e The hotter an object is, the less radiation it emits.

f The sun transfers heat energy to the Earth by the process of convection.

g When an object absorbs radiation its temperature rises.

3 **a** Why does the metal teaspoon you are using to stir a hot cup of coffee get hot?

b Why doesn't a plastic spoon get hot in the same way?

4 **a** A room in a house is heated to 26°C, and the outside temperature is 10°C. When the heater is turned off the temperature inside the room gradually decreases. Why?

b To what temperature would you expect the air in the room to cool to if the heater is left off and the outside temperature stays the same?

5 Use a diagram to describe how a convection current forms in a room with an open fireplace.

6 **a** How does sweating cool you down when you get hot?

b Why does sitting in front of a fan on a hot day make you feel cooler?

7 Refrigerators and freezers are painted white or made of stainless steel, but the coils at the back are painted black. Why is this?

8 The diagram top right shows an experiment to measure how well six different materials conduct heat.

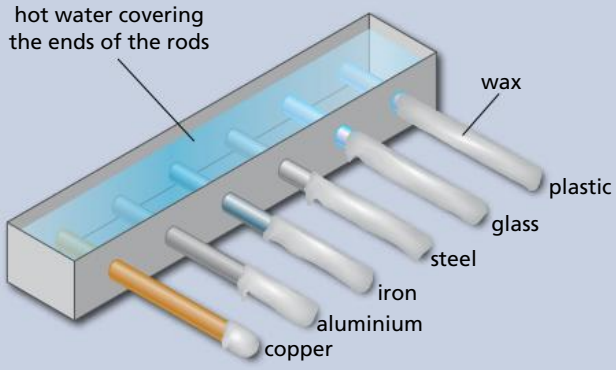
a Which material is the best conductor? How do you know?

b Which material is the best insulator?

c Would food cook more quickly in a glass or an iron casserole dish?

d Why do saucepans often have copper bases?

e Is water more likely to freeze in a plastic or a copper pipe? Explain.



9 Two mugs made from different materials were filled with hot coffee and allowed to cool. The temperature of the coffee in the mugs was measured every 2 minutes and cooling curves plotted as shown.

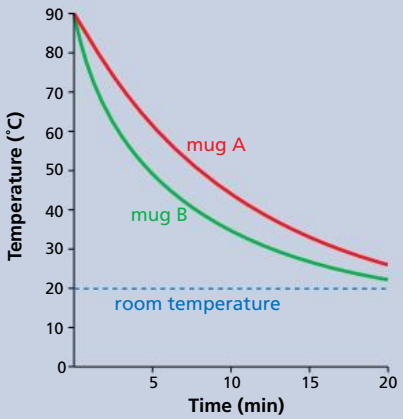
a What was the temperature of the coffee in mug A after 5 minutes?

b How long did it take the coffee in mug B to reach 40°C?

c What was the difference in temperature in the two mugs after 15 minutes?

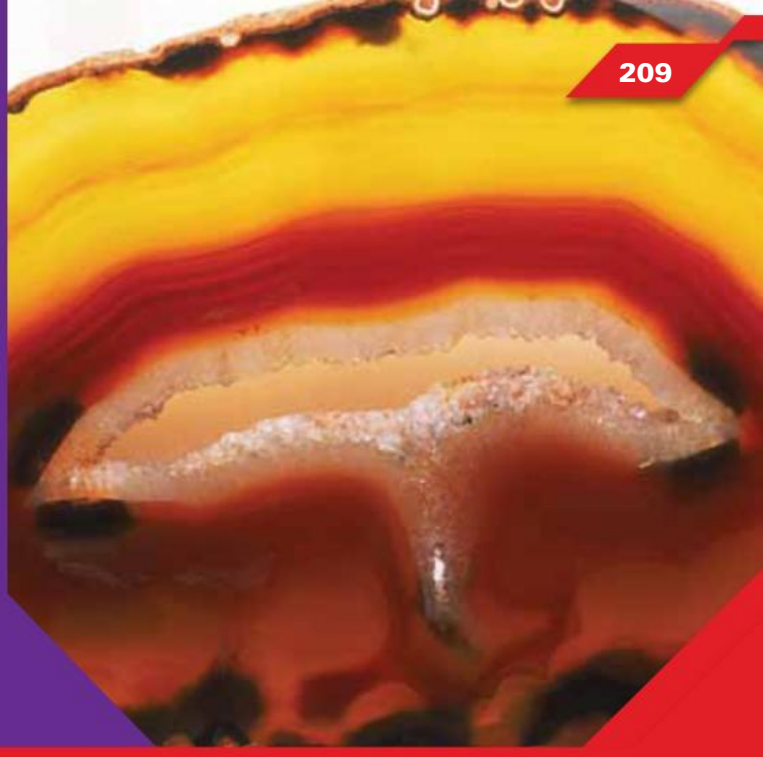
d Which mug is the better insulator? How do you know?

e Predict the final temperature of the coffee in both mugs.



10 What are the similarities and differences between light and heat radiation?

10



Rock hunting

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

Science Understanding

- use granite to show that rocks are a collection of different minerals
- simulate the formation of sedimentary and igneous rocks
- use the rock cycle to develop an understanding of the timescales involved in the formation of igneous, metamorphic and sedimentary rocks

Science as a Human Endeavour

- discuss the career of a scientist studying active volcanoes

Science Inquiry Skills

- use a hand lens to observe the properties of rock and mineral specimens

LITERACY FOCUS

basalt
conglomerate
erosion
extrusive igneous rocks
fossils
granite
igneous rock
intrusive igneous rock
lava
limestone
lithosphere
magma
metamorphic rock
mineral cleavage
radioactive dating
rock cycle
sedimentary rock
sediments
turbidity
weathering



This is the fossil remains of a crab-like marine animal called a trilobite. When it died it fell to the bottom of a large lake and was buried in sand 540 million years ago.

Focus for learning

There are rocks everywhere but you probably haven't noticed them. You may think they are just dull, brownish things. But take a closer look and you will find different colours and sometimes shiny crystals. Some rocks even contain fossils—traces of ancient life. After reading this chapter you will be able to tell the difference between different types of rocks and explain how they were formed.



These flower shapes formed when a naturally occurring solution mixed with sand and evaporated.

PROBLEM SOLVING

Collecting rocks

Your task for this chapter is to collect a variety of rocks from the local area and any other places you go. There are hints and tips on how to do this on the next page. As you work through the chapter you will learn how to identify the different types of rocks and the minerals and fossils you might find in them.

If everyone can collect a few rocks you should be able to make an interesting display in the classroom.



SKILL

How to be a rock-hound

A rock-hound is anyone who enjoys collecting interesting rocks and minerals. You don't need much equipment to get started, and any family outing can easily be turned into a rock hunt. If you become a rock-hound you may become interested in lapidary (LAP-i-DER-ee)—the cutting and polishing of rocks and minerals.

Where to find rocks

You can pick up rocks almost anywhere, but the best places are rocky outcrops, where bare rocks are exposed. This happens on hillsides, cliffs, quarries, building excavations, rocky gullies, stream beds and road cuttings (where the side of a hill has been cut away to make the road). When collecting rocks it is essential to make a note of where the rock came from. If you find a rock at the bottom of a cliff it probably came from the cliff above. If you find a rock in a stream it has probably been washed down from somewhere upstream. However, if you find a rock beside the road it may have come from almost anywhere. If the rocks are on private property you need the owner's permission to collect them, and of course you can't collect rocks in National Parks.

Collecting equipment

You need to be dressed for the outdoors, with sturdy shoes and a hat. Many rocks can be collected without any equipment. However, to see inside rocks you will need a *geology hammer* to break off fresh bits of rock. Your school may have these or you can buy one at a hardware store. Never use the sharp end of the hammer on hard rocks. This end is only for breaking soft rocks apart.

You must be very careful when hammering rocks, as bits of rock break off and may hit you in the eye. For this reason *never hammer when anyone is nearby*, and *always wear safety glasses.*

You have to carry your rock specimens home, so make sure they aren't too big. They should be about the size of a clenched fist, although mineral specimens will normally be smaller than this. It is essential that you number each specimen as you collect it. You should then record in a notebook where you found it.



A geology hammer. An ordinary hammer is not suitable for hammering rocks.

Hints

1. You can often collect good specimens at the bottom of a cliff or cutting, without using a hammer.
2. Stay clear of overhanging cliffs and rock faces where there is a danger of falling rocks.
3. Wrap the specimens collected in newspaper. An empty film canister with toilet paper in the bottom is good for storing small mineral specimens.
4. You will need a backpack to carry your specimens.
5. For a closer look at the specimens you collect it is a good idea to take a hand lens with you. The school will probably have these. Ten-power magnification is the best.



A hand lens

6. A camera is handy to record rock formations and where you found your specimens. You could also draw a map.
7. Once home, you can try to identify the rocks and minerals. You can then classify them and display them for others to see.
8. To get a better idea of what you are looking for you can visit a museum or a rock shop.
9. If you collect better specimens you can throw out earlier ones you collected.
10. If you get interested in rock hunting you may want to join a rock-hound club or buy their magazines.

10.1 Rocks and minerals

All rocks are made of **minerals**. These are naturally occurring solid substances that are usually chemical compounds. In the same way that words are made up of one or more letters of the alphabet, so rocks are made up of one or more minerals. Some rocks contain only one mineral. For example, limestone contains only calcite. Most rocks, however, are a mixture of several different minerals. For example the rock granite is a mixture of three minerals, quartz, feldspar and mica.



A rock like granite is a mixture of minerals.

INQUIRY 1 Minerals in granite

You will need: specimen of granite with large crystals in it, hand lens

1. Observe the granite carefully and see if you can see the three different minerals in it. Quartz is clear to white, mica is black and feldspar is white or pink. These occur as shiny **crystals** with flat sides and sharp edges.
2. Use the hand lens for a closer look at the crystals.
3. Draw a diagram of the granite and label the three different minerals in it.
4. Discuss with other students the difference between a rock, a mineral and a crystal.

Ore minerals

Most minerals are chemical compounds. For example, calcite is calcium carbonate $CaCO_3$, and quartz is silicon dioxide SiO_2. An ore is a mineral from which a useful substance such as a metal can be extracted. For example, iron is extracted from the mineral haematite, which is iron oxide Fe_2O_3. Lead is extracted from galena, which is lead sulfide PbS. A few minerals occur as elements, for example gold and copper.

Properties of minerals

There are about 3000 different minerals, so identifying them can be a problem. To tell one from another you have to look at their *properties*.

1 Colour

Many minerals have a characteristic colour. For example, pyrite (fool's gold) is a brassy-yellow. However colour can be misleading. Stains from other minerals or small traces of impurities can alter the colour, particularly if the pure mineral is white or colourless. An interesting example is corundum, which is made of aluminium oxide. When the mineral is pure it is colourless, but traces of the elements iron and titanium give it a blue colour, while traces of chromium give it a red colour. The blue variety is called sapphire and the red variety is called ruby, both valuable gemstones.

2 Lustre

The *lustre* of a mineral tells you how it reflects light. Minerals that are metal ores have a metallic (shiny) lustre. Minerals with a non-metallic lustre can vary in appearance. For example, quartz looks *glassy*, while mica has a *pearly* lustre, and gypsum has a silky or waxy lustre. Minerals such as clay, which are poor reflectors of light, have a *dull* or earthy lustre.

3 Structure

Minerals are often found in the form of beautiful crystals. These crystals have regular shapes because of the way the particles in the chemical compound are arranged. Each mineral has a characteristic crystal form which is always the same for that mineral. Quartz forms six-sided crystals with pointed ends, as shown. Galena forms cubic crystals. Often, however, the crystals are too small to see.

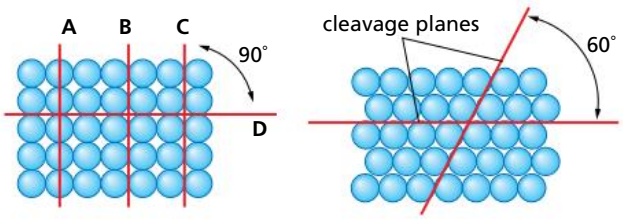


Quartz crystals

4 Cleavage

Cleavage is the way the crystals of the mineral break along flat planes. Galena always breaks into cubes, while mica splits into flat sheets. Some minerals have no cleavage—they simply break unevenly.

To explain cleavage, think of the particles in the crystal. The crystal will split between the particles rather than through them. In the diagram below the crystal tends to split along line B rather than along line A. It will also split along any other lines between particles (for example lines C and D), forming pieces with right-angled corners. In a crystal with a different structure the cleavage will be different. In the right-hand diagram there is an angle of 60° between the two cleavages.



Explaining cleavage in terms of particles

5 Streak

Streak is the colour of the powder of the mineral. The easiest way to observe the streak is to rub the mineral across an unglazed white tile. This leaves a coloured streak on the tile. A few metallic minerals have a powder that does not have the same colour as the mineral. For example haematite is a brown-black colour but its streak is red-brown. Some minerals do not produce a streak.



Testing the streak of haematite

6 Hardness

Have you ever scratched a piece of soap with your fingernail? You can do this because your fingernail is harder than the soap. The hardness of a mineral can be tested by scratching one mineral with another. The harder mineral scratches the softer one.

Mohs' hardness scale lists 10 minerals in order of their hardness. Any mineral on the scale will scratch a mineral with a number lower than it. For example, calcite (hardness 3) will scratch gypsum (hardness 2). The hardest mineral known is diamond (hardness 10), which is why it is used for drill bits.

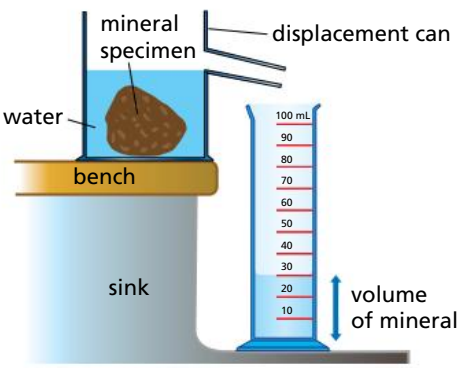
Mohs' hardness scale

Mineral	Hardness	Common test
talc	1	
gypsum	2	scratched by fingernail (with a hardness between 2 and 3, that is 2.5)
calcite	3	scratched by copper coin (hardness 3.5)
fluorite	4	
apatite	5	scratched by penknife blade (5.5) and window glass (6)
orthoclase (feldspar)	6	scratched by steel file (6.5)
quartz	7	scratches steel and glass
topaz	8	
corundum (sapphire or ruby)	9	scratches topaz
diamond	10	scratches all materials

increasing hardness ↓

7 Density

If two mineral specimens are the same size but one is heavier, the heavier one has a higher *density*. To get some idea of whether a specimen is light, medium or heavy for its size, jiggle it in the palm of your hand.



To measure the density of a specimen you need to know its mass and volume. First find its mass in grams. To find its volume in millilitres use a displacement can as shown. Divide the mass by the volume to find the density in grams per cubic centimetre (g/cm^3). Note that 1 mL = 1 cm^3. Quartz is relatively light, with a density of 2.6 g/cm^3. Metal ores are much more dense. Haematite has a density of 5.3 g/cm^3. Galena has a density of 7.6 g/cm^3.

Gemstones

Gemstones are rare minerals used in jewellery and other ornaments. They include diamonds, emeralds, opals, rubies, sapphires and topaz. The value of a gemstone depends on its hardness and its rarity (how hard it is to find). When found, most gemstones have a rough surface and an irregular shape. Skilled people cut and polish the stones to improve their appearance and make them sparkle. They are cut in different ways depending on the type of gem and how it is to be used.

INVESTIGATION

1 Observing minerals

Aim

To observe and compare the properties of a range of mineral specimens.

Risk assessment and planning

Draw up a large data table to record your observations. You will need eight columns, one for each of the properties described on pages 212 and 213. What safety precautions will be necessary?

Hints

- The school will have mineral specimens. You could also observe any that class members have found.
- Use a hand lens to take a closer look at the specimens. Draw any crystals you see.
- It is not necessary to break the specimens to see cleavage. You will be able to see cleavage planes on the mineral by turning it in the light.
- To check the streak of a mineral you will need an unglazed white tile. Scrape an edge of the mineral once across the tile slowly. Is the streak the same colour as the mineral?
- To test hardness you will need to use your fingernail (hardness 2.5), a copper coin (3.5), a penknife (5.5–6), a piece of glass (6) and a small piece of quartz (7). Your teacher may also have a set of Mohs' scale minerals you can use. Only make small scratches on the specimens as other people have to use them.
- You can classify the minerals as light, medium or heavy. To *measure* density you will need a balance, displacement can and a large measuring cylinder.
- When you have completed your table, try to identify an unknown specimen supplied by your teacher.

Over to you

1 Copy and complete these sentences.
   - **a** All rocks are made up of _____.
   - **b** Mineral specimens with definite shapes and sharp edges are called _____.
   - **c** Quartz has a glassy _____.
   - **d** The hardest mineral is _____. On Mohs' scale it has a hardness of _____.
   - **e** A mineral shows good _____ if it splits along flat surfaces.
   - **f** Minerals from which metals or other useful substances are obtained are called _____.

2 Is granite a rock or a mineral? Explain.

3 List the names of six minerals.

4 You have specimens of two different minerals but no other equipment to test them for hardness. How could you tell which mineral is harder?

5 Use the information below to order the six substances mentioned in order from hardest to softest.
   - A *steel file* can scratch a *penknife blade*.
   - *Calcite* scratches a *copper coin*.
   - A penknife scratches calcite.
   - *Quartz* can leave a mark on a steel file.
   - Quartz is scratched by *topaz*.

6 A geologist working for a mining company finds two mineral specimens that could be ore minerals. They are both dark grey and have a metallic lustre. Describe two quick tests that could be done to find out whether they are specimens of the same or different minerals.

7 A piece of magnetite has a mass of 650 g and a volume of 125 mL. What is its density?

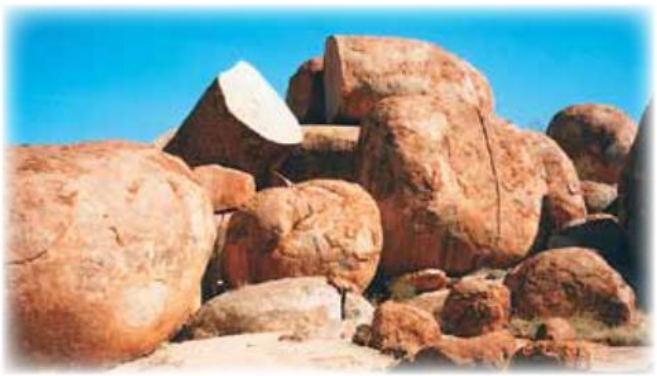
8 Select a gemstone and find out more about it. Make a poster that includes its name, its special properties, its uses, where it is found, and its value.

PROBLEM SOLVING

Have you found any minerals? If you split open coarse-grained rocks such as granite you may find crystals in holes where they have had room to grow. You may find minerals in veins in road cuttings. The most common mineral is quartz, which is usually white. You may also find gold-coloured flecks of pyrite in the blue metal used on roads. It is called fool's gold because it only looks like gold.

10.2 Weathering and erosion

If a car is left out in the weather the paintwork slowly becomes damaged. The lettering on tombstones becomes hard to read after many years. Rocks will also change, given enough time. Look at the photograph below showing the rounded granite boulders of the Devil's Marbles in the Northern Territory. The one at the top has broken in two and the one on the right has a crack through it. The smaller rocks at the bottom have broken off the larger ones. Eventually they will break down to gravel. This slow breaking up of rocks into smaller and smaller pieces by natural processes is called **weathering**. There are two main types—*physical weathering* and *chemical weathering*. Usually both types occur together.



INQUIRY 2 Looking for weathering

You will need: fresh piece of granite, weathered piece of granite, geology hammer (optional)

1. Compare a fresh piece of granite with a weathered piece.
   - What differences do you notice?
2. Try to find examples in the local area of rocks breaking down or weathering. As well as natural rocks, if possible look at rocks in buildings and tombstones. Record what you see by drawing diagrams or using a camera.
3. If you have a geology hammer, use it to chip a piece off the outside of a rock (of course not those in buildings). Remember, never hammer when anyone is nearby, and wear safety glasses.
   - Is the rock the same on the outside as it is inside?

Physical weathering

Physical weathering is the process by which rock is broken up without the minerals in it being changed. Solids expand when they are heated and contract when they cool. Rocks are solids, so they expand on a hot summer day and contract again as they cool down at night or in cooler weather. Over a long period of time this repeated expansion and contraction causes the rocks to crack.

Water gets into any cracks in the rock. In cold areas, such as high up in the mountains or in the cold of a desert night, the water in these cracks freezes. As the water freezes it expands and forces the cracks open slightly. When this happens time and time again the rocks start to break up.

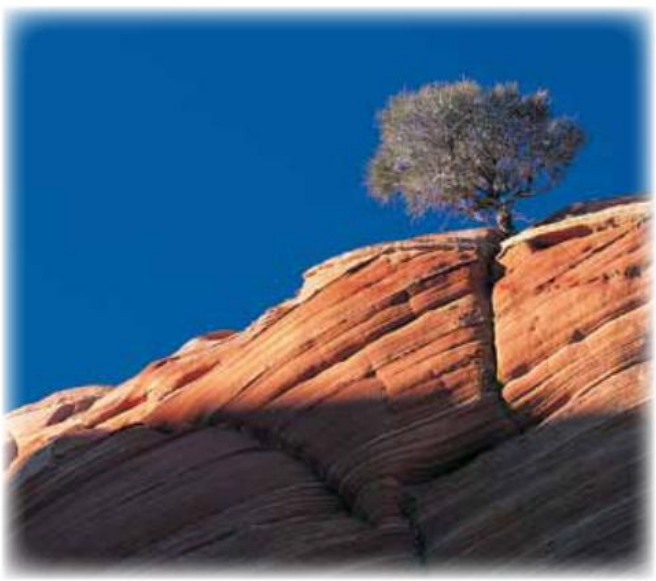
INQUIRY 3 Physical weathering

You will need: small plastic bottle with tight-fitting lid, refrigerator

Fill a small plastic bottle to the brim with water and close the lid tightly. Leave it in the freezer overnight. What happens?

- What does this tell you about the weathering of rocks?

Rocks in the mountains may be shattered if struck by lightning. Also, the roots of plants sometimes grow into cracks. The growing roots can then widen the cracks further and break the rock apart, as shown below.



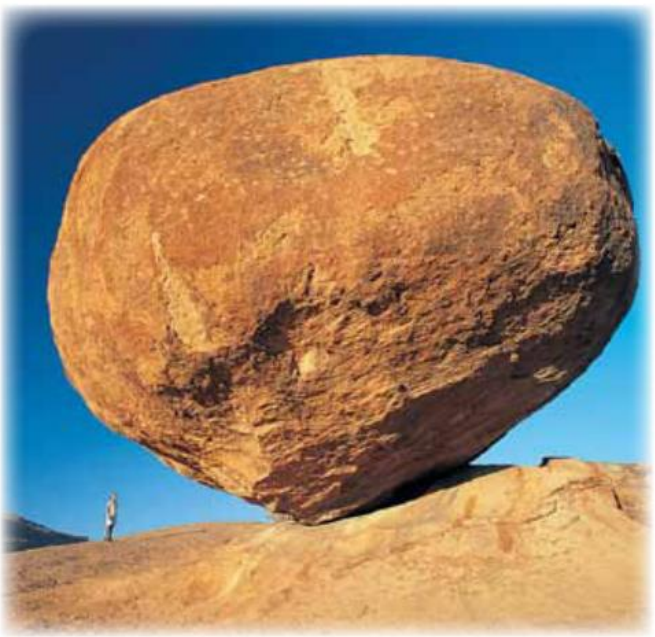
Tree roots play their part in breaking up rocks.

Chemical weathering

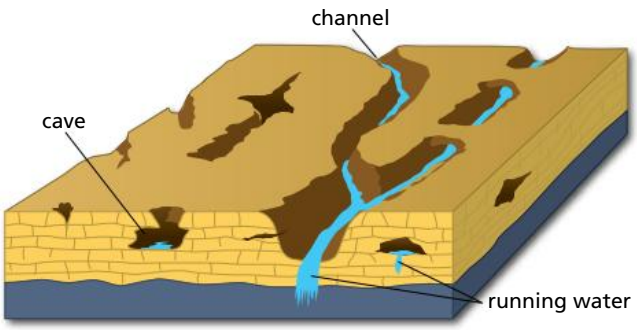
Chemical weathering is the process by which minerals in the rock are changed by chemical reactions. There are many different minerals in rocks, and when water and air react with these, new minerals are formed. These new minerals are usually softer, and this causes the rock to crumble.

In Inquiry 2 you should have noticed that most rocks are brown on the outside. This is because iron is present in many minerals, and it reacts with the oxygen in the air to form brown iron oxide (rust), which is relatively soft. A common mineral in rocks is feldspar and it reacts with air and water to form clay. When the clay gets wet it swells up, and this in turn causes physical weathering.

Look at the photo below of a balancing rock made of granite. It formed this shape over millions of years, as shown in the diagram. First the granite cracked horizontally and vertically, forming huge blocks. As water and air entered the cracks, chemical weathering occurred. Over time the blocks became more rounded, with softer rocks in between them. Eventually these softer rocks were washed away, leaving balancing rocks.



A special type of chemical weathering occurs in limestone and marble, which are made up of the mineral calcite, or calcium carbonate. As rain falls it dissolves some of the carbon dioxide in the air to form carbonic acid. When this acidic water flows over limestone or marble it reacts with it, causing it to dissolve. As the water flows through the limestone it can form channels and caves such as the Jenolan Caves west of Sydney, and the vast underground caverns under the Nullarbor Plain.



Rainwater dissolves limestone and the running water can form channels and caves.

INQUIRY 4 Chemical weathering

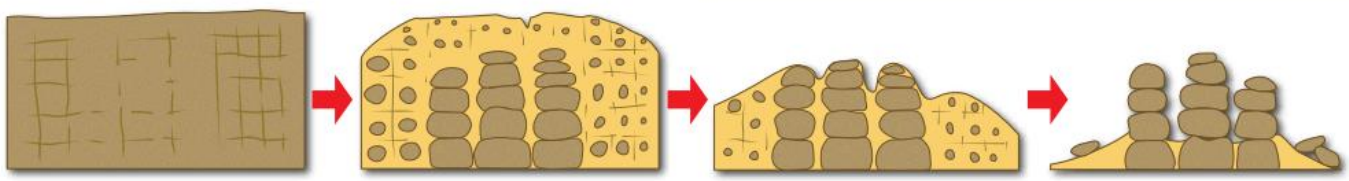
You will need: beaker, steel wool or iron filings, sand, test tube, dilute hydrochloric acid, piece of limestone

1 To model how water reacts with the iron in rocks, place some steel wool just below the surface of some sand in a beaker. Use a spray bottle to moisten the sand with water each day. Observe what happens over a week.
   - How does this explain why most of the rocks you find are coloured brown on the outside?

2 Add two or three drops of dilute hydrochloric acid to a small piece of limestone in a test tube. What happens?

CAUTION: Hydrochloric acid is corrosive.

   - Use the diagram above to explain how caves can be formed in limestone.



Balancing rocks are formed in granite, over millions of years.

Erosion by water

After rocks have been weathered, the pieces left are loose and able to be moved. **Erosion** is the removal of weathered pieces of rock and their transport to another place. In this way weathering and erosion work together to gradually change the surface of the Earth.

The force of gravity may cause weathered rocks to fall down a cliff or mountainside, but the major cause of erosion is running water. When rain falls it forms small trickles of water that run downhill, carrying weathered material down the slope with it. Very soon these trickles combine to form small streams, which join with others into creeks, and creeks join to form rivers. Fast-moving water in gullies, creeks and rivers can carry large amounts of weathered material—mud, sand, pebbles and even quite large boulders. This material will be deposited (dropped) somewhere downstream.

Erosion shapes our landscape and over millions of years can turn mountains into plains. It has been estimated that the rivers in the King Leopold Ranges in north-west Australia have eroded their beds to a depth of 500 metres over 10 million years. In the photo below the cliffs are made of harder rocks that have not been eroded as rapidly as the softer rocks above them.



INVESTIGATION 2

Steam tray erosion

Aim

To investigate how a stream causes erosion.

Risk assessment and planning

If there is a limited number of stream trays you will need to work in groups. It is best to do this investigation outside.

Apparatus

- stream tray
- damp sand
- water container
- bucket
- plastic lid

Method

1. Set up the stream tray with damp sand. Put a block under one end of the tray to make a slope. Put a bucket under the tray's drain hole to catch the overflow.
2. Put a plastic lid at the top of the slope, partly in the sand. This is so the water doesn't wash the sand away too quickly.
3. Pour water steadily into the plastic lid so that it overflows the lid and runs down the slope. If you are doing this in the laboratory, attach a piece of plastic tubing to the tap, instead of pouring the water yourself.
4. Watch the erosion caused by your river, then stop the flow of water and draw what has happened.

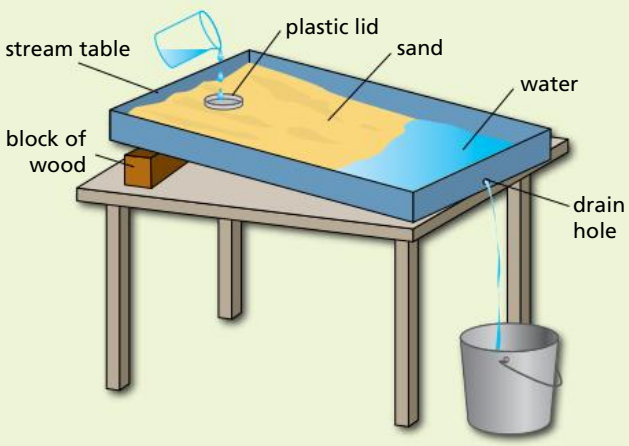
   Where has the sand been eroded? Where has it been deposited?

   ✻ Does the stream change as it goes down the slope?

   ✻ What happened as the stream flowed into the lake at the bottom of the tray?
5. Investigate what happens if you change the slope or change the flow of water.
6. What happens if you mix coarser sand and pebbles with the sand in the tray?

Write your report

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



Coastal erosion

The never-ending action of wind and waves along our coastline can cause severe erosion, especially where the rocks are soft. The spectacular landform in the photograph below is on the Great Ocean Road west of Melbourne. It is called London Bridge. People used to be able to walk out onto it until 1990, when it collapsed due to constant erosion by the ocean. Two people had to be rescued by helicopter from the part left standing in the water.



London Bridge before and after its collapse

Erosion by wind and ice

Have you ever stood on the dry sand at the beach when a strong wind is blowing? If you have you will have felt the grains of sand stinging your legs. Wind-blown sand like this wears away rocks, particularly those that are soft. It is thought that the wind may have played a part in the erosion of Wave Rock in Western Australia. In mountainous areas, glaciers (rivers of ice) also cause erosion.



Wave Rock

Over to you

1 **a** Draw a crack in a rock before and after a root from a tree has grown into it.

b Estimate how long this change would take.

2 Granite is formed under the ground, but there are many places where it can be seen at the surface. How can you explain this?

3 Which comes first—weathering or erosion? Explain your answer.

4 Put the five stages of the weathering and erosion of granite into the correct order.

boulder, coarse sand, fine sand, gravel, solid rock

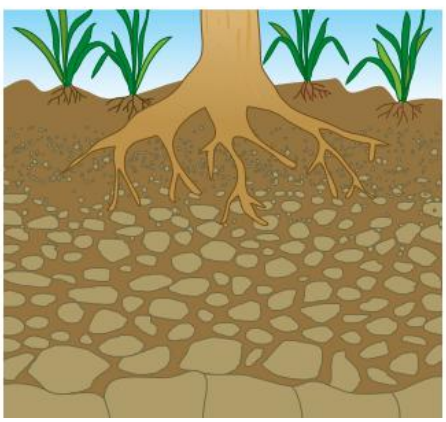
5 Predict which would be carried furthest by a stream—gravel, sand or mud. Explain your prediction.

6 Trail bikes can increase the rate of soil erosion. How?

7 Look at the photo of London Bridge on the left. Explain in your own words how you think it was formed.

8 Cars and factories add extra carbon dioxide to the air. What effect would you expect this to have on city buildings made of limestone or marble?

9 The diagram below shows part of a road cutting. Suggest how the soil at the top was formed.



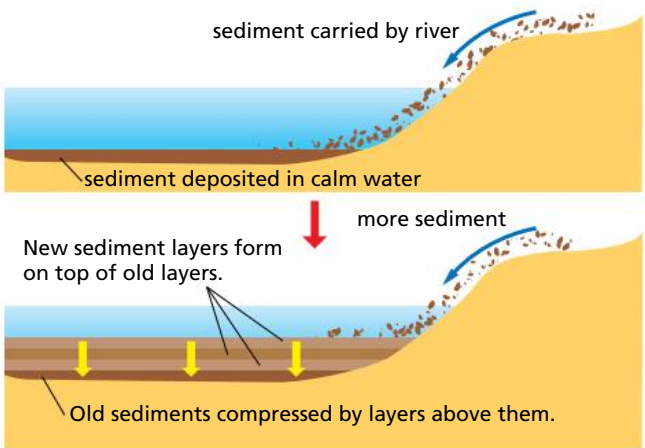
10.3 Sedimentary rocks

Have you seen a cliff face or a road cutting where the rocks are stacked in layers like a pile of sandwiches? If you look closely at the rock you will find it is made from bits and pieces of rock cemented together. The pieces of rock are called sediments, and the rock is called **sedimentary rock**. About three-quarters of the rocks you see are sedimentary.

How sedimentary rocks form

Weathering breaks up rocks into small fragments and these are then moved from place to place by the action of water, wind and ice. Streams become muddy when it rains because of the sediment washed into them by running water. Dust storms carry fine particles of soil high into the air. Over time, huge quantities of material that have been eroded are carried from the land into lakes and oceans, where they settle to the bottom. The various sediments settle one on top of the other, producing the layered appearance that is seen in sedimentary rock.

Layers of sediment build up on the floor of a lake or the ocean. They are compressed by the layers above them and the water is squeezed out. These compressed sediments become cemented together by natural minerals such as clay and calcite to form sedimentary layers. Gradually, with the passing of time, huge forces within the Earth's crust can push the sedimentary rocks above sea level. They can then be weathered and eroded all over again. The whole process takes millions of years.



By looking at the size of the sediment particles in a sedimentary rock you can infer how it was formed. For example, *shale* (or mudstone) is composed of very fine clay particles. These tiny particles indicate that the sediments were deposited by gradual settling from quiet slow-moving water. Places where this could happen include lakes, lagoons and river flood plains. *Sandstone* is made of sand-sized fragments deposited in seas or lakes and cemented together. *Conglomerate* (con-GLOM-er-it) is composed of rounded gravel fragments cemented together by finer sediments. It usually forms at the mouths of fast-flowing streams, which have the energy to carry larger rock fragments as well as smaller ones.



Note the large pebbles in this conglomerate, indicating it was deposited from fast-flowing water. The pen shows how big the pebbles are.

INQUIRY 5 Which settles first?

You will need: 2 L soft drink bottle with lid, clay or mud, coarse sand, fine sand, small pebbles (gravel)

1. You will be mixing the sediments listed above with water and letting them settle. Before you do this, write a hypothesis linking the size of the sediments to the rate at which they settle in water.
   - Use your hypothesis to predict the order in which the clay, coarse sand, fine sand and pebbles will settle.
2. Fill the bottle to a depth of 5 or 6 cm with equal amounts of each of the sediments. Then fill the bottle with water and put on the lid.
3. Tip the bottle upside down several times and shake it. Leave the sediments to settle for 20 minutes or so and observe carefully. If possible leave it for the next lesson.
   - Which sediments settled first? Which settled last?
   - Was the water clear after 20 minutes? If not, how can you explain this?
4. In the next lesson look carefully at the sediments in the bottle. Can you see any layers? You could use a hand lens for a closer look.
5. Draw a diagram of the sediments and label the layers. Was your prediction in Step 1 correct?

Rocks from living things

Limestone is a sedimentary rock that is formed from the remains of sea organisms such as shellfish and coral. The hard parts of these dead animals contain calcium carbonate, and they can be cemented together over a period of time in the same way that sand forms sandstone.

About 250 million years ago much of Australia was covered with swampy forests of giant trees and tree-like ferns. When the plants died they formed thick rotting layers on the ground. The swamps were then flooded by streams or a rise in sea level, and many sediments were deposited on top of the dead vegetation. Over millions of years the pressure of the layers on top of this squeezed out the water. The temperature rose as the plants rotted, and eventually coal was formed. Coal is a type of sedimentary rock.

Uses of sedimentary rocks

Sandstone and limestone were often used as building materials, but are rarely used now because there are cheaper alternatives. You may be able to find buildings made of sandstone and limestone near where you live. These rocks can be carved into various shapes.

Shale is often ground up into clay for making cement, bricks and pottery. Limestone is broken up to produce lime, which is used to make cement, to treat sewage and to put on gardens. Coal is used as a fuel, for example in power stations.

INVESTIGATION

3 Making sedimentary rocks

Aim

To make a variety of sedimentary rocks and investigate their properties.

Risk assessment and planning

Read the investigation carefully before you start and do a risk assessment. It is best to do this investigation outside.

Apparatus

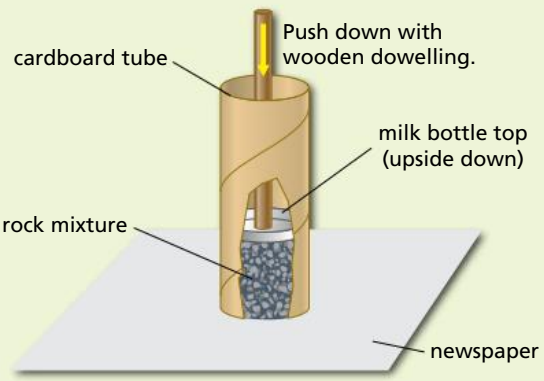
- clean sand, gravel and clay
- plaster of Paris, cement powder, Spakfilla or similar, PVA type glue (not 'super' glue)
- newspaper
- about 6 cardboard tubes from used toilet rolls
- dessertspoon
- mixing container
- about 6 plastic 2 L milk bottle tops
- short piece of wooden dowelling or similar

Method

1 To make sandstone, mix about 5 dessertspoons of sand and one dessertspoon of plaster of Paris. Carefully add water a little at a time, mixing well until you get a thick paste.

2 Put the mixture into a cardboard tube as shown. Squeeze the rock by pushing down on an upside down plastic milk bottle top which fits inside the tube.

3 Leave the rock sample in the cardboard tube to dry for 2 or 3 days. Then tear off the cardboard and examine the rock you have made.



4 Make different sorts of rocks by changing the sediments you use. To make shale, use clay instead of sand. To make conglomerate, mix sand, clay and gravel. You can also vary the proportions of sand, clay and gravel.

5 Try different types of cement. For example, clay makes a good cement. You could also try cement powder, Spakfilla or even PVA glue. Whether the rocks come out hard or soft will depend on the cement used.

6 You can also investigate the effect of pressure. For example, what difference does it make to the final rock if you press down the sediments in the cardboard tube?

7 Once the rocks are dry, examine them closely. How do they compare with real sedimentary rocks? Use a hand lens for a closer look.

Design tests to see how hard they are, how easily they break or how they weather.

✻ Record your observations in a data table.

Fossils

Sedimentary rocks may contain **fossils**—traces of ancient life preserved in rocks. For example, the dinosaur footprints below were found in fine shale near Winton in western Queensland.



There are many small footprints and several larger ones. From this geologists have inferred what happened in this area 95 million years ago. A number of small dinosaurs were drinking on the muddy shore of a lake when they were attacked by a large flesh-eating dinosaur. As they ran for safety they left their footprints in the mud. Soon afterwards there was heavy rain, the lake rose and the footprints were buried in fine mud. Eventually the mud hardened to form sedimentary rock.

When a plant or animal dies it is sometimes buried very quickly in fine soft sediment. In time the remains decay and the sediment hardens into rock, leaving a *mould* of the animal or plant. Sometimes minerals fill the empty mould and harden to form a *cast* in the shape of the original animal or plant. On rare occasions the actual remains are left. These are usually bones.

INQUIRY 6 Making a fossil

You will need: plasticine, plaster of Paris, mixing container, shell or bone

1. Using the plasticine, make a mould of the inside or outside of the shell.
2. Mix up the plaster of Paris as directed by your teacher.
3. Fill the mould with plaster and let it dry.
4. Remove the plasticine. You now have a cast of the inside or outside of the shell.

Over to you

1 **a** How do sediments turn into sedimentary rock?
b Why are sedimentary rocks usually in layers?

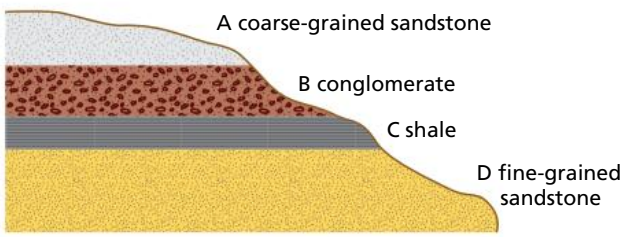
2 Copy and complete the following sentences.
a A sedimentary rock that is made from mud and clay is called _____.
b _____ is a sedimentary rock made from the shells of sea animals.
c _____ is a sedimentary rock formed from the buried remains of dead plants.

3 Which would be best to use as a building material—sandstone or conglomerate? Why?

4 Draw a series of diagrams showing how coal is formed.

5 **a** What would normally happen to the body of a dead fish lying on the bottom of the ocean?
b What would have to happen for a dead fish to become a fossil?

6 A cliff face has four different sedimentary layers, as shown.
a Which layer was deposited first? Last?
b Why are the sediments in the layers different sizes and colours?
c Which layer was most likely formed during a period of floods? Explain your answer.
d Which layer was most likely formed when the area was swampy? Explain.



PROBLEM SOLVING

Have you found any sedimentary rocks? Examine your specimens and see if you can tell whether they are sandstone, shale or conglomerate. If you think a specimen is limestone, test it by adding a drop or two of dilute hydrochloric acid (CAUTION) and see if it fizzes.

Were you lucky enough to find any fossils? They are found in shale and fine sandstone. If you think a rock might contain fossils, try to split it along the layers to see if there are fossils inside it. Fossils, especially fossil shells, are common in limestone.

10.4 Igneous rocks and metamorphic rocks

The Earth is made of three main layers—the crust on the outside, the mantle and the core in the middle. The mantle is under enormous pressure and in parts the rock melts to form **magma**. Sometimes this magma finds its way towards the surface through a weakness in the crust. When this happens the red hot magma cools to form **igneous rock**. The word igneous (IG-nee-us) comes from the Latin word for fire. The words *ignite* and *ignition* come from the same word.

The magma is a mixture of minerals and as it cools these minerals form different-shaped crystals. As more and more crystals form, they grow into each other, fitting together like the pieces in a jigsaw puzzle.

Extrusive igneous rocks

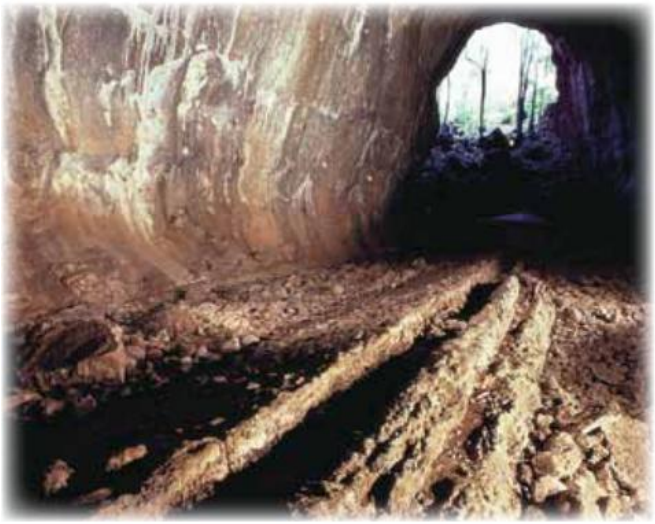
Magma can reach the Earth's surface in a number of different ways. It can ooze up through cracks, it can spill out of volcanoes or it can be shot out in spectacular eruptions. When magma reaches the surface it is called **lava**. When it cools down, crystals start to form and the lava solidifies into a type of rock called **extrusive** igneous rock. These rocks are called extrusive because they are *pushed out* to the surface. The type of rock formed depends on the minerals in the lava and on how quickly it cools.

Two common extrusive rocks are *basalt* and *rhyolite*. Both of these have small crystals because they cooled quickly and the crystals did not have time to grow. The lava also contains gas. If there is only a small amount of gas, the lava pours out quietly, as in the photo below. If there is a large amount of gas, the lava comes out rapidly and may be blown high into the air. Tiny pieces of lava fall back to the ground as volcanic ash, which cools to form a rock called *tuff* (rhymes with rough). There are deposits of tuff at Tower Hill in western Victoria. *Pumice* is formed when gas bubbles are trapped in hardened lava. It looks like a hard, grey sponge and can float on water.

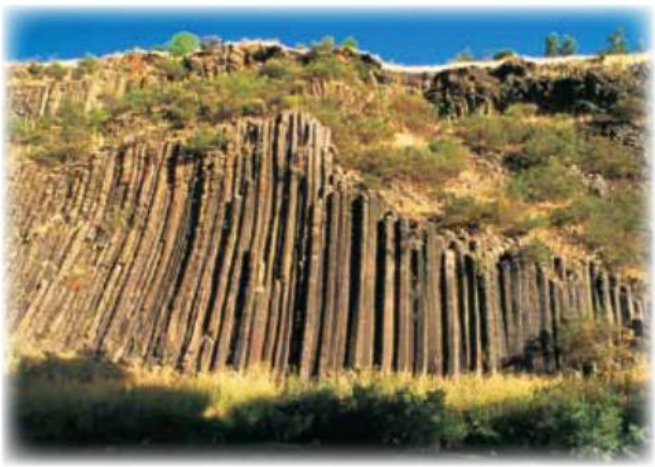
Lava sometimes flows out in long winding 'fingers' as in the photo below. When this happens the lava on the outside hardens into rock and the lava inside continues to flow. Hollow tubes of rock called lava tubes can form. The largest of these are seen at Undara in north Queensland (see that next page).

Flowing lava has destroyed this house in Hawaii.





A lava tube at Undara in north Queensland



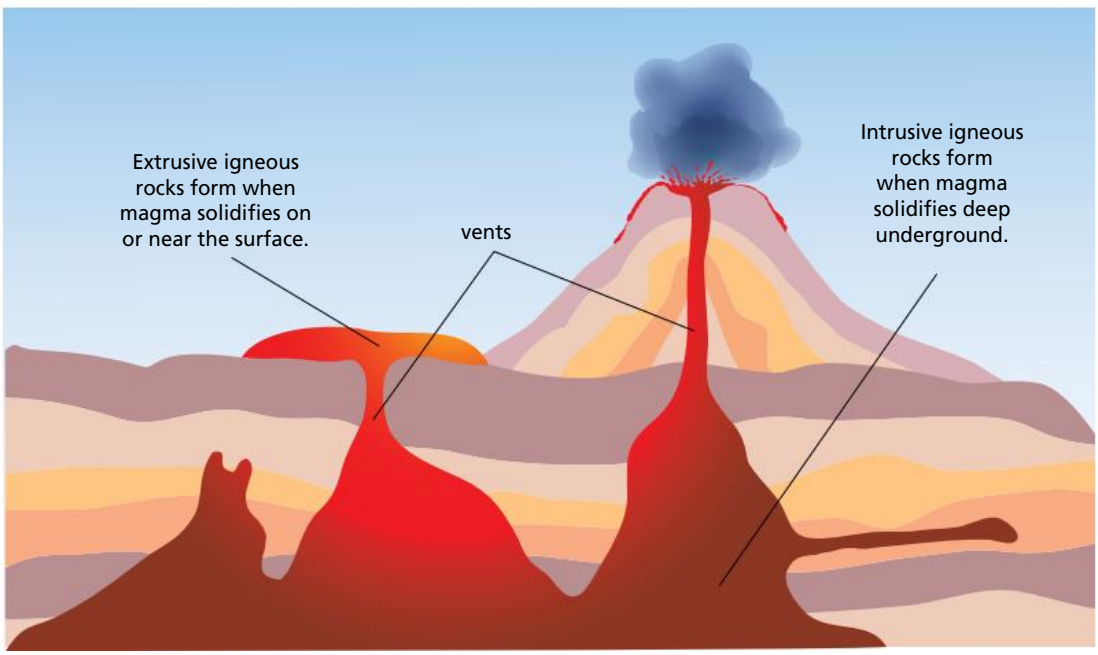
Basalt columns at the Organ Pipes, Victoria

As the lava cools it contracts. When this happens it forms cracks which sometimes join up to form a regular pattern of columns with five or six sides. There is a good example of this at the Organ Pipes, just west of Melbourne.

INQUIRY 7 How igneous rocks form

You will need: copper sulfate, potash alum (aluminium potassium sulfate), stirring rod, 100 mL beaker, watch glass, Bunsen burner equipment

1. Half fill the beaker with water and use the Bunsen burner to heat it. (Don't let it boil.)
2. Add equal amounts of copper sulfate (a blue mineral) and potash alum (a white mineral). Keep adding the two minerals a bit at a time, stirring all the time, until no more will dissolve.
3. Pour some of the solution into a watch glass that has been cooled in the fridge. Leave the rest of the solution in the beaker and leave it to cool slowly overnight.
4. Make a sketch of the crystals that formed in the watch glass and in the beaker.
   - Which solution cooled more quickly?
   - Which container has the larger crystals? Suggest a reason for this.
   - Which mineral was the first to form crystals?
   - Which mineral formed the largest crystals?



Extrusive rocks are formed at or near the surface. Intrusive rocks are formed deep underground.

Intrusive igneous rocks

Often magma starts to cool down while it is still well below the surface. Cooling takes place very slowly, producing large crystals. Such rocks are called **intrusive** rocks because they intrude into other rock layers. (Intrusive means *forced into*.) *Granite* and *gabbro* (black granite) are common intrusive rocks.

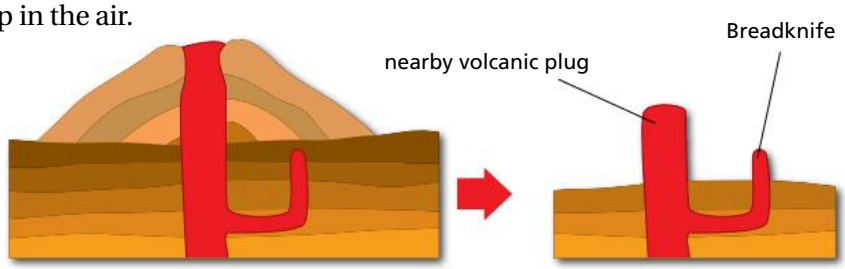
We see intrusive rocks only after the rock that covers them has been worn away. The Breadknife in the Warrumbungle Mountains in New South Wales is a sharp narrow wall of rock 90 metres high and only 2–4 m wide. There was once a volcano in the area. The molten rock in the vent of the volcano solidified to form what is called a volcanic plug. There was also a narrow band of rock that branched off the vent, as shown below. These igneous rocks are harder than the surrounding rocks, which have been eroded away, leaving the Breadknife sticking up in the air.

Uses of igneous rocks

Basalt or bluestone is a very common rock and covers much of the western part of Victoria. It has been widely used as a building stone. It is also crushed up to form blue metal, which is used in road making and on railway tracks as a base for the sleepers.

Granite has a mottled grey-pink appearance and is used as a building stone. It can be polished to make ornamental stone, often used for the floors and walls of the entrances of city buildings. It is also used to build monuments and for tombstones.

Pumice and scoria are both formed from lava. Pumice is used to remove rough skin on your feet and to make lightweight building blocks. *Scoria* is a very light reddish rock which is full of holes. It is used in gardens and for drainage.



A cross-section showing how the Breadknife (below) was formed.



SCIENTISTS AT WORK

Dr Cindy Werner

Imagine travelling by helicopter and landing on an active volcanic island called White Island off the coast of New Zealand. This is part of Dr Cindy Werner's job. She studies the gases produced by volcanoes and regularly flies to the island to measure the levels of carbon dioxide. 'That can be pretty interesting, flying about 65 m above the ocean in a helicopter, downwind of an active volcano', she says. 'It's a bit of a bumpy ride.'

Every year many people are killed in volcanic eruptions. Cindy Werner hopes that scientists will one day find a reliable way of predicting when a volcano will erupt, so that people living nearby can be evacuated. A volcano gives off the poisonous gases sulfur dioxide and carbon dioxide. In her studies Cindy has found that when a volcano is about to erupt the concentrations of these gases change.

Cindy's father inspired her to become a scientist. He was always fixing cars and electronic equipment, and tried to teach his daughters how things work. Cindy studied engineering at university, but switched to geology after a holiday at Yellowstone National Park, a volcanic area in the USA. 'What I love about geology is going out and taking data in the natural world, and then trying to figure out what it is telling me. It is like trying to solve puzzles.'

Cindy says the best thing about her job is that it allows her to travel around the world and visit amazing places. She once visited Stromboli in Italy. 'We hiked up and watched the volcano erupt at night. Each time an eruption occurred, the ground would tremble and light would scatter down the volcano towards the sea. It was nature's fireworks—truly amazing.' Near Naples in Italy Cindy tested a new technique to monitor volcanic gases and she says 'it felt so good to know that the work I was doing was going to benefit the people living in the area'.

Cindy loves mountain biking, hiking, swimming, rock climbing and listening to jazz. Her advice to students is 'never be afraid to ask what you think is a stupid question'.



Cindy at work sampling the gases at White Island, wearing a gas mask and special clothing.

This page is based on 'Picture a scientist' in the CSIRO magazine The Helix, (Dec 2002–Jan 2003). Each month a scientist at work is featured.



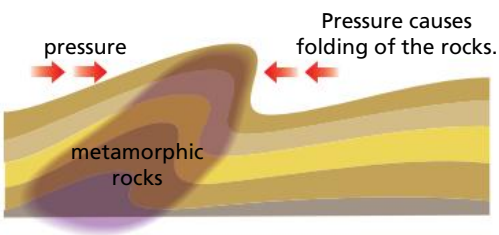
White Island

Metamorphic rocks

Weathering can change rocks by softening them and breaking them up. There is another process that can change rocks and make them *harder*. Just as clay can be changed into bricks by heating it in a kiln, so rocks can be changed by heat and pressure. Rocks formed in this way are called **metamorphic rocks**. *Meta* means 'change' and *morph* means 'form', so metamorphic means 'changed in form'.

One source of heat is magma pushing upwards through the Earth's crust. The rocks in contact with the magma become very hot and are slowly changed to new rocks. For example sandstone is changed to *quartzite*, limestone is changed to *marble* and shale is changed to *slate*. These metamorphic rocks are harder and less porous than the original rocks.

However, the main cause of change in rocks is the massive bending and twisting that occurs in the Earth's crust over millions of years. This is called *folding*, and the pressures that build up in rocks during this process are enormous. Tremendous heat is also generated. Chemical changes occur in the rocks and new minerals are formed. Often the metamorphic rock has a banded appearance. Even igneous rocks can be changed. For example, granite is changed to *gneiss* (NICE).



INQUIRY 8 Parent rocks

You will need: hand lens, samples of gneiss, granite, limestone, marble, quartzite, sandstone, shale and slate

1 Quartzite is a metamorphic rock formed from sandstone. Because quartzite is formed from sandstone, geologists say that the sandstone is the 'parent' rock and the quartzite is the 'child'. Examine the two rocks and note the similarities and differences in their properties.
   - How do the surfaces of the rocks feel?
   - How hard are they?
   - Use a hand lens to examine them.
   - Does a drop of water soak into either rock?

2 Try to sort the other rocks into parent and child pairs, based on your observations.

Uses of metamorphic rocks

Marble is made of crystals of calcite and fizzes with acid, as limestone does. However, it is much harder than limestone. Pure marble is white, but impurities often cause beautiful bands of colour to occur. For this reason marble is a popular building and ornamental stone. It is used in bathrooms and kitchens for tiles and bench tops. Statues are often carved from marble.

Slate is much harder than shale and splits easily into slabs. This is why it is used for wall tiling, paving and for billiard table tops.

Over to you

1 Copy and complete this sentence: Large crystals form when magma cools _____, while small crystals form when lava cools _____.

2 For each term below write a question so that the term is the answer to the question.
   a lava **b** magma
   c extrusive rock **d** intrusive rock

3 What properties of slate do you think would make it useful as a lining for fireplaces?

4 Marble is usually found in regions where the sedimentary rocks have been bent and twisted. Suggest why it is found in these regions.

5 Would you expect to find fossils in igneous rocks? Why or why not? Would you expect to find them in metamorphic rocks? Again explain.

6 In the Snowy Mountains in NSW and in the Victorian Alps there are large areas of granite. How do you think they were formed? A diagram would improve your explanation.

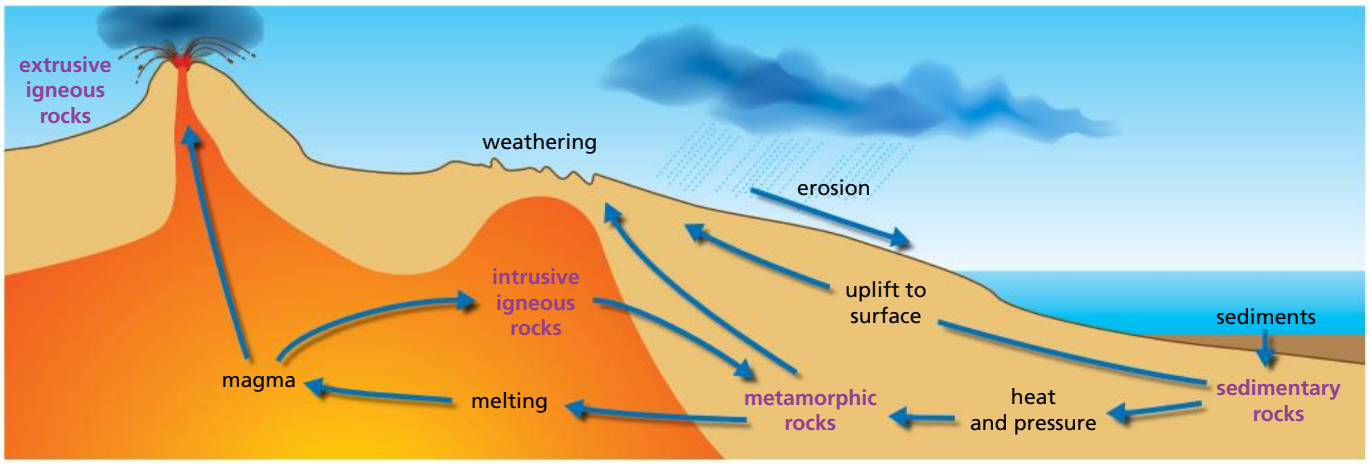
7 The crystals in the rocks on the edge of an old lava flow are smaller than those in the middle of the flow. Why?

PROBLEM SOLVING

Have you found any igneous rocks? They are very hard and made of interlocking crystals. Basalt is the most common. It is grey-coloured and its crystals are too small to see. Granite is also very common and often forms rounded boulders. You may also find small bits of pumice that have been washed onto the beach.

Metamorphic rocks are not that common and fairly difficult to tell from igneous rocks. You may be able to obtain samples of broken slate and marble tiles.

10.5 The rock cycle



We can now summarise what you have learnt in this chapter. There are three types of rocks which are formed in the Earth's **lithosphere** (rocky sphere), which includes the crust and the upper part of the mantle. Sedimentary rocks are formed from sediments, igneous rocks are formed from magma, and metamorphic rocks are formed from any other rocks by heat and pressure.

All rocks are weathered and eroded to form sediments, which then form sedimentary rocks. As layers of sedimentary rocks build up, the bottom layers sink deeper and deeper into the lithosphere where there are high temperatures and pressures. When this happens they are changed into metamorphic rocks. If the temperature is high enough they may melt to produce magma again.

As the magma moves towards the surface it may cool under the ground to form intrusive igneous rocks. These may eventually be exposed at the surface by weathering and erosion. If the magma reaches the surface as lava, it forms extrusive igneous rocks, which are also weathered.

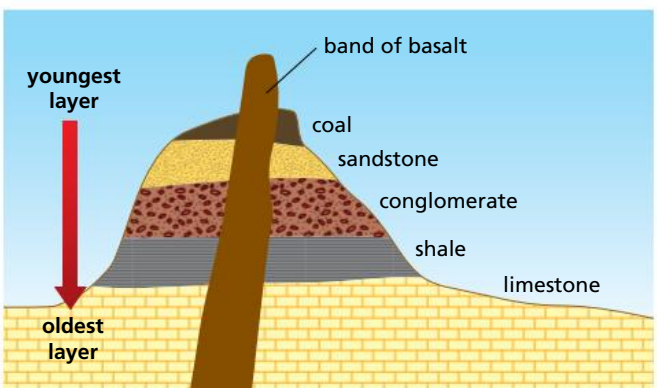
The Earth is more than 4500 million years old, and weathering and erosion have been occurring all this time. Why haven't the mountains all been washed into the oceans? The answer is that there are huge forces inside the Earth that slowly push the crust up in places to form mountains. When this happens rocks are uplifted to the surface where they undergo weathering and erosion, and the whole **rock cycle** starts again.

The age of rocks

How do geologists know how old rocks are? They use two types of age—*actual age* and *relative age*. The actual age gives a number of years, with an allowance for error. For example, a rock may be dated as being 40 000–60 000 years old. The relative age only tells you whether one rock is older or younger than another. For example, your actual age may be 13, but when you say that you are older than your sister but younger than your brother you are giving your *relative* age.

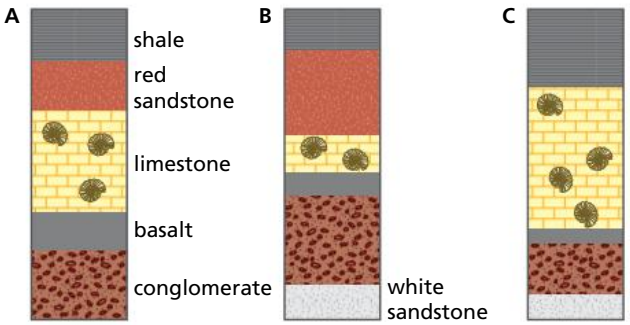
Suppose a geologist finds a road cutting as shown below. There are five layers of sedimentary rocks—one on top of the other. Knowing that sedimentary rocks are formed by the settling of sediments, he infers that the limestone on the bottom was formed first. It is the oldest. The other layers formed on top of it, so they are younger. Therefore the coal on the top is the youngest. There may, of course, be older rocks further down, and there may have been younger rocks that have been eroded away.

Running across the sedimentary layers there is a narrow band of basalt—an igneous rock. Because it cuts across the sedimentary rocks you can infer that it was formed *after* them. In other words, it is the youngest of all the rocks. The geologist knows the relative ages of the rocks, but not their actual ages.



Matching rocks

Suppose a geologist found the rock layers shown below in three different cuttings in the same area. Each of the cuttings has a limestone layer which looks much the same and contains fossils of an extinct shellfish. These shellfish were common throughout the world during the Jurassic period, 150–200 million years ago. Because the limestone at the three locations contains the same fossils, you can infer that it is the same age (150–200 million years old). The geologist can then estimate the ages of the layers above and below the limestone.



INQUIRY 9 Stories in stone

Look at the diagram of the rock layers in the three cuttings.

- At A, which rock would you expect to find under the conglomerate? Why?
- List the rocks from youngest to oldest.
- Suggest why the thickness of the shale layer varies.
- At C there is no red sandstone between the shale and the limestone. Suggest a reason for this.
- How is basalt formed? Suggest why the layer of basalt gets thinner as you go from A to B to C.

Radioactive dating

Some of the minerals in rocks contain radioactive elements that can be used to find the actual age of a rock. The nuclei in the atoms of these elements are unstable and break down or decay at a fixed rate to form more stable elements. The age of a rock can be estimated by comparing the amount of radioactive element in the rock with the amount of the stable element formed from it.

For example, radioactive potassium occurs naturally in some of the minerals in igneous and metamorphic rocks. As soon as the rock is formed, the potassium starts to decay to the gas argon, which remains trapped in the rock. As time passes, the amount of potassium in the rock decreases and the amount of argon increases.

If there is 1 kg of radioactive potassium, it takes 1.3 billion years for half of it to be changed to argon. It takes another 1.3 billion years for half of the remaining 500 g to decay, and so on. Therefore, 1.3 billion years is known as the *half-life* of radioactive potassium. From the ratio of radioactive element to stable element you can estimate the age of the rock. For example, if the ratio is 1 : 1, you have equal amounts of potassium and argon. From this you can infer the rock is 1.3 billion years old.

Radioactive dating, as this method is called, cannot be used to find the age of sedimentary rocks. Their age can be estimated if you know the age of a nearby igneous rock. For example, if the basalt in cutting A is found to be 200 million years old, you can infer that the conglomerate below it is older. You can also infer that the limestone above it, and the fossils in it, are less than 200 million years old. You can also infer that the limestone at B and C is the same age as that at A.

Over to you

1 **a** How can granite be changed into sedimentary rocks?

b Can a sedimentary rock be changed into an igneous rock? How?

2 A road cutting reveals the layers of rock shown in the diagram below.

a Which rock layer is the oldest?

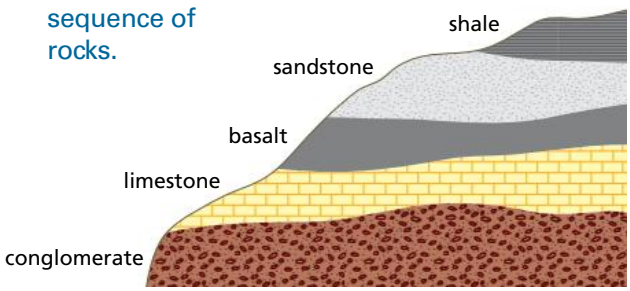
b Which rock is the youngest?

c What evidence is there of volcanic activity?

d Which rock is likely to contain fossils of seashells?

e Why are some layers thicker than others?

f Write a geological history to explain the events that formed this sequence of rocks.



3 Explain why the continents have not been reduced to flat plains due to weathering and erosion.

THINKING SKILLS

1 Why are some beaches muddy, some sandy and some pebbly?

2 Suppose you found a rock with ripple marks on its surface. What can you infer about how this rock was formed?

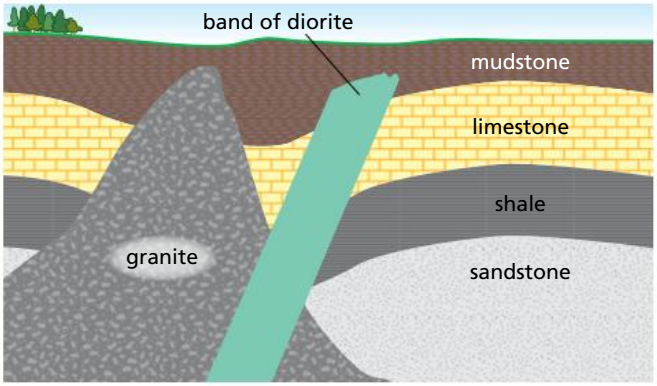
3 A deposit of the volcanic rock tuff contains fossilised wood. Infer how this could have happened.

4 This basalt found on the moon has many holes in it—like the holes in a sponge. How do you think the holes were formed?



5 Why don't all the crystals in an igneous rock specimen have perfect shapes?

6 Work out the order in which the six rocks in this diagram were formed.



7 What would happen to the rock cycle if there was no water on the Earth?

8 People travelling through rocky deserts at night sometimes hear noises like gunshots. Use what you have learnt in this chapter to infer what could cause these noises. Why would they be heard at night and not during the day?

9 Normally you find older layers of rock under younger layers. Sometimes, however, the older layers are on top of the younger ones. How can you explain this? You will need to draw a diagram.

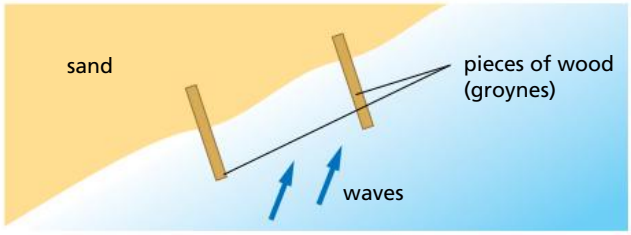
10 Parts of the skeleton of a marsupial lion were found in a cave at Naracoorte in South Australia. The amount of radioactive carbon in the bones is about one-eighth of that found in the skeletons of living animals. If the half life of radioactive carbon is 5700 years, how old is the skeleton?

11 You cannot find the age of a sedimentary rock by radioactive dating. Suggest a reason for this.

12 The Sphinx in Egypt is built from limestone. Weathering has affected it more during the last 50 years than in all the time since it was built thousands of years ago. What do you think has caused the weathering to speed up?



13 Use a stream tray to investigate the effect that groynes (rock walls) have on the erosion of beaches.



14 Design an experiment to show that dry clay expands when it becomes wet. How could this cause physical weathering?

15 Most cities have many buildings made of rocks of various types. Design your own *Rock about* city tour to discover some of these rocks.

Knowing and Understanding

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

1 Rocks are a mixture of chemical compounds called _____. There are three types of rocks—igneous, _____ and metamorphic.

2 Rocks and minerals are used in a variety of ways, depending on their _____.

3 Weathering is the wearing away of rock. _____ is the removal of the weathered material by water, wind and ice.

4 Sedimentary rocks are formed from the weathered remains of older rocks which have been _____ together. They tend to be formed in layers, with the oldest layer at the _____. Sedimentary rocks may contain fossils.

5 _____ rocks are formed by the cooling and hardening of molten rock (magma). Extrusive rocks cool quickly at or near the surface and have small _____. Intrusive rocks cool _____ underground and have large crystals.

6 Metamorphic rocks are formed from other rocks which have been altered by heat or _____ or a combination of both.

7 Rocks can be changed from one type to another over millions of years. This is called the rock _____.

8 By comparing sedimentary rocks in different places it is possible to estimate their _____ age. The actual age of rocks can be found by _____ dating.

bottom
cemented
crystals
cycle
erosion
igneous
minerals
pressure
properties
radioactive
relative
sedimentary
slowly

Self-management

1 Summarising

Copy and complete the table below to summarise what you know about sedimentary, igneous and metamorphic rocks.

Type of rock	How they are formed	Examples	Uses
sedimentary			
igneous			
metamorphic			

2 Creative writing

Imagine that you are a quartz crystal. Write a story describing your adventurous life as you crystallise inside a mass of granite, then become part of a layer of sandstone and end up as part of a quartzite cliff in the mountains. The rock cycle diagram on page 227 should give you some ideas.

3 Which rock am I?

Select a rock or mineral mentioned in the chapter and tell the teacher which you have chosen. Your classmates will try to work out which rock it is by asking you simple questions. For example:

- Are you a rock or a mineral?
- Are you sedimentary, igneous or metamorphic?
- Are you extrusive or intrusive?
- What colour are you? ...

You can only answer yes or no to the questions. If they cannot work out what you are with six questions, you're the winner.



A rock cycle?

Checkpoint

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

OneStopScience

1 A rock is an example of

A an element **C** a mixture
B a compound **D** a mineral.

2 Weathering is best described as:

A the breaking up of buildings and footpaths made of rock
B the action of waves on a coastline
C the breakup of rocks due to exposure to the weather
D the removal of weathered material by water.

3 Lava from a volcano cools to form rock. Which one of the following rocks is formed this way?

A basalt **C** marble
B granite **D** sandstone

4 When geologists say the landscape in the photograph on page 217 has been carved out over 10 million years they are

A guessing **C** observing
B inferring **D** predicting.

5 Which of the following are rocks and which are minerals?

a calcite **e** coal
b conglomerate **f** diamond
c granite **g** mica
d quartz **h** slate

6 Name the rock types that fit the following descriptions.

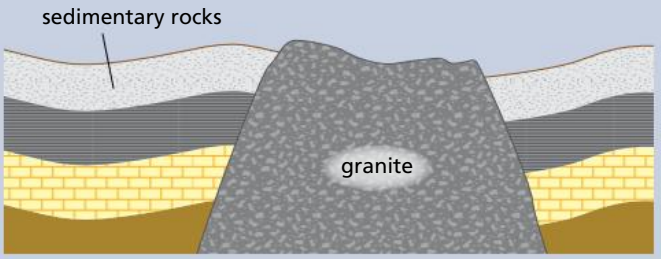
a are hard and compact with interlocking crystals
b formed when other rocks are changed by heat and/or pressure
c often in layers and may contain fossils

7 Concrete is made from sand, gravel, cement and water. Would you classify it as a sedimentary, igneous or metamorphic rock? Explain your answer.

8 A road cutting has a layer of sandstone under a layer of shale. Between them is a much thinner layer of conglomerate.

a Which layer or layers would have formed from sediments deposited in water?
b Which layer would have formed during a period of floods?
c Which layer would have formed when streams flowed quietly into a shallow inland sea?
d Which layer is the youngest? How do you know?

9 The diagram shows a cross-section through a section of the Earth's crust.



a Which type of rock is granite?
b How was the granite formed?
c Why are the layers of sedimentary rock not straight?
d Copy the diagram and mark on it where you are likely to find metamorphic rocks. Explain your answer.
e Draw a diagram to show what this part of the Earth's crust would have looked like just after the granite was formed.

10 Metamorphic rocks are usually formed below the surface of the Earth. However they are often found above the ground—even high in mountain ranges. How can you explain this?

11 The photo shows the Three Sisters in the Blue Mountains west of Sydney. All the rocks are made of sandstone. Using what you have learnt in this chapter, write a description of how you think the Three Sisters formed.



11

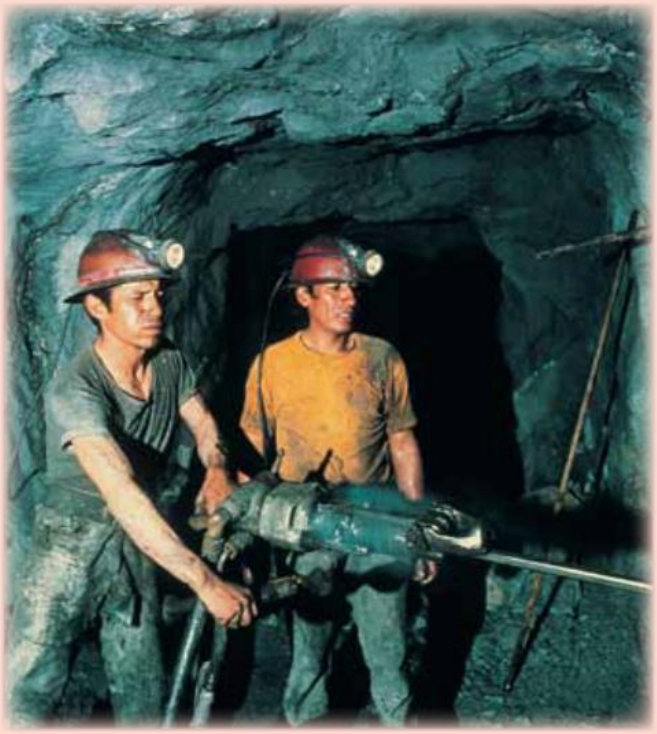


Mining

Focus for learning

Why study mining? Life as we know it in Australia could not exist without the resources (useful materials) that are obtained from mining. In your lifetime, 200 tonnes of coal will be needed to produce the electricity and the many other products such as plastics, medicines, soaps, detergents and cosmetics that you will use. Add to this list the products that are obtained from the mining of metals such as aluminium, copper, tin, zinc and magnesium (see the table on page 234) and you can see the importance of mining. It is a multi-billion dollar industry providing many jobs for Australians.

Australia's history has been shaped by mining. The gold rushes of the 1850s caused towns, cities, agriculture and industries to develop, and brought many different cultures to Australia. In the 1850s, 40% of the gold in the world was mined in Australia. Today Australia produces more than half of the world's mineral sands, just under half of the world's diamonds and a third of the world's bauxite, which is used to make aluminium.



PROBLEM SOLVING

A resource

1 Choose one resource produced from mining (e.g. aluminium or iron) and explain the development of the resource by using a flow chart like this.

What is the resource and why is it needed?

↓

Where is the resource found and how is it mined?

↓

How is the resource processed? (chemical reactions and technology used)

↓

What useful materials are made from the resource?

↓

What environmental problems are caused by the use of this resource?

2 Present your flow chart on an A3 page.

LITERACY FOCUS

activity series
aluminium
bauxite
blast furnace
bronze
carbon monoxide
electroplating
electrostatic precipitator
fault
froth flotation
gangue
haematite
leaching
overburden
rehabilitate
slag
smelting
sulfur dioxide
unreactive
zinc

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

Science Understanding

- distinguish between a rock, a mineral and an ore
- recognise that some rocks and minerals, such as ores, provide valuable resources

Science as a Human Endeavour

- investigate ways in which the environmental impact of mining can be minimised
- explore the use of geological resources by Australian Aboriginal people

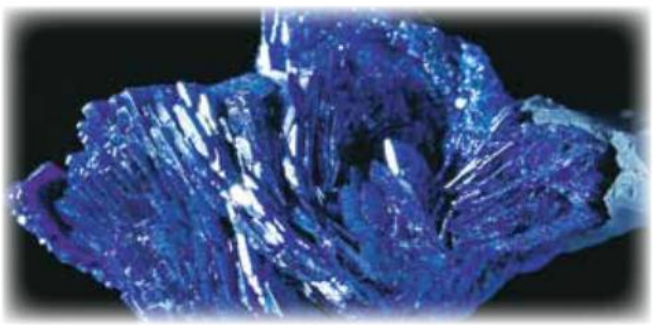
Science Inquiry Skills

- apply a knowledge of chemical reactions to the processing of ores
- use a flow diagram to show the steps in obtaining useful materials from mining

11.1 Ores, minerals and metals

Let's review some terms you should know before continuing. A *mineral* is a naturally occurring substance that has a definite chemical composition and structure. Minerals are usually compounds containing more than one element. For example, bauxite is a compound of aluminium and oxygen. A few minerals occur as elements. For example, diamonds are made up of the element carbon, and gold occurs as an element too.

The pattern of how the atoms are arranged in a mineral can be seen in the form of crystals, which have three-dimensional shapes. They can be columns, prisms, cubes or flat sheets. For example, the photograph shows beautiful crystals of azurite, a copper mineral containing copper carbonate.



Minerals are the building blocks of rocks. A *rock* is made up of minerals in varying amounts. Usually the amounts of useful minerals in rocks are too small to be worth mining. However some rocks contain large amounts of minerals. When rock contains a mineral in large quantities valuable enough to be mined, it is called an **ore**. For example, diamonds are found in an ore called kimberlite. Some common ores are listed in the table on the right.



Aurichalcite is a copper ore.

Most ores contain minerals which are compounds of metals such as iron, gold, silver, lead or copper. In fact the word 'metal' comes from the Greek word *metallon* which means 'mine'. For example, haematite is an iron ore since iron can be extracted from it. Some ores contain non-metals such as sulfur (used to make fertilisers and pesticides), salt, graphite (for lead pencils) and gypsum (an ingredient in plaster of Paris).

INQUIRY 1 Metals and their ores

You will need: a hand lens, samples of metals and their ores

The table below lists some common metals and their ores. Examine as many samples of these as you can.

1. Describe the differences that you can observe between the metal and its ore; for example, how is bauxite different from aluminium? Does the ore have crystals in it? Is it rough, smooth, crumbly, hard or shiny? How do the properties of the ore compare with those of the metal that is extracted from it?
2. From your own knowledge outline the steps that you think would be needed to extract a metal from its ore. You may need to read more of the chapter to answer this.

Metal	Mineral or ore	Uses
gold	gold, sylvanite, calaverite	jewellery, dentistry, space technology, currency
aluminium	bauxite, alumina	drink cans, cooking utensils, car, ship and aircraft construction, aluminium foil
copper	azurite, cuprite	electric motors, utensils, plumbing
iron	haematite, goethite	pipes, appliances, gates, machinery
lead	galena, cerussite, anglesite	pipes, water tanks, sinkers, batteries, TV and computer screens
magnesium	magnesite, magnesia	surface coatings, lining furnaces, paper, fertilisers, paints, plastics
nickel	pentlandite	stainless steel, aircraft, batteries
silver	silver, argentite	jewellery, batteries, utensils
tin	cassiterite	roof tin, batteries, paints, plastics
zinc	sphalerite	dry cell batteries, roof cladding

INVESTIGATION

1 Metal reactivity

Some metals are found combined with other elements, that is, as compounds. For example iron is found combined with oxygen as iron oxide. Some metals like gold and silver are often found as uncombined elements. Whether they are combined or not depends on how reactive the metals are or how easily they take part in chemical reactions.

Aim

Etienne examined different metals to see how reactive they were. Your task is to check to see whether you agree with her results.

Very reactive ⟶ **Least reactive**

sodium calcium magnesium zinc iron tin lead copper silver gold

Risk assessment and planning

Sodium and calcium are extremely reactive metals, so you won't be using them. Your teacher may demonstrate reactions of these metals.

Read through the investigation before starting.

1 What precautions will be necessary?

2 How should wastes be disposed of?

3 Draw up a table like this in which to record your results:

Metal tested	Hydrochloric acid	Sulfuric acid
Zinc		

4 What should you do to make this a fair test? For example, are all your samples granular or powdered?

Apparatus

- samples of iron, copper, zinc, tin, lead, magnesium (all cleaned with steel wool)
- test tubes
- test tube rack
- *dropping bottle of hydrochloric acid (1 M)*
- *dropping bottle of sulfuric acid (1 M)*





Method

Part A

Place a small piece of zinc in a test tube with enough hydrochloric acid to cover it. Record any observations in the table. Repeat this step with sulfuric acid. Now test the other metals.

Results

Rank the metals tested in order from the most reactive to the least reactive. Do your results support Etienne's findings?

Part B

When metals are listed from the most reactive to the least reactive it is called the **activity series**. You will now test some metals that were not listed in the activity series provided by Etienne and decide where they should be placed.

Apparatus

Samples of metals not tested, e.g. aluminium, nickel

Method

Test each of the new metals in the same way as in Part A. Record your results.

Write a revised activity series including the new metals you have just tested. Check this with your teacher.

Discussion

1 Hydrogen is used as a point of reference for the activity series. It is not a metal, but it is produced when a metal reacts with a dilute acid. All metals above the point where hydrogen is placed will react with dilute acids to produce this gas. The metals below this point do not react with dilute acids. Where would you place hydrogen in the activity series? Check this with your teacher.

2 Write word equations for each of the reactions that occurred in this practical. For example:

iron + hydrochloric acid (HCl) ⟶ iron chloride + hydrogen

Sulfuric acid (H_2SO_4) forms sulfates.

Part C

Design an activity to see how long it takes metals such as magnesium, copper, zinc, iron, nickel, tin, aluminium and silver to tarnish (become discoloured) in air and in water. Explain why they tarnish.

Conclusion

Summarise your findings from Parts A, B and C of this investigation. Based on your testing, which metals are likely to be found combined with other metals, and which metals are likely to be found uncombined?

Native metals and compounds

When metals are found in their uncombined state they are called *native metals*. Copper, gold, silver and platinum are often found this way.



Gold is often found as an element because it is very unreactive.

More commonly, metals combine or react with other elements to form compounds. Aluminium is never found as a native metal. It reacts with oxygen to produce aluminium oxide. This compound makes up the ore bauxite.

How reactive a metals is, which you investigated in Investigation 1, determines whether the metal is found as a native metal or whether it is found as a compound. For example gold, silver and copper are very unreactive. They don't take part in chemical reactions easily so they are often found in their uncombined state.

Iron is much more reactive than copper, silver and gold. This is why it combines so easily with the oxygen in the air to form iron oxide (rust). The main ore of iron is haematite, which is also 'iron oxide'. Zinc is more reactive than iron, so it is always found combined with other elements. The ore of zinc is called sphalerite, in which the zinc has combined with sulfur to form zinc sulfide. It also contains small quantities of iron sulfide and other metals, such as lead and copper.

The reactivity of a metal is very important when trying to extract the metal from its ore. Not all metals can be extracted by the same process. This will be looked at in Section 11.3.

Over to you

1 The table below lists the main elements found in the Earth's crust. Present this information as a bar or column graph.

Element	% of Earth's crust
oxygen	46.0
silicon	28.2
aluminium	8.3
iron	5.6
calcium	4.2
sodium	2.4
magnesium	2.3
potassium	2.1
others	0.9

2 When sodium is added to water there is a violent reaction. It whizzes around on the surface of the water and explodes. Suggest a reason for this.



3 Which of these minerals are native metals and which are compounds? Explain why they are found this way.

Ore	Element or compound	Metal obtained
bauxite	aluminium oxide (Al_2O_3)	aluminium
chalcopyrite	copper iron sulfide (CuFeS)	copper
gold	gold (Au)	gold
galena	lead sulfide (PbS)	lead
pitchblende	uranium oxide (U_3O_8)	uranium
rutile	titanium oxide (TiO_2)	titanium
cinnabar	mercury sulfide	mercury
silver	silver (Ag)	silver

4 What type of acid would you use to clean copper?

5 Silverware goes black or tarnishes if it hasn't been cleaned for a while. Suggest why.

11.2 Extracting the ore

To obtain valuable minerals and metals, they have to be removed from the Earth. The ore containing the mineral is found in rock. So, the ore first needs to be removed from the unwanted rock. This process is called mining.

There are different ways to do this. For example, in Australia iron ore is mostly mined by open-cut mining methods. Bauxite, the ore that contains aluminium, is also mined by open-cut methods. Other minerals such as coal can be mined by open-cut or underground mining. Whether open-cut or underground mining methods are used depends on whether the mineral has remained where it formed, deep below the ground, or whether Earth movements have raised the mineral to the surface.

Coal

Coal is a fossil fuel used in power stations to generate electricity. It is also used to make coke for iron and steel making.

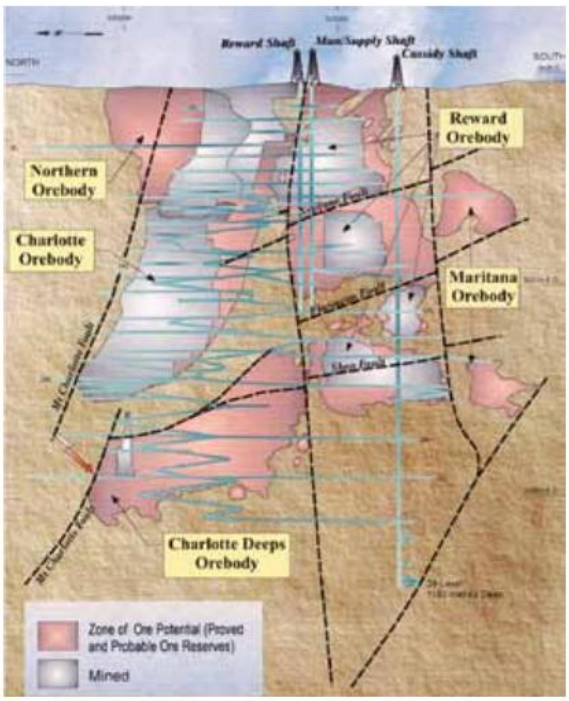
Coal in Australia was formed more than 200 million years ago. At this time many swamps and forests covered the land. When the trees died, they fell to the forest floor and, over time, layers and layers of plant material were squeezed and pressed together in the hot, boggy ground, forming *peat*.

Gradually the peat became buried by more layers of mud and gravel (sediment) that was carried there by waterways. This caused the peat to change. Carbon dioxide was released, and heat and pressure changed the peat to coal. Coal is therefore often found in layers called *seams* in sedimentary rocks deep below the surface of the Earth.

Coal is also found on the surface, where movements in the Earth's crust have caused the rock that the coal is in to be lifted up. In some cases part of the coal seam is raised up and the rest of the seam is still buried deep underground. This can occur along a large crack in the rock called a **fault**. One side of the fault moves up and the other side slips down. Many minerals in the Earth are raised to the surface in this way.

Open-cut mining

If the ore containing the mineral is less than 60 m below the surface, open-cut mining methods are used to remove the ore from the rock. Drilling and blasting breaks up the overburden (the unwanted rock on top of the mineral deposit) and exposes the ore. The ore is mined out of the rock in steps or levels, working downwards. It is then removed and carried away to a crushing plant, where the ore is crushed. This is the first step in the process to extract the mineral. Any leftover waste material, called spoil, is placed in large stockpiles called spoil piles after the ore has been removed.



This map of the Mt Charlotte gold mine shows how gold is found both on the surface and below the Earth, and how faults have affected the position of the gold seams.



An open cut mine showing how the ore is mined out of the rock in steps.

Underground mining

In underground mines, tunnels or roadways are carved out of the rock by machines. Special railway lines or large trucks are used to carry the ore to the surface. For example, coal is mined this way.



The coal is removed in strips along a tunnel. To prevent the tunnel collapsing where the miners and machines are working, large hydraulic jacks and timber or steel frames are used to support the tunnel roof. Once the coal is removed, the roof is allowed to fall in to seal the hole left by the removal of the coal.



PROBLEM SOLVING

Coal is a possible resource you could choose for your chapter task. From this section you should be able to explain how this resource is mined.

INQUIRY 2 **Flow diagrams**

Extracting the ore from the earth is the first step in obtaining useful materials from mining. The flow diagram here shows this:

Raw materials

The raw material can be found as an uncombined element, e.g. gold and silver. Most minerals, like iron, are contained in ores and need processing to extract them from these ores.

↓

Removal of ore

The ore containing the minerals is extracted from the earth.

↓

Processing of raw materials

Uncombined elements extracted from the earth and used as they are go through a manufacturing process to be changed into useful items. For example, gold is melted and moulded to make jewellery.

Mineral ores are processed to obtain the pure mineral.

↓

New materials

Chemical reactions change raw materials into new materials. These can be used as they are or may undergo another manufacturing process to be made into useful items. For example, once iron is made, it can be combined with chromium and nickel to produce stainless steel.

↓

Using materials

The processing of raw materials provides jobs for Australians. Processed materials can be used within Australia to provide goods for Australians. They can also be exported to provide money for Australia from overseas countries.

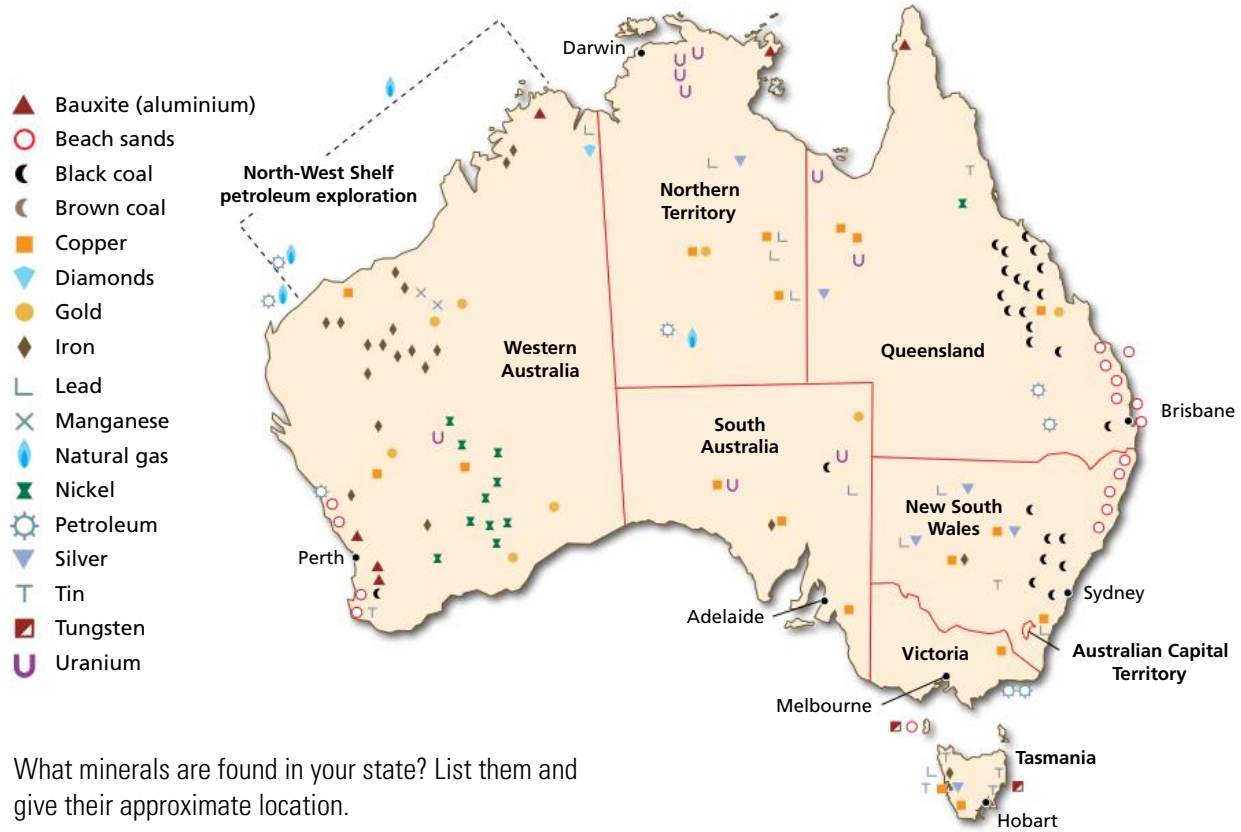
Choose a metal and produce a flow diagram like the one above. You could use information from Section 11.3 or from library research.

INQUIRY 3

Mines in Australia

The following map shows where different mineral deposits are located in Australia.

You will need: a copy of this map, atlas, access to the internet



1 What minerals are found in your state? List them and give their approximate location.

2 Which mineral is the most common in each state?

3 Add these mineral deposits to the map of Victoria.

Coal at Anglesea and Latrobe Valley

Gold at Stawell

Titanium at Horsham

Copper, silver and zinc at Benambra

4 Use the internet to find out where the following open-cut and underground coal mining operations are.

Queensland coal mining operations	
open-cut	Peak Downs, Saraji, Norwich Park, Gregory, Goonyella Riverside, Blackwater, Dawson, South Walker Creek
underground	Crinum
New South Wales coal-mining operations	
open-cut	Mount Owen, Boggabri
underground	West Cliff, Appin, Ulan, Bulga, Abel

5 Are there any patterns to the location of underground mines and open-cut mines? Explain.

6 Find out about minerals in your area and where they are located.

Over to you

1 What is mining and why is it carried out?

2 What is the difference between surface mining and underground mining? Which one do you think is the least harmful to the environment? Explain your answer.

3 In the Australian gold rushes people were able to pan for gold. They washed the sediment from the bottom of a stream around in a pan and collected small pieces of gold. Infer how the gold came to be in the stream.

11.3 Processing the ore

Once the ore has been mined, the mineral must be separated from the ore. The ore usually contains unwanted materials called *gangue* (GANG), which must be removed. For example, iron ore is haematite. It contains 70% iron. It also contains unwanted materials such as sand, manganese, sulfur, phosphorus and water.

Some minerals can be separated based on physical properties such as their density or whether they are magnetic. Non-reactive metals such as gold, platinum and silver are commonly found in their native state. However, metals such as iron are higher on the activity series than silver or gold and therefore more likely to be combined with other elements. Because of this they need to go through a series of chemical reactions to extract them from their ores. The more reactive a metal is, the harder it is to extract it from its ore.

Zinc is found in the ore sphalerite along with small amounts of metals such as copper, gold and silver. Sphalerite is also sometimes found with galena, a lead ore. So a series of chemical processes called **smelting** is needed to remove zinc from its ore and gangue.

The first step is usually to crush the ore and grind it into smaller pieces. Water and chemicals are added to help process the ground-up ore. After this step the different minerals are processed in different ways.

Making copper

1 Mining

The copper ore is mined by using explosives. This breaks up the ore so it can be removed easily.

2 Crushing

The ore is transported to huge crushers where it is broken into pieces less than 30 cm in size.

3 Milling

The copper ore goes through more crushing. It is then ground up further by steel rods and balls. This separates the copper ore particles from the gangue.

4 Froth flotation

The crushed ore is added to flotation cells which contain chemicals. Bubbles of air rise through the flotation cell from the bottom. The air and chemicals are called flotation reagents. The copper sticks to the air bubbles and floats to the surface to be collected. It is now called copper concentrate.



5 Smelting

The copper concentrate still contains unwanted materials. It is placed in a huge furnace and chemicals called fluxes are added to it. The molten copper is removed from the furnace. The fluxes and unwanted materials form waste slag, which is collected and removed.



6 Converting and casting

The copper may go through further heating to remove any remaining unwanted materials. It is then cast into shapes and transported, ready for more processing as required.



INQUIRY 4 Froth flotation

In this activity you will model froth flotation.

You will need: large test tube and stopper, kerosene, a mixture of 50% sand and 50% copper carbonate (the crushed ore), watch glass, hand lens, teaspoon, test tube rack, spatula, detergent

1. Place a teaspoon of the crushed ore in a test tube.
2. Add water to the test tube until it is half full.
3. Add 10 mL of kerosene and 3 mL of detergent to the test tube and stopper it.
4. Shake the test tube well and then place it in the test tube rack to stand.
5. When the mixture has settled, use a spatula to remove the froth. Place this in a watch glass.
6. Use the hand lens to check whether there is any copper carbonate in the froth.
   - What was contained in the crushed ore? How do you know?
   - Where is the sand?
   - What was the purpose of the kerosene and detergent you added?

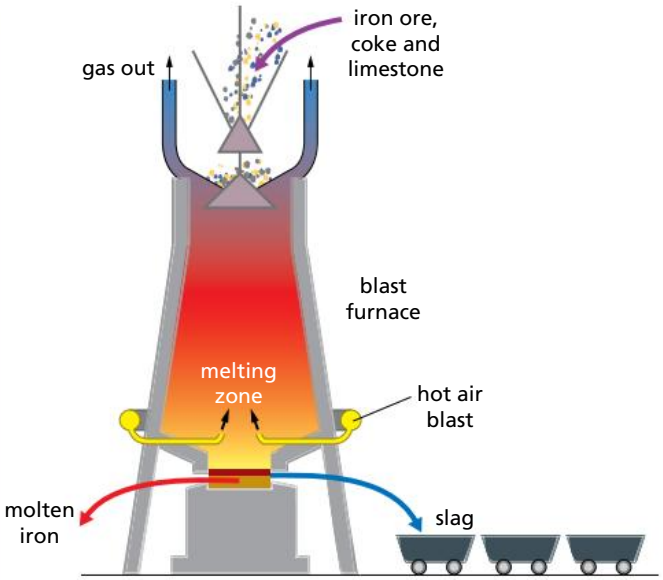
Making iron

Iron ore, coke and flux are needed to make iron. Coke is made from coal, and it provides heat and carbon for the reaction. Flux is a material such as limestone that is added to remove the unwanted materials from the iron. The unwanted materials combine with the flux to form *slag*. The iron ore is usually found as lumps that are crushed to a size of 6–35 mm and used without further processing. If the ore occurs as a fine powder it is processed to make lumps.

Iron is made in a large **blast furnace**. The raw materials enter the furnace on a conveyor belt. Coke burns in the furnace because air (O_2 and N_2) is piped into it through copper pipes. See the diagram top right. As the coke burns in the air, carbon monoxide is produced, and this reacts with the iron oxide to produce iron. In this way iron is separated from its oxide. The reactions that take place are as follows.

1 Carbon from the coke burns in oxygen to produce heat and carbon dioxide:

carbon + oxygen → carbon dioxide + HEAT



2 Carbon then combines with the carbon dioxide to produce carbon monoxide:

carbon + carbon dioxide → carbon monoxide

3 The carbon monoxide then combines with the iron oxide to form iron and carbon dioxide:

iron oxide + carbon monoxide + HEAT → iron + carbon dioxide

So the carbon monoxide and the heat produced in the first two reactions are used in the third reaction.

Iron normally melts at 1537°C, but in the third reaction, the iron absorbs carbon. This enables the iron to melt at a lower temperature than normal (1150°C). However, the temperature of the blast furnace has to be maintained at 1550°C so that the slag will melt. The furnace is coated with special materials so that the walls do not melt and add unwanted materials to the mix.

As the iron ore moves down the furnace it melts in the hotter temperatures and forms iron at the bottom. The slag also collects at the bottom of the furnace. It doesn't mix with the iron, so it is easily separated from it. The iron is collected in special containers and transported to where it is needed, usually to make steel.

The slag is collected and crushed to make cement, which is used as a sand replacement in road making. It was used to build the Sydney Harbour Tunnel and the third runway at Sydney airport. The gases produced by the furnace are recycled and used as fuel in other areas of the iron and steel-making plant.

INVESTIGATION

2 Making lead

Aim

To produce lead and copper from their ores.

Risk assessment and planning

Read through the investigation before starting. What safety precautions will be necessary?

Handle lead oxide carefully as it is toxic. Wash your hands after use. Wear safety goggles.

Apparatus

- long matches
- copper oxide
- distilled water
- Bunsen burner equipment
- lead oxide
- carbon
- hand lens

Method

1. Light a match and let it burn part way up the wood. Blow it out. The burnt end is carbon. Dip it into distilled water and then into lead oxide powder. Heat the match with the powder on it in a Bunsen burner. Look for drops of shiny lead forming. (You may need to break up the material on the end of the match when it is cool and examine it with a hand lens.) Repeat this experiment if you were unsuccessful in producing any lead.
2. Repeat this experiment with copper oxide instead of lead oxide.

Discussion

Write word equations to describe what happened in each reaction.

Making steel

Iron, scrap, flux and alloying metals are all used to make steel. Iron comes from iron ore and scrap is steel that has been recycled from many different sources. At present half the steel we use is recycled. A tonne of scrap saves about three tonnes of natural resources, compared with starting from scratch. Fluxes such as limestone are used to remove impurities such as silicon, carbon, magnesium and phosphorus. Metals such as manganese, aluminium and nickel are added to the steel to give it different properties.

The iron from the blast furnace is 96% pure, and the remaining 4% is mostly carbon. Most of the carbon has to be removed or the steel will be too brittle. The molten iron and the ingredients needed to make steel are added to a furnace, then almost pure oxygen is blown into the mix. The carbon combines with the oxygen to produce carbon monoxide and a lot of heat. The temperature reaches about 1700°C.

carbon + oxygen → carbon monoxide + HEAT

The carbon monoxide then burns to produce carbon dioxide. The scrap melts and slag is formed. It is poured off once all the steel has been removed. The steel produced has a carbon content of about 1%.



Pouring molten iron into the steel-making furnace

Sometimes electricity is used to raise the temperature in the furnace high enough to melt the scrap. Electrodes are put into the furnace and electricity moves between them. The electrodes melt in the process and have to be replaced. The steel is then removed as before.

After the liquid steel has been made it is cast into ingots. These can be reheated and made into other shapes such as steel sheets. The steel also goes through a process called rolling to reduce its thickness. This also makes it stronger.



Rolling steel

Steel products

After rolling, the steel may be coated with other metals, paints or plastics. This makes the steel more attractive and long-lasting. If the steel is to be coated with other metals it is cleaned, then heated and cooled under controlled conditions to soften it (annealing). The steel can then be treated by a hot-dip process, in which it is dipped into the molten metal that it is to be coated with. For example steel can be coated with zinc. This process is called galvanising and prevents corrosion. The steel can also be coated in an electroplating process to produce, for example, tin-coated steel (see Investigation 3).

Painted steel such as Colorbond has many coats of paint applied to it, including a coat that stops corrosion. Steel can also be coated with plastic, which sticks to the steel when the steel is heated.

INVESTIGATION

3 Comparing steel products

You will need: samples of the following steel products from building suppliers:

- galvanised steel (steel coated with zinc)
- ZINCALUME (steel coated with zinc and aluminium)
- tinplate (steel coated with tin)
- terne steel (steel coated with lead and tin)
- PVC film/steel (steel coated with plastic)
- stainless steel (nickel–chrome steel)

Design an experiment to show which steel product:

a resists corrosion the most

b is the lightest and strongest to use

c bends the most or the least

You may need to use safety glasses and gloves to handle the steel.

Report your findings to the class.

Over to you

1 **a** What is produced in a blast furnace?

b Which are the raw material is that go into the blast furnace?

c What unwanted material is produced.

2 Explain in your own words how

a copper is made from copper ore

b iron is extracted from iron ore

c steel is made from iron and other materials.

INVESTIGATION

4 Electroplating

Aim

To design an experiment to see if electroplating a metal reduces corrosion.

Risk assessment and planning

Read through the investigation before starting. What safety precautions are needed?

Use a fume cupboard or a well-ventilated area.

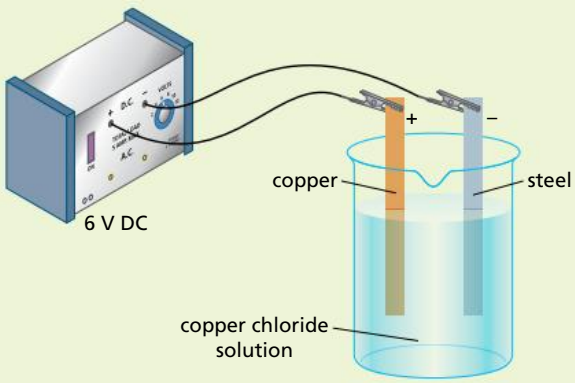
Apparatus

- copper chloride solution (saturated)
- copper electrode
- power pack
- leads with crocodile clips
- 200 mL beaker
- 2 steel strips

Part A

Method

Set up the apparatus as shown. Switch on the power pack (6 V DC) for a few minutes. Record your observations. Alternatively, use 2 V DC over many hours for a better coating of copper.



Results

Describe what happened at each electrode.

Part B

Using your copper-plated steel from Part A, design an experiment to see if electroplating prevents corrosion.

3 What are the advantages of using scrap in the steel-making process rather than using all raw materials?

11.4 Mining and the environment

While there are many mines in Australia, only 0.02% of the country is used for mining, which is less than the area covered by the ACT. However, there is still concern over the environmental damage that mining can cause.

In the past, little was done to repair the damage done to the environment. Nowadays, however, mining companies try to **rehabilitate** or restore the land so that it can be used again. A decision is made before the mine is established, as to what the area will be used for when mining ceases. For example mine sites can be used for nature reserves, botanic gardens, pastures, orchards or sporting fields.

Environmental conditions such as the types of plants, animals, soil, air quality, temperature, rainfall and contours (shape) of the land are noted before mining begins. This information is used to help restore the land after mining.

The type of mining at the site affects the rehabilitation process. For example, open-cut mining removes tonnes of overburden from the ground. Where possible during operations, the pit is progressively back-filled. Overburden is stockpiled in terraces to stop excessive water run-off. Any surface run-off is collected from the area. When mining stops, the overburden is put back, reshaped and covered with topsoil. Fertiliser is added and seeds are planted. The area is then monitored for the growth of plants and the return of native animals.

Water at mine sites

Rainwater accumulates in the pits from which the ore and overburden have been removed. This water is collected in storage dams and re-used as much as possible during mining operations. The waterways around a mine site are tested regularly to see if they contain any harmful chemicals. Water from mines can contain dissolved metals such as copper, lead, zinc and mercury, which are very toxic to living things. Water leaving a mine therefore has to be treated to prevent these metals entering our waterways. For example, water with lead and zinc in it is neutralised by adding lime. The water is left in settling tanks where the metals settle out of the water and form sludge. This material is dried out and returned to the smelter. The water may be passed through many settling ponds or tanks before it is released.

Leaching

Crushed or powdery wastes collected in dumps at mines can cause serious environmental problems. When water moves through the waste, materials dissolve in it and are carried away. This is called *leaching*. Wastes that have sulfur in them often have a problem with leaching, since sulfuric acid is produced when sulfides in the rock are exposed to air and water. If the water in the dump becomes too acidic, naturally occurring bacteria start to grow. The activity of the bacteria causes the water to become even more acidic. Waste dumps must therefore be covered with soil and vegetation to stop run-off and leaching and to prevent bacterial action.

Air quality

Air quality is also a problem where metals are mined and processed. The emissions from smelters and furnaces have to be controlled. In electrostatic precipitators the metal particles in the air are attracted to charged plates and recovered. Dust is also a problem. Water sprays are used to keep it to a minimum. In processing plants dust is collected in baghouses and removed at regular intervals.

Sulfur dioxide and carbon dioxide emissions from mining also contribute to atmospheric pollution. For example, in Queenstown in Western Tasmania, the smelting of copper in the late 1800s and early 1900s caused the trees in the surrounding hills to die. Sulfur dioxide fumes from the smelting and heavy rain produced sulfuric acid, which killed the trees. The mining industry is looking at ways of reducing gas emissions. For example, acid-processing plants that can remove sulfur dioxide have been installed in some Tasmanian smelters.



Queenstown

INQUIRY 5 Weipa case study

Weipa is a town situated on the west coast of Cape York Peninsula in Queensland. It has one of the richest deposits of bauxite in the world, from which aluminium is obtained. One out of every seven tonnes of the aluminium produced in the western world comes from Weipa.

Comalco established open-cut mining operations at Weipa to mine the bauxite. Mining and rehabilitation of the mined areas take place at the same time. The rehabilitation program aims to return some of the land to its natural state, as much as possible, by planting native plants to encourage the return of native animals to the area. This program also aims to investigate whether the area can support tropical fruit orchards for commercial sale. So far rambutans (fruit) and cashew nuts have been grown.



Rambutans

When mining finishes in one part of mine, the ground is re-shaped or contoured so natural drainage can occur. Fresh soil or stockpiled soil is used to cover the area, and then more soil that contains native seeds is spread on top.

Comalco has a plant nursery at Weipa which grows 40 000 native plants each year for rehabilitation. This involves collecting, cleaning and storing native seed from different types of native plants. The native seed is then planted. This takes place just before the monsoon rains start, to ensure the seeds have plenty of water and the warmest temperatures in which to germinate and grow.

The rehabilitated area is then monitored to ensure growth occurs. Some areas are re-sown if the young seedlings do not survive. Bushfires are a problem in the area, so firebreaks are made when the area is replanted. Fire-tolerant plants are used.



Workman planting seedlings

Imagine you are scientist rehabilitating the land at Weipa. Use the following information on Weipa to answer the questions below.

- Climate: tropical—hot and wet in summer, warm and dry in winter
- Annual rainfall: 1980 mm, of which 96% falls between November and April; remaining period called the 'dry season'
- Temperature: maximum 37°C in December; minimum 14°C in July
- Dominant plants: Darwin stringybark, long-fruited bloodwood, Melville Island bloodwood, Cooktown ironwood, nonda plum
- Understorey plants: cocky apple and wattle; ground level: tropical grasses
- Difficulties: surface waterlogging during the wet season and no water in the dry season

1. When is the wettest and warmest time of the year?
2. Why is the mined area re-shaped?
3. When would you recommend planting should take place? Give reasons for your answer.
4. Do you think the land can be returned to its original state? Explain.
5. What other information (not listed above) would you need to help you rehabilitate this land? Explain.
6. Why should the native plants listed above be planted in the area?

SCIENTISTS AT WORK

Dr Graham Taylor

Dr Graham Taylor is a consultant in environmental management, with clients such as the mining industry. He investigates how to dispose of mine wastes to minimise their environmental impact, how to recycle mine wastes and how to restore natural ecosystems at mine sites.

Graham completed English, Maths, Physics, Chemistry and Geography at Year 12 and went on to study Maths, Physics, Chemistry and Geology at the University of Adelaide. He commenced work at CSIRO in February 1966 and developed techniques to find new mineral deposits.

Graham became an expert in identifying the weathered surfaces of sulfide-rich ore bodies and using these for mineral exploration. He has worked at many mines throughout Australia and travelled to places such as Saudi Arabia, Russia and Brazil, sharing his knowledge.



Graham works on techniques to ensure that the environmental impacts of mining are minimised. For example, he researches how different covers of mine wastes can prevent acids forming. For example, he investigated whether the natural formation of cement by sulfides is as effective as a cover of soil and rock in preventing water entering the waste.

Acids are one of many contaminants produced in the management of tailings (the fine wastes produced when the useful minerals have been removed from the crushed ore). Graham's research will help to reduce the impact of acids on soil and water around mine sites.

Over to you

1. What is the first step in mine rehabilitation?
2. List some of the environmental conditions that are recorded before mining operations start.
3. What is leaching? How does it affect natural waterways? How can it be prevented?
4. Explain whether mining causes air pollution.
5. Imagine you work at a large open-cut mine and environmentalists want to close the mine because of the effect it is having on natural waterways around the mine. What suggestions could you put forward to keep the mine open and protect the environment?
6. Why do you think Comalco wants to investigate whether rehabilitated mine sites can grow cash crops such as rambutans and cashews? Of what benefit would such an industry be?
7. The photo shows a mine rehabilitation area in the foreground after three years of growth. The trees in the background are the original vegetation. What differences can you notice between the two areas? Explain how you could use this picture to:
   - **a** convince the government that mining is harmful to the environment
   - **b** convince environmentalists that the land can be rehabilitated after mining.



PROBLEM SOLVING

You should now be able to complete your task by explaining what environmental problems are caused by the mining of the resource you have chosen.

Aboriginal mining

In 1867 Ernest Henry discovered copper where Mount Isa is today. He paid Aboriginal people of the local Kalkadoon tribe to take him to places where there was copper ore. What Henry probably didn't realise was that the Aboriginal people had been mining in the area for 1000 years or so (40 generations).

The Mount Isa Aboriginal People used rocks in their area to make stone axes to trade with other tribes, perhaps as far away as the Flinders Ranges in South Australia (over 1000 km). They used a hard black rock, a type of metamorphic basalt. Boulders of this rock were broken up into smaller slabs using large basalt hammers. These slabs were then broken into axe head shapes by chipping with another rock. Finally the axe heads were ground to form a sharp edge, by rubbing with a softer rock, usually sandstone. This took up to 12 hours and was mostly done by women.



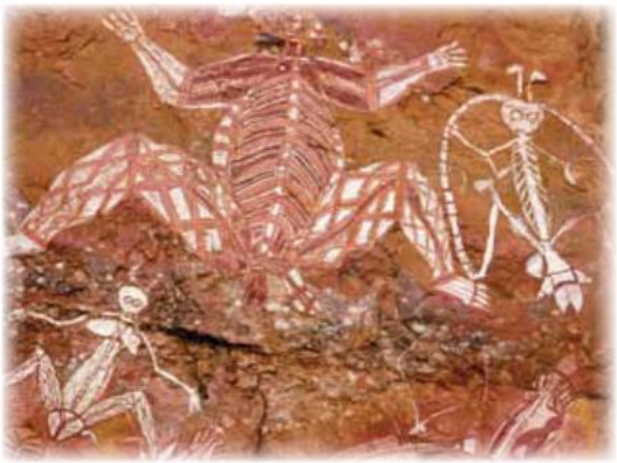
This Aboriginal axe head is about 20 000 years old. It has a ground edge on the right, and was fixed into a wooden handle for easier use.

As well as axes, the Aboriginal people also made hammers, knives and spear heads from stone. The main rocks they used were silcrete (a conglomerate of rock fragments cemented together by silica), chert (a fine-grained sedimentary rock made of silica), granite, quartz, quartzite (metamorphic quartz) and greenstone (metamorphic basalt). Ancient Aboriginal mines were mostly open-cut, but some were underground.

One of the things the Kalkadoon tribe traded for their stone axes was ochre. This is broken down rock of various colours that has been crushed to a powder using a grindstone. The table top right shows some of the ochres used by Aboriginal people.

Name of ochre	Colour	Mineral
haematite	red-brown to bright red	iron oxide Fe_2O_3
kaolin	white	clay minerals
limonite	yellow (or brown)	hydrated iron oxide
charcoal (from fires)	black	carbon

They mixed the ochres with liquids to make pastes suitable for painting cave walls, tools and their own bodies. They used a variety of liquids—for example, saliva, blood, orchid sap, the yolks of turtle eggs, and the fat of fish, emus or goannas. Different colours could be made by mixing different ochres. For many Aboriginal people the colours represent the colours of the body—white for bones, brown for skin, yellow for body fat and red for blood. Red is a sacred colour and often represents the blood of ancestral beings. Ochres also had ceremonial uses. For example the Mungo Man skeleton, dated at least 40 000 years old, was covered in red ochre. This Aboriginal skeleton was discovered in south-west NSW in 1967.



Cave paintings of Dreamtime creation ancestors at Nourlangie Rock in the Northern Territory

- How could you make a grey paint from natural ochres?
- The ochres used in Aboriginal paintings are insoluble in water. Why is this important?
- If your teacher has a piece of haematite, rub it across an unglazed white tile. It will leave a streak, which is the colour of the powdered mineral.

THINKING SKILLS

1 An alloy made by mixing bismuth, lead, tin and cadmium has a very low melting point. It is used to make automatic sprinklers that start working immediately when there is a fire. Explain how you think a sprinkler system like this works.

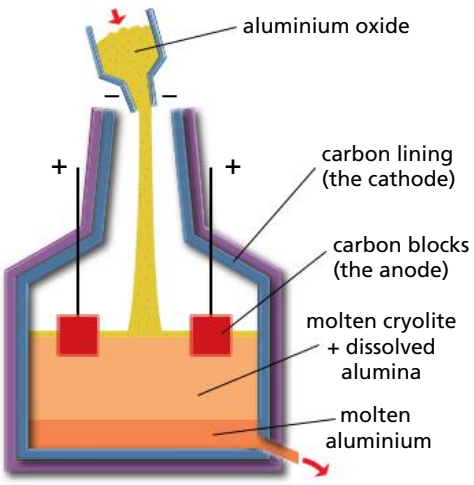
2 An alloy made by mixing aluminium, nickel, cobalt and iron has very good magnetic properties. Suggest what this alloy could be used for around the home.

3 Tungsten steel contains tungsten and chromium. It is hard even when extremely hot. Explain where tungsten steel could be used.

4 Explain whether you agree or disagree with this quotation 'Nothing is a resource until someone has thought of a way to use it.' You could hold a group discussion.

5 Some minerals are separated from unwanted materials by using gravity separation methods in which the density of the mineral is used to separate it from unwanted materials. Design an experiment showing how gravity separation might work.

6 Aluminium is made from the ore bauxite (aluminium oxide). It is very difficult to separate from its ore. Aluminium oxide first has to be dissolved in a tank with molten cryolite. This lowers its boiling point from 2045°C to 950°C. It is then separated by electrolysis (passing an electric current through it). Look at the diagram below.



The carbon lining of the tank is one electrode and the carbon blocks form the other electrode. When electricity flows between the electrodes, aluminium ions (Al^{3+}) are attracted to the carbon lining and a layer of aluminium forms at the bottom of the tank. It can then be removed. The oxygen from the aluminium oxide reacts with the carbon blocks to form carbon dioxide.

a What charge would the carbon lining have? Explain your reasoning.

b The carbon lining is called the cathode. Find out what this means.

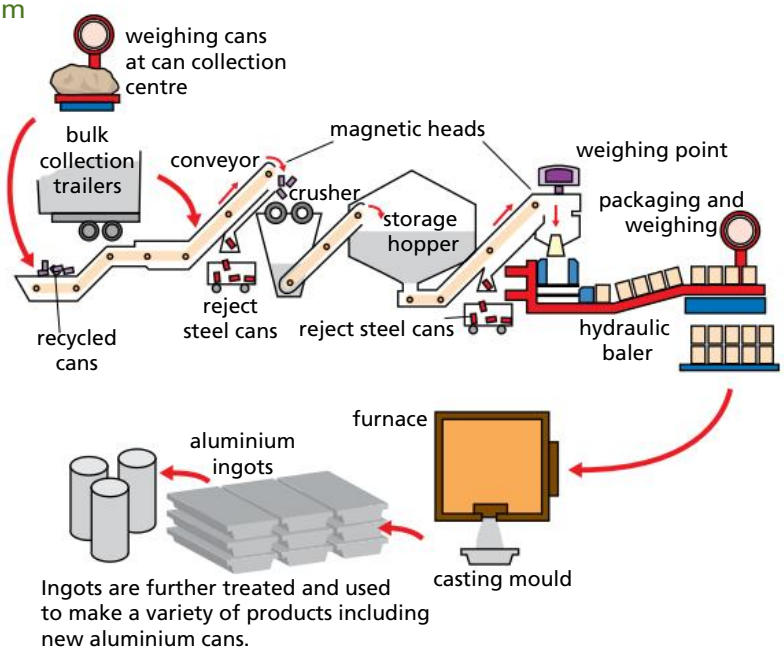
c What charge would the carbon blocks have? Explain your reasoning.

d The carbon blocks are called the anode. Find out what this means.

e Look at the flow diagram below showing the recycling of aluminium cans. Is electrolysis needed in this process? Explain, then describe the process in your own words.

f Draw another flow diagram to show how aluminium cans are made from bauxite. Include the words mining, crushing and electrolysis.

g The amount of energy used to make one new can from raw materials is the same as that required to make 20 cans from recycled cans. Why do you think it takes 20 times as much energy to start from raw materials?



Knowing and Understanding

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

1. A _____ is a substance that has a definite chemical composition and structure. The way the atoms are arranged in a mineral can be seen in the form of _____.
2. When rock contains a mineral in large quantities and is valuable enough to be mined, it is called an _____.
3. Metals can be found in the Earth in their _____ state or combined with other elements as compounds. The extent to which metals form compounds depends on how chemically _____ they are.
4. Before a mineral can be used it must be removed from the earth. This is called _____. Two methods used in Australia are open-cut and _____ mining.
5. A metal ore contains unwanted materials called _____ which must be removed before the metal can be extracted from its ore.
6. _____ are used to purify an ore and extract the metal from it.
7. Mining companies _____ the land after mining in an effort to restore the mined area to what it was like before mining started.

chemical reactions
crystals
gangue
mineral
mining
native
ore
reactive
rehabilitate
underground

Self-management

Know it all game

1. In groups of five, write one question from this chapter under each of the following headings:
   - *Mineral name:* e.g. What mineral has the symbol Au? (gold)
   - *Mineral ore:* e.g. What is the ore of aluminium called? (bauxite)
   - Properties of materials: e.g. Which alloy is strong and hard, but becomes brittle if too much carbon is mixed with it? (steel)
   - *Uses of materials:* e.g. Steel made from iron, nickel, and chromium can withstand high levels of heat and resists corrosion. It is used for kitchen utensils, pots and pans. What is this type of steel called? (stainless steel)
   - *Mining and the environment:* e.g. Name one gas emission from mineral processing that is affecting air quality? (sulfur dioxide)
2. Give the group's questions to your teacher. Your teacher will add questions too.
3. As your teacher reads the questions under each heading, write down as many answers as possible in your notebook. You don't lose points for a wrong answer, so don't be afraid to have a go.
4. The wining group is the one that has the most correct answers.



Checkpoint

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

OneStopScience

1 Copy these sentences and fill in the missing words.

a Minerals can be identified by the type of _____ in them.

b An _____ contains a mineral that is useful and valuable enough to be mined.

c Most minerals contain _____ such as iron, but some contain non-metals such as sulfur.

d Metals such as gold and silver are very unreactive. They are usually found in their _____ state.

2 Which of the following are elements and which are compounds?

a bauxite (Al_2O_3)

b gold (Au)

c lead sulfide (PbS)

d silver (Ag)

3 **a** The photo shows one process involved in producing copper. Name the process.

b Explain what happens in this process.



4 Glass is made from sand (silicon oxide SiO_2), sodium carbonate (Na_2CO_3) and limestone (calcium carbonate $CaCO_3$). Glass is molten when it is first produced and then goes through a process of annealing. It does not have a regular arrangement of atoms in it and therefore no crystals.

a Which elements are used to make glass?

b Is glass a mineral? Explain.

c Lead crystal is used for fine glassware and can be cut into beautiful shapes and designs. Why do you think lead is added to the glass?

5 This chemical reaction describes the smelting of iron ore to produce iron.

iron oxide + carbon monoxide + HEAT → iron + carbon dioxide

a Which are the reactants in this equation? Which are the products?

b Does the reaction produce heat or does it need heat to make it go?

c Which one of the substances in the reaction is an element?

d How many different types of atoms take part in the reaction?

6 Many people say that using solar cells as a source of electricity does not harm the environment and that they are therefore better to use than electricity produced by burning fossil fuels. However sand mining is needed to obtain silicon to make solar cells. Metal, glass and plastic are also used to make them. Explain whether you think solar cells are non-polluting and better to use than fossil fuels.

7 The following photo shows mining operations in Western Australia.

a What type of mining is shown in the picture? How do you know?

b What environmental concerns would there be at this mine site?



12



Investigating space

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

Science as a Human Endeavour

- describe how people through history have made inferences to explain their observations of the night sky

Science Inquiry Skills

- create a tourist brochure about a trip to a planet or moon in the solar system
- assess the difficulty of making Mars suitable for humans to live
- interpret planetary data and draw graphs to analyse the data
- calculate how long it would take to travel to nearby stars

Focus for learning

On 28 April 2001 Dennis Tito, a multi-billionaire from California, became the first space tourist. He paid US$20 million for an 8-day trip on the Russian *Soyuz* capsule that went to the International Space Station.

You watch space movies and hear about new discoveries in space on the news and in the papers. In your lifetime, space tourism is almost certain to grow rapidly. It is an example of how space is very much a part of your everyday life.

LITERACY FOCUS

Alpha Centauri
asteroids
comet
constellations
dwarf planet
ecliptic
extraterrestrial
galaxy
helium
light-year
meteorites
meteors
nebula
Orion
Scorpio
South Celestial Pole
spectroscope
supernova
terraform
zodiac

PROBLEM SOLVING

Space tourism

Imagine you are a travel agent with *Planetary Travel* that runs tourist trips to the planets and moons of our solar system. You use a space vehicle that can cruise at 250 000 km/h.

Your task is to create a tourist brochure to get people to book one of your trips. To do this you will need detailed information on the planet or moon advertised in your brochure. Some of this information you will find in this chapter, but you will need to do extra research in the library and on the Internet. A good place to start is the Nine Planets website (nineplanets.org).

Your brochure should include the following information about the planet or moon you choose:

1. The length of the return trip to the planet or moon, and what you will see along the way.
2. The standards of accommodation on the trip.
3. The atmosphere, surface and weather conditions likely on the planet or moon.
4. Special gear the tourists will need to wear or take with them.



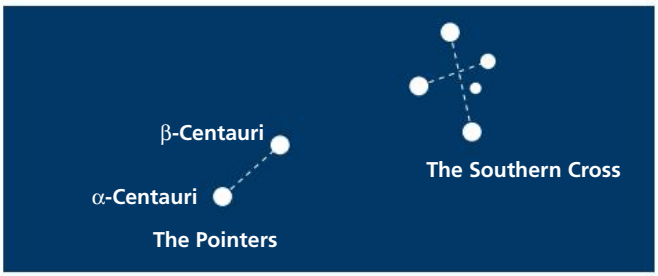
5. Possible excursions and the types of transport to be used.
6. The most spectacular sights the tourist can expect to see.
7. Possible leisure activities, especially those different from on Earth.
8. Hazards they are likely to encounter. (This is essential as you don't want to be sued for false advertising.)

12.1 Stars

Constellations

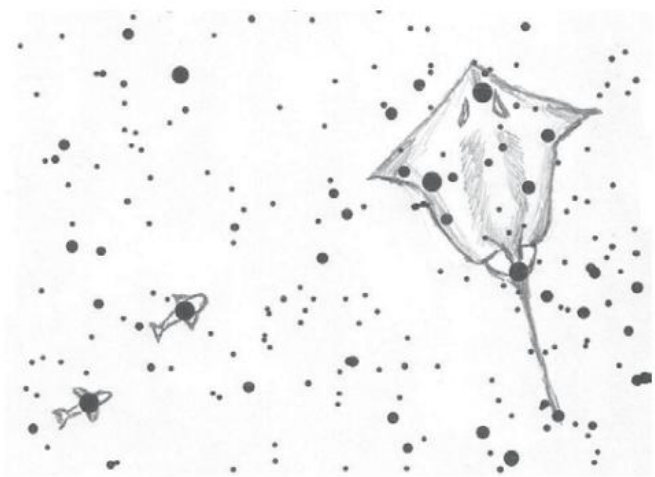
For thousands of years people have been seeing shapes in the stars in the sky. These shapes or patterns are called constellations. The ancient Greek astronomers found and named 48 **constellations**, including Orion the hunter and Scorpio the scorpion. Astronomy books now list 88 constellations, most of them named after characters or objects in ancient Greek mythology.

One of the constellations best known in Australia is the *Southern Cross*. It contains five bright stars, as shown in the diagram.

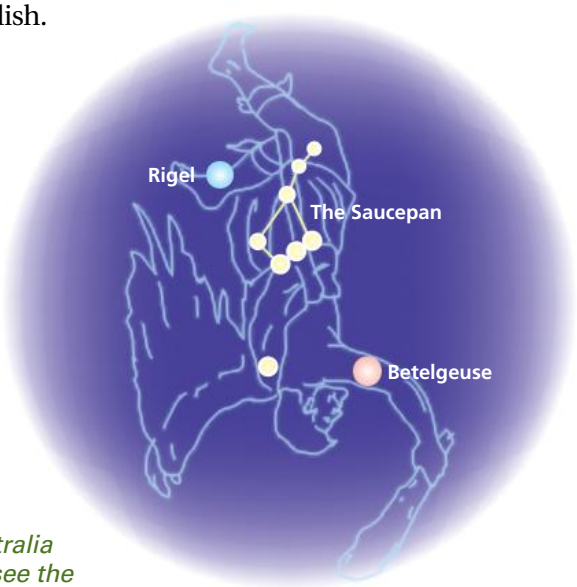


The Southern Cross and the Pointers

The Aboriginal people who came to Australia at least 50 000 years ago were probably the world's first astronomers. The patterns they imagined in the sky were very different from those invented by the Greeks. For example, the Annangu people of central Australia saw the Southern Cross as the footprint of a giant wedge-tailed eagle. And the Ngarrindjeri people who live in the Coorong and Murray Valley of South Australia saw it as a giant stingray. This stingray was being chased by two sharks—the *Pointers*.

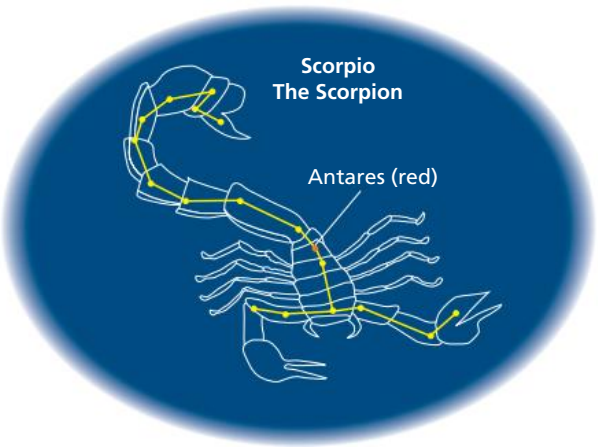


Another easy constellation to find in the night sky is *Orion* (oh-RYE-on) the hunter. You can see Orion in summer and early autumn evenings. To find it you have to look fairly high in the northern half of the sky. You can recognise a pattern in Orion we call the 'saucepan'. This is meant to be Orion's belt and sword. Above and below the saucepan are two very bright stars—Rigel (RYE-gel) and Betelgeuse (BET-el-gerz). Rigel is a bluish-white colour and Betelgeuse is reddish.



In Australia we see the Saucepan as part of the constellation of Orion the Hunter. In the Northern Hemisphere Orion is the right way up.

In ancient Greek tales Orion, the mighty hunter, bragged that he could kill any creature on Earth. However he forgot about the deadly scorpion, which crawled onto his foot and stung him. Orion nearly died but the gods saved his life. They then placed him and the scorpion in the sky in such positions that the two would never be above the horizon at the same time. This is why you see the scorpion in winter and the hunter in summer. The Northern Hemisphere sees the reverse of this.



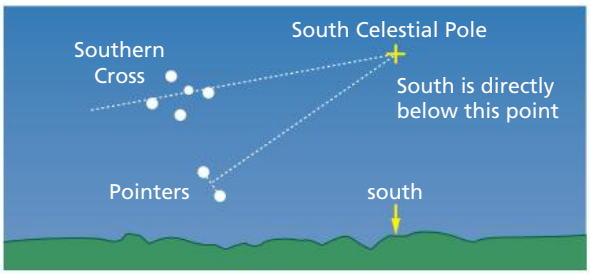
INQUIRY 1 The night sky

Choose a clear night and observe the sky from a point away from bright lights. Avoid the full moon. If possible, do this with someone who knows about stars or visit a planetarium first.

Keep a record of all your observations.

1 Can you find the *Southern Cross* in the south? Use the drawing below as a guide. The *Pointers* should point to where it is. There is another cross-shaped constellation nearby called the *False Cross*. Its stars are more widely spaced and not as bright. You can use the Southern Cross and the Pointers to find south as shown.

Draw the Southern Cross and the Pointers as you saw them, and note the time.



2 In summer try to find *Orion*—the Saucepan. Can you find the bright stars Rigel and Betelgeuse. What colours are they?

In winter try to find *Scorpio*—the Scorpion. Look for the curly tail and the red star Antares.

Draw Orion or Scorpio—as you see it.

3 If you are in the country away from city lights you will be able to see the *Milky Way*—a broad band of faint light stretching across the sky.

4 Keep your eye out for satellites which move slowly across the sky and meteors (shooting stars) which move very rapidly.

5 If you have a star chart you can use it to find more constellations. Draw any that you find.

6 If possible come back in a couple of hours and see if the constellations have moved. How do you know they have moved?

7 You will probably be able to see the 'evening star', the brightest star in the sky, towards the west. It is actually the planet *Venus*.

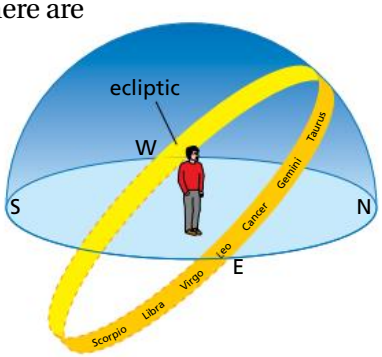
8 If you have a pair of binoculars it is fun to observe the moon. It is best to observe it when it is between a quarter and three-quarters full.

Draw its shape and surface features.

The signs of the zodiac

As you know, the sun, moon and planets all appear to rise in the east and set in the west. This is because the Earth is spinning from west to east on its axis. So as we turn one way, the sun, moon and planets move in the opposite direction. The path that the sun, moon and planets appear to take across the sky is called the **ecliptic** (ek-CLIP-tick). In Australia it is in the northern part of the sky.

Along the ecliptic there are twelve constellations called the zodiac. The signs of the zodiac are the names of these 12 constellations. They were named by the ancient Greeks after the shapes of animals and gods.



INQUIRY 2 Astrology

1 What is your star sign? What does it have to do with the night sky?

2 What do astrologers believe can be found out from your star sign?

3 Discuss in a group if there is any evidence that astrology really works.

4 What is the difference between astrology and astronomy?

The sun is a star

At any one time you can see about 3000 stars in the night sky. Astronomers estimate there are at least 100 000 million of them in our galaxy (the Milky Way). Our sun is just one of these stars, but it appears brighter because it is by far the closest to Earth.

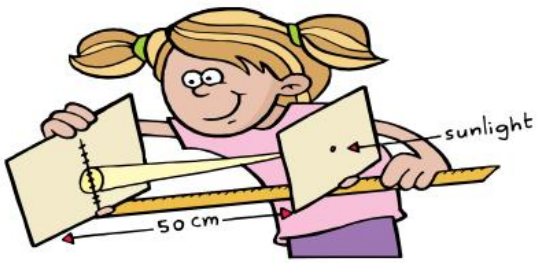
The surface of the sun is more than twice as hot as the flame of an acetylene torch used by a welder, and is even hotter inside. The sun's heat and light is produced by nuclear fusion, as in a giant hydrogen bomb. This is why we say it shines. The moon and the planets do not shine like stars. We can only see them because they reflect light from the sun.

The sun is about 150 000 000 km from Earth, and in Inquiry 3 you can work out how big it is.

INQUIRY 3 Diameter of the sun

You will need: 2 small pieces of cardboard, metre rule, Blu-Tack, pin, ruler

1. Use a pin to put a small hole in the centre of one of the pieces of cardboard.
2. Use Blu-Tack to attach the two pieces of cardboard to a metre rule 50 cm apart, as shown.
3. Tilt the ruler so that the light shining through the pinhole casts a circular image on the second card.
4. Accurately measure the diameter of the spot of light (in millimetres).



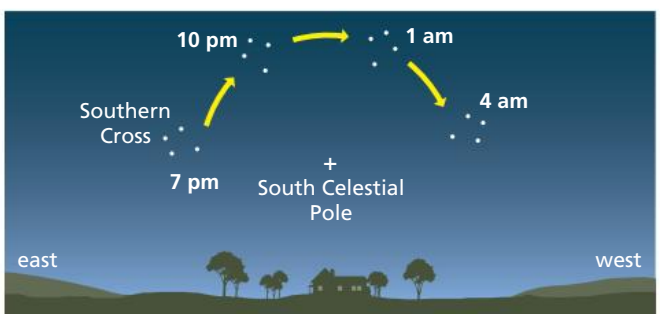
5. Use the formula below to calculate the diameter of the sun in kilometres.

$$\frac{\text{diameter of sun}}{\text{diameter of spot}} = \frac{\text{distance to sun}}{\text{distance from pinhole to spot}}$$

$$\text{diameter of sun (km)} = \frac{\text{diameter of spot (mm)} \times 150\,000\,000\text{ km}}{500\text{ m}}$$

Do the stars move?

If you observe stars at various times throughout the night you will find that they appear to move across the sky from east to west like the sun, moon and planets. This is because of the rotation of the Earth. In Australia the stars appear to move in a circle around the *South Celestial Pole*, an imaginary point directly above the South Pole. In fact if you point a camera towards the south and leave the shutter open for many hours, the stars leave circular trails on the photo as shown top right.



The constellations also move throughout the year. You can always see the Southern Cross, but the others are sometimes below the horizon, depending on the season.



Over to you

1. What is the difference between a star and a constellation?
2. You can sometimes see the moon during the day, but why can't you see stars?
3. When you see a planet in the night sky it looks just like a star. How is a planet different from a star?
4. Why are the moon and most of the planets visible at night even though they don't emit light themselves?
5. Name three constellations that can be seen in the Southern Hemisphere.
6. Why do the stars leave circular trails when photographed over many hours? (See the photo above.)
7. Why do you think some stars are brighter than others?
8. How could you use the stars to find south if you were lost?
9. The sun is huge compared to the moon, yet in the sky the sun appears to be no larger than the moon. How can you explain this?
10. How would a knowledge of the stars be useful to Australian Aboriginal people when hunting and gathering food?

12.2 Exploring space

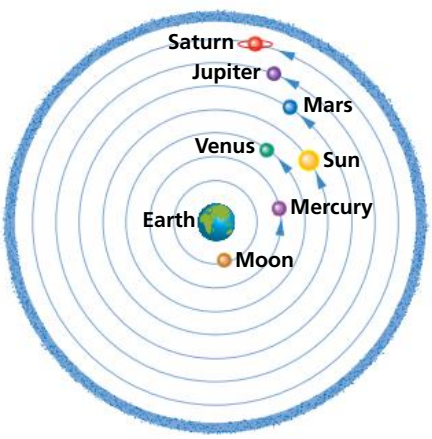
Observations and inferences

People have always been fascinated by the night sky and have made up stories to explain what they saw. For example, some Australian Aboriginal people thought the Earth was flat and circular with the dome of the sky over it. The sky was where supernatural beings and ancestral heroes lived. The stars represented the campfires of these beings.

Some myths say the sky was held up by giant poles at the corners of the Earth. Some Aboriginal people also believed that medicine men could travel between the Earth and the sky by climbing trees and that one such tree was the Milky Way. Under the Earth was the underworld. The sun-woman carried her firestick across the sky each day, setting in the west and then returning via the underworld to rise again in the east. The moon-man did the same.

In most cultures the beliefs were based on a central Earth with the other objects moving around it. These beliefs or inferences were based on observations that the sun, moon, planets and stars all moved around the Earth.

In AD 140 the Greek astronomer Ptolemy (TOLL-em-ee) wrote an encyclopaedia of astronomy detailing the motion of the moon, the five known planets (Mercury, Venus, Mars, Jupiter and Saturn), the sun and the stars all revolving around the Earth.



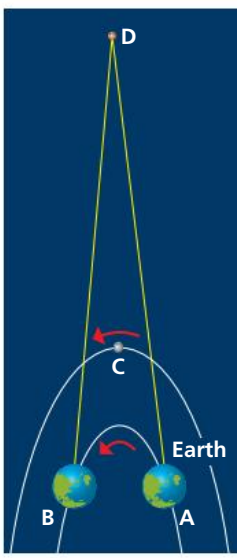
Ptolemy's model of the universe (not to scale)

Ptolemy was an impotant man at the time and his ideas were not questioned for about 400 years. However Ptolemy's model could not explain the movement of planets properly. First, Mercury and Venus are always near the horizon around sunrise and sunset. Second, the planets appear to wander among the stars, and the word planet comes from an ancient Greek word meaning 'wanderer'. Sometimes the planets appear to get ahead of the stars and sometimes they fall behind.

Nicolaus Copernicus (cu-PER-ni-kis) was born in Poland in 1473. While he was in Italy studying medicine he became interested in astronomy. He was not happy with Ptolemy's model and preferred a model in which the planets circled the sun (see page 259). So he set out to show that his model explained the observations better than Ptolemy's did.

Copernicus could not make detailed observations or measurements because there were no telescopes since they had not yet been invented. Instead he used models. With the sun in the centre of the solar system Mercury and Venus would always be near the sun. Hence you would see them only at sunrise and sunset. He was also able to explain the strange movement of the planets in relation to the background stars like this.

Look at the diagram on the right. From Earth's position A, a slower moving planet C seems to be to the left of the star D. In position B Earth has passed the slow moving planet, which now seems to be to the *right* of the star. The planet seems to have moved backwards. This can be explained by the Earth circling the sun, but not the other way around.



According to the Roman Catholic Church at the time, God created the Earth and therefore it must be the centre of the known universe. As a result Copernicus was called a fool to disagree with the teachings of the Church. Despite this criticism he wrote down his life's work in a book called *On the Revolutions of Heavenly Spheres*, but he died on the very day it was published in 1543. The book was banned by the Church.

The Italian astronomer Giordano Bruno supported Copernicus's model and went on to suggest the universe was infinite and consisted of many worlds similar to the solar system. He was arrested for going against the Church and in 1600 he was burnt alive with his mouth clamped shut in an iron gag.

Galileo

In 1610 Galileo built a telescope using lenses, and observed the surface of the moon for the first time. He saw mountains, craters and large flat plains. He also observed the planet Jupiter and noticed four moons revolving around it, like a mini solar system. He used this observation of Jupiter to support his inference that the sun was at the centre of the solar system. He was warned by the Roman Catholic church not to support the ideas of Copernicus, but in 1632 he went ahead and published his ideas.

The following year Galileo was forced, under threat of torture, to publicly say he was wrong. Instead he said that the Bible was intended to teach you 'how to go to heaven, not how the heavens go'. His book was banned and he was sentenced to life imprisonment. Old, sick and losing his sight, Galileo was allowed to serve his sentence in his own home. In 1979 Pope John Paul II officially declared that the Roman Catholic church may have been wrong in condemning Galileo.

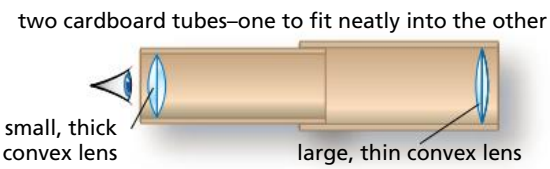


Galileo demonstrates his telescope

INQUIRY 4 Making a telescope

You will need: 2 cardboard tubes (one to fit neatly inside the other), 2 convex lenses (one smaller and thicker than the other), Blu-Tack

1 Make the telescope as shown, holding the lenses in place with Blu-Tack.



2 Look at an object in the room. Move the tubes in and out to focus the image. Repeat this for an object far away. Try viewing the night sky.

- Suggest ways of improving your telescope. You could make this into a project.

SCIENTISTS AT WORK

Caroline Herschel (1750–1848)

Caroline Lucretia Herschel was born in Germany in 1750—one of ten children in a poor family. At 10 she had typhus, a disease that stunted her growth, so she only grew to 130 cm. Her mother strongly opposed her daughter doing anything other than household chores, but Caroline wanted to do more than 'wash, bleach and iron the tablecloth'. Her father encouraged her in this and took her to observe the night sky.

When war broke out her brother William escaped to England where he became a music teacher. Caroline looked after her father for many years, but when he died she went to live with William in England. Here she studied music, mathematics and astronomy and became a soprano soloist in performances conducted by William.

William began making telescopes and Caroline became his assistant. In 1781 he thought he had discovered a comet but it turned out to be the planet Uranus. They then began a detailed study of the skies. Not a clear night would pass without William sweeping the sky with his telescope and Caroline recording his observations. To earn a living they made and sold smaller telescopes, spending hours grinding and polishing mirrors.

In 1786 William was away when Caroline discovered a comet moving slowly through the constellation of Leo. She went on to discover a total of eight comets and completed a catalogue of 2500 nebula (clouds of dust and gases in space).

Caroline was honoured by becoming the first woman member of Britain's Royal Astronomical Society, and she lived until she was 98. Forty years later an asteroid was named *Lucretia* in honour of her life's work.



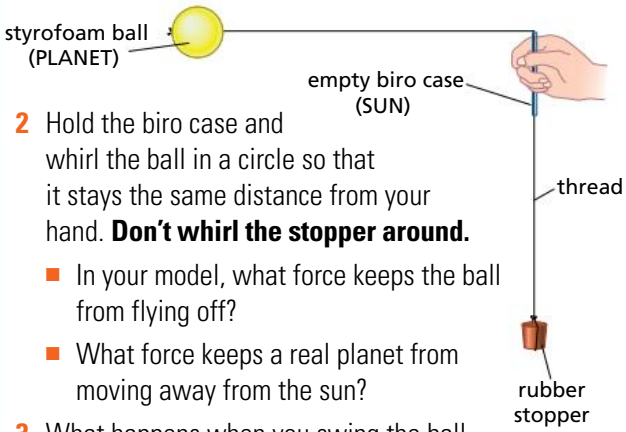
The telescope used by William and Caroline Herschel to map the sky. Its mirror was 1.2 m in diameter.

INQUIRY 5 Planets in orbit

Here is a model to help you understand how the planets orbit the sun.

You will need: piece of thread, styrofoam ball, empty biro case, rubber stopper

1 Fasten a piece of thread to a styrofoam ball. The ball represents a planet. Pass the thread through an empty biro case or piece of hollow tubing. This represents the sun. Tie the other end to a small rubber stopper or similar weight, as shown.



2 Hold the biro case and whirl the ball in a circle so that it stays the same distance from your hand. **Don't whirl the stopper around.**

- In your model, what force keeps the ball from flying off?
- What force keeps a real planet from moving away from the sun?

3 What happens when you swing the ball more slowly? More quickly?

4 What will happen if you cut the string while the ball is orbiting? Try it, but well away from other people. (Cut between the biro case and the weight.)

Telescopes

Larger and better telescopes have been built all around the world. Several of these are in Australia, for example the Anglo-Australian telescope near Coonabarabran in NSW. However, the Earth's atmosphere distorts the images received. One solution to this is to position the telescope in space above the Earth's atmosphere. This is the purpose of the Hubble Space Telescope which was launched in 1990. It orbits the Earth at a distance of 600 kilometres.

Radio telescopes use aerials or dishes up to 300 metres in diameter to collect radio waves rather than light. The Australian Telescope in central NSW consists of six radio telescopes that can be moved along 3 km of railway tracks. Radio telescopes have revolutionised astronomy by detecting things in space we never knew existed, like pulsars that are the remains of massive stars that have exploded.

Space probes

Unmanned spacecraft, called space probes, have discovered much about our solar system. For example, the *Voyager 2* space probe was launched in 1977 and travelled at a speed of 65 000 km/h—about five times the speed of a pistol bullet. It reached Jupiter in 1979, Saturn in 1981, Uranus in 1986 and Neptune in 1989. It took many close-up photos of the outer planets not possible from Earth. It has now left the solar system and is travelling deep into space, but it is still sending data back to Earth.

Some space probes have landed on planets. For example, on the *Mars Pathfinder* mission in 1997 a small remote-controlled vehicle was used to explore the barren rocky surface of Mars (see the next page).

The robotic spacecraft *Cassini* is presently in orbit around Saturn. In 2005 it dropped a probe onto the surface of Titan, one of its moons.



Over to you

1 How was Copernicus' model of the Earth different from Ptolemy's?

2 Why is the Hubble Space Telescope better than telescopes on Earth?

3 **a** Ptolemy's model of the universe on page 256 has only five planets. Why?

b What is the celestial sphere? Does it really exist? Explain.

4 Why did Copernicus, Bruno and Galileo get into trouble with the Roman Catholic church?

5 Draw a picture of the Aboriginal universe (page 256) with its three levels.

6 Why do we have to look fairly close to the sun to see the planets Mercury and Venus?

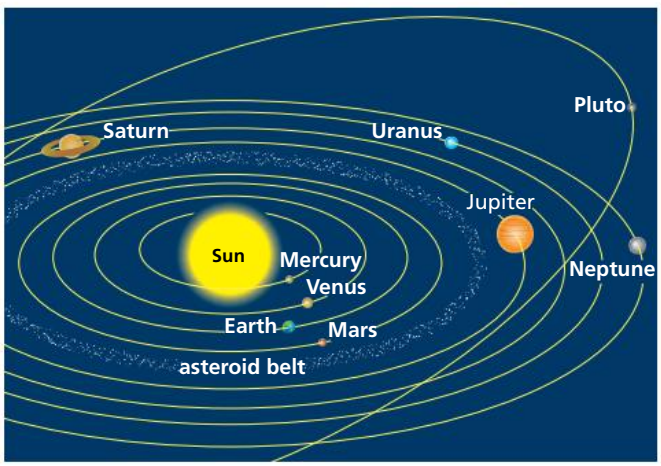
7 What information about planets can space probes gather that cannot be obtained by telescopes?

12.3 The planets

The inner planets

As you know, there are eight planets in our solar system, including the Earth. They all orbit the sun and each of them spins on its own axis. You can use this memory jingle to help you remember their order: **M**y **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**achos. Each bold letter is the first letter of a planet—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.

The planets can be divided into two groups: the *inner planets* and the *outer planets*. The inner planets, sometimes called the rocky planets, are Mercury, Venus, Earth and Mars. They are the planets closest to the sun, and are all relatively small.

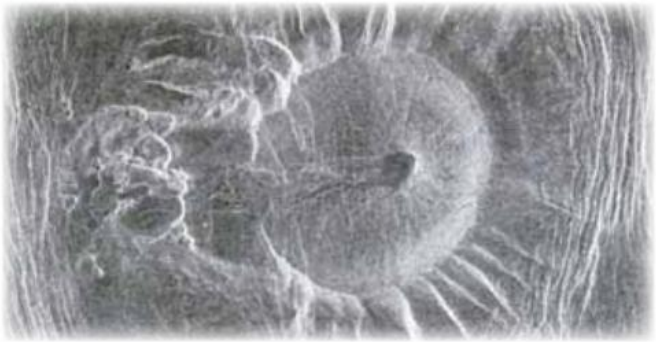


Mercury

Mercury is the smallest planet—less than half the size of Earth. It is the closest planet to the sun, so the sun would appear more than twice as big on Mercury as it does on Earth. Daylight lasts about an Earth month and it gets hot enough to melt lead. The night lasts just as long and it gets cold enough to freeze carbon dioxide. The surface is covered in meteorite craters, very much like Earth's moon. There is hardly any atmosphere since there isn't enough gravity to keep it there.

Venus

Venus is Earth's inner neighbour and about the same size as Earth. It is covered in swirling clouds with winds up to 350 km/h. The atmosphere is very thick, consisting mainly of carbon dioxide. This creates a super greenhouse effect, and the average temperature is almost 500°C. There are also thick clouds of sulfuric acid, making it a most unpleasant planet. The atmospheric pressure is almost 100 times that on Earth, and if we lived there we would need to live in protective buildings to avoid being crushed. There are many volcanoes and lava flows. The planet spins in the opposite direction to Earth so the sun rises in the west and sets in the east.



The Tick volcano on Venus

Mars

Mars is Earth's outer neighbour but is only about half the size. It is colder than Earth and its thin atmosphere is mainly carbon dioxide. The surface is similar to deserts on Earth and is covered in red dust. There are frequent dust storms, giving the sky a pink-red colour. There are huge volcanoes and canyons, higher and deeper than those on Earth. It has seasons like on Earth. Space probes have found no evidence of life but it may have existed there in the past. The planet has two tiny moons, Phobos (fear) and Deimos (terror), which are probably asteroids captured by the gravity of Mars.



A remote-controlled vehicle on the surface of Mars

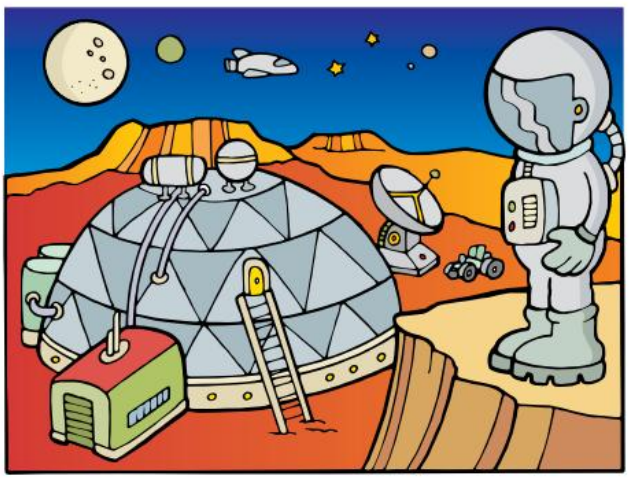
SKILL

Understanding on three levels

Read through the following article on Mars, then answer the questions below to show you understand it.

Mars—the new Earth

Many science fiction books and movies have been written about Mars—aliens invading Earth and humans travelling to Mars. In recent years scientists have been thinking seriously about what would need to be done to *terraform* Mars or make it more suitable for humans to live. Earth is becoming overcrowded and a planetary disaster could force us to look for a new home in space. Of all the planets in the solar system Mars seems to be the most suitable. The atmosphere on Mars will not support life as we know it, but it is in fact very similar to the atmosphere that existed on Earth billions of years ago. So perhaps we can speed up the process.



The first thing that has to be done is to warm up the planet from its present –60°C to at least 5°C. Planetary scientist Dr Chris McKay says this could be done by building factories on Mars to make and release huge quantities of greenhouse gases. These gases would trap heat from the sun and produce global warming of the planet.

Two other terraforming methods have been proposed. Large mirrors could be placed in orbit around the planet to reflect the sun's radiation and heat the surface. Another radical idea is to capture large asteroids made of ammonia (a greenhouse gas) and hurl them at Mars. This would raise the temperature of the planet and also release huge amounts of greenhouse gases and water.

There is evidence of flowing water on Mars in the past, and considerable water ice has been found under the surface and at the poles. If the temperature could be increased this ice would melt and rivers, lakes and even oceans could be formed on the planet.

Genetically engineered microbes could be released to produce oxygen, and then lichens, mosses and flowering plants could be established. This would take about 100 years. The next step would be to plant trees to convert more of the carbon dioxide into breathable oxygen.

In this way Mars could become more like Earth. Some people say we have made a mess of the Earth, so why should we think we can do better on Mars. Others say that the research needed to terraform Mars could help keep Earth a livable planet.

Level 1: Knowledge

Answer the following questions. You may need to re-read the article to find the answers.

1. What does it mean to terraform Mars?
2. By how many degrees would Mars need to be warmed up for us to live there?
3. How is it proposed to increase the amount of oxygen in Mars' atmosphere?

Level 2: Understanding

At this level of understanding you need to use information in the article (and elsewhere) to reach your own conclusions.

1. On Earth global warming may cause a disaster, yet it is proposed to purposely cause it on Mars. What is the difference?
2. Why is Mars considered more suitable for terraforming than Mercury or Venus?
3. Why would people want to leave Earth to live on Mars?

Level 3: Applying your knowledge

Once you understand something properly you can apply your knowledge and form your own opinions.

1. Which of the three methods of warming Mars do you think is the best? Explain your answer.
2. How could terraforming Mars help keep Earth a livable planet?
3. Many people are opposed to terraforming Mars. What arguments do you think they could use?

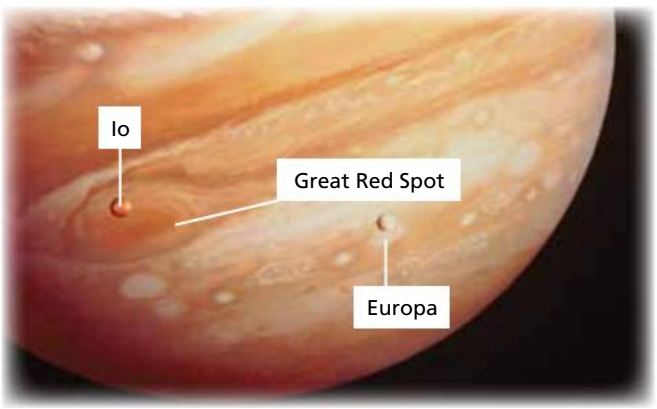
For more information on terraforming Mars you could do an internet search.

The outer planets

The four largest planets—Jupiter, Saturn, Uranus and Neptune—lie well beyond Mars. These planets are called the *gas giants* because they are like huge balls of gas. They do not have a solid surface like the inner planets. Instead they gradually change from gases in their atmospheres to liquids and solids closer to their cores. They are composed mainly of hydrogen, helium and methane. So a spacecraft trying to land on one of these planets would be pulled deeper and deeper into the mysterious interior.

Jupiter

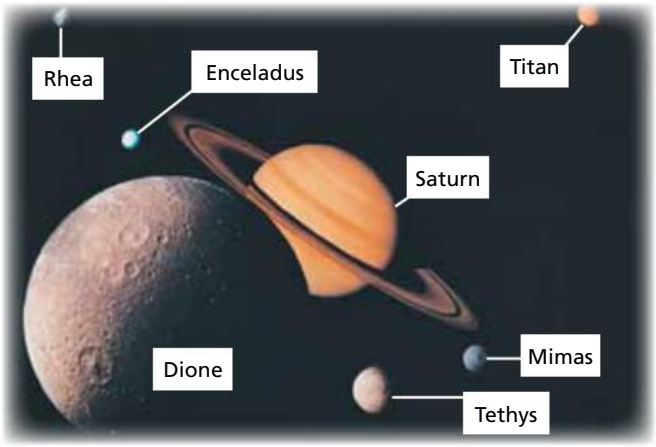
Jupiter is heavier than all the other planets put together, and its gravity is three times what it is on Earth. The planet has a striped appearance and the Great Red Spot is a cyclone twice the size of Earth that has been raging for over 300 years. (We know this because this is when it was first observed using telescopes.) The atmosphere is mainly hydrogen with some helium, and under this is a vast ocean of liquid hydrogen. The temperature at the top of the clouds is –150°C but the temperature in the core may be as high as 30 000°C. It has 63 moons. The largest, Ganymede, is larger than Mercury and Pluto. Io has active volcanoes and Europa is considered a likely place to find life since it has liquid water under its frozen surface. The smallest moons are only 2 km in diameter and may be captured asteroids.



Jupiter and two of its moons

Saturn

Saturn is the most beautiful planet in the solar system. It is a golden colour with spectacular rings around its equator. These are made of bits of water ice or chunks of rock coated with ice. The bits range in size from pebbles up to boulders the size of a house. Saturn is similar to Jupiter, only a bit smaller and a bit colder. It has 62 moons. The largest of these is Titan, which is about the same size as Jupiter's Ganymede.



A view of Saturn from behind one of its many moons

Uranus

Uranus is four times the size of Earth. It is pronounced YOUR-a-nus, not your-A-nus. The planet is a bluish-green colour because of the methane in its atmosphere. It has rings like Saturn. The strangest thing about Uranus is that its axis of rotation is nearly at right angles to the other planets, which means it is lying on its side. Astronomers think this may have happened when it collided with a large body in space. It has 27 moons.

Neptune

Neptune is similar to Uranus, but even colder (–225°C). The sunlight there is only one-thousandth as intense as on Earth. The winds on Neptune are stronger than anywhere else in the solar system—up to 2000 km/h. It has 13 moons, the largest being Triton which is the coldest body in the solar system.

Pluto

In 2006 Pluto was reclassified as a **dwarf planet**. It is in the Kuiper Belt, beyond Neptune. Astronomers have found several other dwarf planets in this area, and they expect to find more. Pluto is smaller than Earth's moon, and astronomers know very little about it because it is so far away. From its density they infer it is 70% rock and 30% water ice, more like the inner planets than the gas giants. Its orbit is not in the same plane as the orbits of the other planets. (See the diagram of the solar system on page 259.) It has its own moon Charon, half as big as the dwarf planet itself.

INQUIRY 6

Interpreting planetary data

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Average distance from sun (millions of kilometres)	57.9	108.2	149.6	227.9	778.3	1429	2871	4504
Time to orbit sun (Earth years)	0.2	0.6	1	1.9	11.9	29.5	84	165
Time to spin on axis (d = days, h = hours)	59 d	243 d	24 h	25 h	10 h	11 h	17 h	16 h
Diameter (kilometres)	4880	12 104	12 756	6794	142 984	120 536	51 118	49 532
Mass (compared to Earth)	0.06	0.82	1	0.11	318	95	14.5	17.1
Average density (water = 1)	5.4	5.2	5.5	3.9	1.3	0.7	1.3	1.6
Gravity (compared to Earth)	0.4	0.9	1	0.4	2.4	0.9	0.9	1.1
Average surface temperature (°C)	167	457	14	-55	-153	-185	-214	-225
Known moons (* = plus rings)	–	–	1	2	63*	62*	27*	13*
Main gases in atmosphere	–	CO_2, N_2	N_2, O_2, Ar	CO_2, Ar	H, He	H, He	H, He CH_4	H, He, CH_4

CO_2 = carbon dioxide, N_2 = nitrogen, O_2 = oxygen, Ar = argon, H = hydrogen, He = helium, CH_4 = methane, CO = carbon monoxide

Interpreting the table

Use the planetary data in the table to answer these questions.

1 Which is the biggest planet?
2 Which planet has the shortest day? The longest day?
3 Which planet has the longest year?
4 Why does the length of the planet's year increase from left to right across the table?
5 Which planet has no atmosphere?
6 Which planets are warmer than Earth?
7 Which planet spins most rapidly on its axis? Explain.
8 Which planet would, in theory, float in water? Explain.
9 What is the total number of moons in the solar system?
10 Which is closer to Earth—Venus or Mars? Explain.
11 On which planet would you be able to jump the highest? How do you know?
12 How many Earths could you fit across the diameter of Jupiter?
13 Which planet is most like Earth? Explain your answer.
14 Which are the most common gases in the atmospheres of the gas giants?
15 Write a generalisation linking the surface temperature of a planet to its distance from the sun.

Column graphs

A Draw a column graph to show the planets in order on the x-axis and the *diameter* of the planet on the y-axis.
- What pattern can you see in the graph?

B Draw a column graph to show the planets on the x-axis and their *densities* on the y-axis.
- Use the graph to divide the planets into two groups. Explain how you did this.
- Write a generalisation linking the diameter of the planet (Graph A) to its density (Graph B).

Line graph

Draw a line graph with distance from the sun on the x-axis and length of year on the y-axis. Use scales on the axes that will make your graph as large as possible.

- If there was a planet halfway between Saturn and Uranus, how long would its year be?
- Where would you expect to find a planet if it took 100 years to orbit the sun?

INQUIRY 7

Planet hunting

It is possible to observe some of the planets with your own eyes, although binoculars or a telescope will help. Planets rise in the east and set in the west. They follow roughly the same path the sun and moon take across the sky, but you have to know *when* to look. To plan your hunting you need to check the planets guide in the weather section of the newspaper. Look at the example below.

Sun, moon and planets		
	Rise	Set
Sun	6.24 am	5.23 pm
Moon	6.47 am	5.48 pm
Mercury	7.25 am	6.48 pm
Venus	8.38 am	8.50 pm
Mars	6.31 am	5.25 pm
Jupiter	5.36 am	4.14 pm
Saturn	3.08 am	1.35 pm

First look at the times the planets rise. On this particular day Mercury, Venus and Mars rise after the sun, so you won't be able to see them because of the sun's light. If you get up early enough you should be able to see Jupiter in the east near the sun and Saturn (higher in the sky). Now look at the setting times. You may be able to see Mercury setting in the west an hour after the sun. Venus doesn't set until 8.50 pm. You won't see Mars since it will be too near the sun, and Jupiter and Saturn set before the sun so you won't see them with so much light in the sky.

Once you have checked the newspaper you know when and where to look. You could also use a star chart or contact a planetarium. Here are some further notes on the planets.

- *Venus* is easily seen in the early morning or evening sky. It is the brightest object in the sky and a yellowish colour.
- *Jupiter* is the second brightest object. With ×10 binoculars you can sometimes see the four largest moons.
- *Mars* is a red colour.
- *Saturn* is an orange colour. To see its rings you need a telescope.
- *Mercury* can sometimes be seen just before sunrise or just after sunset—close to the sun.

Try the activity at home and report back to the class.

Over to you

1 List the planets in order from the sun outwards.

2 Copy and complete these sentences.
- **a** The _____ is the centre of the solar system.
- **b** There are _____ planets in the solar system.
- **c** The Earth is the _____ planet from the sun.
- **d** Mercury, Venus, Earth and Mars form the _____ planets.
- **e** _____ is the largest planet and _____ is the smallest.
- **f** The most distant planet from the sun is _____. The closest is _____.
- **g** Most of the planets have _____ orbiting them.
- **h** Gases in a planet's atmosphere are held there by _____.

3 The planets do not give off any light yet you can see them at night. How is this possible?

4 What holds the planets in orbit around the sun?

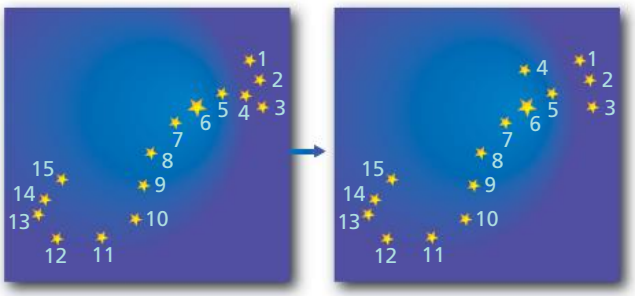
5 There are two groups of planets—the inner planets and the outer planets. What are the main differences between these two groups of planets?

6 Why would it be difficult to land a spacecraft on Jupiter?

7 Mercury is much closer to the sun than Venus, yet Venus is much hotter than Mercury. How can you explain this?

8 In the last 20 years the official numbers of moons of the outer planets have changed many times. Suggest a reason for this.

9 The diagram below shows the constellation Scorpio at the same time on two nights a fortnight apart. Are any of the numbered stars likely to be planets? Which? Explain your answer.



PROBLEM SOLVING

If you haven't already started, now would be a good time to design your tourist brochure on a planet or moon of your choice (see page 252). You will need more information than there is in this section.

12.4 Close encounters

Comets

About 140 million years ago a **comet** at least 600 m in diameter slammed into central Australia. It went deep underground before vaporising and exploding, creating a huge mushroom-shaped cloud of dust. It left a crater 20 km across which is now called Gosse Bluff or Tnorala (no-ra-la).

The Aboriginal people of the area have a Dreamtime story about Tnorala. A group of women danced across the sky as the Milky Way. During this dance a mother put her baby down in a wooden baby-carrier. As they danced this carrier toppled over the edge of the dancing area and crashed to Earth, forming the Tnorala crater.

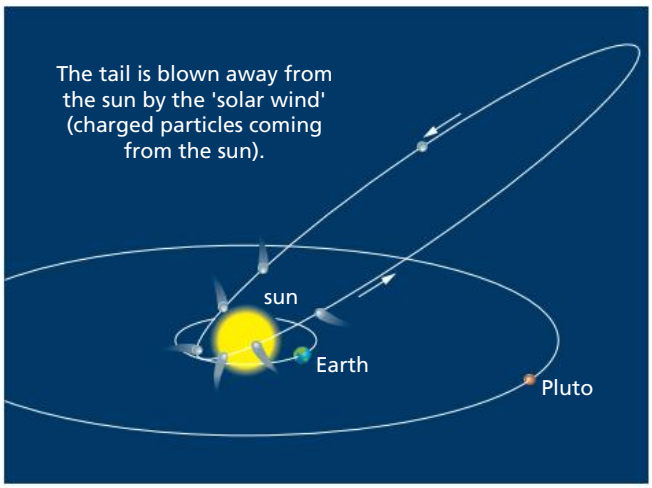


In 1994 people watched on TV as fragments of another comet collided with the planet Jupiter. The comet was 10 km in diameter and almost hit the planet in 1992. Instead it split into 21 fragments, the largest about 2 km across. These fragments continued on their orbit and came back to collide one after the other with the planet over several days in July 1994. Each fragment hit the gas giant at about 60 km/s. The largest one created a fireball which rose 3000 km above the top of the clouds of Jupiter.

Comets are part of the solar system. They orbit the Sun in long, narrow oval-shaped orbits. Many have orbits that go beyond Pluto, but some have very small orbits. The most famous is Halley's comet which orbits the sun every 76 years.



The core of a comet is made of rock and dust stuck together with ice and frozen gases such as ammonia and methane. The core is usually quite small—about 10 km in diameter—but when it approaches the sun, the frozen gases warm up and evaporate. The light from the sun hits the gases and is reflected, giving the comet a glowing tail sometimes millions of kilometres long.



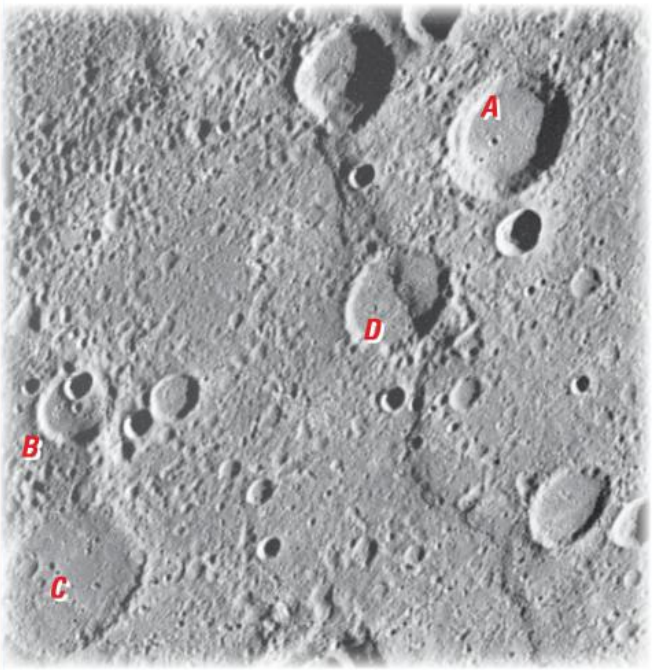
Meteors and meteorites

On a clear night you can see *shooting stars* or **meteors**. These are bits of dust and small lumps of rock in space. Some of them are probably leftover fragments of comets. As they pass through the Earth's atmosphere they become extremely hot due to friction with the air, and flash across the sky as streaks of light.

Usually meteors burn away before they reach the Earth's surface, but occasionally a larger one is not burnt completely and it strikes the Earth. Very large ones may form craters such as those on the surfaces of the moon, Mercury and Mars. The solid remains of meteors are called **meteorites**. As the Earth travels through space it encounters thousands of meteors a day, so you can see how important our atmosphere is in protecting us from falling meteorites.

INQUIRY

8 Interpreting photos



The photo shows part of the surface of the planet Mercury, which is covered in meteorite craters.

1 Which crater (A, B or C) do you think is the oldest? Explain your inference.
2 If crater A is 50 km across (from rim to rim) what is the size of craters B and C?
3 Which crater do you think is the deepest? Explain.
4 You will notice a fault (crack) that runs from the top of the photo to the bottom. Do you think this was formed before or after crater D? Explain.
5 From which direction was the sun shining when the photo was taken? How do you know?
6 Turn the photo upside down. What do you notice?
7 What do you need to know before you can interpret the photo correctly?
8 Suggest a suitable spot for a manned landing in this part of Mercury. Explain your choice.

INVESTIGATION

1 Making craters

Aim

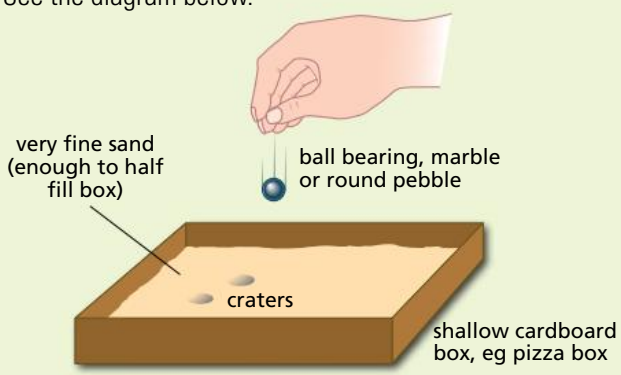
To investigate the formation of meteorite craters.

Risk assessment and planning

Read through the Method. If there are any hazards, what precautions do you need to take?

Apparatus

See the diagram below.



Method

1 Pour some fine dry sand into a shallow cardboard box to a depth of about 2.5 cm. Level it with a piece of wood or old ruler. Shake the box gently to settle the sand.
2 To make a crater, drop a ball bearing or marble into the sand.
   ✻ Observe what happens.
3 Investigate the formation of craters by dropping the ball bearings from different heights so that they hit the sand at different speeds. You could also throw them into the sand at different angles. Note the size and shape of each crater and the height of the rim. Draw them.
   ✻ Write a brief report on your findings.
4 Shine the light on the surface at an angle. This can represent the sun shining on the surface.
   ✻ What is the relationship between the lengths of the shadows and the depths of the craters?

Other things to try

- Before you start, sprinkle a fine layer of paint powder over the sand using a tea strainer. You can now investigate how material is thrown out of the crater on impact. Draw what happens.
- If you use mud instead of sand, you can let the mud dry to preserve the cratered surface.

Huge asteroid headed for Earth

Astronomers have set their doomsday watches for February 2019 after discovering a huge asteroid which is heading for Earth.

US scientists have claimed a chunk of rock dubbed 2002 NT7 posed the biggest asteroid threat yet.

Preliminary calculations suggested it could hit Earth on 1 February 2019, although they cautioned the error margin was in the order of millions of kilometres.

They were hopeful further observations would show 2002 NT7 would pass harmlessly by the planet.

Other calculations have shown the asteroid was more than 2 km in diameter . . . large enough to almost wipe out an entire continent . . .

If it struck at sea, it would cause tidal waves potentially hundreds of metres high which would devastate coastal cities and swamp entire countries.

Brendan O'Malley and Simon Benson, *The Courier-Mail*, 25 August 2002



Asteroids

Movies like *Deep Impact* and *Armageddon* are based on the possibility of an **asteroid** colliding with Earth. Thousands of these odd-shaped rocky and metallic objects orbit the Sun just like the planets. Most of them are between Mars and Jupiter in a region known as the asteroid belt. This region is still quite empty though, with large distances between the asteroids.

The largest asteroid is Ceres, which is classified as a dwarf planet. It has a diameter of almost 1000 km. The smallest asteroids are only about 1 km across. Astronomers think that the asteroids are the remains of the materials which formed the planets billions of years ago.

The orbits of asteroids are more oval in shape than the orbits of the planets. This brings them quite close to the orbit of the Earth, and there have been some near misses. In 1972 an asteroid estimated to be 200 m across came within 50 km of the Earth over Canada. It was seen as a blazing fireball during the day.

Many scientists think that the dinosaurs were wiped out about 65 million years ago when a large asteroid or comet collided with the Earth. Such a collision would have created a massive cloud of dust, volcanic eruptions, global fires and major changes to climate.

Many science fiction stories imagine people living on asteroids. Gravity is very small, making it easy for spacecraft to land and take off again. The asteroids could be mined for the minerals they contain. There is no atmosphere however, so you would need to carry a supply of oxygen with you.



This is the asteroid Ida, photographed by the Galileo spacecraft in 1993. It is 58 km long, 23 km wide and has meteorite craters. It even has its own tiny moon (right).

Over to you

1. What is the difference between a meteor and a meteorite? Which one would you find in a museum?
2. Why do meteors usually burn up before they hit the Earth?
3. A number of craters like those on the moon have been found in various places on the Earth. What has caused these craters?
4. Lucas was looking at the stars when he saw a streak of light dart across the sky and disappear quickly. Did he see an asteroid, a comet, a meteor or a meteorite? Explain your answer.
5. Each time a comet comes close to the sun it is smaller than it was the previous time. Why is this?
6. Why do meteors present a bigger danger to space travellers than to people on Earth?
7. In 1910 the Earth passed through the tail of Halley's comet. During that year there were spectacular meteor showers. Suggest why.

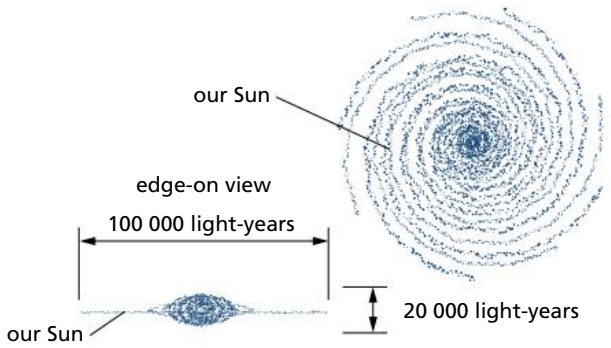
12.5 The universe

Our galaxy

One of the most difficult things to understand about the universe is the size of it. *Voyager 2* travelled at 65 000 km/h. At this speed it would take 23 years to get from one end of the solar system to the other. If we are to travel to the outer planets and beyond, we need to be able to travel much faster than this. But there is a problem here, because as far as we know nothing can travel faster than the speed of light, that is 300 000 km/s. Travelling at this speed it would take 8.3 minutes to get to the sun, and 5.5 hours to reach Pluto.

On a clear night you can see a broad band of stars stretching across the sky from one horizon to the other. This is our **galaxy**, called the *Milky Way*. It contains 100 billion stars, plus planets, asteroids, comets, meteors, dust, gas and other things we don't yet fully understand, like black holes. To measure the vast distances of space, astronomers use a unit called a **light-year**. This is the distance light travels in one year—about 9 500 000 000 000 km or 9.5×10^{12} km.

The Milky Way is shaped like a discus, with four or five spiralling arms. It is 100 000 light-years across, and our Sun and its solar system are located in one of the spiral arms. The nearest star to our solar system is Proxima Centauri, just over four light-years away.



The Milky Way galaxy

Types of stars

Stars vary in size and our sun is an average size. Dwarf stars may be only one-hundredth the size of our sun, and super giants may be 400 times as big. They also vary in colour from blue to white to red. The hottest stars give off a white to blue light, while the coolest ones give off red light.

INVESTIGATION 2

Colour of stars

Aim

To use a light bulb of varying brightness to model the colour of a star.

Risk assessment and planning

1 What precautions are necessary when using electrical equipment?

2 **Don't look directly at the sun through the spectroscope. It can cause permanent eye damage.**

Apparatus

- 12 volt bulb and socket (e.g. from a ray box)
- power pack
- hand spectroscope
- sheet of white paper

Method

1 Connect the bulb and socket to the power pack.

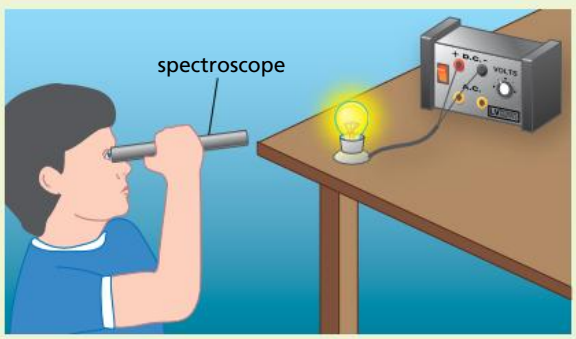
2 Set the power pack on the lowest voltage, then increase the voltage until the filament of the bulb starts glowing.

3 Slowly increase the voltage up to 12 volts and note how the colour changes as the filament gets hotter.

4 To give you a better idea of the colour you can use a spectroscope, which splits light into its colours. Go outside and hold a piece of white paper in bright sunlight. Look at the paper through the spectroscope to observe the spectrum (split-up colours) of the white light from the sun.

5 Back in the lab, observe the colour of the light bulb filament through the spectroscope.

✻ How does the spectrum change as you change the voltage?



Write your report

In your conclusion make sure you try to explain why different stars are different colours.

Other galaxies

Until the turn of the twentieth century the Milky Way galaxy was thought to be the whole universe, but there are now thought to be millions of galaxies. Some are spiral-shaped like our galaxy, some are egg-shaped and some are irregular. The Sombrero galaxy below is 50 000 light-years away. It was photographed by David Malin at the Anglo-Australian Observatory at Siding Spring in New South Wales.

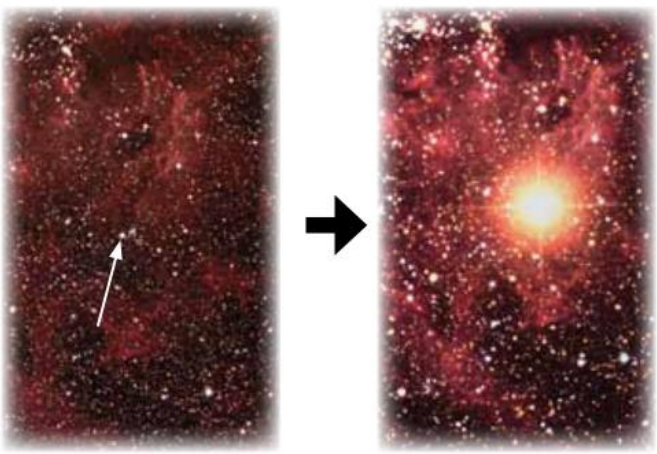


Novas and supernovas

Occasionally a star shines much more brightly than normal. This is known as a *nova*. It is caused by huge explosions peeling an outer layer off the star and blowing hot gases outwards.

Another much rarer event is a **supernova**. When this happens the explosions are much more violent and the star is torn apart. During the process the brightness of the star may increase up to a billion times its normal. Luckily our sun is not big enough to become a supernova.

The photo below shows a supernova that occurred in 1987. The star arrowed on the left exploded to form the supernova on the right. The star is 169 000 light-years away in the Large Magellanic Cloud, the nearest galaxy to the Milky Way. This means the light from the supernova took 169 000 years to reach us. So it actually occurred about 167 000 BC!

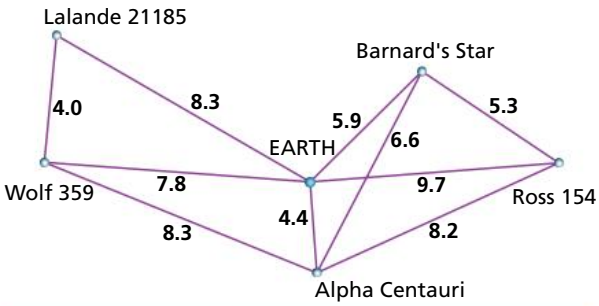


INQUIRY 9

Star travel

According to Einstein's theory of relativity, as you approach the speed of light, time slows down. This causes the 'twins effect' where twin A stays on Earth and twin B takes a trip to a distant star at close to the speed of light. When twin B returns he will be younger than twin A because for twin B time slowed down during the trip.

Imagine you visit the *Centauri Tours* and ask about their trips to stars within 10 light-years of Earth. They give you a star chart like the one below with distances marked in light-years, and a table of travel times. They tell you that their spaceships travel at 99% of the speed of light.



Distance (light-years)	Trip time (years)	
	For people on Earth	For space tourist
2	2.0	0.3
4	4.0	0.6
6	6.1	0.9
8	8.1	1.2
10	10.1	1.4

1. List the stars in order, starting with the one nearest Earth.
2. Trip times are much longer for people on Earth than for the space tourist. By how many times?
3. Calculate how long the trip to Alpha Centauri (the brightest of the Pointers) would take for (a) the people on Earth, and (b) you the space tourist.
4. Suppose your spaceship can carry fuel for 8.5 light-years, but you can refuel at any of the stars. Could you travel to Ross 154? If so, how long it would take for people on Earth and for you the tourist?
5. Antares, the bright red star in the Scorpion, is 425 light-years away. Would it be possible to reach this star in your lifetime, travelling at 99% of the speed of light?

Nebulas

A **nebula** (NEB-you-la) is an extremely large cloud of gas (mostly hydrogen) and dust floating in space. Some nebulas are places where stars are born, some are places where stars are dying and some are leftovers from supernovas when stars blew up. The photo below shows part of the Eagle nebula photographed by the Hubble Space Telescope. The nebula can be seen because of the light from nearby stars, the brightest of which may be 100 000 times brighter than our sun. The large 'elephant trunk' on the left is about four light-years long.



Is there life out there?

In the movie *Contact* the scientist played by Jodie Foster searches the heavens with several large radio telescopes. She is looking for radio signals that would indicate the presence of *extraterrestrial life*—life beyond Earth. We have been unintentionally announcing our presence on Earth since the 1920s with radio waves and TV broadcasts that travel into outer space every day at the speed of light.

However, scientists around the world are conducting a Search for Extraterrestrial Intelligence (SETI) by renting time on radio telescopes, including the one at Parkes in New South Wales. If you are interested you can be a part of SETI by downloading from their website a screensaver program for analysing data on your own computer.

The best chance of finding extraterrestrial life would seem to be on a planet similar to Earth, and the chances of finding solar systems similar to our own are very high. The universe consists of millions of galaxies, each containing millions of stars much like our sun. So even our galaxy must contain many stars with planetary systems.

In galactic terms, planets are small, appear to be close to their parent star, and shine only by reflected light. For these reasons the faint glimmer of a planet is lost in the brilliant glare from its parent star, making it almost impossible to see from Earth. Despite this, astronomers have found over 400 stars with one or more planets orbiting them. They have been able to detect them in two different ways. First, planets exert a gravitational tug on the star as they orbit it, making it wobble slightly. Second, they dim the light of the star if they pass directly in front of it. Some of the planets found are in the so-called 'Goldilocks zone', the distance from a star where it is not too hot and not too cold to support life.

INQUIRY 10 Can you see it?

You will need: Blu-Tack, cotton thread, 100 watt light bulb

Suspend a piece of Blu-Tack the size of a rice grain (the planet) on a cotton thread 3 or 4 cm from a 100 watt light bulb (the sun). Turn on the bulb and observe it and the Blu-Tack from various distances.

- At what distance is it impossible to see the Blu-Tack planet?
- What does this tell you about searching for planets around stars?

Over to you

1. What is a light-year?
2. In astronomical terms the sun is 8.3 minutes from the Earth. What does this mean?
3. What is the name of our galaxy? What shape is it?
4. How many years does it take light to travel the length of our galaxy?
5. Chinese astronomers observed a supernova (exploding star) in AD 1054. This supernova became the Crab Nebula which is 6500 light-years away. In which year did the star actually explode?
6. What can you infer from the colour of a star?
7. The brightest star in the Southern Cross is 230 light-years from the sun. Do you think we could ever visit it? Explain.
8. What is the difference between a solar system, a galaxy and the universe? Use a diagram to help you explain.

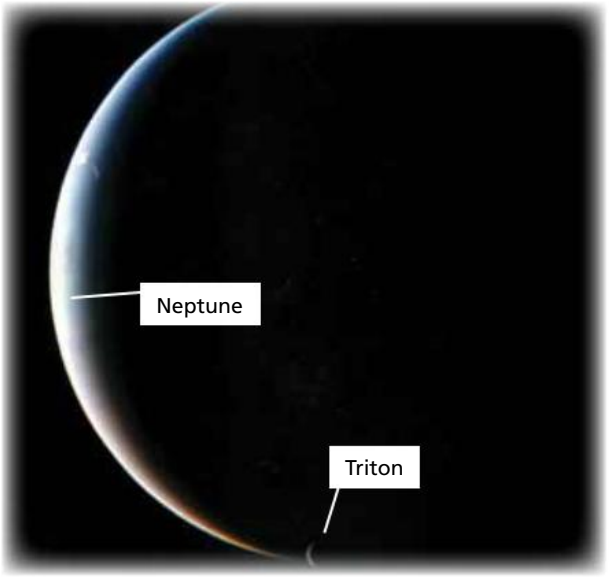
THINKING SKILLS

1 Suppose you are 48 years old on Earth. How old would you be in Jupiter years? How old would you be in Mercury years? (Use the table on page 262.)

2 The gravity on Mars is only 0.4 of the gravity on Earth, while Jupiter's gravity is 2.4 times greater than on Earth. How would the gravity affect humans and spacecraft on these planets?

3 The star Rigel in the constellation Orion is 900 light-years from our sun. Do you think that it is part of our galaxy? Explain your answer.

4 The photo shows Neptune and its moon Triton. Both the planet and its moon are crescent-shaped like a new moon. How can you explain this? A diagram might help.



5 One day on the dwarf planet Pluto is 6.3 Earth days, and its moon Charon takes 6.3 Earth days to orbit the planet. What does this tell you about Charon as seen from Pluto?

6 Imagine it is the year 3000 and you are booked on a flight to the star Sirius, 8.7 light-years away. Your 20-year-old twin is staying on Earth. Use the table on page 268 to estimate how old you will be when you return. How old will your twin be? What year will it be on Earth?

7 Four options have been suggested for dealing with a 'killer asteroid':

A Blast the asteroid to pieces with a nuclear missile.

B Use a missile to change the asteroid's orbit.

C Somehow trap the asteroid in a safe orbit around the Earth.

D Migrate to another planet (e.g. Mars) and return to Earth when it is habitable again.

a What are the advantages and disadvantages of each option? List them in order from the most practical to the least practical.

b Which option would you choose? Why?

c Can you think of any other options? Explain.

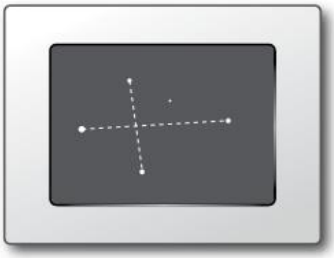
8 Five hundred years ago many people thought the Earth was flat. Imagine you travel back in time 500 years. How could you convince people that the Earth is not flat but spherical?

9 The science fiction writer Larry Niven wrote a story about an asteroid that had been converted into a starship. What would need to be done to make this sci-fi idea a reality?

10 Suppose a spacecraft is to be sent towards the stars. On it will be a special container to hold messages and questions for any intelligent life form that might encounter the spacecraft. Your task is to write five sentences describing Earth and its people, and five questions to ask the life form that finds the container.

11 To give you a better idea of what constellations are like, you can make your own mini-planetarium. You will need diagrams of constellations from books or the internet, some underexposed (black) slides and a pin.

Using a star map as a guide, prick holes in a slide to represent the stars in a particular constellation. Make the holes different sizes to represent stars of different brightness. If you project these slides in a darkened room you will see the stars as points of light on the screen.



12 Write and perform a play about the universe according to some Australian Aboriginal people (see page 256).

Knowing and Understanding

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

1 Because of the rotation of the Earth, the sun, moon, planets and stars all appear to move across the sky from _____ to _____.

2 The stars in the sky form patterns called _____.

3 Ancient astronomers incorrectly inferred that the _____ was the centre of our solar system. These inferences were replaced by the idea of a central ____ with the planets revolving around it.

4 There are _____ planets in our solar system. Mercury, _____, Earth and Mars have rocky surfaces and are relatively small. Jupiter, _____, Uranus and Neptune are huge balls of gas.

5 The Earth's atmosphere protects us from _____, but a comet or an _____ could cause a global disaster if it collided with Earth.

6 Astronomers use light-years to measure the vast distances of space. A light-year is the _____ light travels in one year.

7 Our galaxy, called the _____, is only one of millions of galaxies in the universe. Each galaxy contains billions of stars and clouds of gas and dust called _____.

asteroid
constellations
distance
Earth
east
meteors
Milky Way
nebulas
eight
Saturn
sun
Venus
west

Self-management

1 Which planet am I?

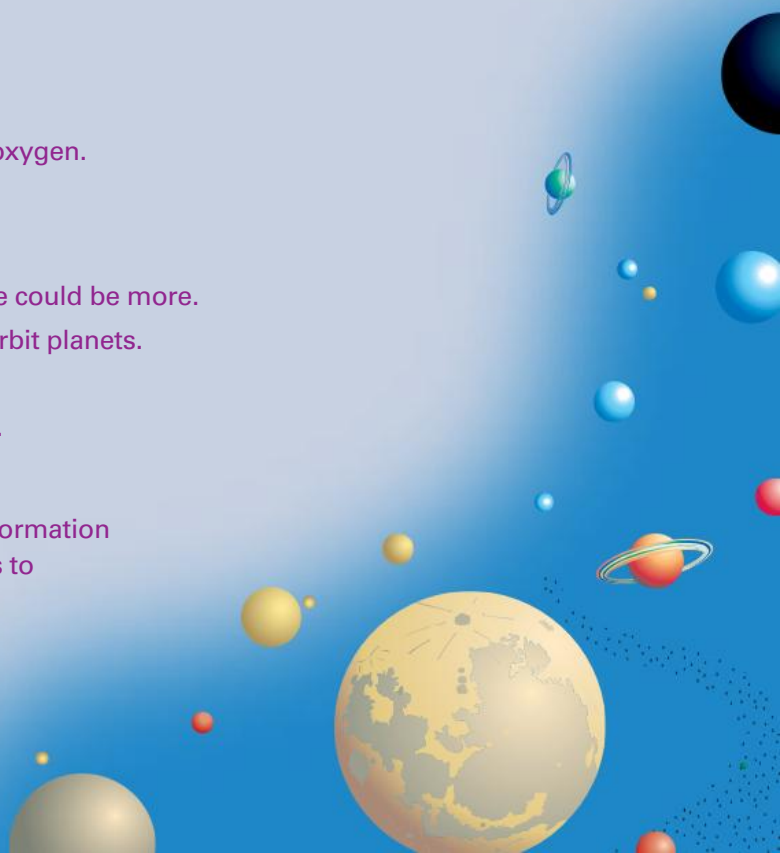
My surface temperature ranges from a chilly –90°C to a hot 50°C.
I have one moon.
I orbit the sun every 365 days.
Two-thirds of my surface is covered by oceans.
The main gases in my atmosphere are nitrogen and oxygen.

2 What are we?

We are smaller than planets.
There are over 100 of us in the solar system, but there could be more.
At least one of us orbits an asteroid, but we usually orbit planets.
We have never been seen near Mercury or Venus.
We go through phases, never looking quite the same.

3 Now it's your turn.

Write a description of an object in space using the information in this chapter and from your research. Take it in turns to test the class with your description.



Checkpoint

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

OneStopScience

1 Kirralee observes the Southern Cross just above the horizon. Four hours later it is high in the sky. This movement is caused by the

A Earth rotating on its axis

B stars orbiting the sun

C great speed of the stars in space

D Earth orbiting the sun.

2 Until the early 1600s, most people believed that

A the sun was the centre of the solar system

B all the planets orbited Jupiter

C all the planets orbited the Earth

D the solar system contained nine planets.

3 Which of the following is in the correct order?

A Mercury–Mars–Venus–Jupiter

B Mercury–Venus–Earth–Mars

C Mars–Venus–Jupiter–Saturn

D Venus–Earth–Jupiter–Saturn

4 The day on Mercury is very long. This is because Mercury

A is so near the sun

B is only a small planet

C orbits slowly around the sun

D rotates very slowly on its axis.

5 The photo below shows the surface of a planet taken from an orbiting spacecraft. Infer which of the planets it is, giving reasons for your choice.

A Jupiter

B Mars

C Uranus

D Mercury



6 A light-year is

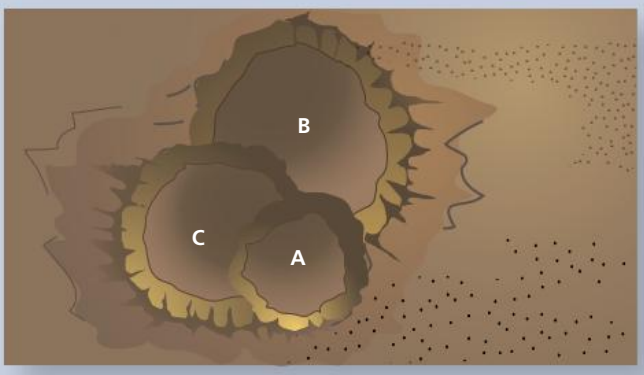
A the distance light travels in one year

B the distance from the sun to the nearest star in our galaxy

C the distance the Earth travels in one year

D the distance from the Milky Way galaxy to the nearest galaxy.

7 The drawing below shows three meteorite craters on the surface of Mercury. Infer which is the youngest and which is the oldest. Explain your answers.



8 Explain the difference between a star, a planet and a moon.

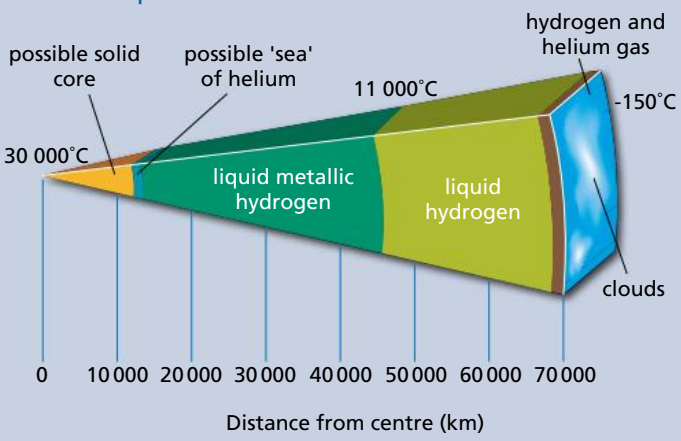
9 The diagram below is a slice of the planet Jupiter showing its inferred structure.

a Write a description of the composition of Jupiter. Which element do you think is the most abundant?

b How thick do astronomers believe Jupiter's solid rocky core is?

c Which is the thickest layer? How thick is it?

d Make a generalisation about the temperature changes from the core to the outer edge of the planet.



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 Fair tests

1 **a** hypothesis
b prediction
c generalisation
d variables
e inference

2 Here is an example.

Greg noticed that there was a python living in the rafters of his shed. He only saw the snake on warm, sunny days (*observation*). He explained this by saying that the snake is probably only active on warm days, when the sun on the roof warms the snake's body (*inference*). His hypothesis was: *Snakes are only active on warm sunny days*. From this Greg could *predict* that on warm sunny days he will see the snake. Greg could now test this by observing the snake on cloudy and sunny days and recording its behaviour.

3 **a** Aspirin dissolves faster in hot water than in cold.
b Cameron could take two aspirins, a glass of cold water and a glass of hot water, with the same amount of water in each glass. He could drop an aspirin tablet in each glass at the same time, and time how long it takes each tablet to dissolve.
c The only variable altered would be the temperature of the water.
d The variables to be controlled would be: the size of the glass, the brand of tablet, the size of the tablet, and the amount of water in the glass.

4 **a** the brand of fabric softener
b the size of the beaker and the size of the fabric sample
c the amount of water, the amount of fabric softener, the time in the solution
d No, you could not accept Debbie's results because there were three uncontrolled variables, so her results are not reliable.

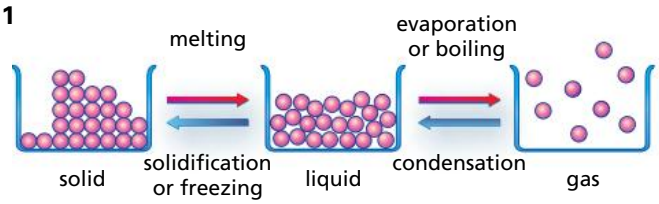
5 **a** a line of best fit
b 75 points
c 73 points
d The individual scores are not that important. The tester wants to establish whether there is a relationship between the two scores, so a line of best fit has been drawn.
e It appears that a person who has a high ability in gymnastics has a high ability in diving.

6 **a** Qualitative data use descriptions and words, whereas quantitative data contain numbers.
b The independent variable is the variable chosen by the person making the test. The tester can decide which values to use for this variable. The dependent variable depends on the independent variable.
c Column graphs are used to show when groups of things are counted or measured at a given time. Line graphs are used to show how one variable changes when you change a second variable. See page 18.
d In a Discussion you analyse the results and the method used, and discuss how accurate you think the results are. In a Conclusion you write a statement summarising your findings, or a generalisation about the results of the experiment.
e A hypothesis is a statement made from all the data, evidence and observations available. It forms the basis of a scientific test. A guess is a statement made without much thought or evidence supporting it.

7 **a** 'The orange juice needs to be stored below 4°C to keep for at least 9 days,' or 'When stored at 16°C the orange juice lasts only 1 day.'
b It will last for at least 9 days.
c The lower the temperature, the longer orange juice will last.
d At this temperature the bacteria in the orange juice will start multiplying rapidly and the orange juice will soon be undrinkable.

Chapter 2 Particles of matter

1

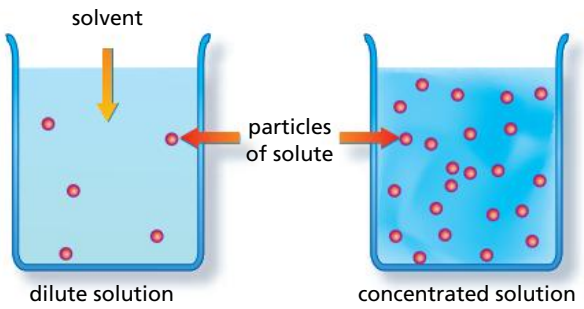


2 **A**

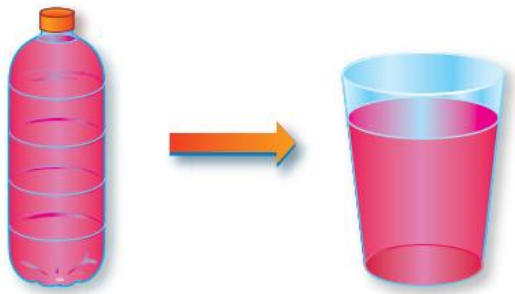
3 **D** There are *weaker* forces between the particles in the vapour.

4 **a** 2
b 3
c 4 (many atoms)
d 1 (many molecules)

5



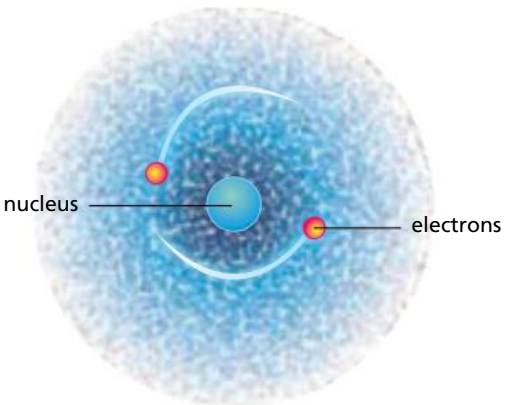
6



7 **a** Density = $\frac{\text{mass}}{\text{volumn}} = \frac{240\,\text{g}}{280\,\text{cm}^3} = 0.9\,\text{g/cm}^3$ ($1\,\text{mL} = 1\,\text{cm}^3$)

b It will float because its density is less than the density of water ($1\,\text{g/cm}^3$)

8 **a**



b 2 electrons

c 2 protons (same as number of electrons)

9 **a** The particles in gases are much more spread out than the particles in liquids or solids. There are fewer particles packed into each cubic centimetre. Hence gases have lower densities than liquids or solids.

b Dissolving occurs when the particles in the solute are knocked out of the solid by particles of solvent colliding with them (see page 37). The particles in warm water move more quickly than those in cold water. This is why they can dissolve the solute more quickly.

c The viscosity of a liquid is due to the attractive forces between its particles (see page 39). The forces between large molecules are stronger than those between small molecules. So liquids containing large molecules will be more viscous than those containing small molecules.

Chapter 3 Elements and compounds

1 **A** It contains two different elements—carbon and oxygen.

2 **a** HCl

b NO_2

c O_2

d CH_4

3 **C** Only NO_2 has nitrogen and oxygen in the ratio 1:2. The ratios of nitrogen to oxygen are:

NO	1:1	NO_2	1:2
N_2O	2:1	N_2O_2	2:2 or 1:1

4 **a** A, B, D and E are pure substances because the atoms or molecules in them are all exactly the same.

b A and B are elements. D and E are compounds.

c C is a mixture of D and E.

5 **a** Ions are atoms that have gained or lost electrons. See page 64.

b If atoms lose electrons they form positive ions. If they gain electrons they form negative ions.

c Non-metals like chlorine and iodine tend to gain electrons. Iodine ions will have a single negative charge I^-, like Cl^-.

6 **a** Barium, calcium, copper, iron and magnesium are metals (to the left of the zig-zag line in the periodic table). Argon and oxygen are non-metals (to the right of the line).

b The metals are solids which conduct electricity, whereas argon and oxygen are gases, therefore testing for electrical conductivity is one test. You could also test for lustre and malleability.

c Barium, calcium and magnesium are in the same chemical family or group (second column on the left of the periodic table).

7 **a** three: carbon, hydrogen and oxygen

b three

c 45

8 **a** B and D because they give a red flame colour.

b B because carbonate reacts with hydrochloric acid to produce carbon dioxide gas.

c C contains copper ions because it gives a bluish-green flame colour. It also contains carbonate ions because it reacts with hydrochloric acid to produce carbon dioxide gas. So compound C is probably copper carbonate.

9 **B** The tests show that the elements hydrogen,copper and chlorine are present. Kam-Sze added the copper, so the acid contains only hydrogen and chlorine.

Chapter 4 Useful materials

1 **D**, see page 75

2 **C** When you mix the two monomers A and B, a polymer is formed that consists of long chains of alternating A and B units.

3 **a** insulator, easily moulded

b light, absorbs shocks

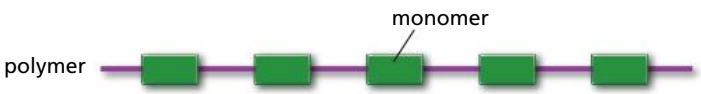
c light, easily moulded

4 **a** **A**, because there are no cross-links between the chains, which can therefore slide over each other when the plastic melts.

b **B**, because it has the most cross-links, holding the plastic together strongly.

5 See page 78.

6 A long train has many carriages linked together. Similarly, a polymer is a long chain of monomer molecules linked together as shown.



7 As you make the rubber you could bubble air into the mixture. This would leave air bubbles in the rubber and make it soft like foam rubber.

8 The outside of space vehicles and rockets gets very hot, so the heat-resistant properties of ceramics make them suitable. Other useful properties are that ceramics are relatively light compared to metals, and they resist wear and tear.

9 **a** During the extrusion process the molten plastic is forced through a ring-shaped metal die. This produces a continuous plastic pipe.

b **B**, milk bottles, because they have an uneven shape, and are closed at the end. They cannot be produced in continuous lengths like drainpipes, plastic film and roof guttering.

10 **a** Carbon (C), hydrogen (H) and oxygen (O)

b **A** and **D** both have the molecular formula C_2H_6O (two carbon atoms, six hydrogen atoms and one oxygen atom).

Chapter 5 Cells—units of life

1 cell: smallest unit or building block that makes up living things

diffusion: the movement of substances from areas of high concentration to areas of low concentration until there is an equal balance.

cell specialisation: the process by which cells change to carry out specific jobs in the body

embryo: an organism in the process of development from a fertilised egg, before birth

organ: many tissues working together to complete a specific task in the body

system: many organs working together to complete a specific task in the body

cell division: process by which some cells of multicellular organisms reproduce by splitting into two

2 **a** cells

b unicellular, multicellular

c one, two

d Hooke

e division

f diffusion

3 **a** 50X, 100X, 200X

b low power 50X; high power 200X

4 iris diaphragm: like a camera shutter which can be adjusted to control the light passing through the microscope

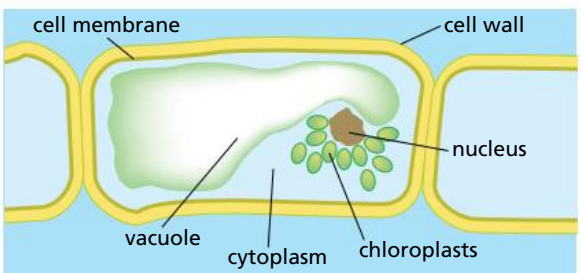
body tube: a tube to which the eyepiece and nose piece are attached

stage: a platform on which the slide is positioned with clips to hold it in place

mirror: reflects light up through the slide to the eyepiece

objective: a lens used to see the detail of the specimen; can be low power or high power

5 **a**



b It is a plant cell because it has a cell wall and chloroplasts.

c mitochondria, ribosomes, endoplasmic reticulum

6 tissue: a group of cells that have a similar structure and function, e.g. muscle tissue, connective tissue

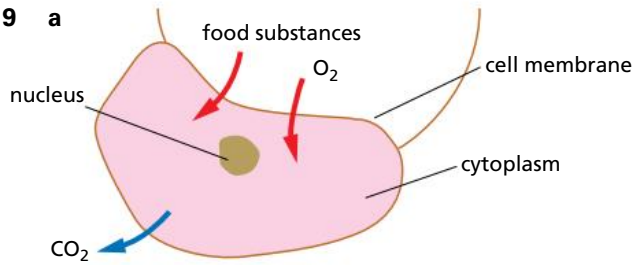
organ: many tissues working together to complete a specific task in the body, e.g. stomach, heart, kidney, liver

system: many organs working together to complete a specific task in the body, e.g. respiratory system, circulatory system, digestive system

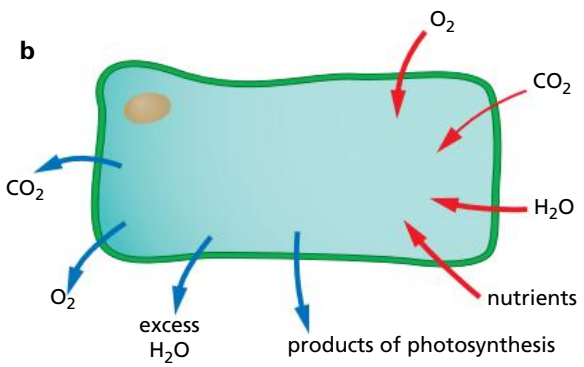
7 Cells in multicellular organisms obtain the substances they need to function by forming tissues, organs and systems, and using cell specialisation. This means that cells work together as functioning units to obtain what they need.

8 Cells are microscopic in size so that they can obtain the substances they need through *diffusion*. If they were larger it would take too long for substances to diffuse into and out of each cell.

9 a



b



Chapter 6 Plant and animal systems

1 a True

b False

c False—Animals need food.

d False—*Peristalsis* is the muscular movement that moves food along the digestive tract.

e True

2 food (glucose) + oxygen → carbon dioxide + water + energy

3 One equation is the reverse of the other. Food and oxygen are the products of photosynthesis, but they are the reactants for respiration.

4 a ovaries

c testes

b uterus

d oviduct

5 Yes—all three observations support the hypothesis. The seeds above the water line didn't grow because they had no water. The seeds below the water line didn't grow either, because they had no oxygen (air). The seeds on the water line grew because they had both water and oxygen.

6 Yes—During photosynthesis plants use sunlight to make food, and all animals rely on this food.

7 How does it obtain its food?

Does it have chlorophyll in its cells?

Does it make food in its cells and does it release oxygen from its body?

Are carbon dioxide and water used up in its cells?

8 a proteins → amino acids

b starch → glucose

c fats → fatty acids and glycerol

9 *Digestive system*:

A mouth

C small intestine

B stomach

D large intestine

Respiratory system:

A trachea

B alveoli

C diaphragm

10 The kidneys remove wastes such as urea and excess water from the blood, and store it in the bladder before being expelled as urine. Carbon dioxide is expelled from the lungs.

11 Reproduction in some plants and animals occurs when a male and a female sex cell join, but some can produce asexually, without the joining of male and female sex cells. In flowing plants, the male and female parts are both found in the flower and insects are needed to carry pollen from the male stamen to the female pistil. On the other hand, animals are mainly male or female. Once the female egg is fertilised by the male sperm it becomes an embryo which devlopes to form a baby animal. In flowering plants and conifers the fertilised egg becomes a seed which germinates.

Chapter 7 Heart and blood

1 a true

b false—Capillaries are one cell thick but veins are much thicker.

c true

d false—White blood cells fight foreign substances in the body.

e true

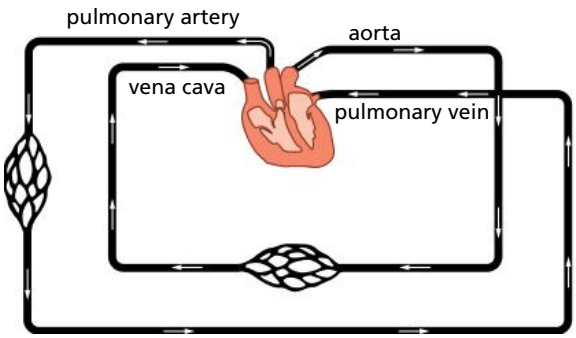
2 **a** An artery carries blood away from the heart. A capillary is a small vessel that connects arteries to veins and allows the exchange of materials in cells.

b The left atrium is the chamber that collects blood returning from the lungs via the pulmonary vein. The right atrium is the chamber that collects blood returning from the body via the vena cava.

c Red blood cells carry oxygen around the body. White blood cells fight invaders.

d The aorta carries blood from the heart to the rest of the body. The pulmonary artery carries blood from the heart to the lungs.

3 **a** and **b**



c Valves will be found in veins, between the atria and ventricles, and where the main arteries leave the heart.

4 **a** a capillary, because it is only one cell thick

b This is where the exchange of materials takes place between the blood and the body cells.

5 **a** **P** artery **R** capillary
Q cell **S** vein

b artery: carries blood away from the heart to the body

cell: one of the small building blocks that make up the body

capillary: small blood vessel linking an artery to a vein

vein: carries blood back to the heart from the body

c It shows what happens in the capillaries.

6 **a** Risk factors for heart disease: high blood pressure, lack of exercise, poor diet, smoking

b Get your blood pressure checked regularly as you get older and avoid fatty foods; exercise for at least 30 minutes a day; eat a diet high in fibre, fruit and vegetables; don't smoke.

7 135/80 means that Peter's blood pressure is normal. Blood pressure is measured and recorded as a fraction, e.g. 135/80 or 135 over 80. Both numbers in the fraction are measured in millimetres of mercury. The first number of the fraction indicates the point at which the pressure in the arteries is at its highest. This is the contraction phase of the heart cycle. The bottom number of the fraction indicates when blood pressure in the arteries drops.

Chapter 8 Using energy

1 **B**

2 **C**

3 **B**

4 **D**

5 **A**—The law of conservation of energy says that energy cannot be made.

6 **A**—Heat energy is transferred from the hot coffee to the cup, but it doesn't change its form.

7 Renewable: ocean waves, the sun, wind, wood

Non-renewable: coal, diesel fuel, LPG gas, uranium fuel

8 **a** The other 95 joules is wasted as heat energy.

b Efficiency of light bulb $= \frac{\text{useful energy}}{\text{input energy}} \times 100$

$= \frac{5}{100} \times 100$

$= 5\%$

9 People often say that electrical energy is made in power stations, but according to the law of conservation of energy, energy cannot be made—you can only change it from one form to another. In a hydro-electric power station you are converting the kinetic energy of falling water into electrical energy. So Sam is incorrect.

10 chemical energy in wood → heat energy → kinetic energy of steam → kinetic energy of spinning wheel → electrical energy in generator → light (and heat) energy in bulb

Chapter 9 Heat energy

1 **A** conduction

2 **a** true

b false—Dull black surfaces are good *absorbers* of heat.

c false—Heat is measured in *joules*.

d false—Heat travels from *hot* objects to *cold* objects.

e false—The hotter an object is, the *more* radiation it emits.

f false—The sun transfers heat energy to the Earth by the process of *radiation*.

g true

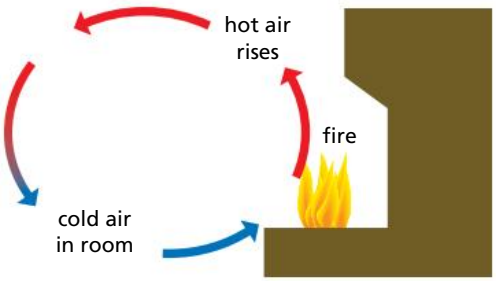
3 **a** The teaspoon is colder than the coffee, so heat travels by conduction from the hot coffee to the spoon.

b Plastic is an insulator of heat, whereas the metal spoon is a conductor.

4 **a** The room is at 26°C and outside is 10°C, so heat will move from hot to cold, and the room will get colder.

b Heat moves from a hot area to a cold area until the two areas are the same temperature (see page 189). The room will eventually cool down to the outside temperature of 10°C.

5



6 **a** Sweat evaporates from the surface of your skin and this produces cooling. See page 129.

b The breeze from the fan makes the sweat on your skin evaporate faster, producing more cooling. See page 129.

7 Refrigerators and freezers are white or stainless steel because these surfaces reflect heat rather than absorb it. The cooling coils at the back are black so that they radiate heat and cool down. See page 198.

8 **a** As heat travels along the rods the wax melts. Copper is the best conductor because the most wax has melted from this rod.

b Plastic, since the least amount of wax has melted from it.

c Iron is a better conductor than glass, so the food would cook more quickly in an iron casserole dish.

d If a saucepan has a copper base it will heat up more quickly, because copper is a good conductor of heat.

e Copper is a much better conductor of heat than plastic, so the water is more likely to freeze in the copper pipe.

9 **a** about 61°C

b about 8 minutes

c about 6°C

d Mug A is a better insulator because the coffee in it doesn't cool as rapidly as in mug B.

e Eventually both mugs will reach room temperature, which is 20°C.

10 Heat and light are both forms of radiation. They travel in straight lines and can move through empty space as well as through transparent matter such as air and glass. Heat radiation, however, has a longer wavelength than light.

Chapter 10 Rock hunting

1 **C** a mixture

2 **C** is the best answer, although **A** is an example of weathering

3 **A** basalt

4 **C** This is an inference based on the depth of the gorge and observations of how rapidly rocks weather.

5 Coal, conglomerate, granite and slate are rocks. Calcite, diamond, mica and quartz are minerals.

6 **a** igneous rocks

b metamorphic rocks

c sedimentary rocks

7 Concrete is like a sedimentary rock, formed by the cementing together of sand and gravel.

8 **a** All three layers are sedimentary—formed from sediments deposited in water.

b The conglomerate is likely to have been formed during a flood, when the streams could carry large pebbles.

c The sandstone probably formed when streams flowed quietly into a shallow inland sea.

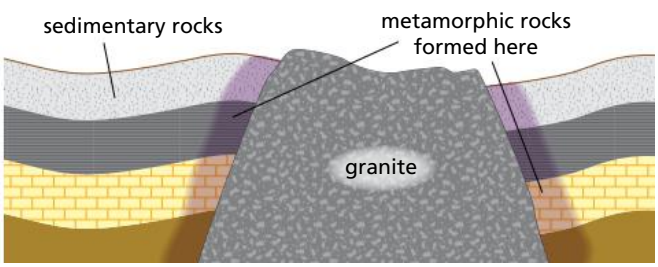
d The shale is the youngest layer because it is on the top.

9 **a** intrusive igneous

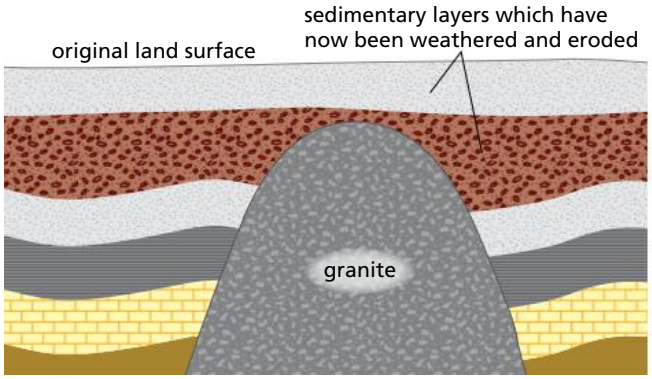
b The granite formed when magma cooled deep underground.

c The layers of sedimentary rocks have been slightly folded (bent).

d The sedimentary rocks in contact with the red hot magma may have been changed to metamorphic rocks, as shown.



e



10 There are huge forces inside the Earth that slowly push the crust up to form mountains. When this happens metamorphic rocks that were formed deep in the crust can be uplifted to the surface where they can be exposed by weathering and erosion.

11 The rocks in the Blue Mountains are sedimentary. Over millions of years streams have eroded a valley through these rocks. The rock in the Three Sisters is probably harder than the surrounding rocks and hasn't yet been eroded away.

Chapter 11 Mining

1 **a** crystals
b ore
c metals
d native

2 **a** compound (aluminium oxide)
b element
c compound
d element

3 **a** Froth flotation
b The crushed ore is added to flotation cells which contain chemicals. Bubbles of air are forced up through the flotation cell from the bottom. The copper sticks to the air bubbles and floats to the surface where it is collected.

4 **a** silicon, oxygen, sodium, carbon, calcium
b Glass does not have crystals, so it is not a mineral. It is a supercooled liquid.
c Lead is added to the glass to make it heavier, stronger and less brittle.

5 **a** The reactants (on the left-hand side of the equation) are iron oxide and carbon monoxide. The products (on the right-hand side of the equation) are iron and carbon dioxide.
b Heat is needed to make the reaction go, as indicated by HEAT on the left-hand side on the equation.
c iron
d three—iron, carbon and oxygen (in the oxides)

6 Mining can harm the environment, so mining for the materials to make solar cells will affect the environment. Manufacturing solar cells will also affect the environment because metal, glass and plastic are needed and the cells have to be processed. This is not much different from fossil fuels, because fossil fuels also have to be mined and processed.

The difference occurs when these products are used. Solar cells do not affect the environment when they are used, whereas fossil fuels do. They don't use up non-renewable fossil fuels or add carbon dioxide to the atmosphere.

7 **a** Open-cut mining, because the land has been cut away on the surface.
b Environmental concerns would be run-off, erosion and leaching.

Chapter 12 Investigating space

1 **A**

2 **C**

3 **B**

4 **D**—The length of the day is determined by the time the planet takes to rotate on its axis.

5 **B**—The surface appears solid so it cannot be Jupiter or Uranus. It has few craters, unlike Mercury's surface. There are canyons which could indicate flowing water in the past. From this you can infer the planet is Mars.

6 **A**

7 The youngest crater is A because it is on top of the other two. The oldest crater is B because the others have been formed on top of it.

8 A star is a large body in space which emits light, similar to our sun. A planet is a smaller body orbiting a sun. A moon is an even smaller body orbiting a planet.

9 **a** Jupiter is composed mainly of hydrogen, mostly in a liquid state. It also contains some helium, and possibly has a solid rocky core.
b Jupiter's solid core is estimated to be 25 000 km in diameter (12 500 km × 2).
c The thickest layer is the liquid metallic hydrogen layer which is about 33 000 km thick.
d The temperature decreases as the distance from the centre increases.

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, foetus (FEE-tus).

activity series a list of the order of reactivity of metals, from the most reactive to the least reactive 235
air pressure the force per unit area caused by fast-moving particles of air hitting a surface 39
alveoli the air sacs in the lungs where gases move into and out of the blood 126
antibodies substances in the body that fight bacteria and disease-causing organisms 145
antigens foreign substances in the body; these can be bacteria and other disease-causing organisms, or the toxins or poisons produced by them 145
aorta the major artery leaving the heart; this artery then branches into smaller arteries to carry oxygen-rich blood to the body cells 147
arteries vessels or tubes that carry blood away from the heart 147
asteroids tiny chunks of metallic rock found orbiting the sun in a wide belt between Mars and Jupiter 266
atoms tiny invisible particles that make up all matter 25
atria (singular atrium) one of two blood collecting chambers in the human heart; blood flows from veins into the atria 152

biodegradable able to be broken down by organisms in soil or water 79
blast furnace a huge oven which blasts air to achieve hotter temperatures; it is used to make iron 241
bronchi (singular bronchus) two large tubes that lead from the trachea to each lung 126
bronchioles smaller tubes in the lungs that lead from the bronchi to the alveoli 126

capillaries a small, fine network of narrow blood vessels in the body, linking arteries to veins 147
cell division a process in which some cells of multicellular organisms reproduce by splitting into two 109
cells smallest units or building blocks that make up all living things 94
ceramics materials such as pottery and porcelain that are hard and rigid, resistant to heat and chemicals, and good insulators 86
chemical bonds forces that hold atoms together 42
circulatory system the system that carries oxygen and nutrients to all cells in the body and takes wastes away from the cells; it consists of the heart, blood vessels and blood 143
comets small bodies which orbit the sun in elongated elliptical orbits; they usually have long glowing tails 264
compound a pure substance that contains two or more elements combined in a fixed ratio; it can be broken down into its elements by chemical reactions 56
concentrated (CON-cen-TRAY-ted) describes a solution containing a large amount of solute, compared with other solutions 37
conduction the transfer of heat energy from one particle to another, which occurs when the particles are very close together, as in a solid 190
conductor a material that allows heat or electricity to move through it easily by conduction 189
conservation of energy this law says that energy cannot be made or destroyed—it can only be changed from one form to another 177
conservation of matter 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 61
constellation a group of stars that forms an unchanging pattern in the sky 253
consumer an organism that eats other organisms 118
control part of an experiment not allowed to change; results obtained in the experiment are compared with this control 11
controlling the variables designing a scientific test so that all the variables that could influence the outcome of the test are kept the same 12
convection the transfer of heat in a liquid (or gas) by the movement of particles, when less dense liquid rises and more dense liquid flows in to take its place 193
crystal solid substance in which the invisible particles are arranged in such a way as to produce definite shapes, e.g. sugar crystals 212

density how much matter is packed into a measured volume; it is measured in grams per cubic centimetre 28
detergent synthetic compound with cleaning properties similar to soap 75
diaphragm a sheet of muscle underneath the lungs that draws air into and out of the body by being flattened and arched 125
dicots (dicotyledons) plants which have two first leaves that form from the seed 136
diffusion the movement of substances from areas of high concentration to areas of low concentration until there is an equal balance 38
digest to break down food into a smaller, more useable form 122
digestive system the organs or parts of the body that work together to break down food into a smaller, more useable form 122

dilute (dye-LOOT) describes a solution containing a small amount of solute, compared with other solutions 37
dissolves when two or more substances mix completely, so that they appear as one; e.g. coffee dissolves in water 35
dwarf planet similar to a planet, but smaller, and shares its orbital space with other bodies of a similar size; at present there are 5 dwarf planets, including Pluto and the asteroid Ceres 261

ecliptic (ek-CLIP-tick) the path followed by the Sun, planets and the constellations of the zodiac in their apparent movement across the sky 254
efficiency a measure of how well a machine uses the energy put into it; a perfect machine would have an efficiency of 100% 177
elastic able to return to its original shape and size after being stretched 81
elastic potential energy the energy stored in compressed or stretched springs or other elastic devices 167
electrons tiny particles carrying a negative charge; they surround the nucleus of an atom 43
element a pure substance made up of only one type of atom; it cannot be broken down into simpler substances by chemical reactions 49
embryo an organism in the process of development from a fertilised egg, before birth 109
energy the ability to make things happen or cause changes; light and sound are two of the many forms of energy 117
energy chain a series of steps in which energy changes form, e.g. chemical energy → heat energy → kinetic energy 172
epiglottis (EP-ee-glot-is) flap of tissue that covers the top of the windpipe or trachea when swallowing 125
equilibrium (equal-LIB-ree-um) the condition of a system in which competing influences are balanced, resulting in no net change
erosion the process by which weathered material is carried away by water; wind and ice can also cause erosion 217
evaporation (e-VAP-or-AY-shun) the process in which a liquid turns into a vapour (gas) and seems to disappear 30
excretion the removal of excess water and waste from cell reactions in the body 128
extrusive type of igneous rock formed from lava that hardened on the Earth's surface, for example basalt 222

faeces (FEE-sees) the undigested waste material from the digestive system 128
fair test an experiment to test a hypothesis where only one variable is altered and all the other variables are kept the same or controlled 12
fault a break in the Earth's crust along which rock slides in opposite directions 237
fertilisation the joining of male and female sex cells, e.g. sperm and egg 133
field of view the diameter of the area that you can see when looking through a microscope 96
foetus (FEE-tus) young animal growing in the uterus 132
formula (chemical) a group of symbols and numbers indicating the elements in a compound and the ratio of these elements; for example H_2O 58
fossil fuels fuels such as coal, oil and natural gas which take millions of years to be made by processes in the Earth 176
fossils the preserved remains or traces of past life on Earth, buried in rocks 221

galaxy a large group of stars that is separated from other similar groups by empty space 267
generalising making a statement that is true most of the time 6
gravitational potential energy the energy stored in a raised object 167

heat a type of energy that can raise the temperature of an object; it is measured in joules 191
hypothesis (high-POTH-e-sis) a statement that explains why something might always happen, based on all available evidence and observations; it can be tested by experimenting 9

igneous rock (IG-nee-us) rock formed by the cooling and hardening of molten rock 222
inference an explanation for an observation 6
insulator material that does not allow the movement of heat through it 78
intrusive type of igneous rock that formed from magma that hardened beneath the Earth's surface, for example, granite 224
ion (EYE-on) an atom that has a positive or negative charge, caused by the loss or gain of electrons 64

joule (J) the unit for measuring energy (and work) 174

kinetic energy (kin-ET-ic) the energy that a moving object has 166

larynx part of the throat used for the production of sound; often called the voice box or Adam's apple 125
lava hot molten material that flows from beneath the Earth's crust onto the surface, usually from volcanoes; it cools to form extrusive igneous rocks 222
light-year an astronomical unit that is used to measure the huge distances between stars; it is the distance light travels in one year 267

lithosphere the rigid outer layer of the Earth; it includes the crust and the upper part of the mantle 227
lymph fluid from body tissues, which returns to the circulatory system through special vessels called lymph vessels that link to form the lymphatic system 145

magma molten rock inside the Earth 222
mass the amount of matter in an object; it is measured in kilograms 26
matter anything that has mass and occupies space 26
menstuation (MEN-strew-AY-shun) the monthly shedding of the lining of the uterus; also known as having a period 131
metals elements which are usually hard, shiny, silver-grey in colour and good conductors of heat and electricity; they usually lose electrons to form positive ions and are on the left-hand side of the periodic table 52
metamorphic rock (met-a-MOR-fik) a type of rock formed from other rocks by the action of heat and pressure 226
meteorites pieces of rock or metal from space that crash into planets or moons 264
meteors small fast-moving objects from space that burn up in the Earth's atmosphere 264
minerals naturally occurring solid substances that are usually chemical compounds; they are the building blocks of rocks 212
model a way of representing something that cannot be observed directly because it is too small, too large or too complicated, e.g. a model of a molecule 31
molecules tiny particles containing two or more atoms; there are a set number of atoms in a molecule, e.g. H_2O 42
monocots (monocotyledons) plants which have a single first leaf that forms from the seed 136

nebula (NEB-you-la) a huge mass of dust and gas in space remaining after a supernova 269
neutrons uncharged particles in the nucleus of an atom 43
non-metals elements which do not have the properties of metals and tend to be poor conductors of heat and electricity; they usually gain electrons to form negative ions and are on the right-hand side of the periodic table 52
non-renewable energy energy resources that cannot be replaced, e.g. coal and oil 176
nucleus (atom) the positively charged centre of an atom; it contains protons and neutrons 43

oesophagus tube leading from the mouth to the stomach 123
ore mineral-containing rock that is suitable for mining and mineral extraction 234
organ many tissues working together to complete a specific task in the body 104
ovulation the release of a developed egg from a follicle in an ovary 131
ovule a flower structure which contains an egg cell and develops into a seed after fertilisation 135

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 25
periodic table a listing of the elements in order of their atomic number (size); elements are grouped according to their chemical properties 49
pharynx (PHA-rinks) throat cavity between the mouth and windpipe; it also connects the mouth and oesophagus, where swallowing occurs 125
phloem (FLOW-em) the tubes or vessels in a plant that carry the products of photosynthesis to where they are needed 158
pistil the female reproductive part of a flower made up of the stigma, style and ovary 135
placenta the part of the body that connects the mother to the baby and through which the baby is nourished 132
plasma the liquid or fluid part of the blood 144
plastics materials that can be moulded when hot; most plastics are synthetic 76
platelets component of blood, responsible for clotting 145
pollination the movement of pollen from an anther to a stigma of a flower 135
polymerisation (pol-IM-er-eyes-AY-shun) a type of chemical reaction in which many small molecules (monomers) link up to form a giant molecule (polymer) 76
polymers compounds made from small units called monomers; poly means 'many' and mer means 'units', so polymer means 'many units' 76
potential energy stored energy, such as chemical energy, available to be converted to other forms 167
prediction a future prediction based on past observations and knowledge 6
producer an organism that makes its own food using the energy of sunlight 118
protons positively charged particles in the nucleus of an atom 43
puberty when a person reaches sexual maturity; when sexual characteristics develop and the person is able to reproduce 131
pulmonary artery an artery leading from the right ventricle which branches to carry blood to the lungs 152
pulmonary vein a vein leading from the lungs which carries blood back to the heart 152

radiation the transfer of heat or light as waves through space (or air) 196

radioactive dating the method of finding the actual age of a rock by measuring the proportions of radioactive elements in it 228
red blood cells red cells in the blood that contain haemoglobin and carry oxygen to the tissues 104
rehabilitation restoring land after mining to its original condition (as close as possible) 244
renewable energy energy resources that can be replaced, e.g. solar energy 176
rock cycle the slow process by which rocks are constantly being formed and changed from one type into another 227

saturated solution a solution that contains the maximum amount of solute that will dissolve at that temperature 37
scientific method the steps or processes involved in carrying out a scientific investigation 3
sediment insoluble substance that settles to the bottom of a suspension 35
sedimentary rock a type of rock formed by the cementing together and hardening of rock particles (sediments) 219
semen (SEE-men) the fluid containing sperm produced by a male 131
sexual reproduction the meeting of male and female sex cells, e.g. egg and sperm, to produce offspring 131
smelting extracting a metal from its ore 240
solute a substance that dissolves in a solvent to form a solution 35
solution a mixture of two or more substances that looks as though it is all one substance, due to the solubility of one or more solutes in a solvent 35
solvent a substance that can dissolve other substances 35
specialised carrying out only one job or function; specialised cells carry out a specific job in the body 104
stamen the male reproductive part of a flower, made up of the anther and the filament 135
stem cells unspecialised cells that can divide when needed to produce new cells 109
stomata (singular stoma) pores or holes in the surface of a leaf that control the movement of gases such as carbon dioxide into and out of the leaf 128
supernova an exploding star, much brighter than a normal star 268
suspension a mixture in which tiny bits of solid (or liquid) are evenly spread through a liquid (or gas), but are not dissolved; if allowed to stand, the suspended matter slowly settles out 35
sustainable an activity is sustainable if it can be continued for a very long time without damaging the environment or using up our natural resources 79
system many organs working together to complete a specific task in the body 104

temperature how hot or cold something is; it is measured in degrees Celsius 191
theory what a hypothesis becomes after it has been supported by the results of many experiments 25
thermoplastic a plastic that can be melted and remoulded repeatedly 77
thermoset a plastic that cannot be remoulded after the initial heating and moulding process 77
tissue a group of cells that have a similar structure and function 104
trachea (track-EE-a) windpipe or tube leading from the mouth to the lungs 125
transpiration the process in which water evaporates from the surface of a leaf 158

urine liquid waste expelled by a living organism; it contains excess water, urea, and minerals 128

variables factors that can affect the outcome of an experiment 9
veins vessels or tubes that carry blood towards the heart; these tubes contain valves which allow blood to flow in one direction only 148
vena cava either of two large veins that carry deoxygenated blood into the right atrium of the heart 152
ventricles one of two muscular chambers in the human heart that force blood from the heart into the arteries 152
verified found to be true; if an experiment is repeated, with the same results, the results are said to be verified 17
viscosity a measure of how easily a liquid flows 39
vocal cords folds of membranes in the larynx that can be relaxed and tightened to produce different sounds 125
volume the amount of space occupied by a solid, liquid or gas 26
vulcanisation the process of heating raw rubber with sulfur to make it strong and flexible 81

weathering the breakdown of rocks by weather; in physical weathering the rocks are simply broken into smaller pieces, while in chemical weathering the minerals in the rocks are changed by chemical reactions 215
wet-mount microscope slide that is prepared by adding a drop of liquid to a very thin slice of tissue, then covering it with a cover slip 97
white blood cells colourless cells in the blood that defend the body against disease 145

xylem (ZI-lem) the tubes or vessels in a plant that carry water from the roots to the leaves 158

Index

Aboriginal
  astronomy 253, 256
  Dreamtime stories 264
activity series 235
adaptations 200
air quality (at mines) 244
air pressure 39
alcohol (making it) 72
alveoli 126
anaemia 145
aorta 152
arteries 147
Archimedes 44
asexual reproduction 136
assignments (doing better ones) 139
asteroids 266
astrology 254
astronomy (history of) 256–257
atoms 42–43, 49, 64
atria 152

Baekeland, Leo 76
bakelite 76–77
balance (measuring mass) 27
Bell, Alexander Graham 2
Benedictus, Edouard 87
binocular microscope 95
biopolymers 79–80
BiVACOR 156
blast furnace 241
blood 144–146
blood pressure 148–149
boiling 30, 32
Breadknife 224
Bruno, Giordano 256
buckyballs 54–55

cancer 109–110, 113
capillaries 147
carbon dioxide test 72
carbon fibre 89
cardiovascular disease 142
casein 76
cells 94, 101–103
  division 109
  drawing them 98
  parts 101
  processes 107
  size of 108
ceramics 86
cervical cancer 116
Chang, Dr Victor 155
changes of state 30, 32
chemical energy 167
circulatory systems
  earthworm 158
  human 152–157
clay (pottery) 86
cleavage of minerals 213–214
coal
  formation 220
  mining 237–238
comets 264
compounds 56
  breaking them 62–63
  making them 60–61
concentration 37
conclusions 17, 20
condensation 30
conduction 189–190
conductors 189
conservation of energy 177
conservation of matter 61
constellations 253–254
control 11
controlling variables 12
convection 193–195, 202
Coolgardie safe 205
cooling (body) 129, 199
Copernicus, Nicolaus 256
copper ions 64, 66
copper smelting 240
cowpox 4
CREST awards 16
cross-links (in polymers) 77, 81
crystals 39–40, 212–213
CSIRO 16

Dalton, John 49
Da Vinci, Leonardo 130
death (causes) 151

density 28–29
  of minerals 213
deoxygenated blood 152
dependent variables 18, 150
detergents 75
diamond 54
dicots 136
diffusion 38, 107
digestion 122
digestive systems
  bird 124
  earthworm 123
  hydra 123
  human 122
discussion of results 17, 175
dissolving 37
distillation (of alcohol) 72

ecliptic 254
Edison, Thomas Alva 2
efficiency 177
elastic potential energy 167
electrical energy 167
electron microscope 100
electrons 43
electroplating 243
elements 49–52
  in Earth's crust 57
  in human body 57
elodea cells 102
embryo 109, 132–133
energy 165–167
  from food 117, 174–175
  measuring it 174
  non-renewable 176
  renewable 176
  transfers 171
  transformations 169–170
energy chains 172, 177
energy converters 169
energy efficiency 177
energy values 174
enzymes 74, 122
erosion
  by water 217
  by wind and ice 218
  coastal 218
evaporation 30, 32
  and cooling 129
excretion 128
excretory system (human) 128–129
expansion and contraction 38
experiments (designing) 13–15, 120
extraterrestrial life 269
extrusion (of plastics) 78, 92

fair tests 11–12, 120
Faraday, Michael 2
female reproductive system 131
fermentation 72
fertilisation 132–133
fibreglass 88
fibres 84
  making them 83
field of view (microscope) 96
flame tests 53
Fleming, Sir Alexander 3
Florey, Sir Howard Walter 3
flow diagrams 238
flowers
  dissection 136
  parts 135–136
foetus 132
formulas (chemical) 58, 65, 73
fossil fuels 176
fossils 221, 228
Franklin, Benjamin 2
froth flotation 240–241

galaxies 267–268
Galileo 257
gemstones 214
generalising 6
gills (in fish) 127
glass 86, 88
glue goo 71, 89
Goodyear, Charles 81
goose bumps 199
granite 212
graphite 54
graphs 18
grasshopper (excretion) 128
gravitational potential energy 167

haemophilia 145
half-life 228
hardness of minerals 213

heart 152
  artificial 156
  dissection 154
  rap 157
  rate 152
  transplant 142–143
heat 166, 189–190, 202
heat energy 167
heat exchanger (in duck) 201
heatstroke 199
Herschel, Caroline and William 257
Hooke, Robert 99
Hu, Dr Eric 205
human body problem 115
hydrocarbons 73
hydrogen test 62
hypertension 148
hypothermia 199
hypotheses 9, 14, 120

igneous rocks 222–224
  extrusive 222
  intrusive 224
  uses 224
independent variables 18, 150
inferences 6–8
injection moulding 78
insulators 189, 202
internet (using it) 181
interpreting
  data 150–151
  diagrams 204
ionic compounds 64–65
ions 64–66
iron for breakfast 48, 66
iron (making it) 241
iron sulfide 60–61

Jenner, Edward 4
joules and kilojoules 174
Jupiter 261–262

Keogh, Professor Anne 155
Kevlar 89
kinetic energy 166

latex (rubber) 81
lava 222
lava tubes 222–223
leaching (of mine wastes) 244
Leeuwenhoek, Anton van 99
light energy (solar energy) 166, 176
light-year 267
line of best fit 18
lung capacity 127
lustre of minerals 212

male reproductive system 131
Mars 259–260, 262
mass (measuring it) 27
matter 26
melting 30, 32
Mendeleev, Dimitri 49, 52
menstruation 131
Mercury 259, 262
metalloids 52
metals 52–53, 234–236
  reactivity 235
metamorphic rocks 226
meteors and meteorites 264–265
methane molecule 73
microscope 95–96
  binocular 95
  electron 100
  monocular 95
  preparing slides 97
Milky Way 254, 267
minerals 212–214, 234
mining in Australia 237–239
mixtures 56
models 31–32, 43
molecular models 58, 73
molecules 42, 56–57
monocots 136
monofilaments 84
Morse code 2
Morse, Samuel 2
mousetrap racer 164

nanotechnology 42
nebulas 269
Neptune 261–262
non-metals 52–53
non-renewable energy 176
novas 268
nuclear energy 167
nucleus (atom) 43
nylon (making it) 83

observations 4–5
  recording them 19
onion cells 102
organs 104
Orion (Saucepan) 253
oxygenated blood 152

particle theory 31–32, 38–39
penguin huddling 201
penicillin 3
periodic table 49–52
phloem tubes 158
photodegradable (plastics) 79
photosynthesis 107
pistil 135–136
planets
  around other stars 269
  data on 262
  inner 259
  observing them 263
  orbiting sun 258
  outer 261
plasma (blood) 144
plastics 76–80
  advantages and disadvantages 78
  biodegradable 79–80
  dissolving 79–80
  shaping them 77–78
platelets 145
Pluto 261
Pointers (stars) 253–254
pollination 135
polymerisation 76
polymers 76–77
polystyrene packing foam 79–80
potential energy 167
predictions 6–8
pregnancy 133–134
projects (science) 180–182
PSZ (partially stabilised zirconia) 86
Ptolemy 256
pulmonary artery 152
pulmonary vein 152
pulse 159
pure substances 56

radiation 196–198
  absorbers and emitters 197–198
  properties of 196
  types of 196
radioactive dating 228
rap song 157
rayon (making it) 85
recycling 79
  of car tyres 82
red blood cells 104
rehabilitation 244–245
renewable energy 176
report writing 17, 19–20
reproductive cycles 134
reproductive system 131
respiration 69, 107
respiratory systems
  fish 127
  human 125–126
risk assessment and planning 17
rocks 212
  age of 227–228
  collecting them 210–211, 214
rubber 81–82
  explaining it 81
  thermoplastic 82

safety glass 87
  making it 88
sandwich structure 89
saturated solutions 37
Saturn 261–262
Schonbein, Christian 76
scientific method 3, 13–14
Scorpio (Scorpion) 253
sea breeze 194
sedimentary rocks
  formation 219–220
  making them 220
  uses 220
sediments 219
seeds (distribution) 135, 137
semen 131
SETI 269
sexual reproduction 131–134
silk (spider) 84
skin 129
skin cancer 93, 109–110
skin cells 103
Skyllas-Kazarcos, Maria 179
slag 240–241
smallpox 4
smelting 240–241

soap
  how it works 75
  making it 74
soap films 24
sodium chloride 61, 65
solar ice maker 205
solar water heater 187, 207
soluble and insoluble 35–36
solutes 35
solutions 35
solvents 35
South Celestial Pole 255
Southern Cross 253–254
space probes 258
space tourism 252, 268
spinnerets 84
spirogyra cells 102
stamen 135–136
starch packing foam 80
stars 254
  colour of 267
  movement of 255
  travel to nearest 268
states of matter 26
steam 30
steel (making it) 242
steel products 243
stem cells 109, 111–112
stomata 107, 128
streak of minerals 213
structural formulas 73
sublimation 30
sun (as star) 254
  diameter of 255
supernovas 268
surface tension 75
surfboards 88–89
suspensions 35
sustainability 79
sweating 129, 199
systems (body) 104

Taylor, Dr Graham 246
telescopes 258
  making one 257
temperature 188, 191
terraforming (Mars) 260
therapeutic cloning 111
thermals 195
thermometers 188
thermoplastics 76–77
thermos 204
thermosets (resins) 77
Timms, Dr Dan 156
tissues 104–105
Tnorala comet 264
trachea 125
transpiration 158–159
twins 132

understanding on three levels 260
unicellular organisms 102–103
universe 267
Uranus 261–262
urine 128
uterus 131

vaccination 4
vanadium battery 179
variables 9–12, 120
veins 148
vena cava 152
ventricles 152
Venus 259, 262
verifying results 17
villi 122
viscosity 39
volcanoes 222–224
vulcanisation 81

wasted energy 177
water bag 205
water vapour 30
wavelength (of radiation) 196
weathering 215–216
  chemical 216
  physical 215
Weipa case study 245
Werner, Dr Cindy 225
wet-mounts 97
white blood cells 145

xylem 158

zodiac 254

Macmillan

Science Essentials 8 Australian Curriculum edition

Developed specifically for the Science Australian Curriculum, this new edition of *Science Essentials* includes full coverage of the Science Understanding, Science as a Human Endeavour and Science Inquiry Skills strands, as well as Overarching Ideas and General Capabilities.

Science Essentials integrates knowledge, skills and Science processes to create a deeper understanding of Science and its relationship to the world. Chapter introductions present real-life problems to be investigated, building knowledge and providing the means to solve them through activities, articles and assignments.

Key features

- investigative, problem-solving and thinking curriculum approach
- effectively links science to real-life applications
- hands-on inquiries and investigations
- skill sections that develop a variety of practical and theoretical skills
- scientists-at-work case study in every chapter
- thinking skills questions that check depth of knowledge and understanding
- self-management section and checkpoint questions at the end of each chapter, which help to summarise and revise that chapter.

OneStopScience

www.OneStopScience.com.au

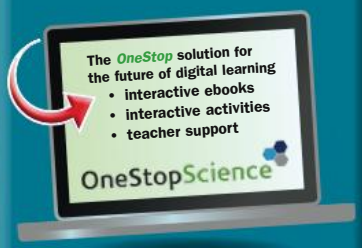
Included in this textbook is a code that provides access to the ebook version of *Science Essentials 8 Australian Curriculum edition* and OneStopScience student support:

- an interactive ebook copy of the student book, linked to supporting resources
- online testing to enhance learning
- drag-and-drop activities, animations, simulations, crosswords, worksheets and much more.

OneStopScience teacher support

Purchasing access to the OneStopScience teacher support provides a wealth of materials to save you time and effort, including:

- an interactive ebook version of the student book, linked to supporting resources
- an electronic markbook to track student results for the online review tests
- downloadable teacher resources, including curriculum guides and assessment support
- the ability to create and share your own activities using OneStopBuilder
- presentations, drag-and-drop activities, animations, simulations, crosswords, worksheets and much more.



www.onestopscience.com.au

www.macmillan.com.au





Also available

Science Essentials 7
978 1 4202 2973 8

Science Essentials 7 Digital-only version
978 1 4202 3039 0

Science Essentials 7 Online teacher support
978 1 4202 2998 1

Science Essentials 8
978 1 4202 2974 5

Science Essentials 8 Digital-only version
978 1 4202 3040 6

Science Essentials 8 Online teacher support
978 1 4202 2999 8

Science Essentials 9
978 1 4202 2975 2

Science Essentials 9 Digital-only version
978 1 4202 3041 3

Science Essentials 9 Online teacher support
978 1 4202 3000 0

Science Essentials 10
978 1 4202 2976 9

Science Essentials 10 Digital-only version
978 1 4202 3042 0

Science Essentials 10 Online teacher support
978 1 4202 3001 7

ISBN 978-1-4202-2974-5
9 781420 229745