PEARSON science

# S.B.



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# Contents


Acknowledgements iii
How to use this book x
Verbs xii



## 1 Working with scientific data

1.1 First-hand data 2
1.1 Unit review 7
1.1 Practical activities 9
1.2 Second-hand data 11
1.2 Unit review 15
1.2 Practical activities 16
1.3 Presenting and analysing data 18
1.3 Unit review 23
1.3 Practical activities 25
1.4 Planning your own scientific research 27
Science as a human endeavour 30
*The pendulum* *30*
1.4 Unit review 32
1.4 Practical activities 34
Chapter review 36
Thinking scientifically 37
Glossary 38



## 2 Cells

2.1 Making things bigger 40
2.1 Unit review 44
2.1 Practical activities 46
2.2 Natural building blocks 48
Science as a human endeavour 51
*Cells and microscopes* *51*
2.2 Unit review 53
2.2 Practical activities 55
2.3 Specialised cells 57
2.3 Unit review 61
2.3 Practical activities 63
2.4 Cell to organism 65
Science as a human endeavour 69
*Growing cells* *69*
2.4 Unit review 71
2.4 Practical activities 72
Chapter review 73
Thinking scientifically 75
Glossary 76



## 3 Living systems

3.1 Digestion 79
3.1 Unit review 85
3.1 Practical activities 87
3.2 Breathing and respiration 89
3.2 Unit review 94
3.2 Practical activities 96
3.3 Circulation 98
Science as a human endeavour 104
*Transplants* *104*
3.3 Unit review 105
3.3 Practical activities 106
3.4 Muscles and bones 109
3.4 Unit review 115
3.4 Practical activities 116
3.5 Waste disposal 118
Science as a human endeavour 122
*Ultrasound imaging* *122*
3.5 Unit review 123
3.5 Practical activities 124
Chapter review 126
Thinking scientifically 128
Glossary 129



## 4 Growth and reproduction

4.1 Life cycles 132
Science as a human endeavour 135
*Customs and quarantine* *135*
4.1 Unit review 137
4.1 Practical activities 138
4.2 Reproduction and survival 139
4.2 Unit review 146
4.2 Practical activities 148

# Contents


4.3 Human reproduction and growth 151
4.3 Unit review 155
4.3 Practical activities 157
4.4 Pregnancy 158
Science as a human endeavour 162
*Drugs and pregnancy* *162*
4.4 Unit review 163
4.4 Practical activities 164
Chapter review 165
Thinking scientifically 166
Glossary 167




## 5 Using energy


5.1 Energy around you 171
5.1 Unit review 175
5.1 Practical activities 177
5.2 Energy changes 179
5.2 Unit review 185
5.2 Practical activities 187
5.3 Energy-efficient design 190
Science as a human endeavour 195
*The development of aircraft* *195*
5.3 Unit review 197
5.3 Practical activities 198
Chapter review 200
Thinking scientifically 201
Glossary 202




## 6 Physical and chemical change


6.1 When substances change 204
Science as a human endeavour 210
*Recycling* *210*
6.1 Unit review 211
6.1 Practical activities 212
6.2 Understanding physical change 214
6.2 Unit review 218
6.2 Practical activities 219
6.3 Density 221
6.3 Unit review 227
6.3 Practical activities 228
6.4 Chemical reactions 231
Science as a human endeavour 237
*The alchemists* *237*
6.4 Unit review 239
6.4 Practical activities 241
Chapter review 242
Thinking scientifically 243
Glossary 244




## 7 Elements, compounds and mixtures


7.1 Elements 246
Science as a human endeavour 252
*The many faces of carbon* *252*
7.1 Unit review 254
7.1 Practical activities 255
7.2 Compounds 257
Science as a human endeavour 261
*Supramolecular chemistry* *261*
7.2 Unit review 263
7.2 Practical activities 264
7.3 A closer look at atoms 266
7.3 Unit review 270
7.3 Practical activities 271
Chapter review 273
Thinking scientifically 274
Glossary 275




## 8 Rocks


8.1 Igneous rocks 278
Science as a human endeavour 284
*All four engines have failed!* *284*
8.1 Unit review 285
8.1 Practical activities 287
8.2 Weathering 289
8.2 Unit review 295
8.2 Practical activities 296

8.3 Sedimentary rocks 297
8.3 Unit review 302
8.3 Practical activities 303
8.4 Metamorphic rocks 305
8.4 Unit review 309
8.4 Practical activities 310
Chapter review 311
Thinking scientifically 312
Glossary 313



## 9 Exploration and mining

9.1 Resources in the rocks 315
Science as a human endeavour 322
*Golden bacteria* *322*
9.1 Unit review 323
9.1 Practical activities 324
9.2 Exploration 326
9.2 Unit review 331
9.2 Practical activities 332
9.3 Mines and wells 334
Science as a human endeavour 338
*Environmental effects of mining* *338*
9.3 Unit review 340
9.3 Practical activities 341
Chapter review 342
Thinking scientifically 343
Glossary 344
Index 345

# PEARSON science



## Student Book

Written specifically to meet the requirements of the Australian Curriculum, the student book acts as a guide for both student and teacher.

- Written specifically for the Australian Curriculum Science course
- Utilises an inquiry approach throughout
- Offers content and activities that enhance the development of Achievement Standards. The content is presented in a range of contexts within the three interrelated strands of Science Inquiry Skills, Science as a Human Endeavour and Science Understanding.

## Activity Book

The activity book is a write-in resource designed to enrich students' skills by providing a variety of activities and questions to reinforce learning outcomes.

- Supports and extends the student book
- Caters for a range of learning styles.

## Teacher Companion

The teacher companion makes lesson preparation easy by combining full-colour textbook pages with teaching strategies, ideas for class activities and fully worked solutions.

- Ties the entire **Pearson Science** package together
- Includes all answers to the student and activity book.

AUSTRALIAN CURRICULUM

# ALWAYS LEARNING

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PEARSON

# How to use this book

## PEARSON science 8 Student Book

PEARSON science 8 has been designed for the Australian Curriculum: Science course. It includes content and activities that enhance the development of the Year 8 Achievement Standards within the three interrelated strands of Science Inquiry Skills, Science as a Human Endeavour, and Science Understanding. The content is presented through a range of contexts to engage students and assist them to make connections between science and their lives.

The Cross-curriculum priorities and General Capabilities are addressed throughout the series.

PEARSON science 8 is designed for an inquiry approach to science learning. Its engaging design, unambiguous features and clear easy-to-understand language make this a valuable resource for students of all interests and abilities.



### Chapter opening page

The chapter opener engages students through questions that get them thinking about the content and concepts to come.

The key ideas reflect the elaborations and standards relevant to the chapter.



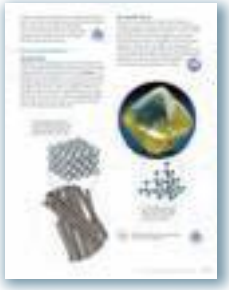
### Look who is using science

Careers pages spread throughout the book look at careers that involve and use science.



### Unit opening

Each chapter is divided into self-contained units. The unit opener includes an introduction that places the material to come in a meaningful context.



### Photos and illustrations

Stunning and relevant photos and illustrations are clearly referenced from within the text to assist students to understand the idea being developed.

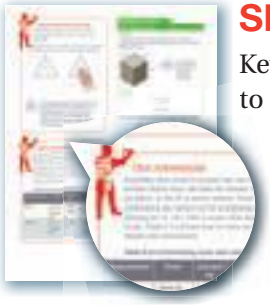


### science 4 fun

Inquiry-based activities using everyday materials assist students to understand key concepts under development.

These can be used as a focus or context for the unit.

Icons indicate whether an activity is suitable to be done at home or requires teacher supervision.



### Skill builder

Key skills are outlined in clear steps to support science learning.



### Worked example

Worked examples of problems and techniques assist students to master and apply key skills.



## SciFile

SciFiles include quirky information to engage students.



## Unit review

Each unit finishes with a set of questions and activities organised under the headings of Bloom's Taxonomy of Cognitive Processes. To further students' understanding of the intent of a question and level of explanation expected, bolded verbs are used throughout. A list of all verbs and their meanings can be found on page xii.

The final heading is 'Inquiring'. These questions challenge students to use their inquiry skills to go further with the unit content.



## Practical activities

Practical activities are placed at the end of each unit. Practical activity icons appear throughout the units to indicate suggested times for practical work.

A student-design investigation icon indicates that an activity includes student design.

Safety boxes highlight significant hazards.

A safety glasses icon reminds students when appropriate to wear safety glasses.



## Science as a human endeavour

The Science as a Human Endeavour strand is addressed throughout the units and in Science as a Human Endeavour spreads. Many of these are developed and extended in the Activity Book.



## Chapter review

Each chapter finishes with a set of questions and activities organised under the headings of Bloom's Taxonomy of Cognitive Processes.



## Thinking scientifically

Following the Chapter review are Thinking scientifically style questions relevant to that chapter. These test students' science and interpretive skills.



## Glossary

Every chapter concludes with an illustrated glossary that engages students and provides a ready reference for the key terms of the chapter.



## Activity Book icon

This icon indicates a related Activity Book worksheet that enhances or extends this area.

**The PEARSON science 8 package**

Don't forget the other PEARSON science 8 package components that will help engage and excite students in science:

- PEARSON science 8 Activity Book
- PEARSON science 8 Teacher Companion
- PEARSON science 8 Pearson Reader

# Verbs

The verbs below, based on Bloom's Taxonomy, appear in **bold** text throughout this book. The verbs help students know the level of response required for a question and provide a common language and consistent meaning in the Australian Curriculum documents.

| **Remembering** | |
|---|---|
| **enter** | Place data into a computer program by key strokes or copying from a digital source, e.g. CD, DVD, USB storage device |
| **label** | Add annotations to a diagram or drawing |
| **list** | Write down phrases or items only without further explanation |
| **name** | Present remembered ideas, facts or experiences |
| **present** | Provide information for consideration |
| **recall** | Present remembered ideas, facts or experiences |
| **record** | Store information and observations for later |
| **specify** | State in detail |
| **state** | Provide information without further explanation |
| **Understanding** | |
| **account** | Account for—state reasons for, report on. Give an account of—narrate a series of events or transactions |
| **calculate** | Ascertain/determine from given facts, figures or information (simply repeating calculations that are set out in the text) |
| **clarify** | Make clear or plain |
| **define** | State meaning and identify essential qualities |
| **describe** | Provide characteristics and features |
| **determine** | Find out the size or extent, either by using an equation, counting, estimating, or similar method |
| **discuss** | Identify issues and provide points for and/or against |
| **draw** | Use a pencil to produce a likeness onto a page, or sketch to provide a representation or view |
| **explain** | Provide a sequence to make the relationships between things evident; provide why and/or how |
| **extract** | Choose relevant and/or appropriate details |
| **gather** | Collect items from different sources |
| **modify** | Change in form or amount in some way |
| **outline** | Sketch in general terms; indicate the main features |
| **predict** | Suggest what may happen based on available information |
| **produce** | Provide |
| **propose** | Put forward for consideration or action |
| **rank** | Place in order of size, age, or as instructed |
| **recount** | Retell a series of events |
| **summarise** | Express, concisely, the relevant details |
| **write** | Compose or construct a sentence that explains a feature |
| **Applying** | |
| **apply** | Use, utilise, employ in a particular situation |
| **calculate** | Ascertain/determine from given facts, figures or information |
| **demonstrate** | Show by example |
| **examine** | Inquire into |
| **identify** | Recognise and name |
| **use** | Employ for some purpose |

| Analysing | |
|---|---|
| **analyse** | Identify components and the relationship between them; draw out and relate implications |
| **calculate** | Ascertain/determine from given facts, figures or information (requiring more manipulation than simply applying the maths) |
| **classify** | Arrange or include in classes/categories |
| **compare** | Show how things are similar or different |
| **contrast** | Show how things are different or opposite |
| **critically (analyse/ evaluate)** | Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/evaluate) |
| **discuss** | Identify issues and provide points for and/or against |
| **distinguish** | Recognise or note/indicate as being distinct or different from; to note differences between |
| **infer** | Recognise and explain patterns and meaning and relationships |
| **interpret** | Draw meaning from |
| **research** | Investigate through literature or practical investigation |
| **Evaluating** | |
| **appreciate** | Make a judgement about the value of |
| **assess** | Make a judgement of value, quality, outcomes, results or size |
| **conclude** | Come to a judgement or result based on the reasoning or arguments that you present |
| **critically (analyse/ evaluate)** | Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/evaluate) |
| **deduce** | Draw conclusions |
| **evaluate** | Make a judgement based on criteria; determine the value of |
| **extrapolate** | Infer from what is known |
| **justify** | Support using an argument or conclusion |
| **propose** | Put forward (for example a point of view, idea, argument, suggestion) for consideration or action |
| **recommend** | Provide reasons in favour |
| **select** | Choose one or more items, features, objects |
| **Creating** | |
| **construct** | Make; build; put together items or arguments |
| **design** | Provide step for an experiment or procedure |
| **investigate** | Plan, inquire into and draw conclusions about |
| **synthesise** | Put together various elements to make a whole |

# SCIENCE TAKES YOU PLACES

## Look who is using science

### LABORATORY TECHNICIAN



**I'm Penny Lee, the laboratory technician (lab tech) at a state secondary school. As a lab tech, I need to prepare the chemicals for the experiments teachers will run with their classes.**

As part of my job, I need to measure out, mix and dissolve chemicals, and prepare solutions that contain acids and bases. Before I start, I check whether the chemicals are safe or not, and what precautions (safety measures) need to be taken when handling them. I then make sure that these chemicals are correctly labelled with their safety information. I also make sure that the school laboratories and equipment, such as Bunsen burners, are safe and in good working order.

Occasionally I help a science teacher in the classroom, especially if they are running an experiment that could be dangerous, or if another adult is needed to check the students' work. Sometimes I even demonstrate how to perform a certain skill, such as using specialised equipment or how to dissect a heart or rat.

### ADVANCED CARE PARAMEDIC



**My name is Gayle Moras and I am an advanced care paramedic with my state's ambulance service.**

Paramedics need a good knowledge of the human body. As the first trained people to arrive at a medical emergency, we need to understand the structure within the human body at all levels—from chemicals, cells and organs to organ systems.

There are chemical reactions happening in your body all the time. These chemical reactions bring about all your body's processes—movement, digestion, the pumping of your heart and even your thoughts. Chemistry and biology help us to understand the functions of the body. Knowing about the structure of the body helps me to identify and diagnose illness, disease and damage.

### METEOROLOGIST



**My name is Robert Rizzo and I am completing a science degree. Much of my study is in atmospheric science, which is the study of the Earth's atmosphere and weather.**

While I was a student at school, I discovered my passion for the weather and am now trying to become a weather observer at the Bureau of Meteorology.

I love forecasting the weather, chasing thunderstorms, taking photographs of clouds, giving talks on the weather at local schools, and collecting climate data from my weather station at home. I am lucky enough to have appeared on television programs on Channels 7 and 10 and in the newspapers, speaking about the weather and giving long-range forecasts. My ultimate dream is to become a weather presenter on the television and provide the public with the most accurate and complete weather forecasts in Australia.

# Working with scientific data

# 1



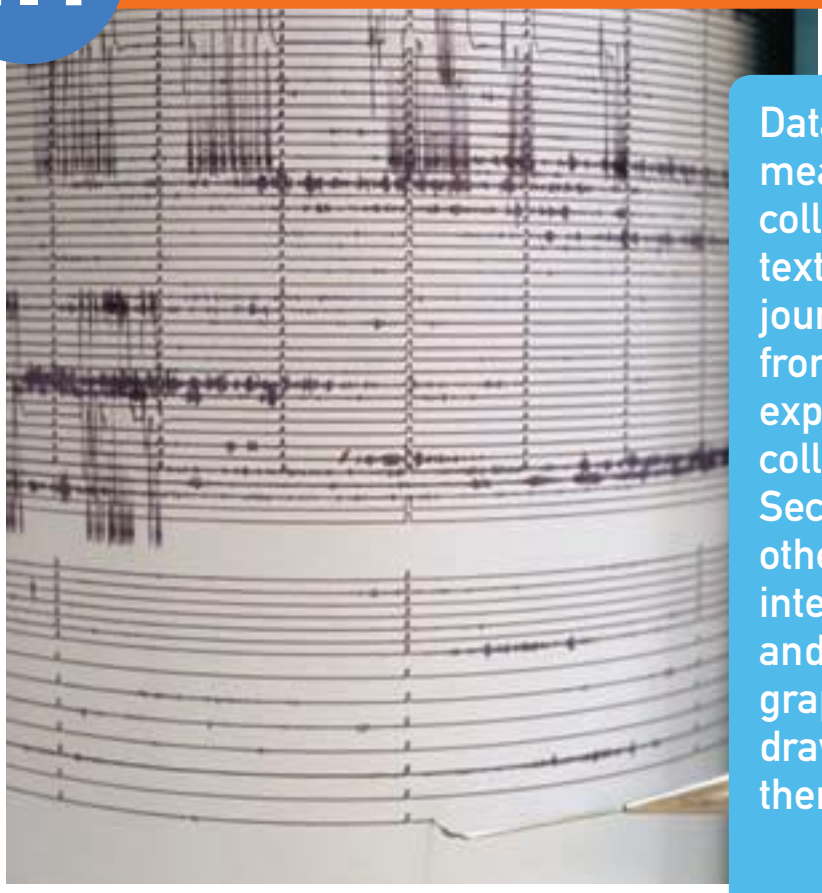
## HAVE YOU EVER WONDERED…

- what the difference is between a mistake and an error?
- why scientists take multiple measurements?
- what the .com, .au, .org or .edu at the end of a website address means?

## After completing this chapter students should be able to:

- construct graphs, keys and models to represent and analyse patterns or relationships
- apply strategies and techniques for effective research using secondary sources, including use of the internet
- use digital technologies to access information
- identify controlled, dependent and independent variables
- identify scientific problems to investigate
- work collaboratively to assess how best to approach an investigation.

# 1.1 First-hand data



Data is all the information and measurements that are collected by scientists from textbooks, encyclopedias, journals and the internet, or from carrying out their own experiments. First-hand data is collected from experiments. Second-hand data comes from other sources such as the internet. Scientists collect data and organise it into tables and graphs. They analyse the data, draw conclusions from it and then write it all up so that other scientists can understand it.

## Data

**Data** is the term given to all the observations and measurements that can be used to describe something. For example, you could be described by your personal data. This would include your height and weight, your hair, skin and eye colour, distinguishing features (such as a scar, birthmark or severely broken nose), when and where you were born and the names of your parents. Data on the parrot in Figure 1.1.1 would include its colour and sex.

### Types of data

Much of the data you find will be measurements that are written as numbers with units attached to them. This type of data is known as **quantitative data**. Other data can only be described in words. This data is **qualitative data**. Take as an example data about Mt Kosciuszko in New South Wales shown in Figure 1.1.2.



**Figure 1.1.1**

Data on this parrot would include its size and mass, the environment it lives in, what it eats, its body temperature, the number of tail feathers it has, the average number of eggs it lays, the type of nest it uses and the age at which it first flies.



Figure 1.1.2 Mt Kosciuszko is 2228 metres high (an example of quantitative data) and its main rock type is granite (an example of qualitative data).

- Quantitative data include its coordinates (36°27´S, 148°16´E), its height (2228 metres above sea level) and average temperatures (–6°C in July, 21°C in January).
- Qualitative data include its Aboriginal name (Tar-Gan-Gil), rock type (granite), the animals that live there (wombats, spotted-tailed quoll, pygmy possum, corroboree frog, flame robin, mountain galaxia and wingless grasshopper) and the wildflowers found there (alpine stackhousia, hoary sunray and snow beard heath).

Data can also be classified according to where you obtain it from.

- **First-hand data** is data that you or your practical team personally find out by running your own experiments. Any measurements that you take are first-hand data.
- **Second-hand data** is data that comes from work of other people. Second-hand data is the measurements and information that you find on the internet, TV, DVD and video, encyclopedias and textbooks, newspapers and magazines. Second-hand data can also be obtained by interviewing experts.

SciFile

### A near disastrous mistake!

In 2009, an Airbus A340/500 jet was taking off from Melbourne with 275 people on board bound for Dubai. It ran out of runway, scraped its undercarriage, shattered a landing light and only just missed the boundary fence. It's suspected that the pilots mistakenly entered a wrong number into the on-board computer, making the plane 'think' that it was 100 tonnes lighter than it really was!







# Collecting your own data

You can generally trust first-hand data since you collected it yourself from experiments that you ran. If the data is wrong, then it's probably because you made a mistake.

**Mistakes** are things that can be avoided if you take a little more care. Mistakes happen whenever you spill material, use the wrong equipment (or the right equipment wrongly), carelessly read an instrument or incorrectly write or copy the measurement down. All these are obvious mistakes since all are careless and can be easily avoided.

**Errors** are not mistakes. Errors are small and unavoidable variations that naturally occur in measurements. Errors will always happen no matter how careful you are. This means that nothing is exact—even 'accurate' measurements have small variations and errors in them.

Some common forms of errors are:

- **parallax error**—your eye can never be exactly over the marking of a measuring device. Everyone looks at markings at slightly different angles so everyone will take slightly different readings. This is shown in Figure 1.1.3.

SciFile

### Discovery by mistake

Mistakes and accidents have led to some important scientific discoveries including an artificial sweetener (saccharine), the first antibiotic (penicillin) and the first plastic (Bakelite). Accidental discoveries have also changed the way we use products. Coca-Cola® and Viagra® both started off as relief for headaches and microwave ovens started off as radar!

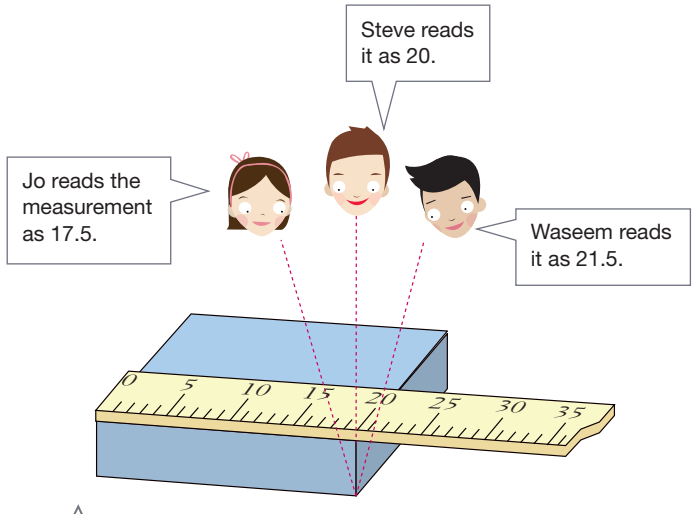



Figure 1.1.3 Parallax errors can be reduced by keeping your eye in line with the measurement.

- **reading errors**—measurements often fall between the markings of a measuring device. So you need to estimate your measurement as shown in Figure 1.1.4.

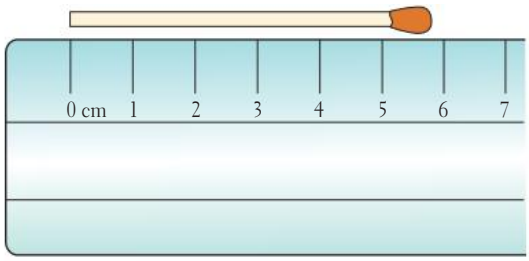



**Figure 1.1.4** This match is not quite 6 cm long, but is it 5.7, 5.8 or 5.9 cm?

- **instrument errors**—sometimes an instrument may be faulty and will never give the right reading. Some instruments give correct readings only at certain temperatures and will give small errors if used at any other temperature. For example, a metal ruler expands when hot, pushing its markings further apart. As Figure 1.1.5 shows, this makes measurements taken on a hot day slightly smaller than those made on a cold day.

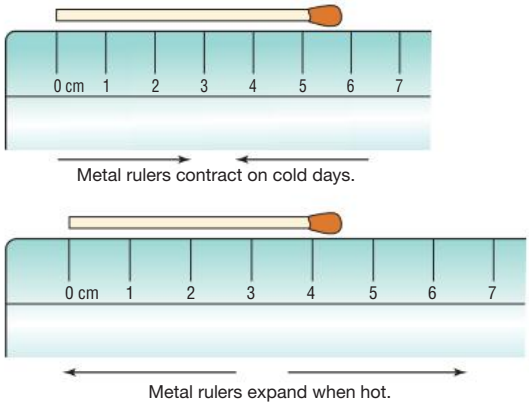



**Figure 1.1.5** Metal rulers give different measurements on different days. Although exactly the same, this match will appear 'longer' on cold days.

- **human reflex**—a stopwatch typically reads to one-hundredth of a second (0.01 second). The best human reaction time is around 0.110 second and so stopwatches are much more accurate than us. Everyone has different reflex times and so everyone will measure times slightly differently when using a stopwatch.

1 p9

- **zero errors**—an instrument such as a beam balance or electronic balance should read zero when nothing is placed on it. If it doesn't read zero, then everything you measure will be a little out and all measurements will have a zero error. Balances can usually be adjusted to read zero once more.




### Tare

When you **tare** an electronic balance, you are re-setting it to read zero when something like a beaker is placed on it (Figure 1.1.6). You can then add material without having to worry about the mass of the beaker since it has already been subtracted from the total mass.

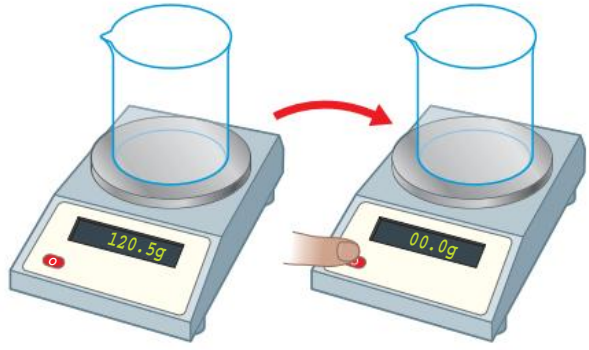



**Figure 1.1.6** The tare button on an electronic scale re-sets its zero so that you don't have to worry about the mass of the beaker that is on it.

## Improving first-hand data

Errors always exist and each person in a team will probably take slightly different measurements of exactly the same quantity. No-one is wrong (unless they made a mistake) and everyone's measurement is 'correct'.

One easy way of improving the accuracy of your data is to repeat your measurements. For example, each member in your practical team could take the same measurement so that they can be compared and obvious mistakes eliminated. Once a collection of different measurements is taken, an **average** or **mean** can be obtained.

2 p10

## A little give and take

It is useful to write measurements with an estimation of how big the error might be. Scientists allow a little 'give and take' by showing the error as ± (standing for 'plus or minus').

Figure 1.1.8 on page 6 shows the temperature on a thermometer. The exact temperature falls between the markings and a little guesswork is needed to measure it. It looks as though it should be about 27°C, but it could be a little higher or lower, perhaps by as much as 1°C. The measurement might be written as 27°C 'give or take' 1°C. Scientists write this as 27 ± 1°C.




### Finding averages

To find an average:

1. Delete the highest and lowest measurements. They are the measurements most different from all the others and so mistakes may have been made when taking them.
2. Add the rest of the 'good' measurements together.
3. Divide by how many 'good' measurements were taken.

INQUIRY science 4 fun

### Internet reaction times




How fast can you react?

**Do this…**

1. Use the key words *reflex tester* or *reaction time* in your internet search engine to find interactive games that will measure your reaction time.
2. Although most of the games involve detecting a change in colour of the webpage, some shoot tranquiliser darts into sheep while in others you play baseball! Try as many as you can to determine your average reaction time.

**Record this…**

**Describe** what happened.

**Explain** why you think this happened.

## WORKED EXAMPLE

### Calculating an average

#### Problem

The members of a prac team each measured the length of the mouse's tail in Figure 1.1.7. Their measurements are shown below.

| Team member | Length (cm) |
|---|---|
| Karen | 8.1 |
| Evan | 8.4 |
| Rebecca | 7.9 |
| Alicia | 8.2 |
| Mark | 8.5 |
| Andrew | 12.9 |

Andrew's and Rebecca's results can be ignored since they are the highest and lowest measurements and are most likely to be inaccurate.

To obtain the most accurate measurement, average the other four 'good' results:

$$8.1 + 8.4 + 8.2 + 8.5 = 33.2$$

Every member of your team will take slightly different measurements because of errors. This scientist is using the correct, humane way to pick up a mouse.

Figure 1.1.7



Four 'good' results were taken, so this sum needs to be divided by 4:

$$\text{Average length} = \frac{33.2}{4} = 8.3 \text{ cm}$$

No-one actually measured 8.3 cm but this is the average and is the most accurate measurement based on the data collected.

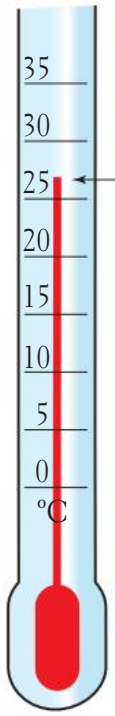



**Figure 1.1.8** The temperature shown on this thermometer might be written as 27 ± 1°C. To cover all types of errors (and not just reading errors), scientists usually increase their error estimates. They make the error half of the smallest of the divisions of the instrument they are using. The markings on the thermometer are 5 degrees and so the maximum error is 2.5°C. This means that scientists would usually write this measurement as 27 ± 2.5°C

## WORKED EXAMPLE

### ± errors

#### Problem

In the previous Worked Example, six students measured the length of the tail of a mouse. Present this measurement as an average ± error.

#### Solution

Based on the 'good' results obtained, the mouse tail ranged from 8.1 to 8.5 cm with an average of 8.3 cm. This result could be written as 8.3 cm but the highest good measurement was 0.2 cm higher than this. Likewise, the lowest good measurement was 0.2 cm lower than the average. The result could therefore be written as 8.3 cm 'give or take' 0.2 cm but is better written as 8.3 ± 0.2 cm.




## Safety

Running experiments can be dangerous and so every laboratory has a set of safety rules that must be followed. One common rule is shown in Figure 1.1.9. Others common to all laboratories are:

- Always follow instructions from your teacher or laboratory technician.
- Move about the lab in a safe way. Do not run, push or shove.
- Always wear safety glasses when using chemicals.
- Unless instructed to do so by your teacher or lab technician, do not eat, taste, drink or sniff anything in the lab.
- Always tell your teacher if you break something or if you are unsure about what to do.
- Turn on the tap before placing anything under it. Otherwise the pressure might break whatever you are holding.
- When heating something, always tie back long hair. Otherwise it's a fire risk!
- If you need to leave a Bunsen burner, then turn it to a visible yellow safety flame
- Only use matches to light Bunsen burners. Do not use lighted scraps of paper.
- Always use tongs to pick up objects that have been heated.
- Hotplates, Bunsen burners, tripods and gauze mats remain hot for a long time. Allow them to cool before packing them away.



**Figure 1.1.9** When heating a test-tube, ensure that it is pointed away from everyone (including you).

# 1.1 Unit review

## Remembering

1 **State** whether the following statements are true or false.
   - **a** All measurements are exact.
   - **b** An average is also called the mean.
   - **c** A mistake is the same as an error.
   - **d** A measurement of 56 ± 2°C means that the measurement is somewhere between 54 and 58°C.
   - **e** Human reflexes are always fast and accurate.

2 For Mt Kosciuszko, **state** three pieces of:
   - **a** quantitative data
   - **b** qualitative data.

3 **Name** four types of errors.

4 **State** the biggest and smallest values these measurements could be.
   - **a** Elvir wrote that the length of an insect as 2.1 ± 0.1 cm.
   - **b** Mang measured the temperature of the lake as 12 ± 3°C.

5 **State** what these measurements would be with a ± error.
   - **a** The volume of a glass of soft drink was measured by Kim as 185 mL give or take 5 mL.
   - **b** Iona measured the temperature that salt water boiled at as somewhere between 102 and 104°C.

## Understanding

6 **Explain** why errors cannot be avoided.

7 Scientists generally take multiple measurements for the same quantity. **Explain** why.

8 Metal rulers are inaccurate in extremely hot and cold temperatures. **Explain** why.

## Applying

9 **Identify** whether the measurement made with a metal ruler will be too high or too low on a:
   - **a** hot day
   - **b** cold day.

10 Eliminate the highest and lowest measurements and then **calculate** the average for the remaining 'good' measurements:
   - **a** 39 mm, 61 mm, 38 mm, 42 mm, 41 mm, 30 mm, 40 mm
   - **b** 25.3°C, 26.8°C, 38.1°C, 27.4°C, 21.2°C
   - **c** 45 mL, 39 mL, 47 mL, 46 mL, 58 mL, 46 mL.

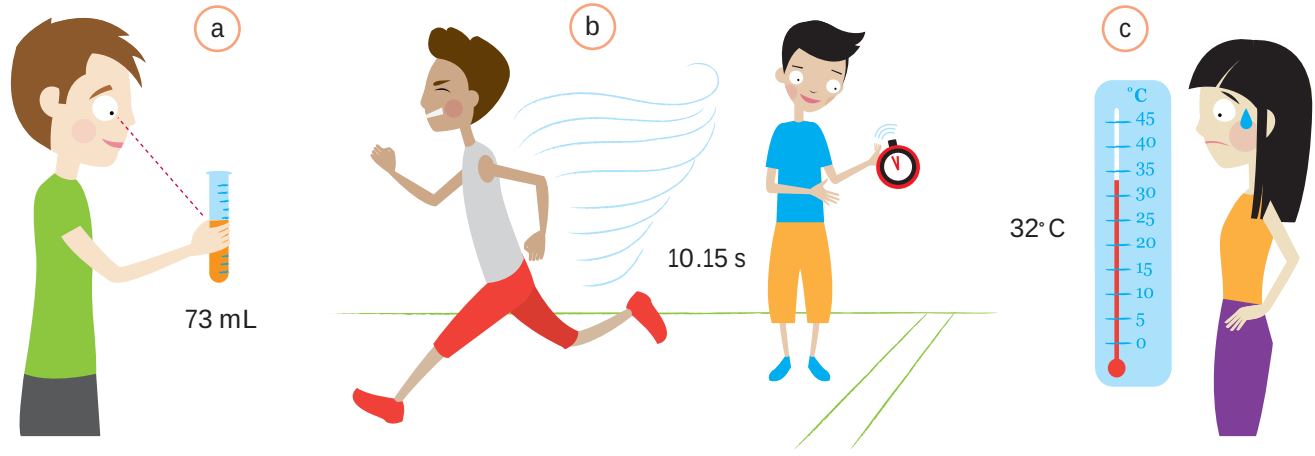
11 The time a ball took to drop down a 15.0 m cliff was measured by different members of a prac team. Their results are shown below:

| | | | |
|---|---|---|---|
| Rebecca | 1.61 s | Frank | 1.74 s |
| John | 3.23 s | Stavros | 1.83 s |
| Christine | 1.68 s | | |

   - **a** **Identify** who most likely made a mistake.
   - **b** **Calculate** the average drop time of the ball.
   - **c** **Identify** the error that is likely to be the most important in this experiment.

12 **Identify** the types of error shown in Figure 1.1.10.

Figure 1.1.10



# 1.1 Unit review

## Analysing

13 **Classify** the following as either mistake or error.
- a Liz poured water from a measuring cylinder but could not get every drop out.
- b Sam spilt some of the chemicals he was to use in an experiment.
- c Jon didn't bother cleaning the dirt off the balance he used.
- d Liana found it difficult to decide on measurements that fell between the markings on a tape measure.
- e Michael's electronic scale was reading 0.1 g when empty and he didn't 'zero' it.

14 **Classify** the data on the parrot listed in Figure 1.1.1 (on page 2) as quantitative or qualitative.

## Evaluating

15 Suppose a watch-glass has a mass of 50 g. **Propose** a way of measuring 10 g of salt onto a watch-glass:
- a without using the tare button
- b with the tare button.

16 **Propose** reasons why you should:
- a not run or push others in the laboratory
- b always wear safety glasses when using chemicals
- c leave hotplates or Bunsen burners for a while before packing them away.

## Creating

17 **Construct** diagrams to explain these types of errors:
- a parallax errors
- b reading errors.

## Inquiring

1 The Mars Climate Orbiter (also known as the Mars Surveyor '98 Orbiter) crashed onto Mars in 1999 because of a silly and easily avoided mistake. Research this mission and:
- a state its launch date, country of origin and the cost of the mission
- b describe where and when it was supposed to land on Mars
- c describe what the Mars Climate Orbiter was supposed to do on Mars
- d describe the mistakes made in planning the mission that meant that the Mars Climate Orbiter could never land successfully.

2 Research the internet for measurement games that test how well you can take measurements. Use them to test how good you are.

3 Accidents caused the following discoveries to be made or caused another use for them. Research one of them:
- bakelite (Leo Hendrik Baekeland)
- Coca-Cola® (John Pemberton)
- heart pacemaker (Wilson Greatbatch)
- microwave oven (Percy L. Spencer)
- penicillin (Alexander Fleming)
- radioactivity (Henri Becquerel)
- Teflon® (Roy Plunkett)
- saccharine (Constantin Fahlberg)
- vulcanised rubber (Charles Goodyear).

Whichever one you choose:
- a state the year of the discovery
- b describe the accident that caused it to be made
- c describe the current use of the discovery
- d list biographical details about its discoverer.



Figure 1.1.11 Many important scientific discoveries have been made by accident. For example, mould (like that found on this bread) led to the discovery of the first antibiotic, penicillin.

# 1.1 Practical activities

## 1 Reaction times

### Purpose

To determine your reaction time.

### Materials

- 30 cm ruler
- access to a calculator
- stopwatch

### Procedure

1. Construct a table like that shown in the Results section in your workbook.
2. Work with a partner. Hold the ruler vertically with its zero in line with the top of your partner's hand, as shown in Figure 1.1.12.
3. Without warning, let go of the ruler. Your partner needs to catch it as quickly as possible with their fingertips.
4. Note the reading of the ruler (in centimetres) at the top of your partner's open hand.

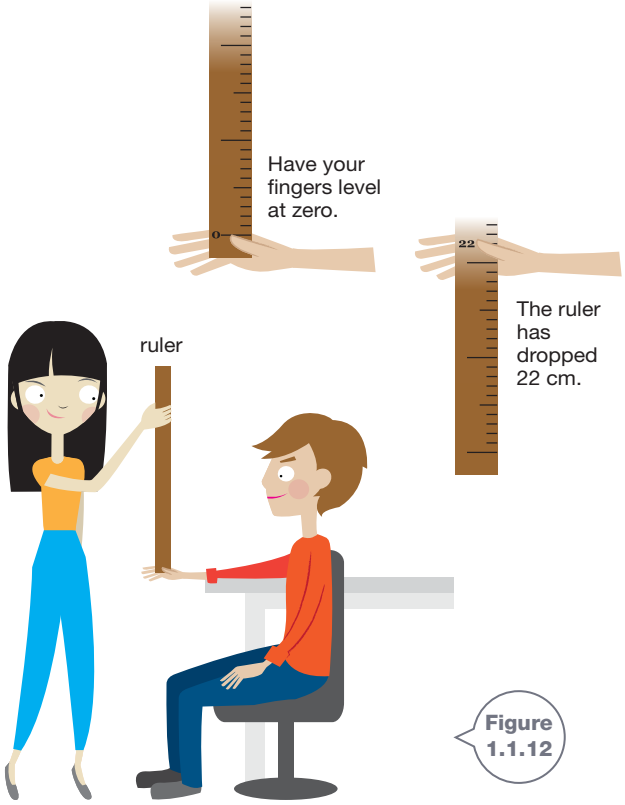



Figure 1.1.12

4. Have two trial runs and then record in your table the distance dropped for the next three runs.
5. Repeat the experiment, but this time count down the ruler drop.
6. Try again, but have another student distract your partner (such as by talking to them or tickling them).

### Results

1. Record all your results in a table like that shown below.

| Experiment | Distance ruler dropped (cm) | | | Average ruler drop (cm) | Average reaction time (s) |
|---|---|---|---|---|---|
| No distractions, no warnings | | | | | |
| With countdown | | | | | |
| With distractions | | | | | |

2. Calculate your reaction time using the mathematical formula:

$$t = \sqrt{\frac{d}{490}}$$

To do this, follow these steps on your calculator:

- [÷] your average ruler drop by 490.
- Push the [=] button.
- Push the [√] (square root) button.

The final answer is the time in seconds that you took to react.

### Discussion

1. Digital stopwatches normally measure to the nearest 0.01 second. **Compare** this with your reaction time.
2. Your measurements using a stopwatch should never be thought of as perfect. **Explain** why.
3. **List** other factors that affected your reaction time. Specify whether they made it better or worse.

## 2 Repeated measurements

### Purpose

To take repeated measurements and calculate their averages.

### Materials

- measuring tape
- thermometer
- stopwatch

### Procedure

Measure each of the following as carefully as you can. Have each member of your prac team do the same.

- Length of the laboratory
- Temperature of tap water
- Number of heartbeats in a minute
- Time it takes for a pen to drop 2 metres to the floor
- Time it takes for a flat piece of A4 paper to flutter from a height of 2 metres to the floor

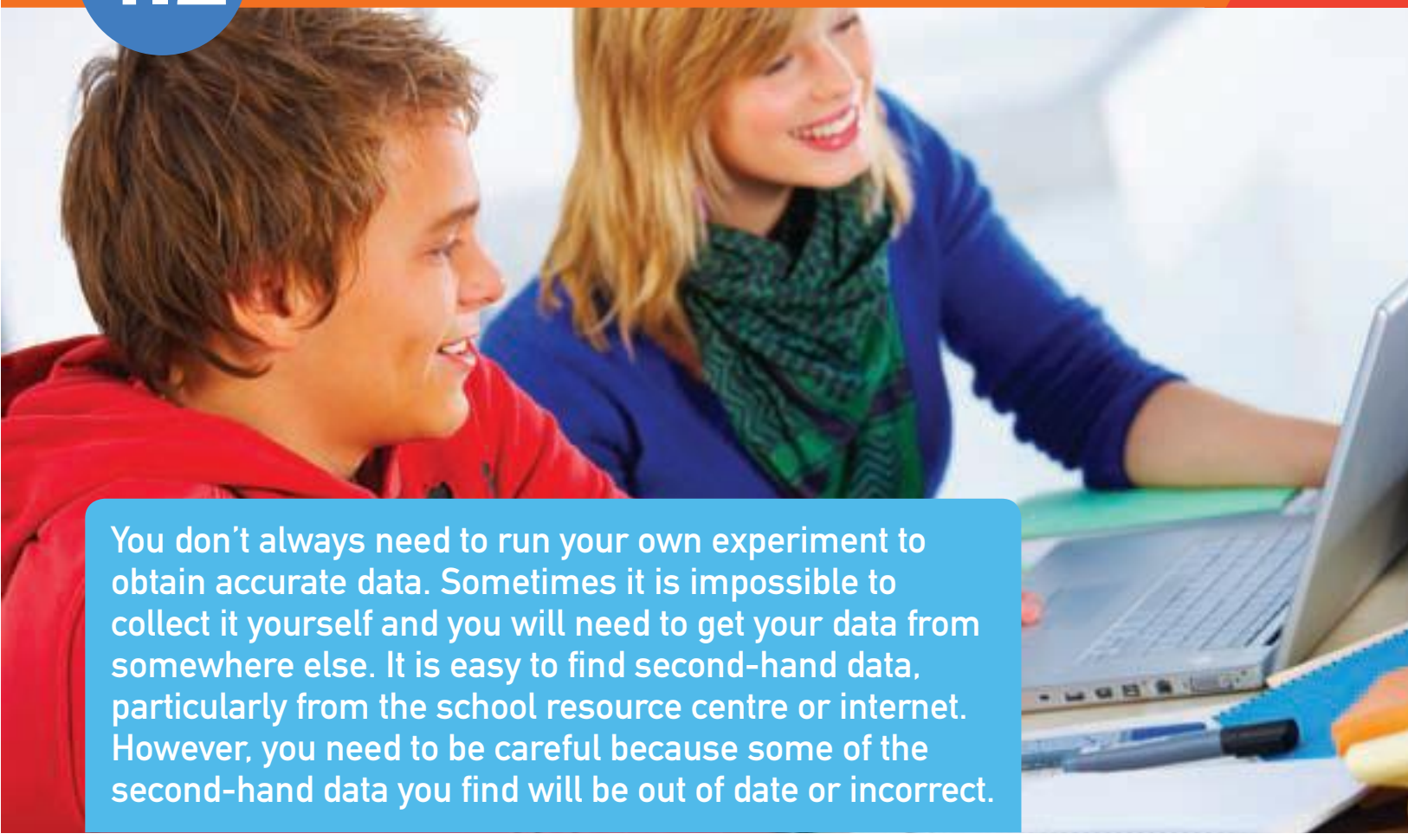
### Discussion

1. **Explain** why scientists repeat their measurements instead of taking just one.
2. **Calculate** the average for each measurement.
3. **State** each measurement as average ± error.



Figure 1.1.13 How to measure your pulse. Each pulse represents one heartbeat.

# 1.2 Second-hand data



You don't always need to run your own experiment to obtain accurate data. Sometimes it is impossible to collect it yourself and you will need to get your data from somewhere else. It is easy to find second-hand data, particularly from the school resource centre or internet. However, you need to be careful because some of the second-hand data you find will be out of date or incorrect.

## Data that's ready to go

You cannot always run your own experiments or take your own observations and data. This could be for a number of reasons.

- Many experiments require training that is well beyond Year 8 Science. This is why science is offered as a subject throughout secondary school and into university. You learn a bit more each year, allowing you to run more and more of your own experiments and collect more of your own data.
- Many experiments require equipment that is not available at school because of its expense, size and maintenance requirements. For example, your school might have a powerful optical telescope that allows you to see the Moon and planets but it won't have a radio telescope such as that in Figure 1.2.1, which allows you to see into the deeper universe. Likewise, your school will have optical microscopes but not more powerful electron microscopes.



**Figure 1.2.1** Your school is unlikely to have a radio telescope such as this one at Parkes, New South Wales. This means that you can only use second-hand data to find information about the wider universe.

- Other experiments take far more time than that available in Year 8 Science. For example, a forest takes many years to grow after a bushfire and you will need that long to study it. Genetic diseases pass from generation to generation and so studying the inheritance of them will take generations to do properly.
- Other observations can only be made in swamps, on top of mountains, in the frozen Antarctic, at the bottom of the ocean or in space. It is unlikely that you will ever go there, especially to run a science experiment.

If you can't run your own experiment, then you need to turn to second-hand data. Second-hand data is information that has already been found out by other scientists. This data and the scientific analysis of it can easily be found in textbooks and encyclopedias, scientific magazines and journals and on the internet. All this information is second-hand data. You might be using the data right now but it once belonged to someone else.




**Figure 1.2.2** Data on climate change is changing so rapidly that it quickly becomes out of date. These two photos were taken from the same spot of the same Swiss glacier in 2002 and 2003.

# Improving second-hand data

Second-hand data is easy to find but is not always accurate. Simple checks can ensure that the data you find can be trusted.

## How old is the data?

Some data never changes. Ice, for example, melts at 0°C at sea level and will always do so. Hence, it doesn't matter where you get the information from or how old the information is. However, other data quickly becomes out of date and will not accurately describe what is happening right now. For example, climate change is happening much quicker than scientists first thought. As Figure 1.2.2 shows, glaciers and Arctic and Antarctic icesheets are melting faster than predicted and so data describing them must be as recent as possible for it to be accurate: data from a year ago is already so inaccurate that any predictions based on it are bound to be wrong.

You can check how old data is by finding the **imprint page** of the book or magazine, such as that shown in Figure 1.2.3. This page can usually be found in the first few pages of any book, magazine or journal. Websites should have the date they were created and last updated at the bottom of their opening pages.

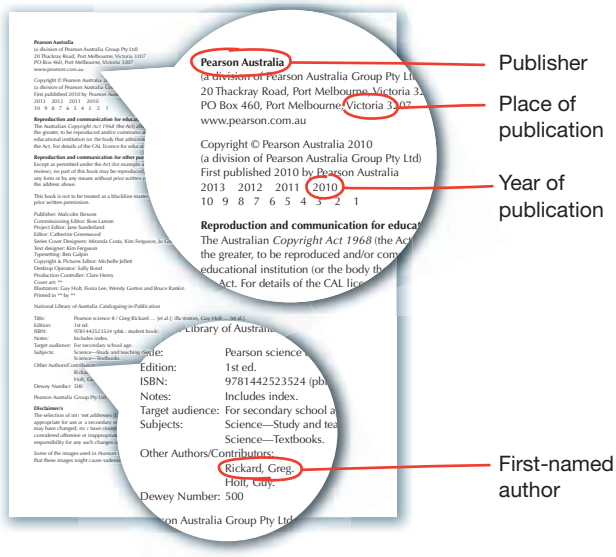



**Figure 1.2.3** The imprint page shows who published the book or magazine and when it was published.

## Where did it come from?

Encyclopedias, scientific journals and science textbooks can usually be trusted to provide accurate data. As discussed earlier, however, the data may be old.

Data can also be trusted if it comes from respected scientific magazines such as *New Scientist*, *COSMOS*, *Scientriffic*, *Scientific American* and *National Geographic*. Many of these magazines will be found in your school's resource centre or your local library.

Gossip and celebrity magazines cannot be relied on to provide accurate data and information.

## What's the URL?

The internet will probably be your first choice when looking for data and information. However, some of what you find will be incorrect. Links that don't work are one sign of a suspicious site. More information comes from the last part of its **URL** address (referred to as its **domain**). This tells you who created the website and it gives you some idea whether it can be trusted or not.

**Australian sites (.au)**
Sites that have URLs ending in .au are based in Australia and need to meet Australian laws. The origin of other sites can also be determined by their domain. A few are shown in Table 1.2.1.

Table 1.2.1 Country domains

| Country | Domain |
|---|---|
| USA | None |
| Australia | .au |
| United Kingdom | .uk |
| Canada | .ca |
| India | .in |
| United Arab Emirates | .ae |

SciFile

### TIM and the www

Before 1989, the only people able to use the internet were the US military, organisations such as CSIRO and various universities around the world. In that year Tim Berners-Lee, an English computer scientist working at the CERN laboratory in Switzerland, wrote software that allowed anyone to access the net. He called his system TIM! We now know it as the world wide web (www).

**Educational institutions (.edu)**
URLs ending in .edu indicate that the website is hosted by an educational institution such as a school, college, university or even kindergarten. Most of the material you find there can be trusted. However, students can sometimes use the school server and .edu domain to construct their own personal webpages. That expert on brain surgery you've found online might be another Year 8 student!

SciFile

### Mentos + Diet Coke = nothing!

Plenty of video clips on the internet show the eruption that occurs when Mentos® are added to Diet Coke®. However, try it yourself and nothing much happens. This is because most of the video clips come from the USA where Mentos are different from those you can buy here. This shows that you should always check where your information comes from.




**Government (.gov or .gov.au)**
Governments have multiple sites ranging from health, finance, immigration and the arts to science. If the URL ends in .gov, then the site belongs to a branch of the government of the USA. If it is an Australian government site, then the URL will end in .gov.au. The data on government sites can be considered to be accurate and up to date.

**Commercial businesses (.com)**
Businesses want you to buy their products. Their websites will usually be accurate but will be biased towards their products, making them look good. They are unlikely to include links to negative reviews or compare their product with opposition products.

**Organisations (.org)**
The first site that comes up in most searches is Wikipedia. This is an example of an .org site. Wikipedia is a not-for-profit site that allows anyone to enter information. The accuracy is checked later by others. Most of the information on Wikipedia is accurate and up to date. If it isn't, then it is usually quickly deleted.




Figure 1.2.4 Zoo websites are .org sites and can be trusted to have accurate and up-to-date data about animals and their welfare.

Other .org sites that can be trusted are the Australian Red Cross, the United Nations, zoos such as Taronga Zoo (New South Wales) (Figure 1.2.4) and Healesville Sanctuary (Victoria), the WWF (World Wildlife Fund for Nature) and various help groups for diseases such as cancer and multiple sclerosis.

However, some .org sites display a strong bias and only provide information that will support their point of view. Websites regarding evolution, stem cell research and abortion are often biased for or against the issue and so they need to be treated with care.

**Networks (.net)**

These domains include all the other sites that don't fit within one of the other domains. Many of them will be personal sites. If so, then their URL is likely to include a ~ (tilde). Many of these websites will be biased and some will contain incorrect information.

1 p16 2 p17

# The need to compare

All second-hand data should be checked against data found in other sources. If it agrees, then it is probably accurate. If it doesn't match up, then you need to keep looking until you find sets of data that do match.

Data is best collected from a range of resources. In research assignments and projects, try and gather material from at least one:

- textbook
- encyclopedia (it could be an online or CD-version)
- trustworthy internet site.

# Resource lists

A resource list (sometimes called a **bibliography**) is a list of every textbook, encyclopedia, scientific journal and webpage from which you collected information or used to check the accuracy of data you found. Although each type of resource is listed in their own special way, you should try to include the following.

**Author(s):**

- Write the author's surname first.
- If the author's name is not given, then try and find the editor instead and write 'ed.' after their name.
- Encyclopedias often do not have authors or editors listed. In this case do not include any author.

**Title:**

- If you are using a magazine or newspaper, then you should also give the title and page numbers of the article you used.
- If you are using a website, then you should give its title and its URL.
- Always underline the title or URL.

**Year or date of publication:**

- Give the year or date of publication or the date of its most recent update.

**Publisher:**

- This is the group or the institution that put it all together. The domain in a website's URL will help you here.

**Place:**

- Include the city or place that the resource has come from (if known).

Some possible entries in a resource list are shown in Figure 1.2.5.

Book: Hopler, Paul and Torok, Simon, Amazing Science, 2005, ABC Books, Sydney.

Encyclopedia: Visual Encyclopedia of Science, 2004, Dorling-Kindersley, London.

Magazine: Catchpole, Heather, 'The atom factory'. COSMOS, 2007, Volume 014, p77.

Newspaper: Medew, Julia, 'Insurance fears deter gene tests', The Age, 7 September 2009, p3.

Website: www.wecare4rabbits.com/rabbits.asp

Figure 1.2.5 Entries in a resource list

# 1.2 Unit review

## Remembering

1 **State** what the following domains stand for.
- a .gov
- b .gov.au
- c .au
- d .com
- e .edu

## Understanding

2 **Explain** why:
- a .net sites need to be treated with care
- b .com sites cannot be expected to give a fair assessment of their products.

3 **Predict** whether the following magazines could be trusted to give accurate scientific data.
- a *New Idea*
- b *COSMOS*
- c *Woman's Day*
- d *Popular Scientist*
- e *Dolly*

4 **Explain** why some data is known as second-hand.

5 **Explain** why it would be difficult to run your own experiment to:
- a measure the weathering and erosion of rocks
- b detect signals from the outer universe
- c measure the wind speeds on top of Mt Everest
- d determine the mathematical equations that describe the movement of water down a creek.

## Applying

6 **Identify** whether you would use first-hand or second-hand data to find:
- a the types of shops that are in your town or suburb
- b how tall your classmates are
- c the population of the major cities of Australia
- d how long an ice cream takes to melt
- e the length of Australia's coastline.

7 For the following resources, **identify**:
- i what the resource is (e.g. text, website, magazine)
- ii its author(s)
- iii the title of resource
- iv the year of publication.

a Devlin, Jacinta, Helen Cochrane, Rhonda Coffey, *Heinemann Science Links 1*, 2005, Heinemann, Port Melbourne.

b Govindasmay, Siva, 'Ready for take-off', *Flight International*, 1–7 September 2009, p46.

## Evaluating

8 **Assess** whether the following websites are likely to give unbiased information.
- a www.dubbo.org/explore/western-plains-zoo
- b www.antiabortion.org/helpline
- c www.pretendwecare.net
- d www.chrissolarpanels.com.au
- e www.physics.unitas.edu.au
- f www.doctors4stemcellcures.org
- g www.en.wikipedia.org/wiki/frdi
- h www.donkey.org.it/~guido

9 You should use a range of resources to collect second-hand data. **Propose** reasons why.

## Creating

10 Gary used the resources shown in Figure 1.2.6 to complete a science assignment. From his rough list, **construct** a resource list.

The science of the X-Files written by Michael White in 1996. It was Published in London by Random House.

1976, Snakes of Australia, pub Angus and Robertson. SYD. Written Graeme F. Gow.

The article was called Hair today, gone tomorrow and was on page 102 of an old Newton magazine from 2000. It was Vol 2 and it was written by Bob Guntrip.

Figure 1.2.6

## Inquiring

1 Most secondary schools have their own guidelines for constructing a resource list. Ask your school librarian or resource centre manager for your school's guidelines on how you should construct yours. Summarise what you find out.

2 Search the internet for videos on:
- a elephant toothpaste
- b cartesian divers.

3 Investigate ways in which chemical waste is disposed of from homes and schools. This waste would include leftover paint, oil and insecticides from home, and toxic and organic chemicals from school laboratories.

# 1.2 Practical activities

## 1 Elephant toothpaste

### Purpose

To make elephant toothpaste and then search the internet to find out what happened.

### Materials

- empty 500 mL plastic soft-drink or water bottle
- 3–6% solution of hydrogen peroxide
- dishwashing detergent
- food colouring
- live powdered yeast
- very warm water
- 100 mL measuring cylinder or plastic cup
- plastic teaspoon
- funnel
- beaker
- newspaper or tray to 'catch' the toothpaste
- safety glasses





**SAFETY**

Hydrogen peroxide is an irritant if it gets in your eyes. It is also a bleach. Wear gloves and safety glasses at all times.



### Procedure

1. Place the tray on your workbench or cover the bench with newspaper. Alternatively, perform the prac outside.
2. Place about 8 teaspoons of very warm water into the beaker and add about 1 teaspoon of yeast powder. Mix with the plastic teaspoon and then allow the mixture to sit for about 5 minutes.
3. Insert the funnel into the opening of the plastic bottle and use it to pour 100 mL (about half a cup) of hydrogen peroxide solution, a good squirt of dishwashing liquid and three or four drops of food colouring. Swirl to mix thoroughly.
4. Place the bottle on the tray or newspaper or take it outside. Then add the yeast mixture all at once. Quickly remove the funnel and stand back.
5. Once the reaction has started, feel the sides of the plastic bottle.

### Discussion

1. **Describe** what you saw.
2. **Describe** what you felt when you touched the bottle.
3. Search the internet to obtain the following data regarding this prac.
   - **State** the address of the website you obtained it from.
   - **Identify** what type of site it was (for example, government, educational or commercial).
   - **Assess** whether the information you found was able to be trusted or not.

   Find:
   - a the chemical formulas for hydrogen peroxide and water
   - b the reaction in which hydrogen peroxide breaks down
   - c what a catalyst is and what it does (yeast is a catalyst in this experiment)
   - d what an exothermic reaction is.
4. The 'toothpaste' formed in this prac is just bubbles of oxygen, water and food colouring. **Assess** whether it is safe to touch.
5. **Propose** reasons why the 'toothpaste' grew out of the bottle.

## 2 Cartesian diver

### Purpose

To construct a cartesian diver and use it to demonstrate buoyancy.

### Materials

- 2 L soft-drink bottle
- a 'diver' such as:
  - an eye-dropper or Pasteur pipette
  - plastic straw, paperclip and Blu-Tack®
  - lid of a ballpoint pen and Blu-Tack
- digital camera or mobile phone with video function (optional)

### Procedure

1. Completely fill the 2 L bottle with water.
2. Prepare your diver. Your diver needs to be heavy enough so that it just floats upright in water. To do this:
   - draw water into the eyedropper
   - attach Blu-Tack to the end of the lid of the ballpoint pen as shown in Figure 1.2.7
   - bend the plastic straw over and hold it in place with the paperclip as shown in Figure 1.2.7. Add Blu-Tack to the paperclip.
3. Slip your diver into the bottle and screw the cap on tightly.
4. Squeeze gently on the sides of the bottle and observe what happens to the diver.
5. Watch what happens when you release the bottle.
6. Perhaps video what you see using a digital video camera or mobile phone.

### Discussion

1. **Describe** what happened to the diver when you:
   - a squeezed the bottle
   - b released it.
2. Search the internet to obtain the following data regarding this practical activity.
   - **State** the address of the website you obtained it from.
   - **Identify** what type of site it was (for example, a government, educational or commercial site).
   - **Assess** whether the information you found was able to be trusted or not.

   Find:
   - a what buoyancy is
   - b why the diver moved up and down in the bottle
   - c other designs for a cartesian diver that use a soy-sauce 'fish' and a tomato sauce sachet
   - d who the word 'cartesian' is named after
   - e what cartesian coordinates are.

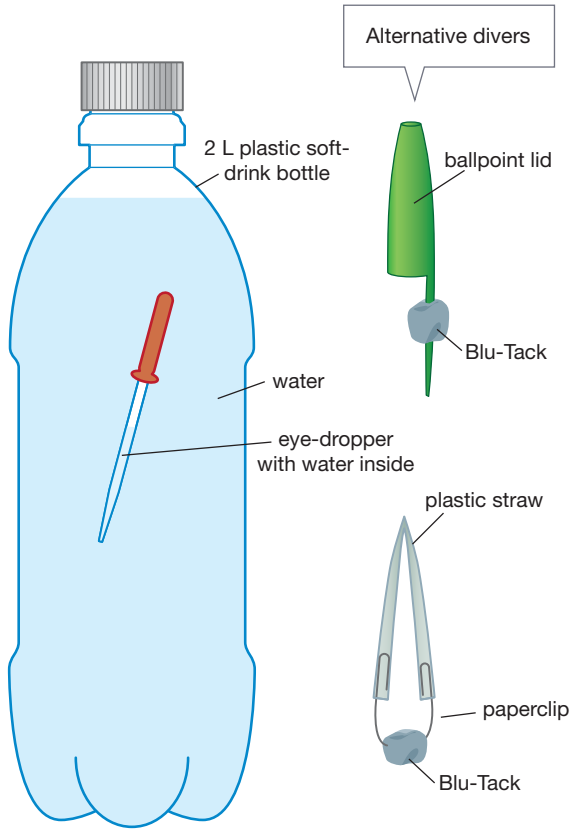
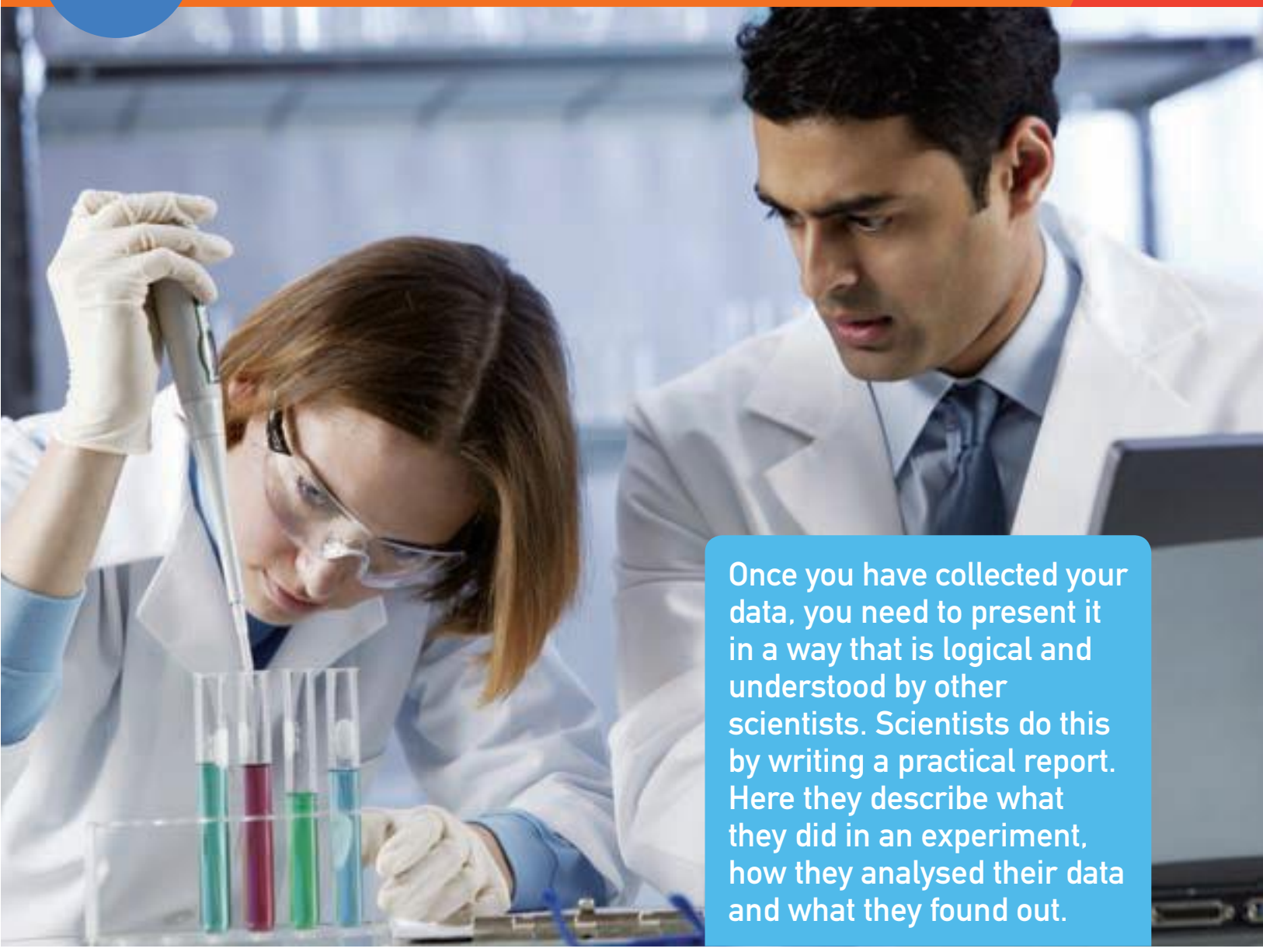



Figure 1.2.7

# 1.3 Presenting and analysing data



Once you have collected your data, you need to present it in a way that is logical and understood by other scientists. Scientists do this by writing a practical report. Here they describe what they did in an experiment, how they analysed their data and what they found out.

## Prac reports

Prac reports should include the following sections.

### Heading

In your heading, include the name and date of the prac activity and a list of partners who were in your team.

### Purpose or aim

The **aim** or **purpose** is where you describe briefly what you are trying to do.

### Hypothesis

You generally have some idea of what will happen in an experiment from your previous experiences and what you have already studied in science. A **hypothesis** is an educated guess about what might happen in an experiment and what might be found out.

### Materials, equipment or apparatus

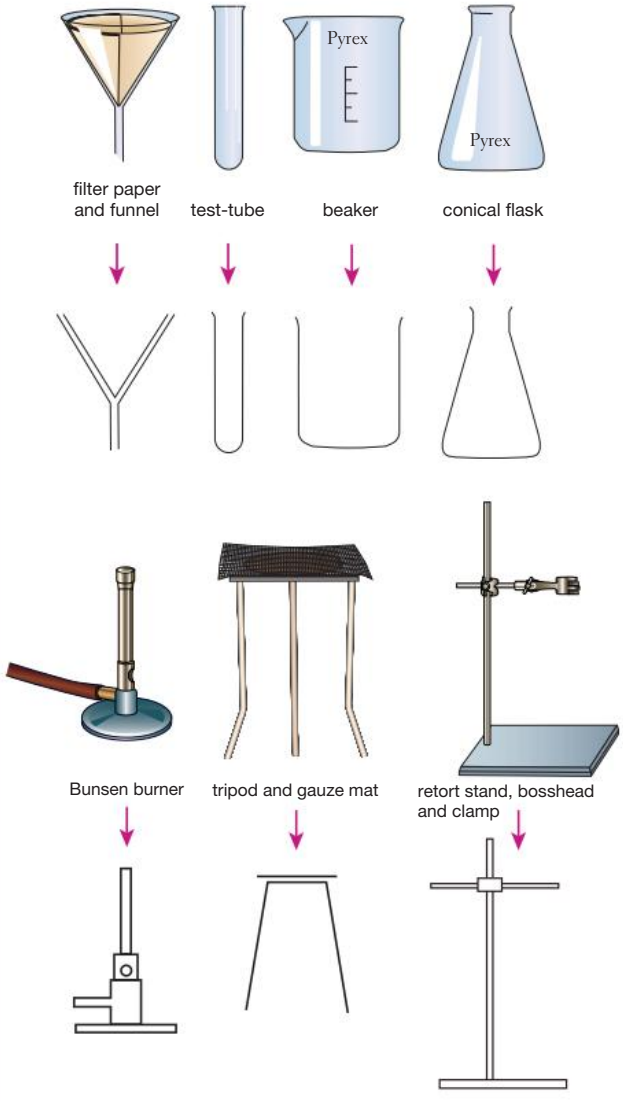
This is a comprehensive list of everything that you used in the experiment. Use the correct names for scientific equipment and specify their size if they come in different sizes (such as a 100 mL beaker).

## Identifying laboratory equipment

Figure 1.3.1 shows some of the equipment commonly found in the laboratory and how the equipment is usually represented in a diagram. Some pieces are used to take measurements (quantitative data) while others are used to run experiments in.

1.3

**Figure 1.3.1** Equipment commonly found in the laboratory




## Writing a good procedure

The method you write should not be a story and should not be a recipe. Recipes give a set of instructions for someone else to follow and do not record what you or your team did. Follow these guidelines to write a good method.

1. Write procedures in the past tense. Use words such as *was* and *were*.

   A measuring cylinder was used to measure out 100 mL of water. ✔

   Use a measuring cylinder to measure out 100 mL of water. ✗

2. Your procedure should state what equipment was used.

   A trundle wheel was used to measure the length of the oval. ✔

   We used a trundle wheel to measure the length of the oval. ✔

   The length of the oval was measured. ✗

   We measured the length of the oval. ✗

3. Include quantities and units with all your measurements.

   The water was heated until it reached 40°C. ✔

   We heated the water until it reached 40°C. ✔

   The water was heated. ✗

   We heated the water. ✗

## Procedure or method

The **method** or procedure is a description of everything that you did in the activity, perhaps as a list or series of dot points. A labelled diagram is a good way to describe how equipment was set up.

1.4

## Results and observations

This includes a complete list of your observations and your measurements. The best way to display your measurements is in a table.

## Analysis or discussion

This is where you:

- analyse your results
- plot graphs
- calculate required quantities (such as averages, the slope of a graph, speed)
- discuss what you think your results show
- include second-hand data that relates to the activity
- describe the problems encountered and what was done to overcome them
- include ideas for further experiments.

## Conclusion

The **conclusion** is a brief summary of what you found out in the experiment.




### Writing a good conclusion

A good conclusion is short (no more than two short sentences) and directly answers the Purpose.

As expected, cooking oil flowed slower than water but faster than honey. ✔

The experiment was fun and we learnt a lot. ✗

## Resource list

A report sometimes ends with a list of all resources used in gathering information about the experiment. This is sometimes called a **bibliography**.

# Tables of data

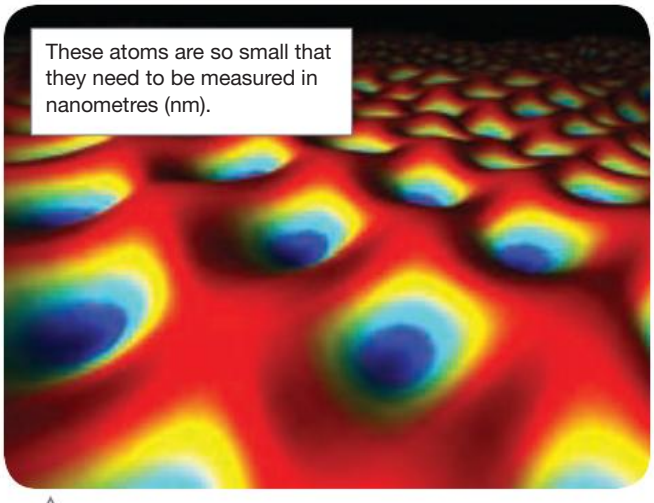
Quantitative data (measurements) is best shown in a table or computer spreadsheet. This makes any patterns that may exist more obvious.

## Units

The measurements in your results tables are useless unless you specify the units they are measured in. In science, most of your measurements will be measured using metric or SI (Système Internationale) units. Length is measured in metres (m), mass in grams (g), liquid volumes in litres (L) and time in seconds (s). Other units, such as newtons (N) for weight and force, and joules (J) for energy, depend on these units. Sometimes, however, measurements will be too big or too small to be sensibly measured with these units. Other units have been developed from them using a series of letters before the unit name. These letters are known as prefixes, the most common of which are milli, centi and kilo. They are shown in Table 1.3.1. There are other prefixes that are used to measure extremely large or small quantities such as those shown in Figure 1.3.2.

**Table 1.3.1 Common metric unit prefixes**

| Prefix symbol | Prefix name | Size | Decimal notation | Example |
|---|---|---|---|---|
| G | giga | one billion | 1 000 000 000 | GL |
| M | mega | one million | 1 000 000 | ML |
| k | kilo | one thousand | 1000 | km |
| c | centi | one-hundredth | $\frac{1}{100}$ or 0.01 | cm |
| m | milli | one-thousandth | $\frac{1}{1000}$ or 0.001 | mg |
| μ | micro | one-millionth | $\frac{1}{1\,000\,000}$ or 0.000 001 | μg |
| n | nano | one-billionth | $\frac{1}{1\,000\,000\,000}$ or 0.000 000 001 | nm |



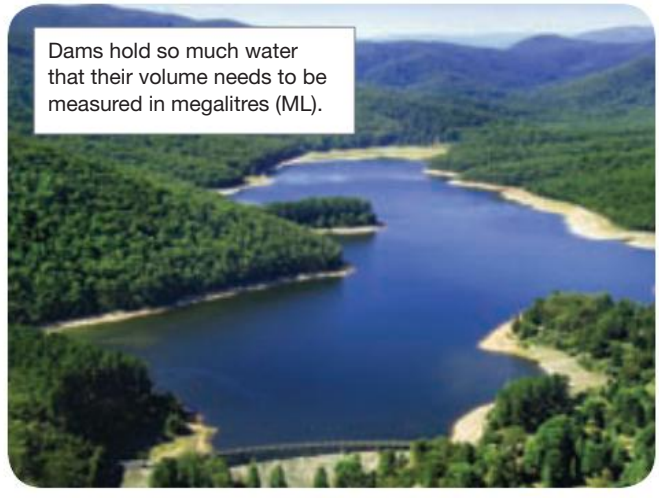




**Figure 1.3.2** Prefixes allow scientists to measure extremely small and extremely large quantities.

# Drawing line graphs

Graphs are better at showing patterns in measurements than tables are. Pie graphs and bar and column graphs are useful but cannot be used to predict missing measurements or ones that were never actually taken in the experiment. Only line graphs can do this.

## Line or curve of best fit

Sometimes your data will produce perfect straight lines or perfect curves. At other times, your data might produce something that looks more like a dot-to-dot picture. This is when you try and construct a **line of best fit** or **curve of best fit**.

All experiments have errors in them. This means that the points on your graph have errors too and their positions are not exact. Connecting up the points in a dot-to-dot manner suggests that there is no error. It is more sensible to draw a straight line or smooth curve roughly through the 'centre' of your points. These lines or curves of best fit make patterns in your results easier to see. They also allow you to predict any missing measurements.

Figure 1.3.3 shows how a baby mouse (Figure 1.3.4) grew over its first week or so of life. The pattern in this data is shown by a line of best fit.

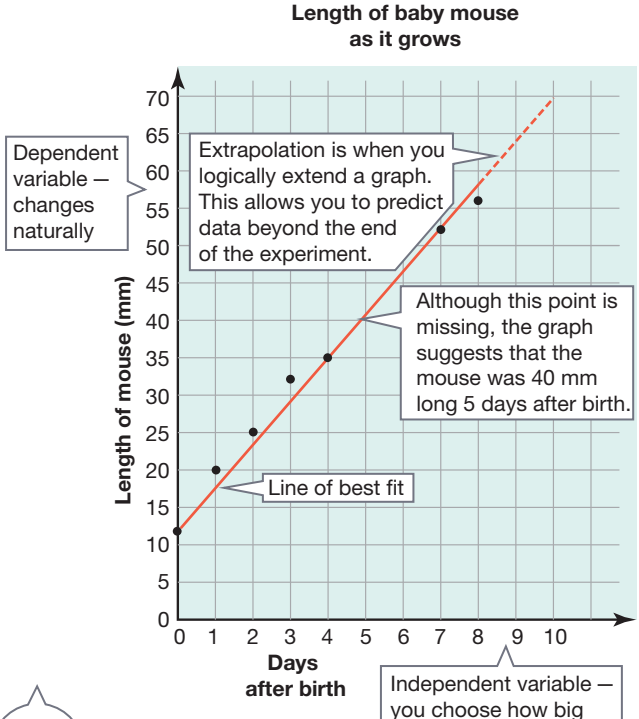



**Figure 1.3.3**

Do not connect the points up dot to dot but draw a straight line or curve through their 'centre'. This gives you a line of best fit.



**Figure 1.3.4** Baby mice grow quickly. A line graph best displays their growth.

A line of best fit doesn't explain the cooling of water, however. Figure 1.3.5 shows that the pattern in its data is displayed better by a curve.

Line graphs can also be extrapolated. **Extrapolation** is when a line graph is extended beyond its final measured value, allowing you to predict further measurements.

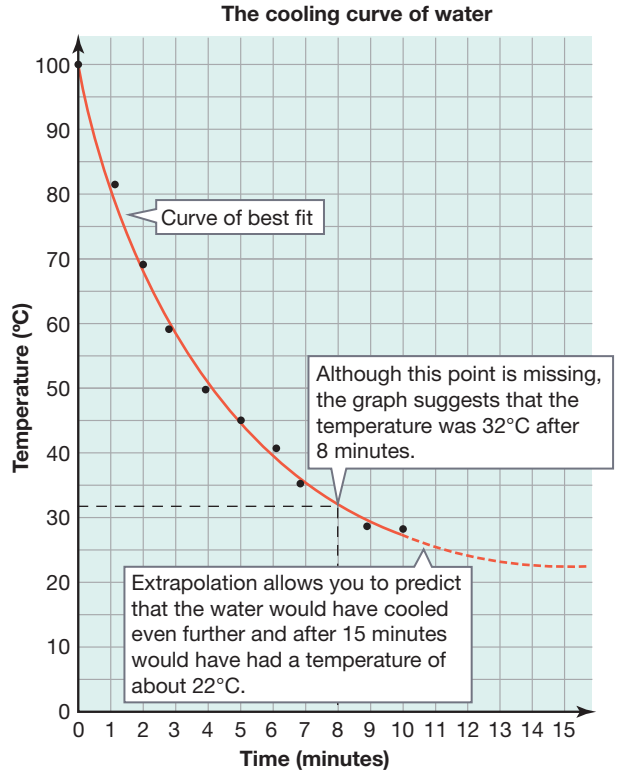



**Figure 1.3.5** Lines and curves of best fit can be used to predict data that was never actually collected in the experiment.

## How to avoid making common mistakes in line graphs

Some of the most common mistakes made by students in plotting line graphs are shown in Figure 1.3.6. It also shows the correct way of plotting them.

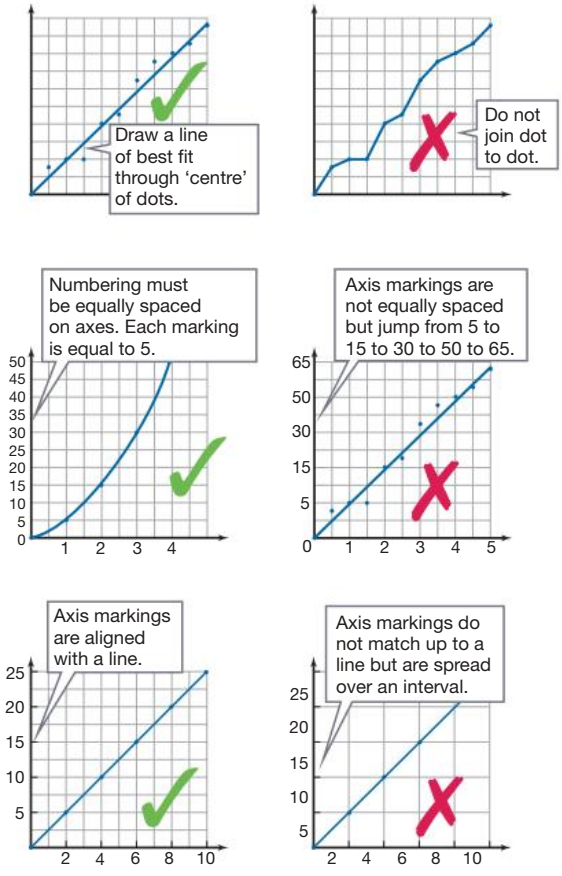



**Figure 1.3.6** Correct and incorrect ways of plotting line graphs

## Describing patterns

Graphs that produce straight lines or logical curves indicate that there is a pattern, rule or relationship between the variables that you tested. Some ways of describing these rules are shown in Figure 1.3.7.

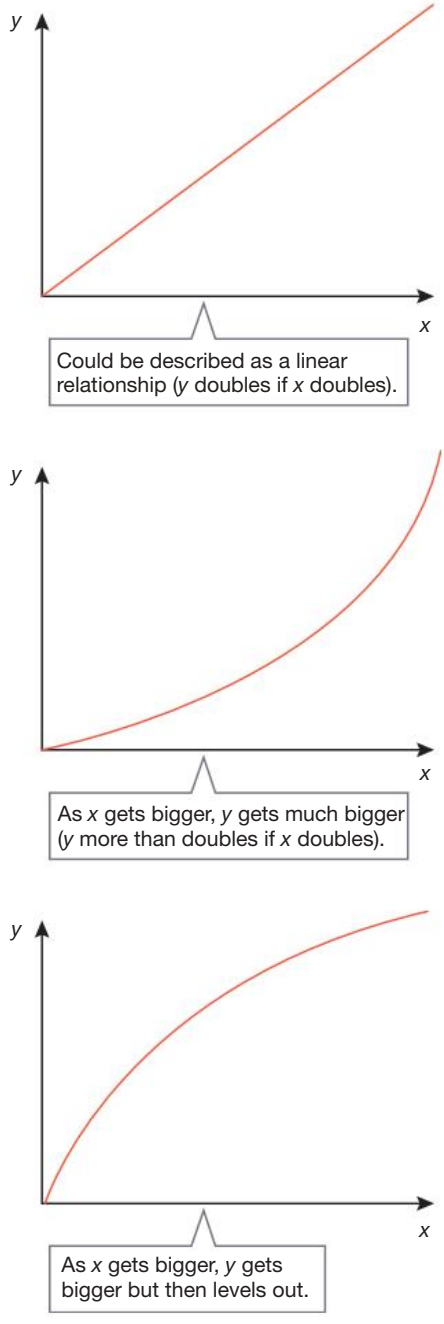



**Figure 1.3.7** Three ways of describing the shape of a line graph

1.6 1 p25 2 p26

# 1.3 Unit review

## Remembering

1 **List** in order the features that must be included in a practical report.

## Understanding

2 **Describe** the shape of the line graphs in Figure 1.3.8.

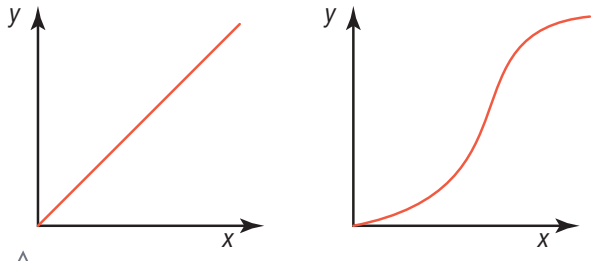



Figure 1.3.8

## Applying

3 Below are four similar sentences that could be used in a method. **Identify** which one is best.

- **A** Measure the temperature of the water.
- **B** We measured the temperature of the water.
- **C** A thermometer was used to measure the temperature of the water.
- **D** We are going to measure the temperature of the water.

4 A Year 8 prac had the purpose 'To find out if snails remember a path leading to food'. **Identify** which of the following four possible conclusions is best.

- **A** I learnt a lot about snails from this prac.
- **B** Snails cannot remember a path that leads to food.
- **C** Snails like food.
- **D** The prac was fun and I would do it again.

5 **Use** the graph in Figure 1.3.3 on page 21 to **predict**:

- **a** how long the mouse is likely to be after 10 days
- **b** when the mouse is likely to be 45 mm long.

6 **Use** the graph in Figure 1.3.5 on page 21 to **predict** the:

- **a** likely temperature of the water at 4.5 minutes
- **b** time at which the temperature was likely to be 25°C.

7 **a** **Identify** the point that is probably a mistake in the graph in Figure 1.3.9.

**b** Ignoring this mistake, **describe** the shape of the graph.

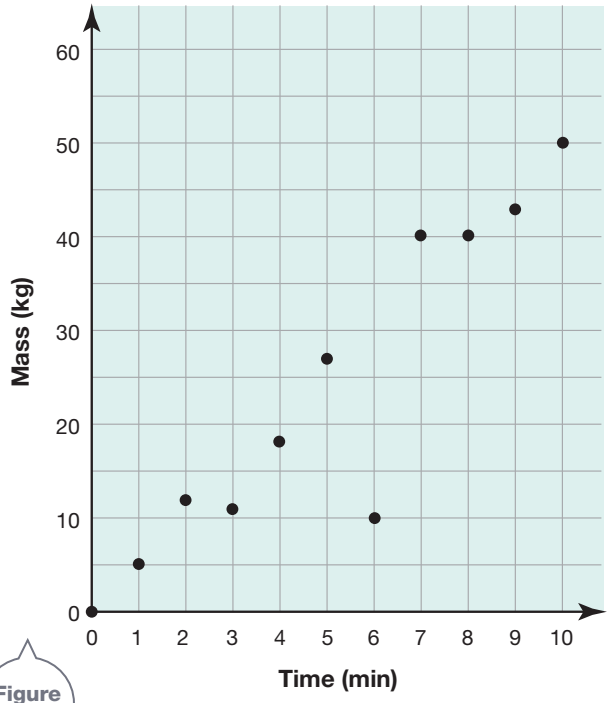



Figure 1.3.9

## Analysing

8 **Use** Table 1.3.1 on page 20 to **convert** the following units.

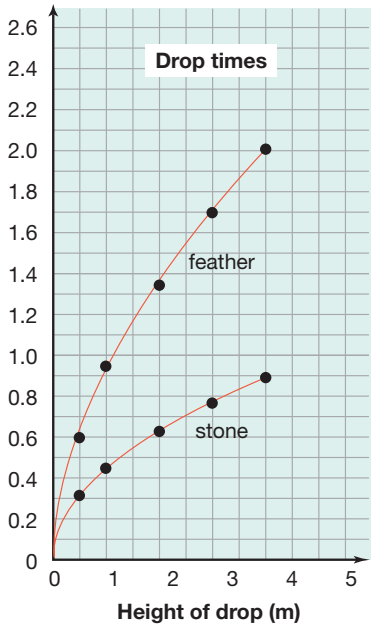
- **a** 5 ML into litres
- **b** 37 mL into litres
- **c** 500 000 mm into metres
- **d** 6 000 000 000 nm into metres

9 The metric prefixes milli, centi, kilo and mega are not used for time. If they were, then **calculate** what these times would be equivalent to.

- **a** 1 kilosecond or 1 ks
- **b** 1 centiminute or 1 cmin
- **c** 1 kiloday or 1 kd
- **d** 1 megasecond or 1 Ms

# 1.3 Unit review

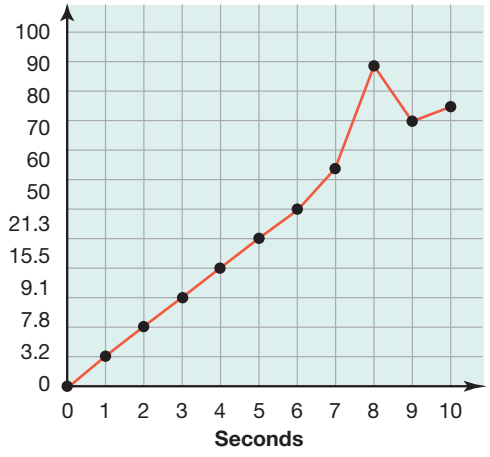
Figure 1.3.10




**10** Nell measured the times it took for a feather and a stone to fall from different heights so that she could compare them. She came up with the graph shown in Figure 1.3.10.

- **a** **Use** her graph to **predict** the drop time for the feather and stone from:
  - **i** 1.5 m
  - **ii** 2.5 m
  - **iii** 5.0 m.
- **b** **Use** her graph to **predict** the height the feather and the stone were dropped from if it took this long to fall.
  - **i** 0.5 s
  - **ii** 0.8 s
  - **iii** 1.0 s

Figure 1.3.11




**11** **Analyse** the graph in Figure 1.3.11 and **identify** five things that are wrong about it and the way it is plotted.

## Evaluating

**12** **Propose** reasons why:

- **a** you need to include the names of your partners in a prac report
- **b** all scientists use the same units for their measurements.

**13** The World Health Organization recommends people eat 10.9 MJ of food each day. On average in Australia we eat 13 500 kJ.

- **a** **Calculate** what these numbers represent in joules.
- **b** **Use** this information to **assess** the diet of Australians. Do we eat too little, just enough or too much?

## Creating

**14** **Construct** a table to show the data contained in Figure 1.3.9 on page 23.

## Inquiring

**1** Research what the following unit prefixes mean.

- **a** deci (d)
- **b** pico (p)
- **c** tera (t)

**2** Find what a tonne is and state how many kilograms it is equivalent to.

**3** Find what the following units are used to measure.

- **a** megatonne (Mt)
- **b** decibel (dB)
- **c** gigabytes (Gb)

**4** Use the key words *skillswise unit conversion* to find games on the internet that test how good you are at converting units.

**5** Advertising often uses data to make claims about particular products. Describe an advertisment that does this and outline how the data is used to make the product look good.

# 1.3 Practical activities

## 1 Candles and rising water

### Purpose

To plot a line graph and use it to make predictions.

### Materials

- 6–8 birthday candles
- matches
- small lump of plasticine or Blu-Tack
- 2 elastic bands
- shallow pan
- 250 mL beaker, gas jar or tall, narrow drinking glass
- 30 cm ruler

### Procedure

1. Make a small mound of plasticine or Blu-Tack in the centre of the pan and then fill the pan with water.
2. Stick one candle in the plasticine. Place both elastic bands around the glass and then place the glass over the candle as shown in Figure 1.3.12. If using a beaker, ensure that the water level is well over its pouring lip.
3. Roll the lower elastic band down to mark the water level.
4. Remove the glass, light the candle and quickly replace the glass over the candle.
5. Roll the other elastic band to mark the new water level.
6. Use the ruler to measure the change in water level. Record the change in a table like that shown in the Results section.
7. Repeat the experiment with three, five and seven candles. Each time, record the change in water level in your results table.

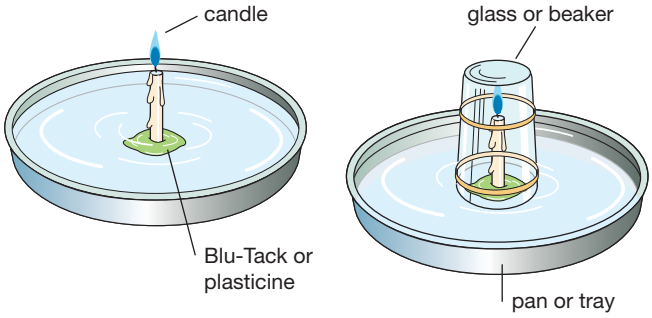



Figure 1.3.12

### Results

1. In your workbook, construct a table like the one shown below.

| Number of candles | Rise in water level (mm) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |

2. Plot a line graph showing what happened to the height of the water as more candles were added.
3. Use the graph to predict the water rise for two, four, six and eight candles.
4. Run the prac again for four, six and eight candles to check your predictions.

### Discussion

1. **Describe** the shape of the graph your plotted.
2. Does your graph suggest a relationship between the number of candles and the rise in the water level? **Justify** your answer.
3. **Predict** what would happen if you kept the number of candles the same but changed the following instead:
   - a the volume or depth of water in the tray
   - b the height or diameter of the gas jar
   - c the amount of plasticine.
4. **Propose** a reason why the water rose in this experiment.

## 2 The greenhouse effect

### Purpose

To demonstrate the greenhouse effect.

### Materials

- 2 thermometers
- clear plastic bag
- A4 sheet of white cardboard
- sticky tape
- stopwatch, watch or clock

### Procedure

1. Cut the A4 sheet of cardboard in two.
2. Stick one thermometer on each half so that they have a stiff backing.
3. Place one thermometer inside the plastic bag as shown in Figure 1.3.13. Tie it tightly so that no air can escape.
4. Place the plastic bag and the other thermometer side by side in direct sunlight.
5. Record the reading of each thermometer every minute for 15 minutes. Record the temperatures in a table like that shown in the Results section.
6. After 15 minutes, shift both to the shade to let cool. Continue reading each thermometer every minute for another 15 minutes.

### Results

1. In your workbook, construct a table or spreadsheet similar to the one shown below.

| Time (min) | Temperature in plastic bag (°C) | Temperature in the open (°C) |
|---|---|---|
| | | |
| | | |
| | | |

2. On the same set of axes, plot a line graph for the measurements from each thermometer.

### Discussion

1. **Identify** the thermometer that showed the faster increase in temperature.
2. **Identify** the thermometer that showed the faster drop in temperature.
3. **Describe** the shapes of each graph.
4. **List** the errors involved in this experiment.
5. Most scientists think that global warming and climate change are being caused by the enhanced greenhouse effect. **Propose** ways in which this experiment relates to global warming.

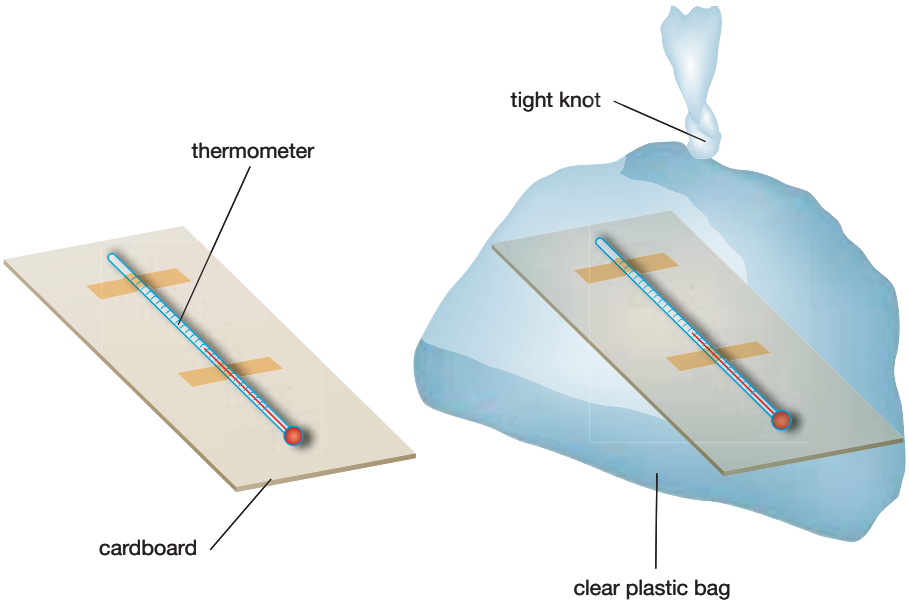



Figure 1.3.13

# 1.4 Planning your own scientific research



Science would never progress if scientists only ever used second-hand data. Progress happens because brand-new, first-hand data is obtained through experiments and scientific research. This research must be carefully planned or else the data obtained will not be trustworthy.

## Variables

**Variables** are factors that might have some influence on an experiment.

As an example, think of a simple experiment in which you are trying to determine the time it takes to toast a slice of bread. How long this takes will depend on many factors or variables.

A few are:

- the type of bread (Is it light and fluffy or heavy and dense?)
- the thickness of the slice (Is it thick, thin or in-between?)
- how dry the bread is (Is it old, dry and stale or new, fresh and moist?)
- the make of toaster (Is it Sunbeam, Breville or another brand?)
- the age of the toaster (Is it new or old?)
- how clean the toaster is. (Is it clean or covered in crumbs?)

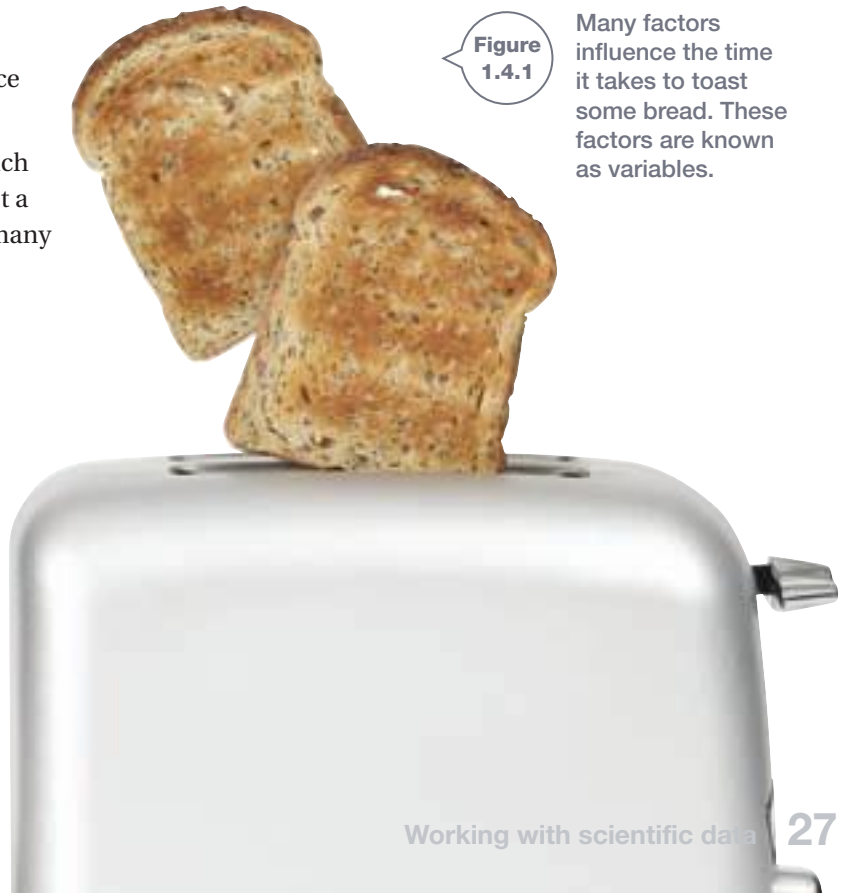


Figure 1.4.1 Many factors influence the time it takes to toast some bread. These factors are known as variables.

Not all variables are equally important. Some will greatly influence the experiment while others will have little or no effect. Important variables here are the type of bread, its dryness and thickness and the type of toaster (Figure 1.4.1 on page 27). The cleanliness and age of the toaster will have some effect (old and dirty ones will have crumbs on their elements that might affect their performance) but not as much as other variables.

## Independent variables

Once you have identified all the variables involved in an experiment, you then need to pick one to test. The variable you choose is known as the **independent variable**. It is the one you are going to change.

For the toast experiment, you might choose the thickness of the slice as your independent variable. You would change the thickness of the slice and test its effect on the cooking time (Figure 1.4.2).



Figure 1.4.2 The thickness and type of bread will affect how long it takes to toast it.

## Dependent variable

What you are trying to test is known as the **dependent variable** (because it depends on the independent variable). Change the size of the independent variable and the size of the dependent variable is likely to change too. The dependent variable in the toast experiment is the time it takes to toast the slice—it *depends* on the thickness of the slice.

## Controlled variables

Any experiment that you run needs to be a **fair test**. This means that only one variable should be changed at any time. All the other variables need to be controlled and held constant. For this reason, these variables are referred to as **controlled variables**. If they were changed too, then you would never know which variable caused changes in the experiment.

In the toast experiment, the controlled variables would be:

- the type of bread (choose one type of bread and use it throughout the experiment)
- how dry the bread is (all the bread you test would need to be the same dryness and age)
- the make, age and cleanliness of the toaster (stick with one toaster and don't change it).

# Scientific research

An experiment only changes one variable at a time. If you want to change another variable, then you need to run another experiment. This means that you could potentially run six or more different experiments to fully investigate the time it takes to toast bread!

A group of related experiments such as this is known as **scientific research**. Each new experiment changes another variable (with all the others kept constant) until you have tested them all.

Scientists do not carry out unrelated experiments but carry out scientific research on the one topic. This gives them a thorough understanding of it and allows them to become experts in it.

# Teamwork

Scientists generally do not work by themselves but work as part of a **team** like the one in Figure 1.4.3. Everyone is good at something and teamwork allows these strengths to be shared. Equally, we all perform less well at some things and teamwork allows others to help out when one of their members is struggling.

There are many different ways that teams can be organised. One that works well in the school laboratory is the following model in which there are four team members.



Figure 1.4.3 You will usually work as part of a team when carrying out scientific prac work.

- Manager—this team member oversees the whole team and prac. They make sure that everyone is on task and that the prac work is completed on time.
- Communicator—this team member communicates with the teacher and laboratory assistant. All communication to and from the team should pass through the communicator. The teacher may, for example, gather all the communicators together to go through the safety concerns of the prac or to show them how to use a particular piece of equipment. The communicator then passes on this information to the team.
- Equipment specialist—this team member collects all the required equipment and materials and makes sure the equipment is cleaned and returned to the correct spot at the end of the prac. They report any broken equipment to the communicator who passes on the information to the teacher.
- Recorder—this team member records all the observations and measurements that are taken throughout the prac. They also ensure that all the other team members have their own copy of results before they leave the laboratory.

1.7 1 p34

INQUIRY science 4 fun

## Researching on your own

Yes

Which paper towel and toilet paper are the most absorbent?

### Collect this …

- a collection of different absorbent paper towels and toilet papers
- equipment such as glasses or beakers
- equipment that can be used to measure volumes of water (e.g. eyedroppers, teaspoons, 10 mL measuring cylinders)

### Do this …

1 Brainstorm the variables that would influence how absorbent paper towels are.

2 Design and run two pracs that will test two of these variables.

### Record this …

**Describe** what happened.

**Explain** why you think this happened.

# SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

## The pendulum

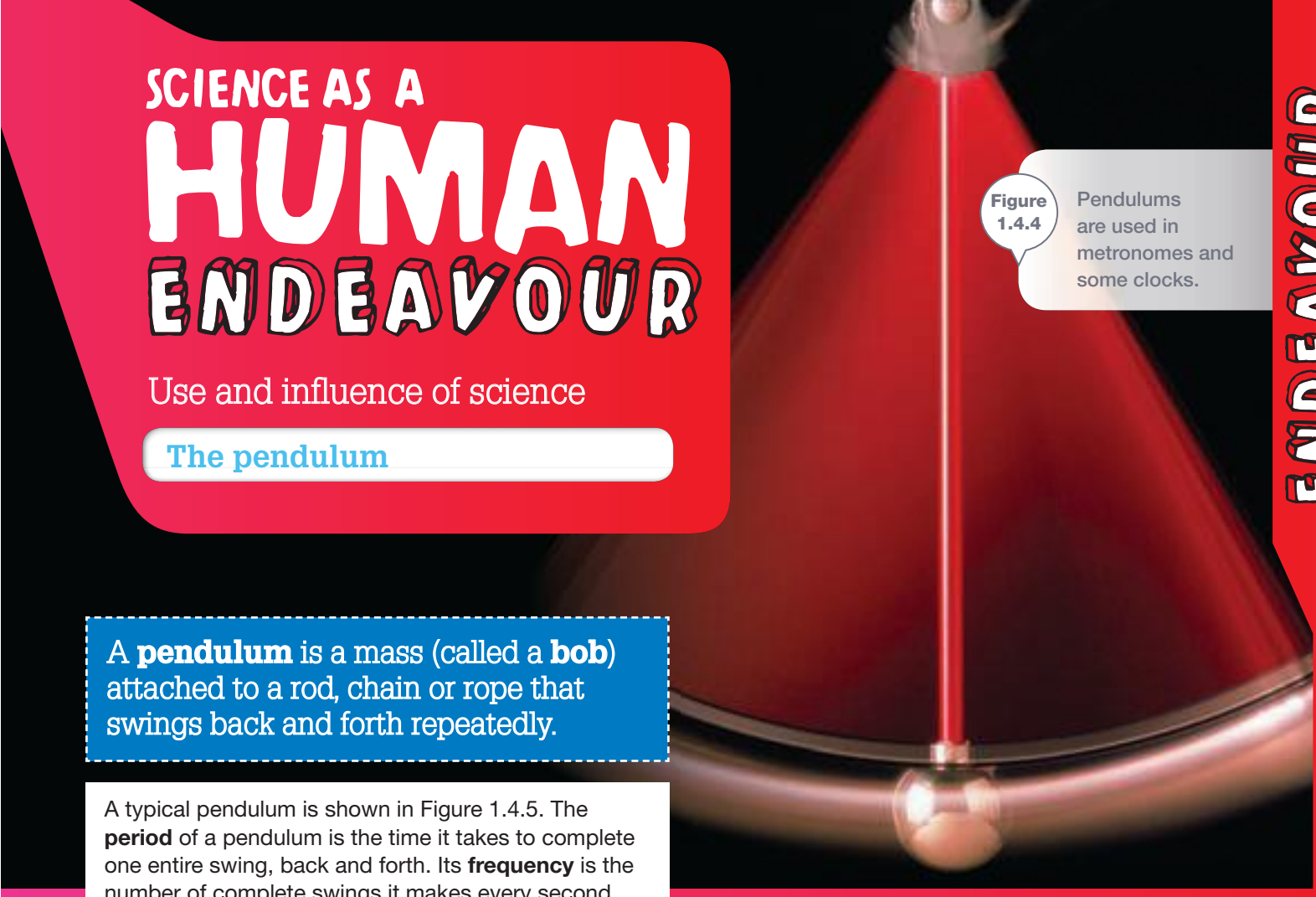
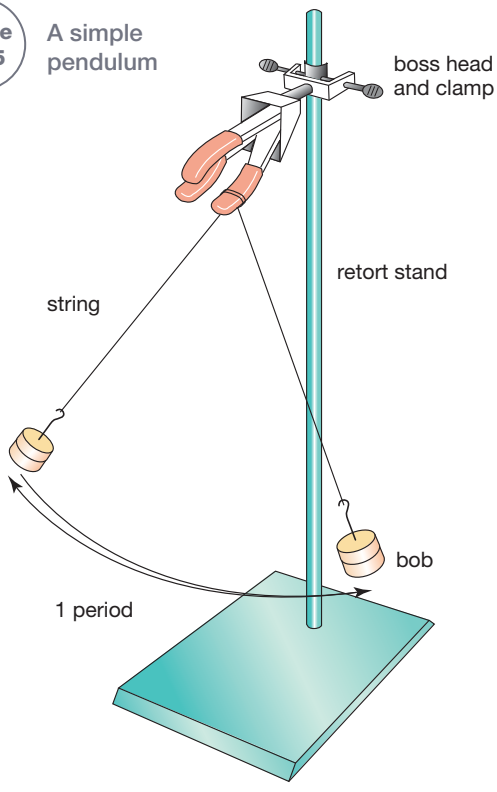


Figure 1.4.4 Pendulums are used in metronomes and some clocks.

A **pendulum** is a mass (called a **bob**) attached to a rod, chain or rope that swings back and forth repeatedly.

A typical pendulum is shown in Figure 1.4.5. The **period** of a pendulum is the time it takes to complete one entire swing, back and forth. Its **frequency** is the number of complete swings it makes every second. Period is measured in seconds (symbol s) and frequency is measured in **hertz** (symbol Hz).

Figure 1.4.5 A simple pendulum




### Foucault's pendulum

Every swing a pendulum makes is in a slightly different direction due to Earth's rotation about its own axis. After 24 hours, the pendulum returns to its original direction. A pendulum that does this is known as Foucault's pendulum and it is evidence that Earth is spinning.

### WORKED EXAMPLE

Period and frequency

**Problem**

A pendulum swings 10 times in 5 seconds. Calculate its period and frequency.

**Solution**

Period = time it takes to complete one swing

$$= \frac{5}{10} = 0.5\,\text{s}$$

Frequency = number of complete swings per second

$$= \frac{10}{5} = 2\,\text{Hz}$$

## Pendulum variables

Important variables that could affect the period of a pendulum are the:

- length of the string
- mass of the bob
- angle of the bob from the vertical at the start.

Gravity is another important variable but it is unlikely that you will ever be able to change it or test it. Without gravity, a pendulum would never swing. Gravity is the force that causes the bob to swing back and forth. The higher the gravity, the faster the bob will swing (giving a shorter period and an increased frequency).

2 p35
3 p35
1.8

## History of the pendulum

In 1602, the Italian scientist Galileo Galilei studied the pendulum and its variables in detail. His findings allowed scientists of the seventeenth century to develop new instruments and ways to measure the world around them.

## Timekeeping

Pendulums swing regularly back and forth when allowed to swing from angles of less than 10° from the vertical. This fact allows pendulums to be used in clocks. Before 1656, clocks were often 'out' by as much as 30 minutes. However, in that year, Dutch scientist Christian Huygens built a pendulum-based clock that was accurate to within a few seconds. Pendulums are still used to regulate the timing of grandfather and older-style mantle clocks. The bob of a grandfather clock is shown in Figure 1.4.6.

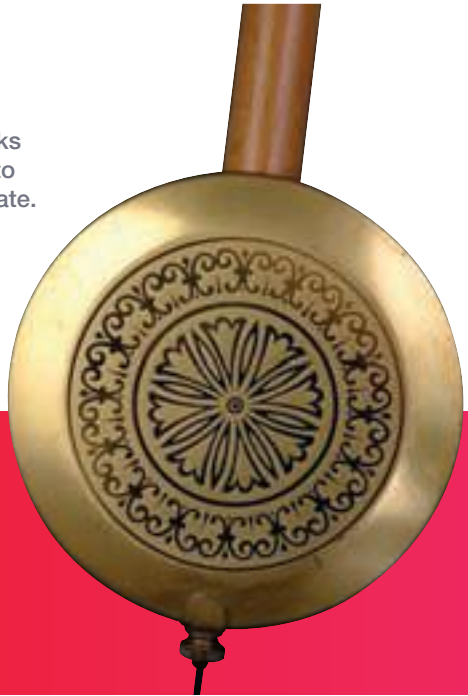


**Figure 1.4.6** Grandfather clocks use a pendulum to keep them accurate.



**Figure 1.4.7** A metronome is an 'upside-down' pendulum. Its period matches the timing of the music being practised.

**SciFile**

### Metronomes

Musicians use metronomes to keep in time when practising. A typical metronome is shown in Figure 1.4.7. A metronome uses a pendulum to regulate its time. The pendulum can be made to go quicker by sliding the mass down the rod and go slower by pushing it upwards.

## Navigation

Early explorers were often unsure of where they were on Earth because they had no way of accurately measuring their longitude (how far they were east or west on Earth). The invention of accurate clocks gave them the technology to measure time accurately. They set their clocks when they left port against standard Greenwich Mean Time. At noon, the Sun is directly overhead and the clock should read 12. If it didn't, then it meant that they had travelled east or west. Every hour their clock was 'out' represented another 15° they had travelled from longitude 0°. From this early explorers were able to calculate their longitude.

## Determination of the shape of the Earth

Gravity is one of the variables on which the period of a pendulum depends. The swings of a pendulum can therefore be used to measure the value of gravity around the globe. Pendulums swing a little slower at the Equator than at the poles. This proves that Earth is not perfectly spherical but is thicker at the Equator.

# 1.4 Unit review

## Remembering

1 **Recall** the different types of variables by matching them with their correct descriptions:

| | |
|---|---|
| independent | fixed |
| dependent | changes naturally |
| controlled | changed by you |

2 **List** four variables that are likely to influence the period of a pendulum.

3 **List** three areas in which pendulums assisted scientists in their understanding of Earth.

## Understanding

4 a **State** how many variables should be changed in the one experiment.
b **Explain** why.

5 **Define** the following terms.
a pendulum
b bob
c period
d frequency

6 **Explain** how explorers can use a clock to determine where they are on Earth.

7 **Explain** how seventeenth-century scientists determined that the Earth was not a perfect sphere.

## Applying

8 A pendulum takes 20 seconds to swing 40 times. **Calculate** its:
a period
b frequency.

9 Foucault's pendulum changes its direction continually but repeats its motion every 24 hours. **Use** the Earth's rotation to **explain** why.

## Analysing

10 **Analyse** the following experiments and **identify**:
i the dependent variable
ii two independent variables that are likely to be important.
a Prac A: To determine the amount of sugar that can be dissolved in water.
b Prac B: To determine the amount of time a pet dog sleeps per day.
c Prac C: To determine how long a parachute takes to drop 50 metres.
d Prac D: To determine the growth rate of a plant seedling.

11 **Contrast** scientific research with an experiment.

## Evaluating

12 **Propose** advantages that the managerial model brings to the:
a team
b teacher.

13 Someone in your team just got hurt in a prac. You want to tell the teacher but your team is organised on the managerial model and you're not the communicator. **Propose** what you should do.

14 A pendulum is used to control the timing of a grandfather clock.
a For this pendulum, **predict** its period and frequency.
b **Justify** your predictions in Part a.



## Inquiring

1 Search available resources such as textbooks, encyclopedias and the internet to complete the following tasks.
   - **a** Construct a timeline of the major discoveries involving the pendulum.
   - **b** Research how pendulums were used to prove that gravity differs slightly around the Earth.
   - **c** Research how pendulums caused clocks to become more and more accurate.
   - **d** Construct a diagram of a compound pendulum.

2 A pendulum normally swings back and forth directly under its support. However, if you start it swinging 'off-line' (not directly under its support), then it will swing around, tracing loops and circles.
   - **a** Use the ideas shown in Figure 1.4.8 to design a pendulum that could draw sand pictures.
   - **b** Check your design with your teacher and then construct it.

3 Construct a series of diagrams or collect a series of photos that show how the parachute has changed over time. Label each diagram or photo with its date.

4 Search the internet to find videos showing:
   - **a** how pendulum clocks work
   - **b** parachute drops and skydiver formations.

Figure 1.4.8

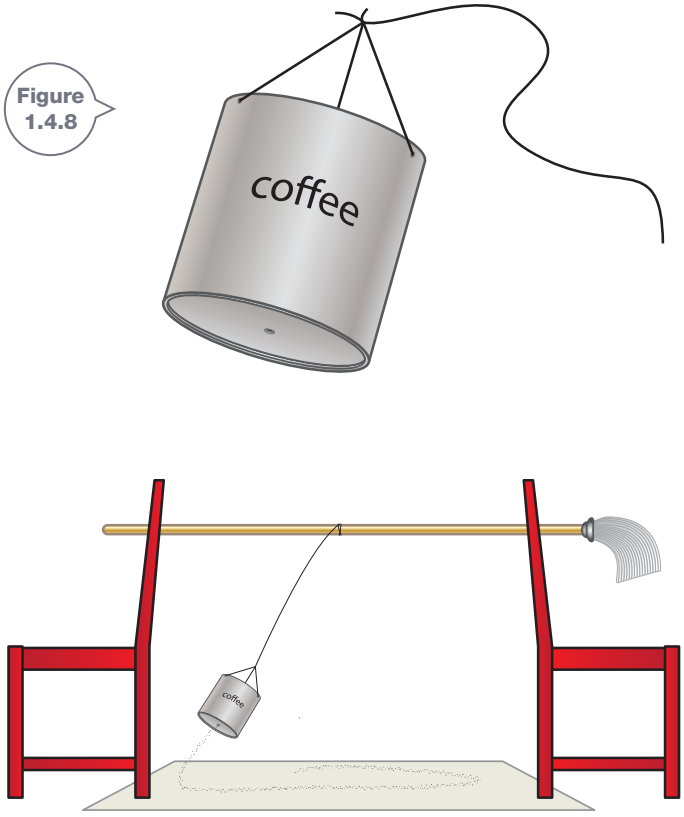





Figure 1.4.9 Skydivers in formation

# 1.4 Practical activities

## 1 Parachute drop time

### Purpose

To determine what influences the drop time of a parachute.

### Materials

- lightweight materials (such as tissue paper, plastic sheet from garbage bags, newspaper)
- fine cotton
- access to a hole punch
- sticky tape
- small masses (plasticine or paperclips are ideal)
- access to electronic balance
- stopwatch
- metre ruler or tape measure

### Procedure

1. Brainstorm all the variables that could affect the drop time of a parachute.
2. Select the two variables that your prac team thinks will have the most effect.
3. Design two experiments that will test your two variables. Remember to keep everything else the same.
4. When constructing your chutes, reinforce the string holes with patches of sticky tape like the one shown in Figure 1.4.10.
5. Drop your chutes from a height of at least 2 metres.
6. Make repeated measurements of the time they take to hit the ground, recording them in a table or spreadsheet.

### Results

1. Construct a line graph for each experiment.

### Discussion

1. **List** the variables that your prac team thought may be important in this experiment.
2. **Explain** why you chose the variables you tested and not others.
3. **Describe** the shape of all graphs you plotted.
4. **Construct** conclusions for both experiments.

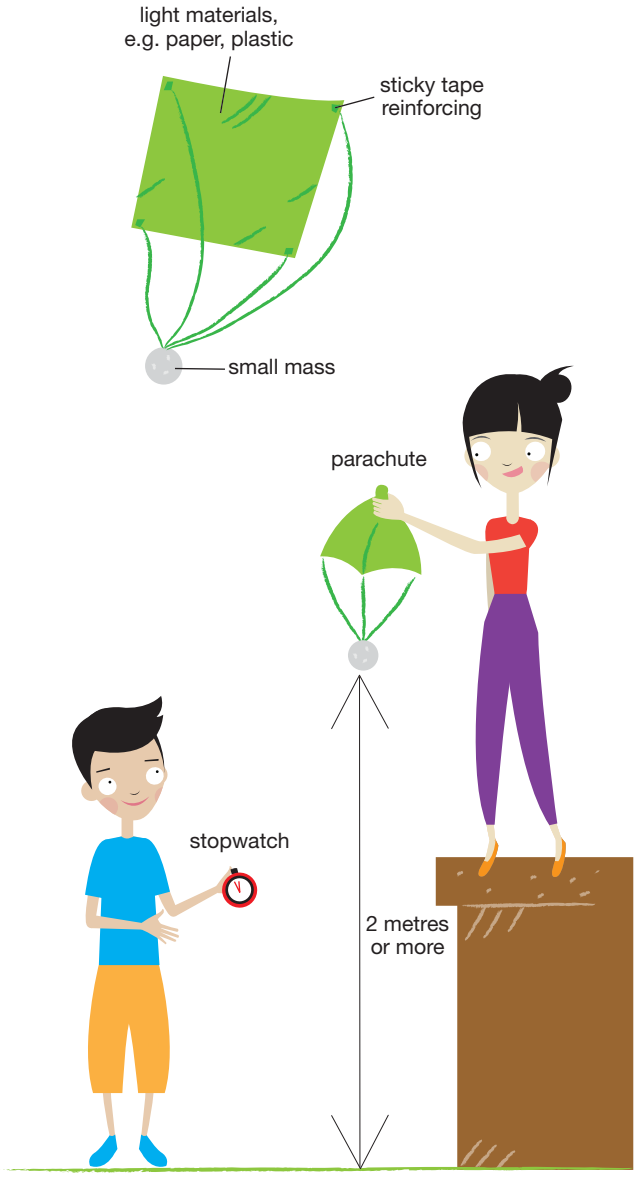



Figure 1.4.10

## 2 The pendulum and length

### Purpose

To test how the length of a pendulum affects its period.

### Materials

- materials to construct a pendulum
- stopwatch or appropriate datalogging equipment
- protractor (optional)

### Procedure

1. The independent variable here is the length of the pendulum and so you need to keep the mass and the angle the pendulum is swung from the same throughout the prac. Decide what values you will use.
2. Decide on the lengths that you will test. At least five different lengths should be tested.
3. You need to repeat measurements for the time taken for ten complete swings. Decide how many times you will repeat each experiment.
4. Run your experiment, recording the time taken in a table.

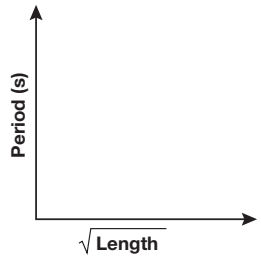
### Results

1. Construct a table or spreadsheet for the measurements you take.
2. Calculate the average time for ten swings and for one swing (the period).
3. Plot a graph of period versus length.

**Extension**: One aim of a scientist when analysing results is to try and get a straight line when plotting graphs. If you didn't get a straight line, then try the next few steps.

4. Make another column in your table. Use a calculator to take the square root $\sqrt{\ }$ of the lengths you used and enter these into the new column.
5. Plot a new graph of period versus square root of length like that shown in Figure 1.4.11.

Figure 1.4.11




### Discussion

1. **Describe** the shape of each graph that you plotted.
2. **List** the controlled variables in this experiment.
3. **State** the independent and dependent variables in this experiment.
4. **Construct** a conclusion for what you found out.

## 3 The pendulum, mass and starting angle



### Purpose

To test if mass and starting angles change the period of a pendulum.

### Materials

- materials to construct a pendulum
- stopwatch
- protractor

### Procedure

1. Your task is to design and report on an experiment that tests how starting angle or mass affects the period of a pendulum.
2. Whatever variable you test, include in your report a line graph of period versus your variable.

### Discussion

1. **Explain** how you controlled all the variables other than the starting angle in this experiment.
2. **Construct** a conclusion that summarises what you found out.

# 1 Chapter review

## Remembering

1 **State** whether the following are true or false.
- a A measurement ranging from 10°C to 14°C could be written as 12 ± 2°C.
- b A measurement of 21 ± 1 cm spreads from 21 to 22 cm.
- c Human reactions cannot be faster than 0.5 seconds.
- d A line of best fit connects its points dot to dot.
- e 'The prac was fun' is a good conclusion for an experiment.
- f The period of a pendulum is the time it takes for it to swing from one side to the other.

2 **List** three pieces each of qualitative data and three pieces of quantitative data that would help describe where you live.

3 **List** five types of errors.

4 **Name** the variable that:
- a is changed by you
- b varies naturally as the experiment proceeds
- c is fixed.

5 **List** four variables that might be expected to influence:
- a the period of a pendulum
- b a person's fitness
- c the time it takes to fry a sausage
- d the temperature reached inside a parked car.

## Understanding

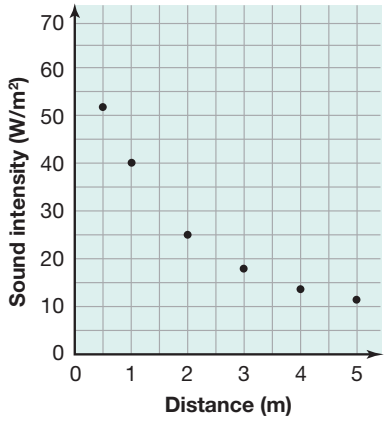
6 **Define** the following terms.
- a purpose
- b hypothesis
- c conclusion
- d bibliography
- e pendulum

7 **Explain** what a fair test is.

## Applying

8 **Use** the graph in Figure 1.5.1 to **predict** the sound intensity (measured in watts per square metre) at:
- a 2.5 m
- b 3.5 m
- c 150 cm

Figure 1.5.1




9 Extrapolate the graph in Figure 1.5.1, extending it logically backwards to zero. **Use** your extrapolation to predict what the sound intensity at a distance of 0 metres would be.

10 **Use** the graph in Figure 1.5.1 to **predict** the distance at which the sound intensity was:
- a 45 W/m²
- b 15 W/m²

11 **Identify** the variables that could logically influence:
- a how much liquid paper towelling absorbs
- b how quickly iron rusts
- c how quickly a banana ripens
- d how often you go to the toilet to urinate
- e how good you are at sport.

## Analysing

12 Consider the following list of volumes: 87 mL, 82 mL, 90 mL, 86 mL, 97 mL, 93 mL
- a **Identify** the results that should be eliminated.
- b **Calculate** the average.

## Creating

13 **Construct** a labelled diagram showing the parts of a simple pendulum.




14 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

| | | |
|---|---|---|
| data | internet | experiment |
| first-hand | second-hand | variable |
| independent | dependent | fair test |
| controlled | | |

# Thinking scientifically

Anila ran an experiment in which she measured the period of a pendulum. This is the time it takes for a mass on a length of string to swing back and forth once. The data she obtained is shown in the table below.

| Mass of bob (g) | Length (cm) | Angle swung from | Time for 10 complete swings (s) | Average period (s) |
|---|---|---|---|---|
| 50 | 50 | 10° | 142 | 1.42 |
| 50 | 100 | 10° | 201 | 2.01 |
| 50 | 150 | 10° | 246 | 2.46 |
| 50 | 200 | 10° | 283 | 2.83 |
| 50 | 250 | 10° | 317 | 3.17 |

**Q1** Identify the two variables that Anila controlled in her experiment.

- **A** Mass and length
- **B** Length and angle
- **C** Mass and angle
- **D** Average period and time for ten swings

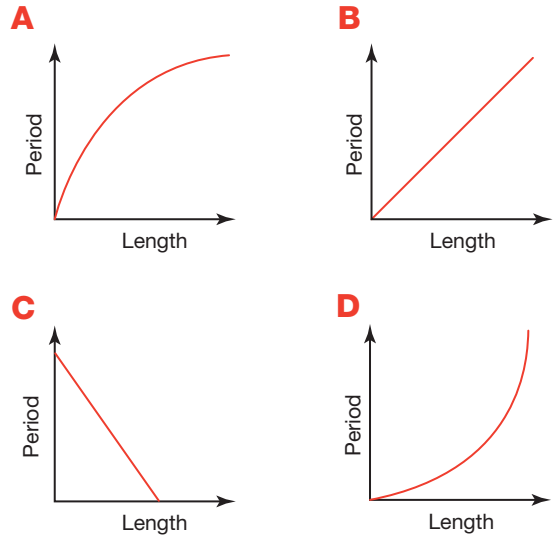
**Q2** State which is the most likely aim for her experiment.

- **A** To test the effect of changing mass on the period of a pendulum
- **B** To test the effect of changing length on the period of a pendulum
- **C** To test the effect of changing angle on the period of a pendulum
- **D** To test the effect of changing times for ten complete swings on the period of a pendulum

**Q3** Anila did not try to time a single swing but instead timed ten complete swings. Identify the most likely reason explaining why she did this.

- **A** She can count to ten.
- **B** It reduced the effect of errors in her timing.
- **C** The change in period only becomes noticeable after ten swings.
- **D** It was the only way to test her chosen variable.

**Q4** Identify which of the four sketch graphs A–D best describes her results.




**Q5** Identify the best conclusion for her experiment based on her results.

- **A** Pendulums control the timing of grandfather clocks.
- **B** A pendulum will swing faster if it is started at a greater angle.
- **C** Heavier masses cause a pendulum to swing faster.
- **D** Increasing the length of the pendulum increases its period.

# Glossary

## Unit 1.1

**Average:** mean; add up all the 'good' values and divide by how many there are

**Data:** measurements and observations about something

**Errors:** small changes to measurements that cannot be avoided, even with care

**First-hand data:** data you collect yourself from an experiment

**Instrument error:** error due to a faulty instrument or using it at a temperature it is not designed for



First-hand data

**Mean:** average; add up all the 'good' values and divide by how many there are

**Mistakes:** can be avoided with care; mistakes are not errors

**Parallax error:** error caused by not having your eye directly in line with the measurement

**Qualitative data:** observations that are descriptive only

**Quantitative data:** measurements that use numbers (and usually units)

**Reading error:** error due to guesswork needed when a measurement falls between an instrument's markings

**Second-hand data:** data you have not found through an experiment; comes from textbooks, encyclopedias, internet etc.

**Tare:** changing the zero on an electronic balance

**Zero error:** error due to instrument giving a small reading when it should read zero

## Unit 1.2

**Bibliography:** resource list

**Domain:** last part of a website's address or URL

**Imprint page:** includes all relevant data about a book such as publisher and year of publication

**URL:** website address



URL

## Unit 1.3

**Aim:** purpose; what you are trying to do in an experiment

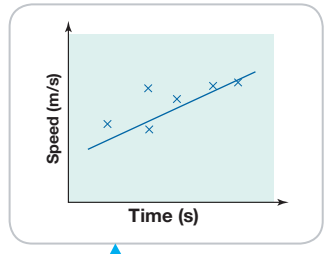
**Bibliography:** resource list

**Conclusion:** a short summary of what you found out in an experiment

**Extrapolation:** logical extension of a line graph

**Hypothesis:** an 'educated guess' about what might happen in an experiment

**Line or curve of best fit:** straight line or curve drawn through the 'centre' of points on a graph




Line of best fit

**Method:** a description of what you did in an experiment

**Purpose:** aim; what you are trying to do in an experiment

## Unit 1.4

**Bob:** the mass on the end of a pendulum

**Controlled variable:** the variable kept constant throughout an experiment

**Dependent variable:** the variable you are measuring; it changes as the independent variable changes

**Fair test:** when only one variable is changed in an experiment

**Frequency:** the number of complete swings of a pendulum in 1 second

**Hertz:** the unit for frequency (symbol Hz)

**Independent variable:** the variable changed by you; it will probably cause a change in the dependent variable

**Pendulum:** a mass that swings back and forth

**Period:** time taken for pendulum to complete one swing, back and forth

**Scientific research:** a series of experiments on the one topic

**Team:** your prac partners and you

**Variables:** factors that may influence an experiment

# Cells

# 2



## HAVE YOU EVER WONDERED…

- what your skin and hair would look like if they were magnified?
- why plants are green but humans are not?
- why animals need a skeleton but plants do not?

## After completing this chapter students should be able to:

- recall that cells are the basic units of living things
- use a light microscope to examine a variety of cells
- distinguish plant cells from animal or fungal cells
- identify structures within cells and describe their functions
- recall that some organisms consist of a single cell
- describe the specialised cells and tissues involved in structure and function of particular organs
- explain that mitosis is the type of cell division used for growth and repair.

# 2.1 Making things bigger



Sometimes people wear glasses to help them to see clearly. Even if you have very good eyesight, some things in our world are so small or so far away that you will need help to see them. Astronomers use telescopes to observe distant stars or details of the surface of the Moon and planets. Binoculars help bird watchers identify birds high in a tree. Using microscopes, scientists can see things that are invisible to the naked eye.

INQUIRY science 4 fun

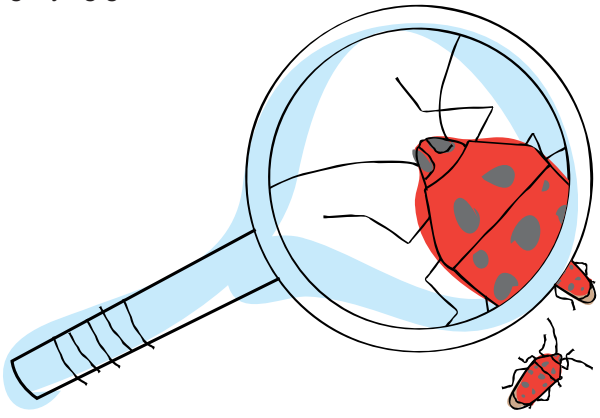
## It looks different!

Yes

What can you see using a magnifying glass that you could not see before?

### Collect this…

- magnifying glass



### Do this…

Use the magnifying glass to look at familiar things around you. Some suggestions are your fingerprint, the hairs on the back of your hand or arm, soft leaves, soil, an ant and pictures from a newspaper.

### Record this…

**Describe** what you could see with the magnifying glass that you could not see with your naked eye.

**Explain** why you were able to see things differently.

# Microscopes

Small things need to be **magnified** or made bigger so that they become visible to us. Scientists use **microscopes** to do this. Objects that can only be seen using a microscope are described as **microscopic**. Microscopes allowed scientists to see the tiny building blocks that make up living things and to see for the first time microscopic living things such as bacteria. Figure 2.1.1 compares the detail you can see with and without a microscope.

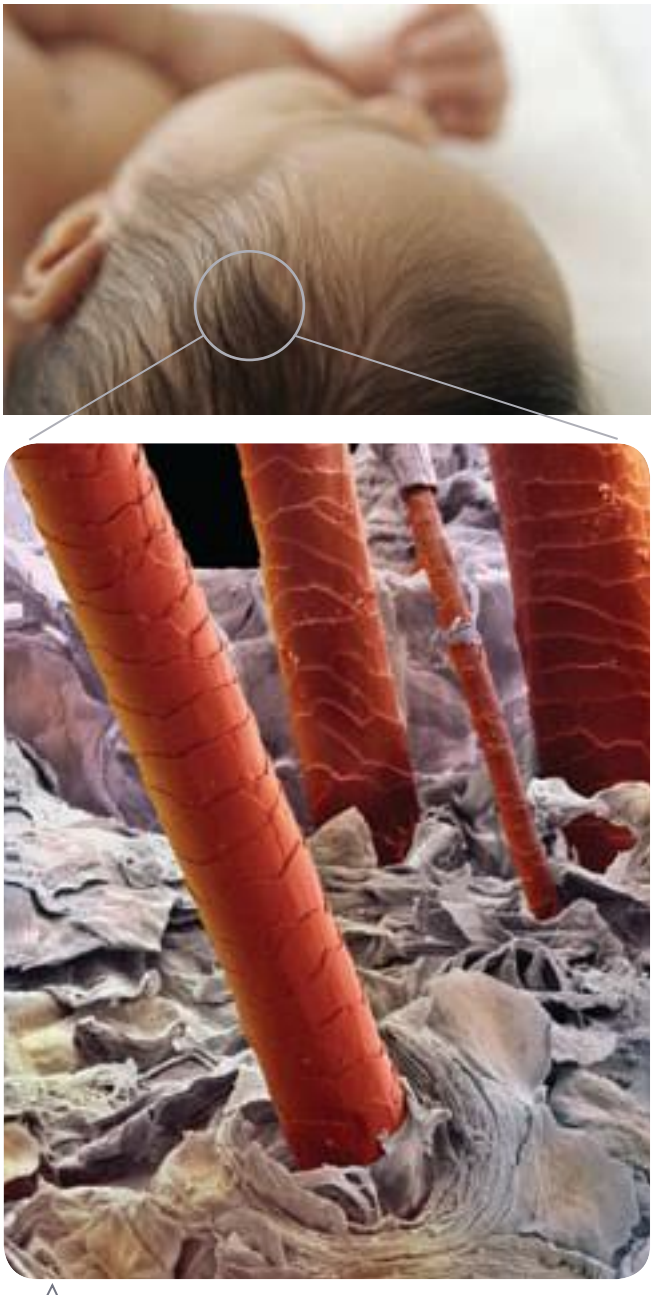


**Figure 2.1.1** In the picture on the top, you can see the baby's hair and scalp, but a microscope can show so much more than your naked eye can. Using a very powerful microscope, you can see single hairs surrounded by skin cells of the scalp.

The type of microscope used in schools and many laboratories is a **light microscope**. Light from a mirror or a lamp passes through a **specimen** or object. The specimen being looked at must be very thin so that the light can pass through it easily. The light then passes through a series of lenses that cause the specimen to appear bigger. What you see through the microscope is called the **image**. You will probably use a microscope like the one shown in Figure 2.1.2. This is a monocular light microscope (**monocular microscope**) because it has only one eyepiece or ocular lens. Many light microscopes have two eyepieces or ocular lenses. They are **binocular microscopes**.

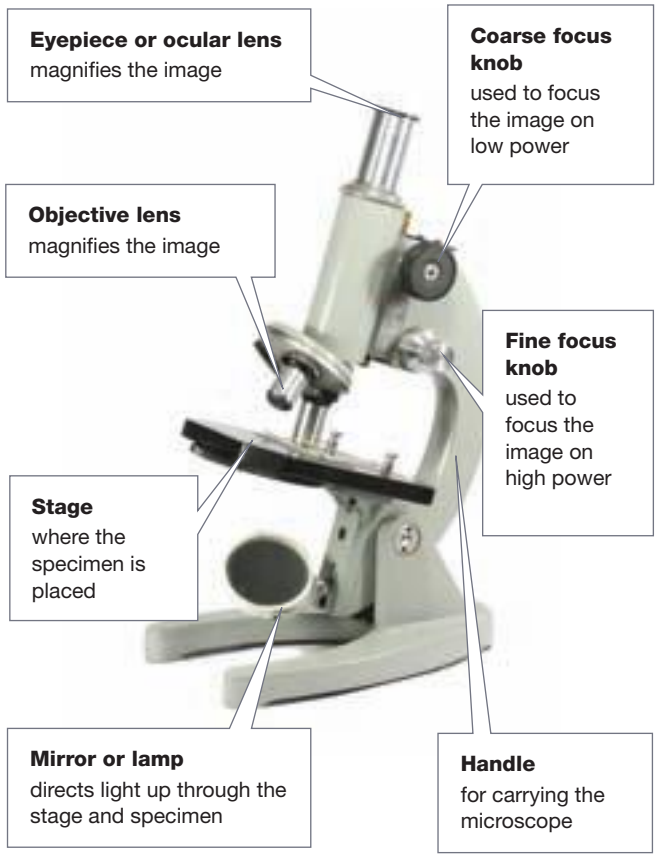



**Figure 2.1.2** This photograph shows how the parts of a microscope are organised.

1 p46

2.1

## Stereo microscopes

When you hear music in stereo or see an image in stereo, it means that the information is coming from two different directions. Using a **stereo microscope** is like having two monocular microscopes joined together, with each one focusing on the same point but from different angles. The image you see is therefore in three dimensions.



**Figure 2.1.3** Stereo microscopes give a realistic 3D view of the specimen. The distance between the specimen and the objective lens also leaves room for scientists to work on the specimen.

The light source for stereo microscopes may be lamps or reflected light from the Sun. Light shining onto the specimen is reflected back up through the lenses to create the image. Light does not pass through the specimen, and therefore the specimen does not have to be thinly sliced or prepared in any other way. This means that anything can be placed under a stereo microscope.

The distance between the objective lens and the specimen is much greater than in a monocular or binocular microscope. This means that you can work on the specimen as you are viewing it. This gives the stereo microscope its other name of dissecting microscope. A **dissection** is when a scientist cuts apart a dead plant or animal to study it. Scientists can carry out dissections while they are looking through the microscope: the scientist in Figure 2.1.3 is dissecting a plant.

When you move a specimen under a stereo microscope the image moves in the same way. That is, you move the specimen to the right and the image also moves to the right.

Table 2.1.1 compares monocular or binocular microscopes with stereo microscopes.

**Table 2.1.1 Comparison of types of light microscope**

| Monocular or binocular microscope | Stereo microscope |
|---|---|
| Provides a two-dimensional image of the specimen. | Provides a three-dimensional image of the specimen. |
| Maximum magnification about ×1000. | Maximum magnification about ×100. |
| When viewed through the microscope, the image appears to move in the opposite direction to the actual movement. | When viewed through the microscope, the image appears to move in the same direction as the actual movement. |
| Light passes through the specimen. | Light reflects off the specimen. |
| Specimen is placed on a slide. May be complete objects such as microscopic organisms or fibres. However, specimens are frequently a very thin slice. | Specimen can be anything—no preparation is required. |
| When the specimen is sliced, it provides a view of the inner structure of the specimen. | Provides a view of the surface of the specimen. |
| Shows colour of the original specimen; however, stains or dyes can be used to increase the contrast between parts. | Shows colour of the original specimen |

## Magnification

The **magnification** of the microscope tells you how much bigger the image is than the real object. If the microscope has a magnification of ×10, then the image is ten times bigger than the actual object. (The symbol × stands for *magnified by*.)



### Calculating magnification

The microscope in Figure 2.1.2 on page 41 has two lenses—the eyepiece or ocular lens, and the objective lens. Both lenses magnify the specimen. To calculate the total magnification, you multiply the magnification of the ocular lens by the magnification of the objective lens. Some examples are shown in Table 2.1.2.

**Table 2.1.2 Calculation of common magnifications**

| Ocular lens magnification | Objective lens magnification | Calculation and total magnification |
|---|---|---|
| × 10 | × 4 | × 10 × 4 = × 40 |
| × 10 | × 10 | × 10 × 10 = × 100 |
| × 10 | × 40 | × 10 × 40 = × 400 |

As the magnification increases, then the amount of the specimen you can see (the **field of view**) gets smaller.

The maximum magnification achieved by light microscopes is about ×1000. At this magnification some of the largest bacteria are just visible.

2 p47

The magnification of stereo microscopes is lower than in monocular or binocular microscopes, with ×100 the usual maximum magnification.

## Very small measurements

Units like metres (m) or centimetres (cm) are normally used to describe your height, and centimetres or millimetres (mm) to describe the diameter of a coin or the length of a pin. However, it is difficult to measure the diameter of the full stop at the end of a sentence because a full stop is less than one millimetre in diameter. You will either have to estimate the size of the full stop as a fraction of a millimetre, or use a smaller unit. Many of the objects observed using a microscope are smaller than the full stop and so must be measured in units smaller than a millimetre.

A **micrometre** (μm) is one-thousandth of a millimetre, or one-millionth of a metre. It is the unit most often used by scientists to measure microscopic objects.

# Electron microscopes

**Electron microscopes** are much more powerful than light microscopes. You can see this in Figure 2.1.4. Electron microscopes use beams of tiny particles called electrons instead of light, and they are able to magnify up to a million times. There are two types of electron microscopes: transmission electron microscopes (TEM) and scanning electron microscopes (SEM). Table 2.1.3 compares these two types of microscopes.

**SciFile**

### Discovering bacteria

The 17th century Dutch scientist Antonie van Leeuwenhoek discovered bacteria by observing the plaque from between his own teeth under a microscope.

**Table 2.1.3 Comparison of TEM and SEM**

| TEM | SEM |
|---|---|
| Specimen is a very thin slice. | Specimen can be anything. No need to slice. |
| Electrons pass through the specimen. | Electrons reflect off the surface of the specimen. |
| Provides a view of the inner structure of the specimen (e.g. a cell). | Gives greatly magnified views of objects (e.g. insects, leaf surface, bacteria). |
| Image is black and white but can be coloured to increase contrast. | Image is black and white but can be given false colour using computers. |

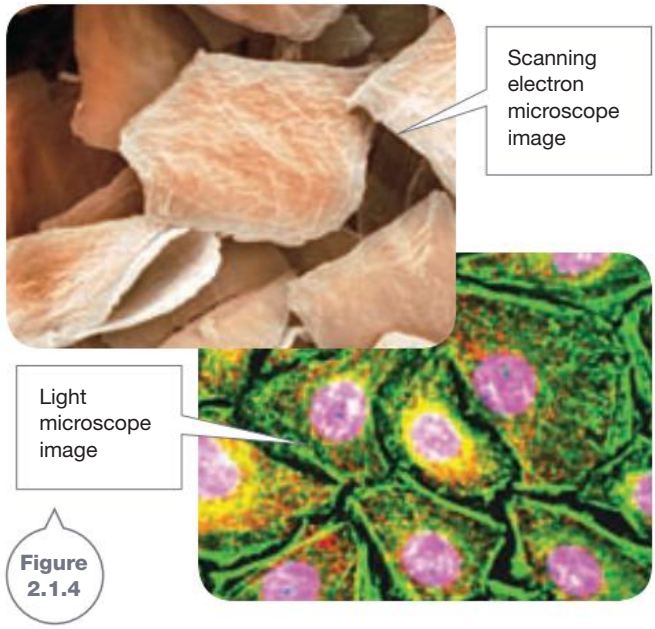



**Figure 2.1.4**

Light microscopes and scanning electron microscopes provide very different images of the same cells.



## Converting units of length

Scientists use many units of length and often have to convert one to the other. In the metric system, these conversions are carried out by multiplying or dividing by a factor of ten such as 10, 100 or 1000. Table 2.1.4 shows you how to make some conversions.

**Table 2.1.4 Converting units of length**

| Unit of length | Convert by | To |
|---|---|---|
| Kilometres (km) | × 1000 | Metres (m) |
| Metres (m) | × 100 | Centimetres (cm) |
| Centimetres (cm) | × 10 | Millimetres (mm) |
| Millimetres (mm) | × 1000 | Micrometres (μm) |
| Metres (m) | ÷ 1000 | Kilometres (km) |
| Centimetres (cm) | ÷ 100 | Metres (m) |
| Millimetres (mm) | ÷ 10 | Centimetres (cm) |
| Micrometres (μm) | ÷ 1000 | Millimetres (mm) |

# 2.1 Unit review

## Remembering

1 **Name** the lenses found in a light microscope.

2 **Recall** the units used to measure microscopic objects.

3 **Recall** what happens to the field of view as the magnification used increases.

4 **Name** two different types of:
- **a** light microscope
- **b** electron microscope.

## Understanding

5 **Explain** why people examining a crime scene might use a magnifying glass as they search for clues.

6 **Define** the following terms.
- **a** microscopic
- **b** specimen
- **c** image

7 **Describe** what happens to the image seen in a monocular microscope when the slide is moved:
- **a** to the left
- **b** to the right
- **c** downwards.

8 **Explain** why the specimen prepared for a monocular microscope must be very thin.

9 **Describe** how to calculate the magnification of a microscope.

10 **Explain** why there is more detail in an image produced using a TEM than in the image from a light microscope.

## Applying

11 **Calculate** the numbers missing from the following unit conversions.
- **a** 5 cm = ____ mm
- **b** 8000 µm = ____ mm
- **c** 1 m = ____ µm

12 **Calculate** how many micrometres are in 3 millimetres.

13 **Calculate** the total magnification in the following examples.

| | Ocular lens | Objective lens |
|---|---|---|
| **a** | ×4 | ×10 |
| **b** | ×10 | ×100 |
| **c** | ×4 | ×40 |

14 The image of the specimen shown in Figure 2.1.5 was obtained using a magnification of ×40. **Apply** your knowledge of magnification to draw a picture of the image magnified ×80.

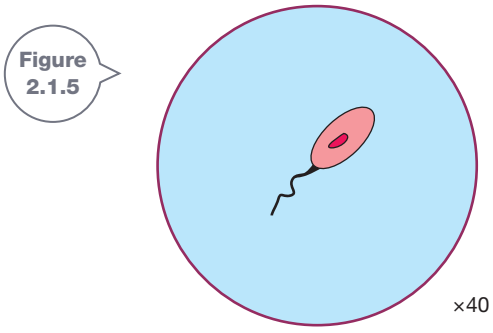



Figure 2.1.5

## Analysing

15 Use the information in Figure 2.1.6 to **compare** the size of a human cheek cell, a fat cell, a red blood cell and a white blood cell.

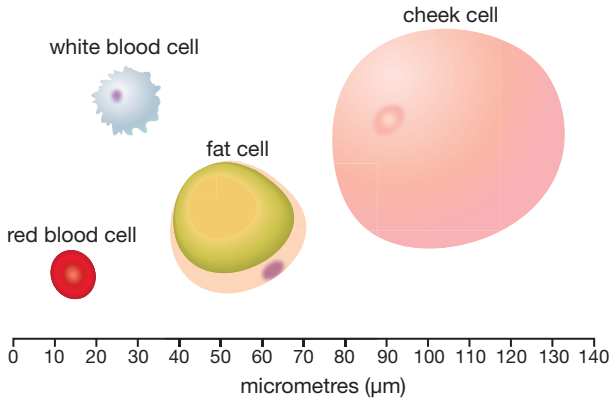



Figure 2.1.6

16 **Compare** the way the electrons move to produce the images in a SEM and a TEM.

17 **Compare** the way that specimens are prepared for a stereo microscope and a monocular microscope.

18 **Compare** the image seen using a stereo microscope with the image created with a SEM.

## Evaluating

19 a **Identify** the type of microscope that most likely produced the image shown in Figure 2.1.7.

b **Justify** your answer.

## Creating

20 **Construct** a table that lists the parts of the microscope and summarises the functions of each part.

## Inquiring

1 Research microscopes and state the maximum magnification that can be achieved by different types.

2 Research electron microscopes and state when the first one was built and who built it.

3 Investigate ways that electron microscopes are used in a variety of workplaces.

4 Use available resources to research and describe an electron.

Figure 2.1.7



# 2.1 Practical activities




## Preparing a wet mount

1 Place a drop of water onto the specimen on the microscope slide. If a stain is being used, then it can be added to the drop of water at this stage.

2 Gently lower a thin glass cover slip onto it as shown in Figure 2.1.8.

3 Soak up any excess water or stain with a piece of filter paper or tissue.

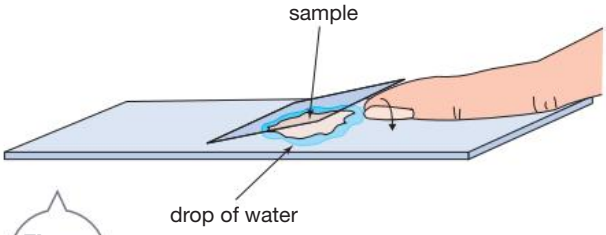



Figure 2.1.8

1

## Getting to know the microscope

Before starting this activity, make sure that you have read and understood the Skill Builders 'Preparing a wet mount' and 'Using a microscope' at the top of these pages.

### Purpose

To make a wet mount and view it using a monocular or binocular microscope.

### Materials

- monocular microscope
- microscope lamp (if needed)
- a section of newspaper containing small print
- eye-dropper
- glass microscope slide
- cover slip



**SAFETY**

Cover slips and microscope slides break easily. Treat them with care.

### Procedure

1 Cut out a small section (1 cm × 1 cm) of newspaper with small print. Make sure that there is a letter 'e' in the section.

2 Use the newspaper to prepare a wet mount slide by following the procedure described in the Skill Builder above.

3 Set the microscope to the lowest magnification and focus the image of the newsprint. Try to get the letter 'e' into the field of view.

4 Slowly move the slide containing the newsprint to the left, and record which way the image appears to move.

5 Record how the image moves when the slide is moved to the right, away from and towards you.

6 Increase the magnification and then observe the news print again.

### Results

For two different magnifications:

1 Sketch what you see in a field of view.

2 Record the magnification used.

3 Count how many letters fit in the field of view.

### Discussion

1 **Recall** whether the letter 'e' was the same way up as on the newsprint, or upside down.

2 **Recall** how the letters in the specimen appeared to move by copying the following sentence into your notebook and filling in the blanks as you go.

*When I moved the slide to the right, the letters appeared to move to the ____. Moving the slide towards me seemed to make the letters move ____ from me. Then, when I moved the slide away from me, the letters moved ____ me. Every time I moved the slide, the letters seemed to go in the ____ direction.*

3 **State** how many letters fitted into the field of view at each magnification.

4 **Explain** the relationship between the field of view and the amount of the specimen that can be seen.




## Using a microscope

1. Place the slide on the stage and secure it using the clips.
2. Adjust the mirror or diaphragm so that the maximum amount of light is passing through the slide.
3. Select the objective lens with the lowest magnification.
4. Looking at the microscope from its side, adjust the coarse focusing knob to bring the stage and objective lens as close as possible to each other.
5. Looking through the eyepiece, turn the coarse focusing knob so that the stage and objective lens move further apart.
6. Keep doing this until the specimen is in focus.
7. Adjust the fine focusing knob to sharpen the focus on the specimen.
8. If you miss the point of focus, go back to step 4 and start again.

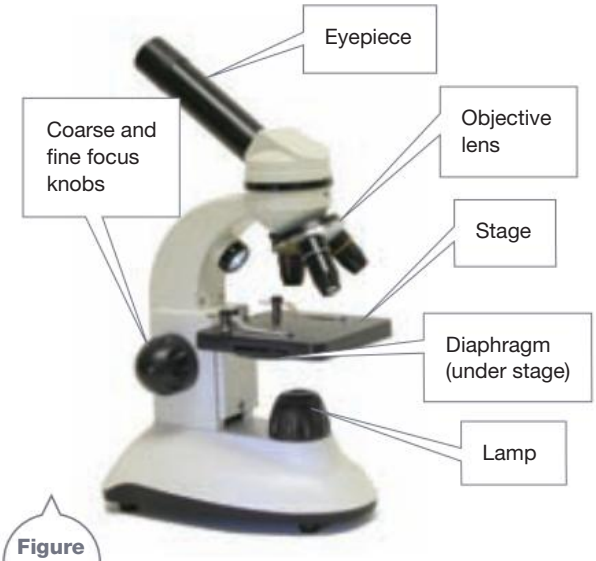



**Figure 2.1.9**

## 2 I can see more!

Before starting this activity, make sure that you have read and understood the Skill Builder 'Using a microscope' above.

### Purpose

To observe common objects at various magnifications.

### Materials

- monocular or binocular microscope
- microscope lamp
- glass microscope slides
- cover slips
- eye-dropper
- small samples suitable for viewing under a microscope, such as a sugar crystal (both plain and caster), salt, copper sulfate, hair, clothing fibres, leaf, insect, writing sample (in ballpoint pen ink), mini grid (optional). Note: These do not need to be viewed as wet mounts.



**SAFETY**

Cover slips and microscope slides break easily. Treat them with care.

### Procedure

1. Observe a small specimen of each item under the microscope.
2. If you do not see an image, try shining the microscope lamp onto the surface of the object. You may notice that this works very well with solid objects.

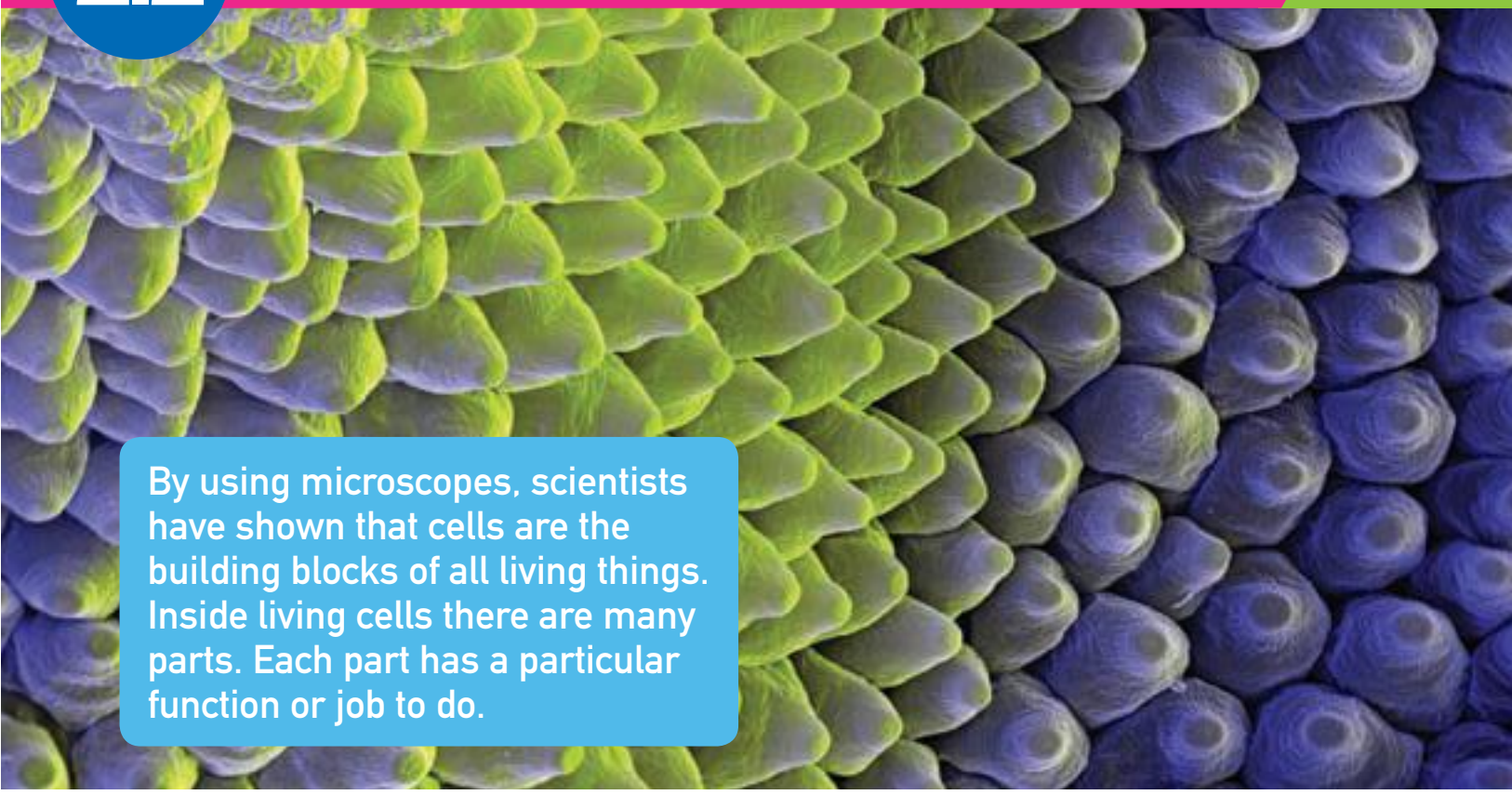
### Results

Sketch what you see in each case and record the magnification used to obtain the clearest image.

### Discussion

1. **Describe** in words how each specimen appeared. In your description note observations that were not possible without the microscope.
2. **State** which specimen you found most interesting, and **explain** why.

# 2.2 Natural building blocks



By using microscopes, scientists have shown that cells are the building blocks of all living things. Inside living cells there are many parts. Each part has a particular function or job to do.

## Animal cells

**Cells** are the building blocks of all living things, including animals. If an animal cell was made big enough to hold in your hands, then it would probably feel like a clear balloon filled with water or thin jelly. You would also be able to see that there are tiny things inside the cell. These things are usually only visible using a microscope. Figure 2.2.1 shows the structure of a typical animal cell.

An electron microscope is needed to see some even smaller cell parts in the cytoplasm. These smaller parts are known as **organelles**. Each organelle has a special function:

- **Mitochondria** are the powerhouses of the cell, which release energy from food.
- **Ribosomes** are microscopic factories that produce the proteins used by the body for growth and repair.
- **Lysosomes** are the garbage disposal units that get rid of wastes from the cell.
- **Endoplasmic reticulum** form pathways that allow materials to move quickly and easily through the cell.

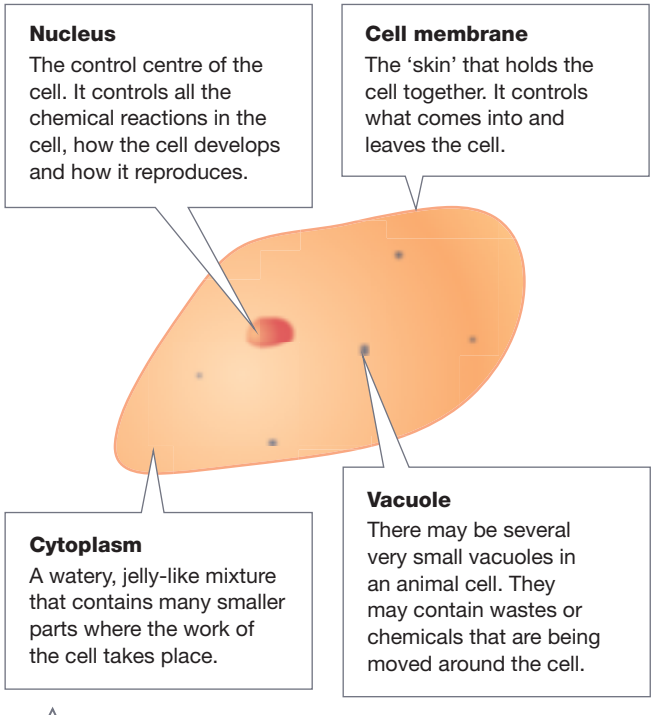



Figure 2.2.1 This typical animal cell contains smaller parts known as organelles. Each organelle has its own specific job to do within the cell.

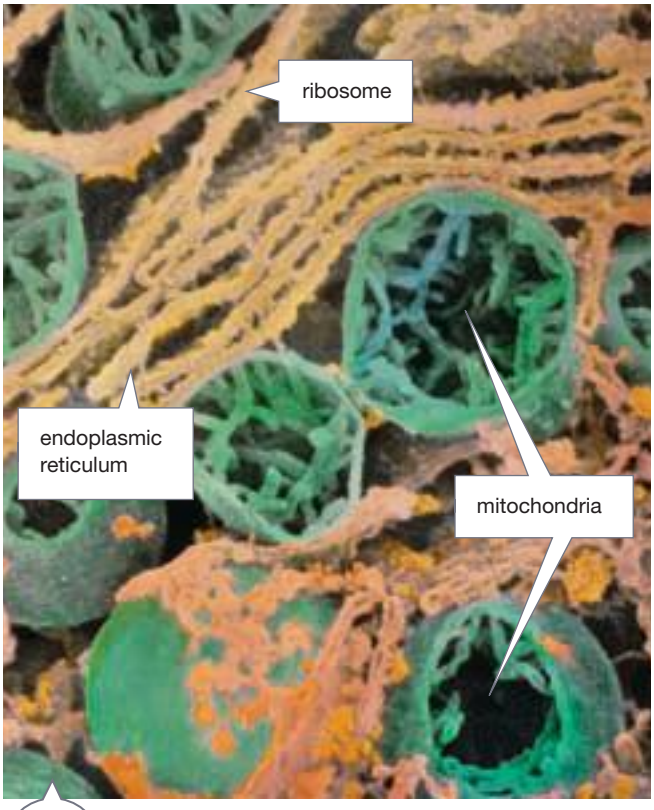



**Figure 2.2.2** The organelles within a cell are so small that they can only be seen clearly with an electron microscope at magnifications of over ×100 000.

# Plant cells

Plants have the same parts as animal cells plus a few extra parts. Figure 2.2.3 shows the structure of a typical plant cell. Like animal cells, plants cells have a cell membrane, cytoplasm and a nucleus. The vacuole in a plant cell is much larger than in animal cells. Plant cells also have a **cell wall** outside the cell membrane. The cell wall helps support the plant and gives it shape. Many plant cells contain additional organelles called chloroplasts. **Chloroplasts** contain a green substance called chlorophyll and are the site of photosynthesis. Plants cannot go hunting for their food. Instead, they make it themselves using energy from the Sun to chemically combine water and carbon dioxide (one of the gases in air) to make a sugar called glucose. This process, called **photosynthesis**, takes place in chloroplasts, which are found in the green parts of plants.

p55 p56

2.2 2.3 2.4

INQUIRY science 4 fun

## Human cells

What do your cells look like?

No

### Collect this ...

- monocular microscope
- lamp
- commercially prepared slide of cheek cells

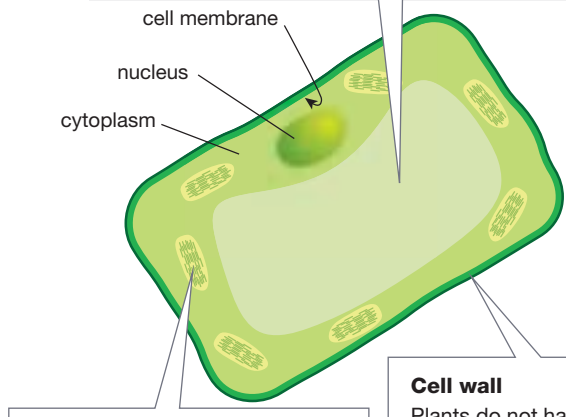
### Do this ...

1. Place the prepared slide of cheek cells on the microscope stage. These cells have probably been prepared using a stain that makes them easier to see.
2. Observe the cells first under low power and then under high power.

### Record this ...

**Describe** what you saw.

**Explain** the function of each feature you observed in the cell.




**Vacuole**
The vacuole in plant cells is large and occupies most of the cell. It is filled with sap and stores water, wastes and nutrients. When it is full the vacuole pushes against the cell wall and helps to keep the plant rigid.

**Chloroplast**
Plants make their own food from water and carbon dioxide (one of the gases in air) using energy from the Sun. Photosynthesis takes place in chloroplasts, which are found in the green parts of plants.

**Cell wall**
Plants do not have a skeleton like you, so they need something else to keep them upright and to keep their shape. This is the function of the cell wall, which lies outside the cell membrane.

**Figure 2.2.3** A typical plant cell has all the organelles that an animal cell has but also has chloroplasts and a cell wall.

### How many?

There are about 50 trillion cells in your body. They come in different shapes and sizes, each with their own special job to do. For example, cells in the heart cause it to beat. Some blood cells fight infection, while others carry oxygen around your body.

SciFile

# Fungal cells

Cells of fungi have the same parts as animal cells. As shown in Figures 2.2.5 and 2.2.6, fungal cells also have a cell wall like a plant cell. However, plant and fungal cell walls are made of different chemicals. Fungal cells do not have chloroplasts; therefore they cannot make their own food. Fungi produce substances that digest the material they are growing on. They then absorb the digested materials into their cells.

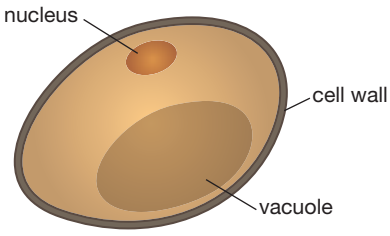
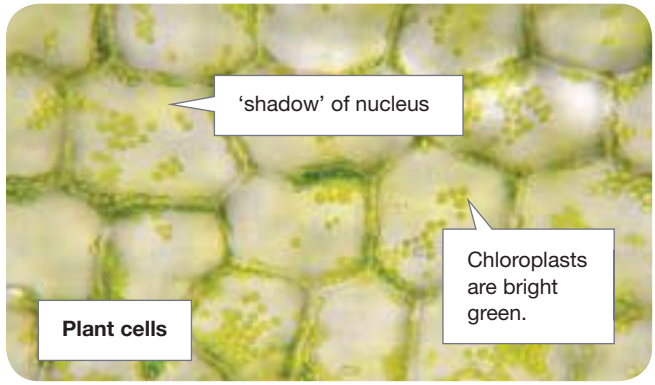


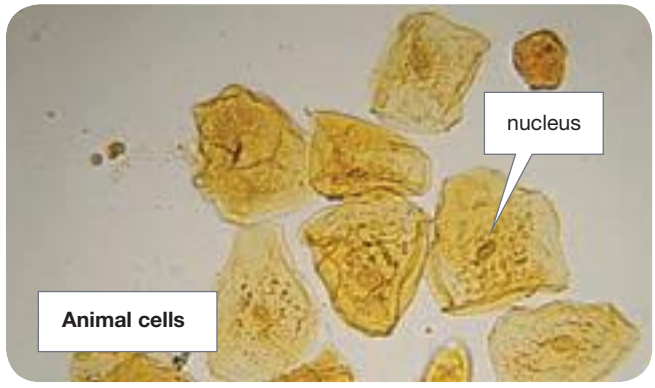

**Figure 2.2.4** A typical fungal cell has the same organelles as an animal cell. It also has a cell wall like that found in a plant cell.

### Tough stuff

The cell walls of plants are so 'chemically tough' that animals cannot digest them without help. Bacteria in the stomach of cows and other plant-eating animals digest the cell walls, making the nutrients available to the animals. When humans chew, they crush plant cells, releasing the contents, but the cell wall leaves the body undigested. This undigested cell wall is the fibre in our diet.

SciFile



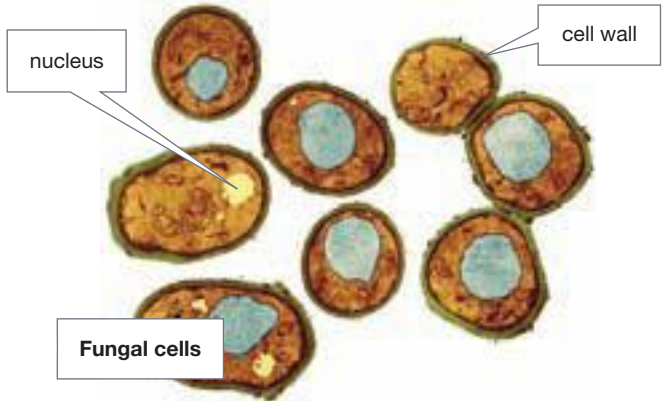




**Figure 2.2.5** A nucleus is present in all cells, animal, plant and fungal.



**Figure 2.2.6** Yeast is a fungus made of only one cell. Most fungi, however, are made up of many cells. This mushroom is an example.

Figure 2.2.7 A microscope is needed to see red and white blood cells.

# SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

## Cells and microscopes

Zaccharias Janssen and his son Hans made reading glasses. In about 1590 they were experimenting with their lenses and placed two lenses inside a tube. They then looked through it. Objects placed close to the tube appeared much larger. This observation was the first step towards inventing the microscope.

In 1665 the English scientist Robert Hooke used a microscope like the one shown in Figure 2.2.8 to investigate cork. He saw that cork resembled a honeycomb. The cork was made of small boxes that Hooke described as *cellulae* (a Latin word meaning 'little storage rooms'). You can see them in his drawing in Figure 2.2.9. Hooke had discovered cells. Cork cells are dead plant cells and have nothing inside them; therefore Hooke saw only cell walls. Since the time of Hooke, the term *cellulae* has changed to become cells.

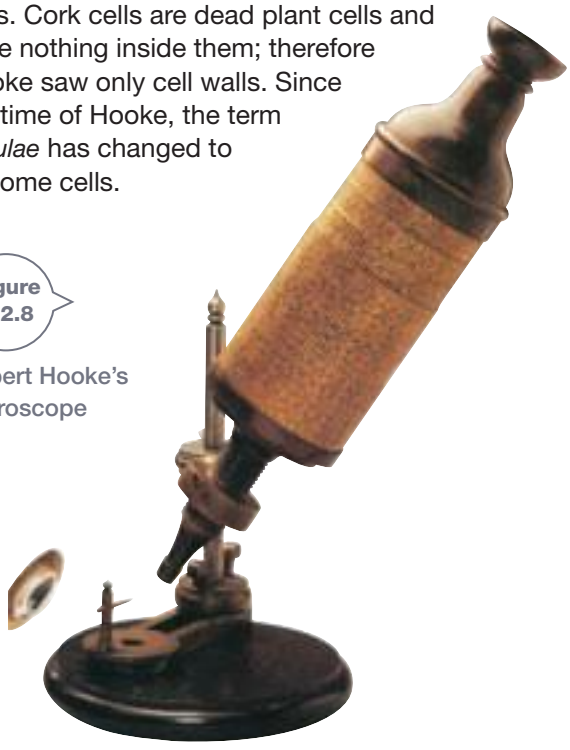


Figure 2.2.8 Robert Hooke's microscope



Figure 2.2.9 Hooke's original 1665 drawing of cork cells

A few years later, in 1674, the Dutchman Antonie van Leeuwenhoek used a microscope to look at pond water and saw small things moving about. What he was seeing were small, single-celled (unicellular) living things. This made Leeuwenhoek the first person to observe and describe microscopic living things. He was also the first person to observe and describe human red blood cells and bacteria. To do this, Leeuwenhoek had improved on the early microscopes and he achieved magnifications of up to ×250.

Many years later, in 1833, the Scottish scientist Robert Brown discovered that plant cells were not just empty boxes but that they had a nucleus inside them. It took another 70 years to identify other organelles such as the chloroplasts.

In 1838 Matthias Schleiden, a German scientist, analysed the known information about plant cells. He proposed that cells are the basic building blocks of all plants, and that new plants start off as a single cell. As plants grow, new cells are produced.

A year later a friend of Schleiden's, Theodor Schwann, proposed that all animals are made of cells and that the cell is the basic unit of life. Identifying this link between plants and animals is regarded by scientists as one of the most important discoveries in the development of biology.

In 1842 the Swiss scientist Karl Nägeli observed cells dividing to make new cells. This was the first time that scientists understood that new cells came from existing cells.

In 1855 the German scientist Rudolf Virchow linked the observations of Nägeli and Brown. He proposed that all cells develop from existing cells and don't just spring up from nowhere.

The work of these people led to the development of cell theory, which explains the relationship between cells and living things. Cell theory states:

- All living things are made up of one or more cells.
- Cells are the basic building blocks of all living things, making up their structure and allowing them to function.
- New cells are produced from existing cells. This is what is happening in Figure 2.2.10.

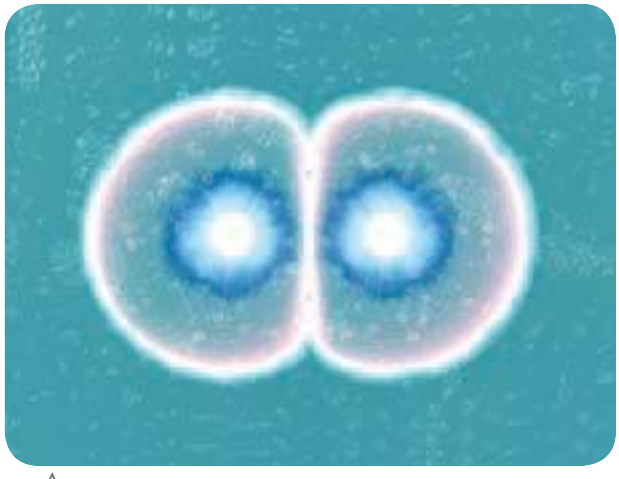


**Figure 2.2.10** One cell dividing to produce two cells

In 1931 the German engineer Ernst Ruska (Figure 2.2.11) designed and built the first electron microscope. This allowed scientists to see even smaller things such as viruses, which are too small to be seen using light microscopes.



**Figure 2.2.11** Ernst Ruska

It had been known since 1898 that 'invisible agents' called viruses caused diseases in plants and animals. However, it was 1935 before these agents were made visible using an electron microscope and viruses were seen for the first time.

Since their invention, the magnification of electron microscopes has improved and they are now capable of magnifying an object up to 1 000 000 times. A typical electron microscope is shown in Figure 2.2.12.

2.5



**Figure 2.2.12** A scanning electron microscope

# 2.2 Unit review

## Remembering

1 **Name** the part of animal cells that:
   - a controls the movement of materials into and out of the cell
   - b controls all the chemical reactions within the cell
   - c is a watery jelly-like liquid.

2 **Name** the part of plant cells:
   - a that controls the movement of materials into and out of the cell
   - b in which photosynthesis takes place
   - c that forms the skeleton of the plant.

3 **Name** the parts of the cell labelled A, B and C in Figure 2.2.13.

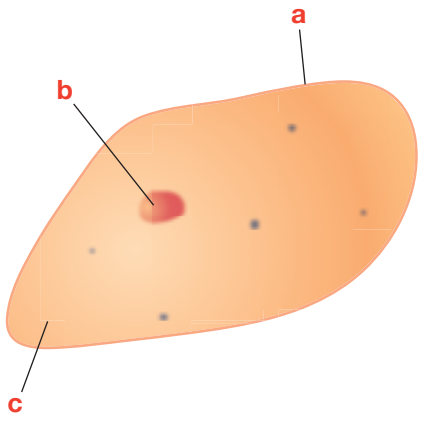



Figure 2.2.13

4 **Name** the parts of the cell labelled A, B and C in Figure 2.2.14.

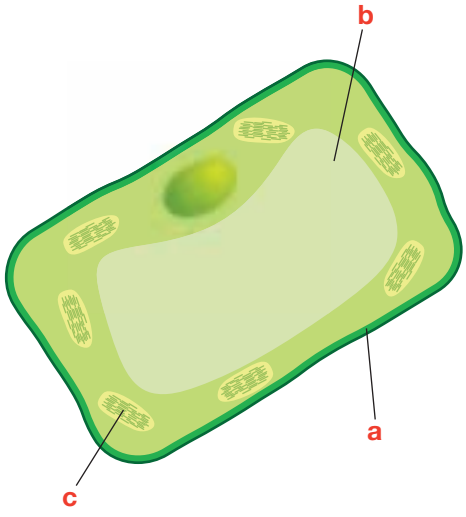



Figure 2.2.14

5 **Name** the process by which plants manufacture their food.

## Understanding

6 **Explain** why microscopes are needed to study cells.

7 **Predict** what would happen if:
   - a the membrane of a cell burst
   - b the nucleus was removed from a cell
   - c plant cells had no chlorophyll.

8 **Explain** why it is important to record the magnification used when drawing cells seen using a microscope.

## Applying

9 **Identify** which organelles would be present in large numbers in cells that:
   - a require a lot of energy
   - b manufacture proteins
   - c carry out photosynthesis.

10 **Identify** the type of cell or organelle being described in each of the following sentences.
   - a It is rigid, and when examined under a very high power on the microscope, no green structures could be seen.
   - b The picture produced by an electron microscope showed channels that criss-crossed the cell.
   - c Chemical tests revealed that energy was released in large quantities.
   - d There was a rigid outer layer surrounding a watery jelly with distinct green areas.

## Analysing

11 **Compare** plant and animal cells.

12 **Contrast** plant and fungal cells.

13 **Discuss** the benefits and disadvantages associated with cells having a cell wall.

# 2.2 Unit review

## Evaluating

14 **Propose** reasons why humans need a bony skeleton.

15 Sketch a Venn diagram like that shown in Figure 2.2.15. From the descriptions of cells on pages 48–49, **select** the characteristics that would go in each part of the diagram.

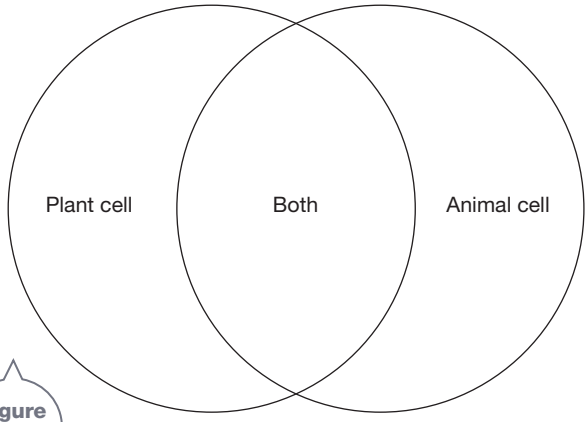



Figure 2.2.15

16 a **Classify** the type of cell shown in Figure 2.2.16 as a plant or an animal cell.

b **Justify** your answer.

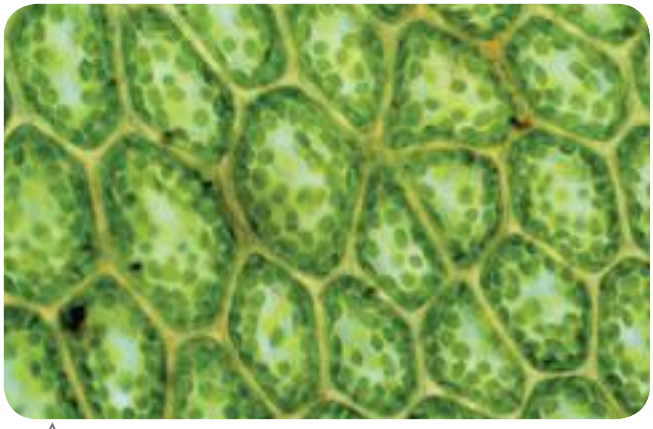


Figure 2.2.16

17 a **Classify** the cell shown in Figure 2.2.17 as an animal or a fungal cell.

b **Justify** your answer.

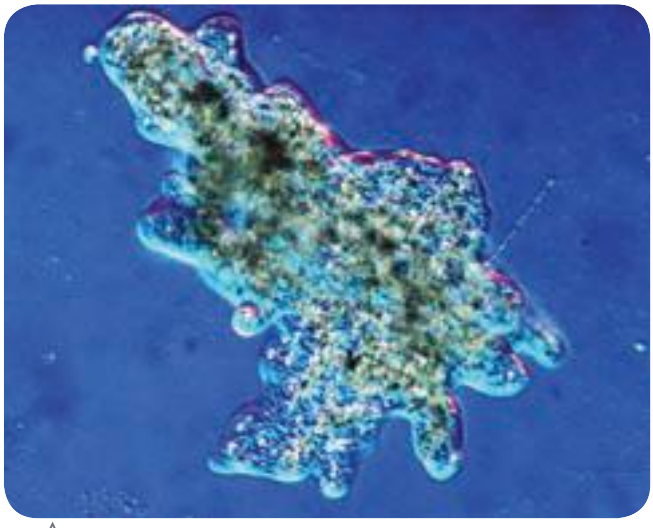


Figure 2.2.17

18 Students were once allowed to prepare their own slides using samples of their own cheek cells. This is now not allowed. **Propose** reasons why.

19 **Propose** the advantages of using prepared slides rather than students making their own slides.

## Creating

20 As large organisms such as humans grow, they make more and more very tiny cells. What if they were made of only a very few cells and these cells just got bigger and bigger? **Construct** a scenario (or possible outcome) of how that would change the way we live.

## Inquiring

1 Research what people thought living things were made of before cells were discovered.

2 Research the life and times of one of the scientists mentioned on pages 51–52 who helped develop our understanding of cells. Prepare a short biography of the person's life and achievements.

3 Investigate the development of microscopes from the first use of lenses to electron microscopes and the scanning probe microscopes used today. Relate the development of the technology to our knowledge of cells.

# 2.2 Practical activities

## 1 Observing cells

Before starting this activity make sure you have read and understood the Skill Builders 'Drawing from the microscope' and 'Increasing magnification' below.

### Purpose

To observe and draw cells.

### Materials

- microscope and lamp
- filter paper
- microscope slide and cover slip
- eye-dropper
- water
- iodine
- slices of onion and rhubarb leaf stalk
- tweezers



**SAFETY**

Iodine stains. Avoid contact with skin and clothes.

### Procedure

1. Carefully peel a thin (one cell thick) layer of onion skin.
2. Use tweezers to place a small sample of the onion skin onto a glass microscope slide. Make sure the skin is not folded.
3. Place a drop of water and a drop of iodine on the sample and carefully place a cover slip on top of the onion skin and water. The iodine stains the cells and makes them easier to see.
4. Use the microscope to observe the cells at two different magnifications.
5. Carefully peel a thin layer of skin from the outside of the rhubarb leaf stalk. Repeat the procedure, but do not use the iodine stain.

### Results

Sketch a few cells at the higher magnification. On your diagram record the type of cell you have drawn and the magnification used.

### Discussion

1. Refer back to the diagram of the typical plant cell shown in Figure 2.2.3 on page 49. Of the parts labelled on that diagram, **list** the parts you were able to see clearly in the onion skin cell and in the rhubarb skin cell.
2. **List** the parts you could not see. **Explain** why you were not able to see them.
3. **Compare** the onion cells and rhubarb cells.
4. **Propose** a reason why onion cells were stained with iodine but rhubarb cells were not.




### Drawing from the microscope

Follow these steps to draw what you see through the microscope.

1. Use a sharp lead pencil.
2. Draw only the lines that you see. Don't use shading or colouring.
3. Each diagram should take up one-quarter to one-third of an A4 page.
4. Record the magnification used to draw this specimen next to its diagram.
5. State the name of the specimen and the date of the observation.
6. A written description below the diagram is also often helpful.
7. When the image has many cells of the same type, you only need to draw a few cells to represent the specimen.




### Increasing magnification

When you want to change the magnification of a microscope from a lower magnification to a higher magnification, follow these steps.

1. Make sure that the specimen, or the part of the specimen that you want to look at, is in the centre of the field of view.
2. Focus the specimen on low power.
3. Without moving anything else, carefully turn the objective lenses around so that one with a higher magnification is above the slide.
4. Look through the eyepiece. If the specimen is not in focus, use the fine focus only to sharpen the image.

## 2 Membrane at work

A hen's egg is really just a very large cell with a shell around it. When you break an egg, you can sometimes see a very thin skin just under the shell. That skin is the membrane of the egg.

### Purpose

To observe a membrane at work.

### Materials

- 2 eggs
- 500 mL white vinegar
- salt
- 500 mL distilled water
- electronic balance or beam balance
- 200 mL measuring cylinder
- container large enough to hold two eggs immersed in vinegar
- 2 wide-mouthed glass jars with lids

### Procedure

#### Part A

1. Place the two eggs in a container of vinegar so that both eggs are completely covered.
2. Leave the eggs undisturbed for 2 days. By this time the vinegar should have dissolved the eggshell and the membrane inside the shell becomes the outer layer of the egg.

#### Part B

3. Make a concentrated salt solution by adding a tablespoon of salt to 250 mL of distilled water.
4. Label the two glass jars 'salt water' and 'distilled water'.
5. Measure out 200 mL distilled water and pour it into the container labelled 'distilled water'.
6. Measure out 200 mL of the salt water and add it to the container labelled 'salt water'.
7. Carefully remove the eggs from the vinegar and rinse them. Pat them dry with paper towel.
8. Use a balance to determine the mass of each egg and record the mass in a table like the one shown in the Results section.
9. Place one egg in each container of water and put on the lid or cover with plastic wrap.
10. Each day, for the next 3 days, measure and record the mass of the egg.
11. Predict what you think will happen to the eggs. Record your prediction
12. On day 3 measure and record the volume of the water remaining in each of the containers.

### Results

1. Observe and record any changes to the eggs.

| Treatment | Mass of egg (g) | | | | |
|---|---|---|---|---|---|
| | Day 0 | Day 1 | Day 2 | Day 3 | Change |
| Distilled water | | | | | |
| Salt water | | | | | |

2. Record any change in volume of the water.

| Treatment | Volume of liquid (mL) | | |
|---|---|---|---|
| | Day 0 | Day 3 | Change |
| Distilled water | 200 | | |
| Salt water | 200 | | |

### Discussion

1. **Describe** the changes that took place in the two eggs.
2. **Describe** any change in the volume of the water in the two containers.
3. **Propose** reasons for the changes in the amount of liquid.
4. **Propose** reasons for the changes in the eggs.
5. **Explain** what you think was happening to the eggs and the role the membrane played.
6. **Compare** the actual results with your predictions.

# 2.3 Specialised cells

Many of the living things on Earth are made up of only one cell. This single cell has to carry out all the functions of life. These living things are too small to be seen with the naked eye. The living things that we can see, such as plants and animals, are made up of many cells of different types. Each type of cell is specialised to carry out a particular job.

## Unicellular organisms

Living things that are made up of only one cell are known as **unicellular organisms**. The prefix *uni* means one and *organism* means a living thing. Therefore a unicellular organism is a living thing that is made up of a single cell. **Bacteria** are unicellular organisms. Some bacteria cause disease and infection like the infected wound in Figure 2.3.1. Others live on and in your body and help you to stay healthy. Bacteria are also used in the production of cheese and yoghurt.

Many different types of unicellular organisms live in watery environments. A drop of pond water seen through a microscope can reveal a variety of living things you will not have seen before like the diatoms and rotifers shown in Figure 2.3.2. Unicellular organisms belong to a group called the **protists**. Most protists are harmless, but some can make you very sick. The water that comes through the taps has been treated to kill any harmful organisms. If you are in the bush and using untreated water, then for your health's sake it is best to boil it before you drink it.

1 p63



**Figure 2.3.1** The yellow pus on infected wounds is an accumulation of dead white blood cells that have died trying to fight harmful bacteria.

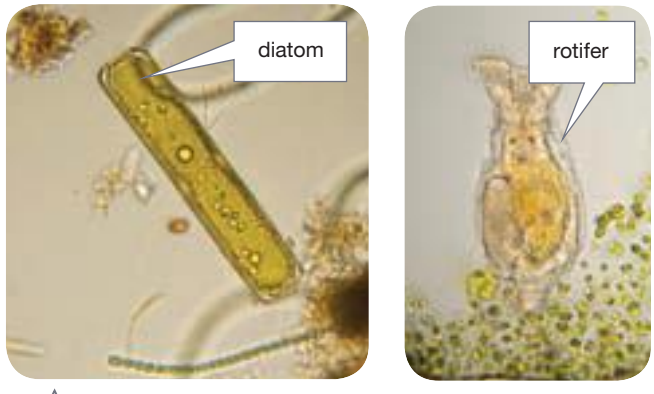



**Figure 2.3.2** Microscopic organisms such as diatoms and rotifers are found in pond water.

**Inside me!**

You probably have ten times more bacteria living in your gut than you have cells in your body. You could live without these bacteria but you are healthier when they are present. They help with digestion, produce vitamins and train your immune system to fight disease.

SciFile

# Multicellular organisms

Other living things such as humans, fish and the tree and koala in Figure 2.3.3 are made of millions and millions of cells. They are called **multicellular organisms**—*multi* means many.

In multicellular organisms, all the cells work together but they do not all do the same thing. Cells are **specialised**. This means that they have a special job to do in the body, and they have a structure that makes them better able to do their job.

2.6



Figure 2.3.3 This koala and the tree in which it is sitting are both multicellular organisms.

## Specialised animal cells

Animals are more complex than plants and they have a greater variety of different cell types. The human body contains about 50 trillion cells and more than 200 different types of cells. A few of these 200 types are described below.

### Muscle cells

The three types of muscles in your body are voluntary muscles (also called skeletal muscles), involuntary muscles (also called smooth muscles) and cardiac muscles.

Surrounding the bones of your skeleton are muscles that you use to move around. You can choose to make these muscles move (or not) and so they are referred to as voluntary muscles. For example, your biceps and triceps are voluntary muscles that help control your arm. You can see a magnified view of voluntary muscle in Figure 2.3.4.

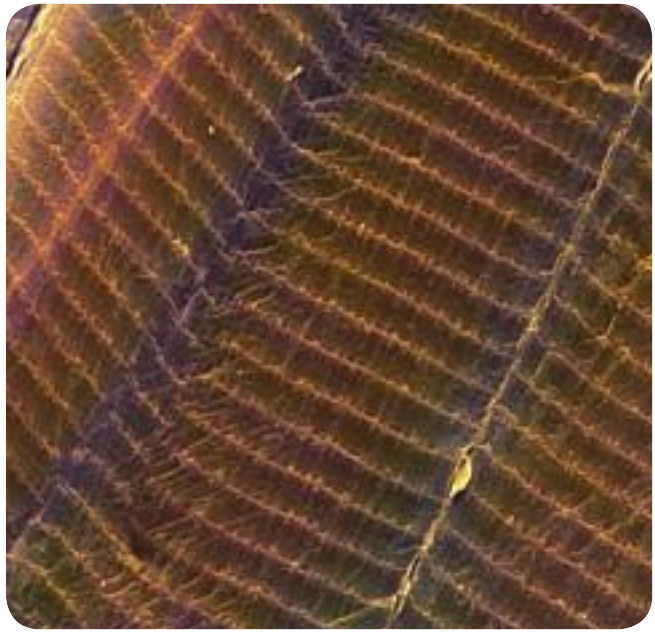
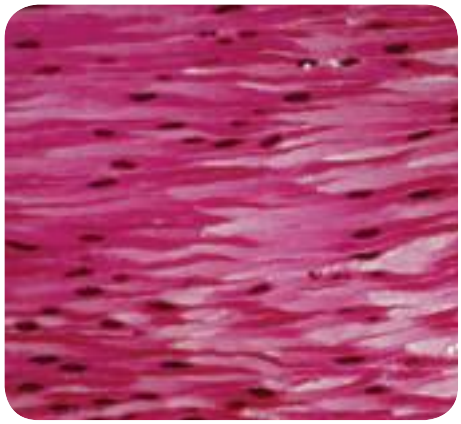


Figure 2.3.4 The voluntary muscles (skeletal muscles) attached to our bones have a striped appearance and are also known as striated (striped) muscles.

You have other muscles in your body that work without you having to think about it. They are the muscles involved in breathing and those that keep food moving though your gut. These muscles are known as involuntary muscles. Your diaphragm controls your breathing and is an involuntary muscle, as are the muscles in the wall of your digestive tract or gut. An image of involuntary muscle is shown in Figure 2.3.5.

Figure 2.3.5



Most of the involuntary muscles do not have a striped appearance and are also known as smooth muscles.

All muscles (voluntary or involuntary) contain a large number of mitochondria. This is because muscles require a lot of energy to keep working and it is the mitochondria that provide the energy.

Cardiac muscle (Figure 2.3.6) is the type of muscle in the heart. Cardiac muscle is involuntary muscle but it has a striped appearance like voluntary muscles. Unlike other muscles that are striped, cardiac muscle does not get tired. It has very large numbers of mitochondria to provide a continuous supply of energy. These characteristics allow the heart to beat continuously.

Figure 2.3.6



Cardiac muscle is an involuntary muscle that has characteristics of both striated muscle and smooth muscle.

### Nerve cells

**Nerve cells** make up your brain. They also carry information from your brain to other parts of your body such as your muscles, and from your muscles back to your brain. As Figure 2.3.7 shows, some nerve cells have very long fibres called **axons** extending from the cell. These allow the cell to carry messages over long distances. The longest axon of a human nerve cell reaches from the base of the spine to the toes, and can be over a metre long.

**SciFile**

**New blood**

Red blood cells are the only cells in the human body that do not have a nucleus. This means they can't reproduce and need to be continually replaced. Your body makes billions of new red blood cells every day.



Figure 2.3.7

Nerve cells like this one can be found in your brain. The axons make connections with other brain cells.

### Blood cells

Figure 2.3.8 shows some blood cells. **Red blood cells** carry oxygen from your lungs around your body to the cells where it is used to release the energy you need. They also carry some of the waste carbon dioxide from the cells back to your lungs so that you can get rid of it from your body. The **white blood cells** have a very different job. They are part of the immune system and help the body to fight infection.

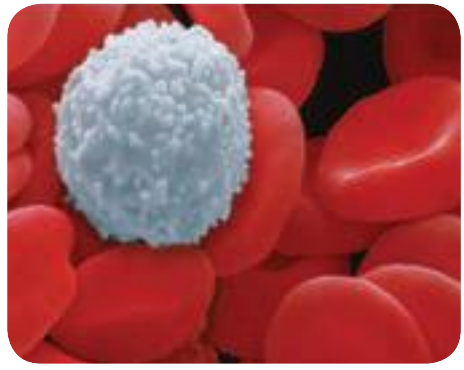


Figure 2.3.8

There are many more red cells in your blood than white cells.

### Fat cells

You have two different types of fat cells in your body. Brown fat cells are used to produce heat for the body, especially when it gets cold and you are shivering. The white fat cells in Figure 2.3.9 are used as a store of energy. They also form an insulating layer under the skin that helps to keep your body at a constant temperature.



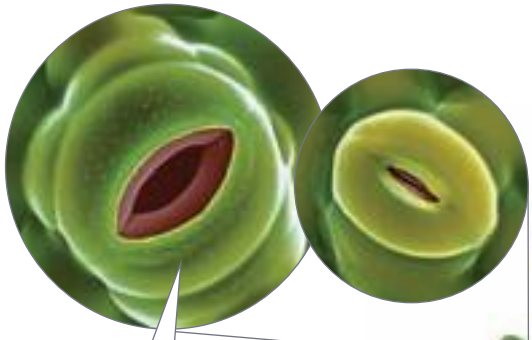
Figure 2.3.9

White fat cells (here stained purple) are found under the skin where they provide an insulating layer that helps to keep you warm.

2.7 p64

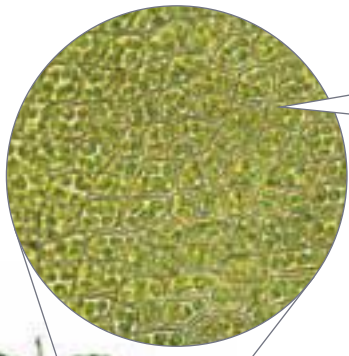
## Specialised plant cells

Plants contain cells of many shapes and sizes. Each type of cell is specialised to carry out a different function within the plant. Figure 2.3.10 shows some different plant cells that have different functions.



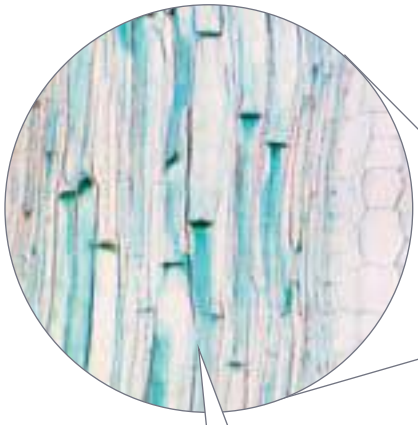
**Guard cells**

**Guard cells** are found on the leaves and stems of plants. Guard cells work in pairs to open and close very tiny pores (or holes) in the leaves called **stomata**. Gases needed by the plant enter through open stomata and unwanted gases leave the same way. Guard cells close the stomata when plants need to reduce water loss.



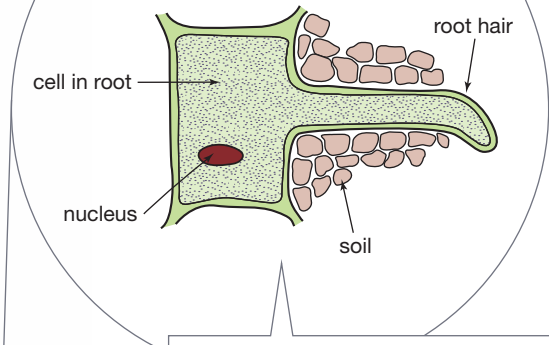
**Photosynthetic cells**

Cells near the surface of the green parts of stems and leaves have large numbers of chloroplasts. In the chloroplasts is a green chemical called **chlorophyll**. This chemical traps the Sun's energy, which the plant then uses in photosynthesis. Plant cells that are not exposed to sunlight, such as those in the roots, do not contain chloroplasts and are not green.



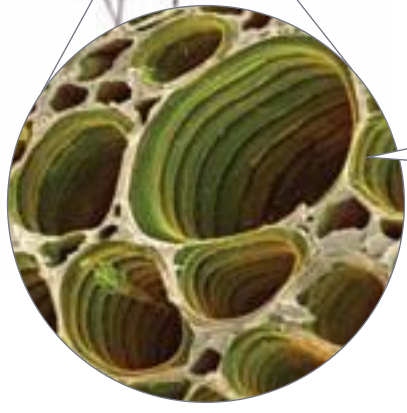
**Conducting cells**

Plants take in water from the soil through their roots. The water is needed in the leaves for photosynthesis. This means that water has to be transported from the roots to the leaves. Plants make their food in the leaves but the cells of the roots and stems need food if they are going to stay alive. This means the food has to be transported from the leaves to the roots and stems. Inside the plant there are cells that are specialised for transported water and food. These conducting cells are long thin tubes like drinking straws.




**Root hairs**

Plants cannot move around to get water from where it is available. This means they need an efficient way of taking in water where they are growing. Water comes into plants from the soil through the surface of their cells. The more surface they have in contact with the soil, the more water they will be able to take in. Some of the cells on the outer surface of roots have extensions called **root hairs.** These root hairs increase the surface area of the root by a large amount.



**Structural cells**

The cell walls act as the skeleton of plants. When plants grow they become bigger and heavier. Then their skeleton needs to get stronger. The cell walls of many cell types, especially the water-conducting cells in the plant stem, become thicker and stronger, providing more support. The wood of tree trunks is mostly cells with walls that are so thick that the cell has died. The living part of a tree trunk is just below the bark.

**Figure 2.3.10** Different plant cells have different jobs to do.

# 2.3 Unit review

## Remembering

1 **List** three specialised cell types found in plants.

2 **List** three specialised cell types found in animals.

3 **State** which has more different types of cells: plants or animals.

4 **State** what the following prefixes mean.
- a *uni* as the prefix to unicellular
- b *multi* as the prefix to multicellular

5 **Name** the following types of cells.
- a leaf cells where the plant's food is made
- b animal cells that send electrical messages around the body
- c animal cells that help fight infection
- d cells that control the gases going into and leaving a leaf

6 **Recall** the different types of animal cells by matching the ones below with their specialised tasks.

| | | |
|---|---|---|
| a | fat cells | cells that contract, causing bones to move |
| b | cardiac muscle | carry oxygen from the lungs to the cells |
| c | red blood cells | where the body stores energy |
| d | skeletal muscle | muscle that does not get tired and keeps the heart pumping |

## Understanding

7 a **Define** the term *specialised cell*.
- b **Explain** why the cells of multicellular organisms are not all the same.

## Applying

8 There are about 5 million red blood cells in every millilitre of blood. **Calculate** the number of red blood cells in an:
- a average blood donation of about 450 mL
- b adult human (about 6 litres of blood).

## Analysing

9 **Classify** each of the organisms in Figure 2.3.11 as unicellular or a multicellular.



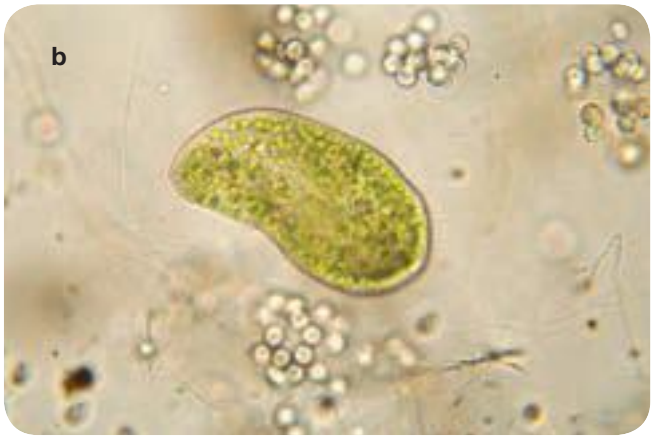







Figure 2.3.11

# 2.3 Unit review

10 **Compare** unicellular and multicellular organisms.

11 **Classify** the following muscles as voluntary or involuntary.
- a muscles of upper leg
- b tongue
- c muscles in the oesophagus (the tube carrying food from the mouth to the stomach)

12 **Contrast** the three types of muscle of the human body.

## Evaluating

13 a **Propose** ways in which a cell from the root of a plant would be different from a leaf cell.
- b **Justify** your answer.

14 What if the cells in your body were all the same? **Propose** ideas of how this would change the way your body works.

15 There are many mitochondria in the muscle cells of animals.
- a **Propose** which type of plant cells could also have very high numbers of these organelles.
- b **Justify** your answer.

## Creating

16 **Construct** a table with three columns.
- a In the left-hand column, **list** four specialised plant cells.
- b In the middle column, **describe** what the cells do.
- c In the right-hand column, **describe** how the cell is specialised to do this job.

17 You have been shown a type of cell you have never seen before. It is a small cell but the membrane on the outside has many extensions, giving it a very large surface area.
- a **Create** a picture of what this cell would look like.
- b Use your knowledge of specialised cells to **predict** the sort of job this cell would do and whether the cell is from a plant or an animal.

## Inquiring

1 Jellyfish have very specialised stinging cells. Investigate how these cells help the jellyfish to survive.

2 Considering the function of red blood cells, research why the lack of a nucleus is an advantage.

3 a Research the characteristics of cells of fungi and diatoms.
- b Compare their characteristics with the cells of plants and animals.
- c Discuss the classification of these cells.

4 Bacteria are very simple unicellular organisms. They are very important to humans for many reasons. Research bacteria and why they are important to humans.

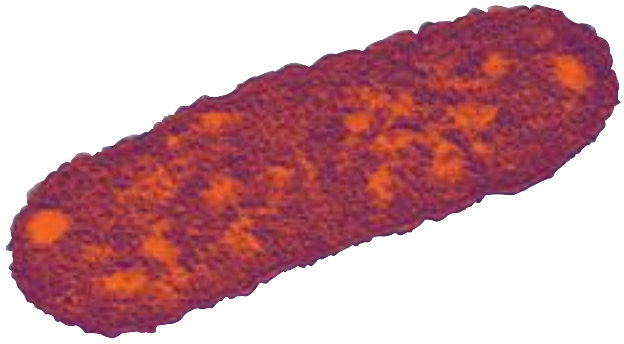


Figure 2.3.12 Bacteria are simple, very small organisms made of just one cell. A bacterium has no organelles.

# 2.3 Practical activities

## 1 Looking at pond water

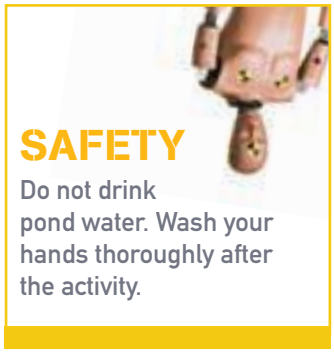
### Purpose

To observe microscopic organisms in pond water.

### Materials

- light microscope
- microscope slides
- cover slip
- pond water
- eye-dropper
- cotton wool
- paper towel or tissue






### Procedure

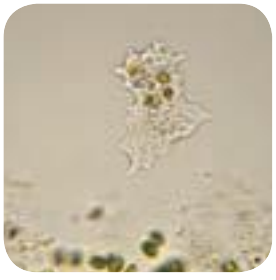
1. Place two drops of pond water on a slide.
2. Tease out a few fibres of cotton wool and place them on the slide.
3. Carefully lower the cover slip onto the slide and dry off any excess water.
4. Examine the slide using the low power of the microscope.
5. Now try high power. Remember that you are not only magnifying the size of the organisms but it also looks as though you are magnifying the speed at which they move.

### Results

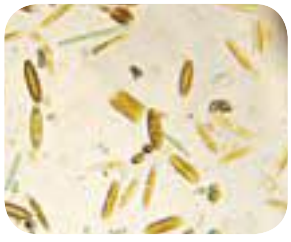
1. Record the number of different types of organisms.
2. Sketch the organisms you see and label any parts you can identify.
3. Use Figure 2.3.13 to identify the organisms you saw.

### Discussion

1. a **List** the different types of organisms you saw.
   b For each organism:
   i **state** whether it was unicellular or not
   ii **describe** its characteristics.
2. **Describe** the difficulties you had when observing the organisms.
3. **Propose** a reason why the fibres of cotton wool were added to the slide.
4. **Describe** the most interesting organism you observed.


Amoeba


Euglena

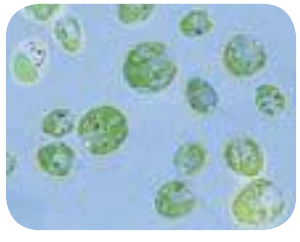

Diatoms


Cyclops


Spirogyra


Nematode


Paramoecium


Chlamydomonas


Daphnia

Figure 2.3.13

## 2 My cell

### Purpose

To make a model of a cell.

### Materials

You can decide on your own materials.
Suggestions include:

- plastic food wrap or freezer bags
- cotton wool, wool, thread
- gelatine and hot water
- container for mixing gelatine
- container for heating water
- buttons, marbles, lollies such as jelly beans
- stiff cardboard



**SAFETY**

Be careful if you are using hot water or sharp instruments.

### Procedure

1. Decide whether you are going to make a plant cell or an animal cell, a typical cell or a specialised cell.
2. Make a list of the parts of the cell and their characteristics.
3. Decide what you could use to represent the cell parts. Make a list of your choices, giving a reason for each choice.
4. Construct your cell.
5. Explain to other members of the class how you have constructed your cell and why you chose the material you did.

### Discussion

1. **Assess** how successful your model cell was.
2. **List** the positive comments others in the class make about your cell.
3. **List** the suggestions of areas you could improve on.
4. **Describe** what you would change if you were to make another cell.



Figure 2.3.14 This model of an animal cell was made using felt, fabric and toy stuffing.

# 2.4 Cell to organism

Wombats and wattles, fish and frogs, crows and crabs are all complex organisms that perform a variety of functions. They breathe, reproduce, digest food and get rid of wastes. To perform these functions, the cells of multicellular organisms are organised into tissues, which in turn are organised into organs and then into systems.



INQUIRY science 4 fun

## Soft bones

Bones are complex organs with living cells and deposits of calcium. Vinegar is a weak acid that dissolves calcium.




### Collect this...

- 2 uncooked chicken bones
- vinegar
- jar

### Do this...

1. Fill a jar with vinegar and place one chicken bone in the jar overnight.
2. Leave the other chicken bone untreated.
3. Observe the bones the next day.
4. Predict what you think will happen to the bone in the vinegar.
5. Compare the two bones the next day.

### Record this...

**Describe** what happened. Was your prediction correct?

**Explain** why you think this happened.

## Tissues and organs

Many different things need to happen in an organism if it is going to stay alive and function well. There is a need for some form of organisation. In complex organisms such as the human and dog in Figure 2.4.1 on page 66, there are several different levels of organisation. These levels are shown in Figure 2.4.2 on page 66.

- **Tissues**: Cells that perform the same function are not scattered throughout the body; they are grouped together to form tissues.
- **Organs**: The next level of organisation is into organs. An organ is a structure that contains at least two different types of tissue that work together to complete a task.
- **Organ systems:** Organs are then arranged into organ systems. Organ systems have two or more different organs that work together.



Figure 2.4.1 The boy and the dog are both complex organisms. Their cells are organised into tissues, tissues into organs, and then organs into systems.

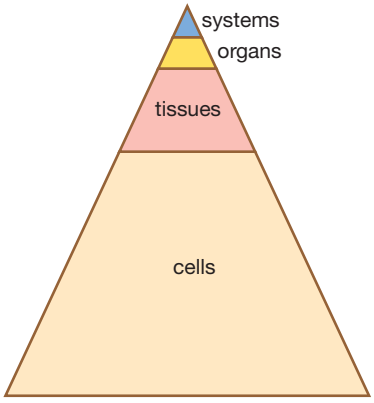



Figure 2.4.2 In a complex organism, there are many more cells than there are tissues, many more tissues than organs, and many more organs than systems.

## Tissues

In the human body there are four different types of tissues:

- epithelium
- connective tissue
- muscle tissue
- nerve tissue.

**Epithelium** is just another name for skin. The cells of an epithelium form a continuous layer that is more than just the skin covering the outside of your body. It continues into the body. It lines the inside of your mouth right down to your stomach and through the rest of your insides. It also covers all the organs of the body. You can see epithelium cells in Figure 2.4.3.

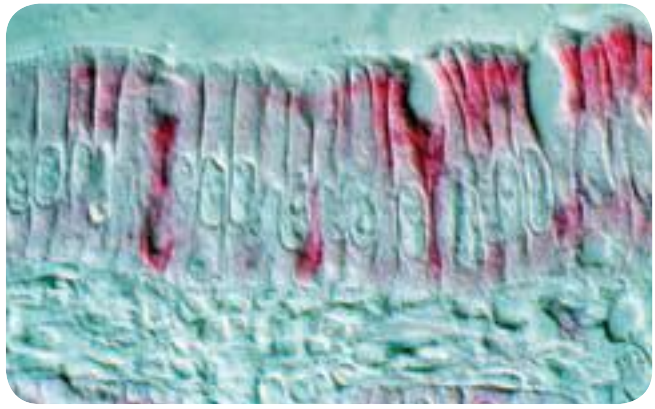


Figure 2.4.3 Column-shaped cells make up the epithelium lining your small intestine.

**Connective tissue** adds support and structure to the body. Examples of connective tissue are fat, bone, cartilage, ligament and tendon such as that shown in Figure 2.4.4. Some types of connective tissue are strong and fibrous. Ligaments hold bones together at the joints. If you sprain your ankle or wrist badly, then it is likely that you have torn some of the fibres of the ligaments holding the bones together. Tendons join muscles to bones.

**Muscle tissue** is a specialised tissue that can contract, becoming shorter and fatter. For example, the muscle on the front of your upper arm (the bicep) bulges when you pull up your forearm. You can see this in Figure 2.4.5. Each individual cell of the muscle has contacted. However, one cell on its own, or even a few cells contracting, would not be strong enough to pull up your arm. It takes thousands of cells working together to move the bones of your arm.

1 p72



Figure 2.4.4 The white tissue in this model is tendon. It connects muscles and bone.

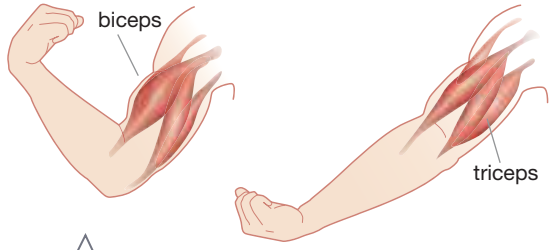



Figure 2.4.5 Muscles in the front of the arm contract to pull the arm up. Muscles cannot expand. Another set of muscles (the triceps) at the back of the arm contract to pull the arm back down.

**Nerve tissue** such as that in Figure 2.4.6 can send electrical signals around the body. These electrical signals are managed by nerve tissue in the brain and passed down the spinal cord (a large bundle of nerve tissue) to the body. One nerve cell would not be able to pass information around your body effectively. Thousands of nerve cells are grouped together to form your nerves.

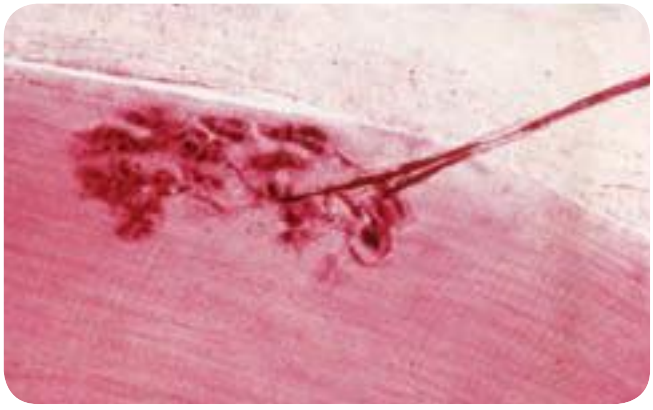


**Figure 2.4.6** These nerve endings are attached to the muscle. The message passing along the nerve causes the muscle to react.

## Organs

Tissues are grouped together into organs. All the different tissues contribute to the job that the organ has to do. There are many different organs in your body, such as the liver, kidneys and heart. Even your skin is an organ—the largest organ of your body. As you can see in Figure 2.4.7, it has many different parts.

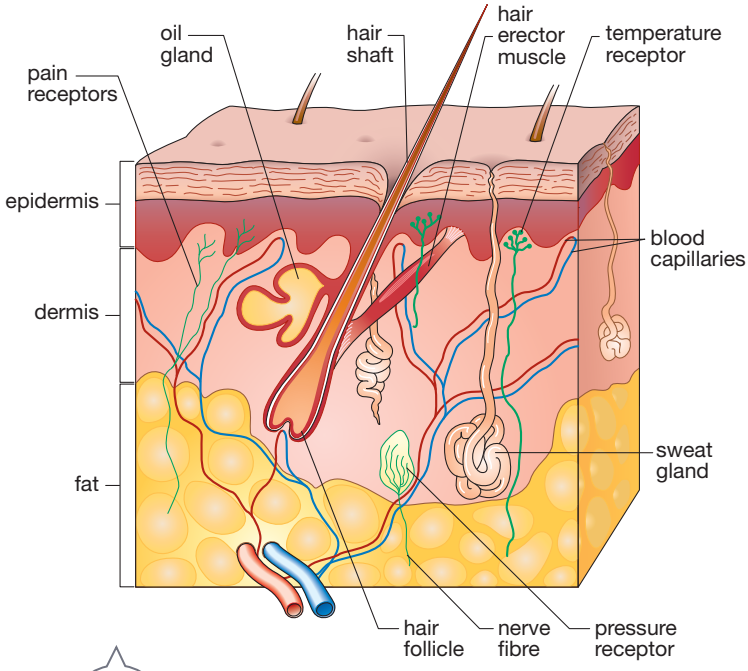



**Figure 2.4.7** The skin is a complex organ.

In the heart shown in Figure 2.4.8, the tissues are grouped together for the specific purpose of ensuring that the blood flows round your body, carrying to the cells all the things they need to function. Your blood also carries away wastes that could harm your cells.

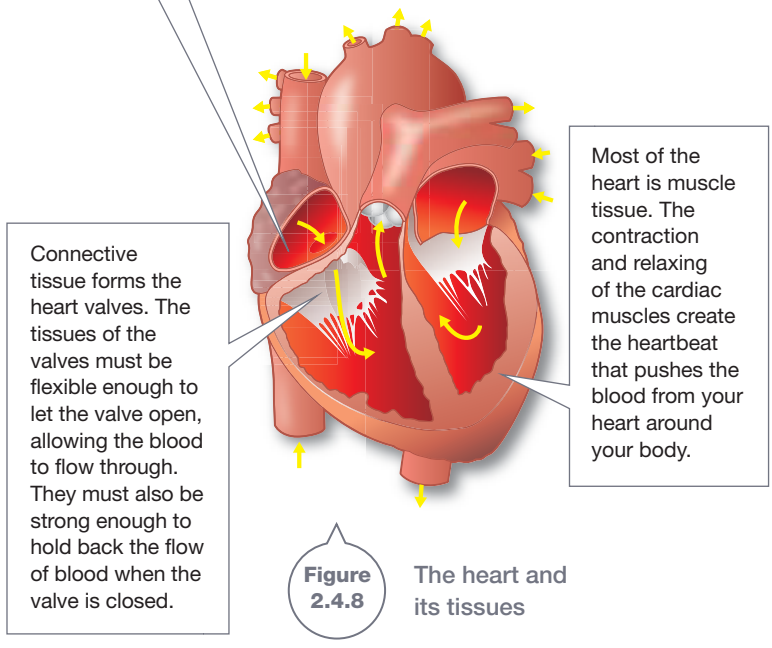



**Figure 2.4.8** The heart and its tissues

# Systems

The organs of your body do not work independently. Organs are organised so that they can work together to complete a task. These organs then form a system. For example, a series of organs work together to change the food you eat into a form that the body can use. This system digests the food. The system is therefore called the digestive system. It is shown in Figure 2.4.9 on page 68.

There are other systems in your body such as the:

- respiratory system, which gets oxygen from the air into your body and gets rid of waste carbon dioxide
- skeletal system, which is your skeleton and muscles
- excretory system, which gets rid of wastes from the body
- nervous system, which sends messages from your sense organs to the brain and from the brain to other parts of the body, including the muscles
- reproductive system.

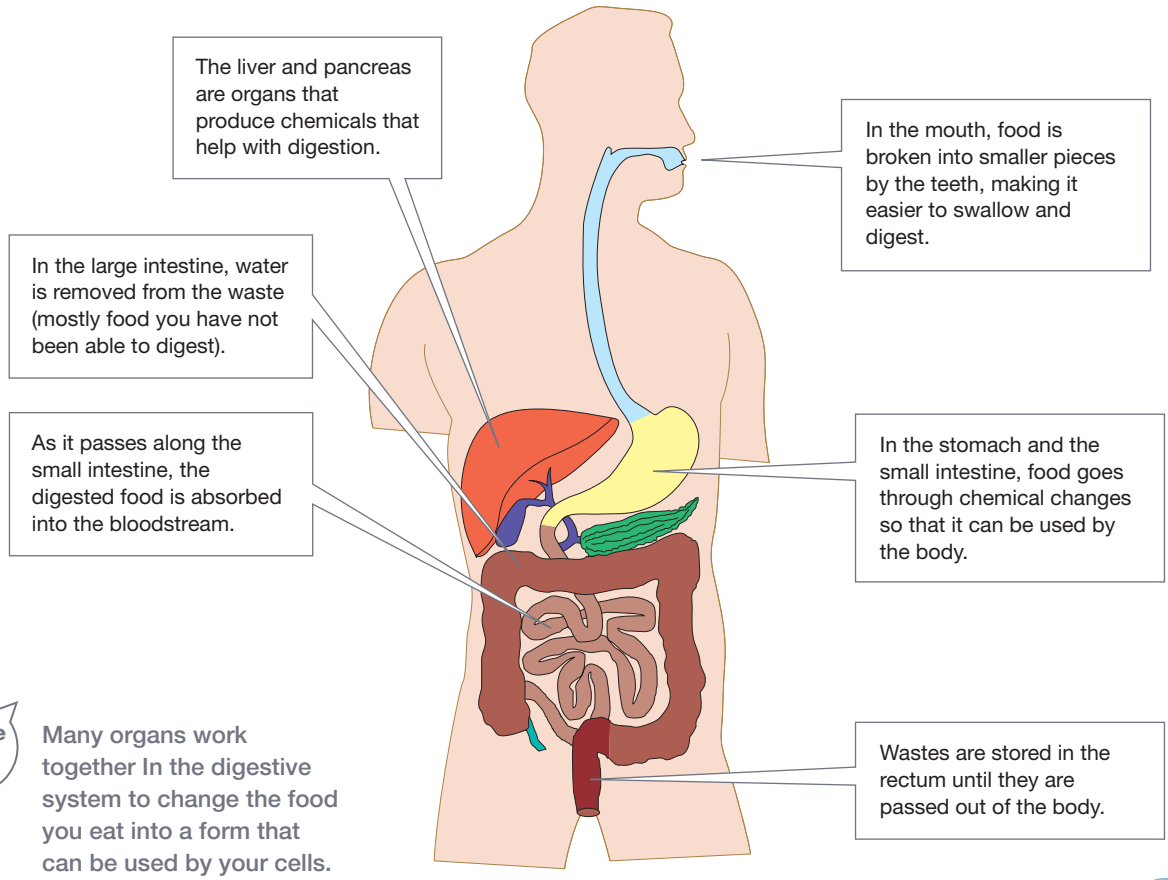



**Figure 2.4.9** Many organs work together In the digestive system to change the food you eat into a form that can be used by your cells.

2 p72

# Dividing cells

Unicellular organisms reproduce by their cell dividing to produce two new identical cells; that is, two new organisms. Multicellular organisms grow because existing cells divide to produce new cells. This type of cell division is called mitosis. **Mitosis** is cell division that produces two new identical cells. This process is happening in Figure 2.4.10

At the beginning of mitosis, there is one cell. First the nucleus divides into two. Then the cytoplasm divides. At the end of the process, there are two identical cells.

You started life as a single cell. Now your body is made of billions of cells. Most of the cells in your body were produced by mitosis. Each time you cut yourself or scrape the skin off your knee, the damage is repaired by mitosis producing new cells.

Bacteria do not have a nucleus, but their cells can still divide to produce two identical bacteria. One way of controlling bacteria that cause disease is to find ways of preventing them reproducing.

Cancer is a disease caused by uncontrolled mitosis. Scientists are looking for ways of controlling cell division in these cells and hope that will help to cure the disease.

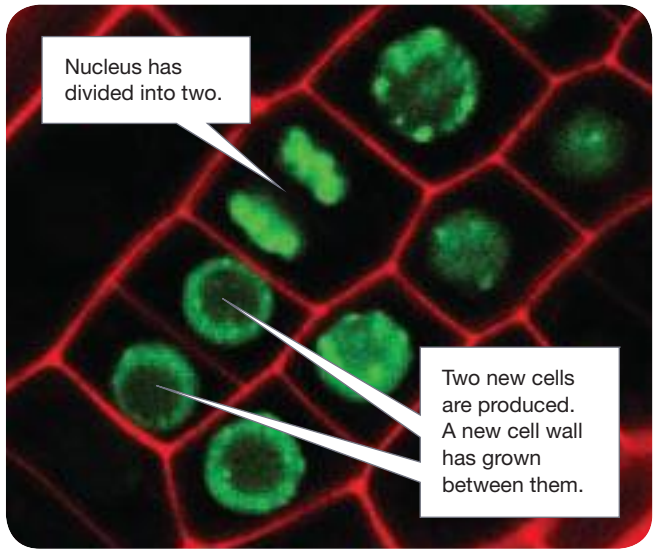



**Figure 2.4.10** These cells are dividing by mitosis.



Figure 2.4.11 Stem cells have the ability to become different types of body cells.

# SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

## Growing cells

All living things are made of cells regardless of how big or small, simple or complex the organism is. The cells from all living things have many features in common and so the study of cells can provide information about all living things.

In the last 100 years scientists have learnt how to grow cells separate from the organism they came from. This process is called **cell culture**. The cells are kept at the correct temperature and in a solution that provides them with all the minerals and nutrients they require to keep them alive. You can see a scientist working with cultured cells in Figure 2.4.12.

Cultured cells have been used to produce the vaccines that protect us from diseases such as measles, rubella, mumps, chickenpox and polio. These cells are also used to produce agents that can help fight cancer.

Most cultured cells are not from humans. However, there are times when human cells are cultured. The bottles in which they are cultured are shown in Figure 2.4.13.

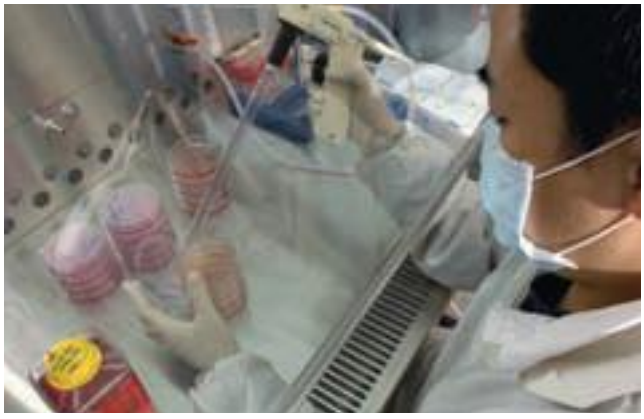


Figure 2.4.12 This researcher is working in a tissue culture laboratory.



Figure 2.4.13 Tissues are cultured in flat bottles like these.

### Growing tissue

When your body is damaged or new cells are required to replace ones that are worn out, the cells in your body divide. Skin cells divide to produce new skin cells, and muscle cells produce new muscle cells. In the human body, there are also special cells called **stem cells**. Stem cells are able to become different types of cells under special conditions. They can be found in the roots of your hair. Cells from a few hairs could be very useful if you had a large wound such as a burn. You can see some stems cells in Figure 2.4.14 on page 70.

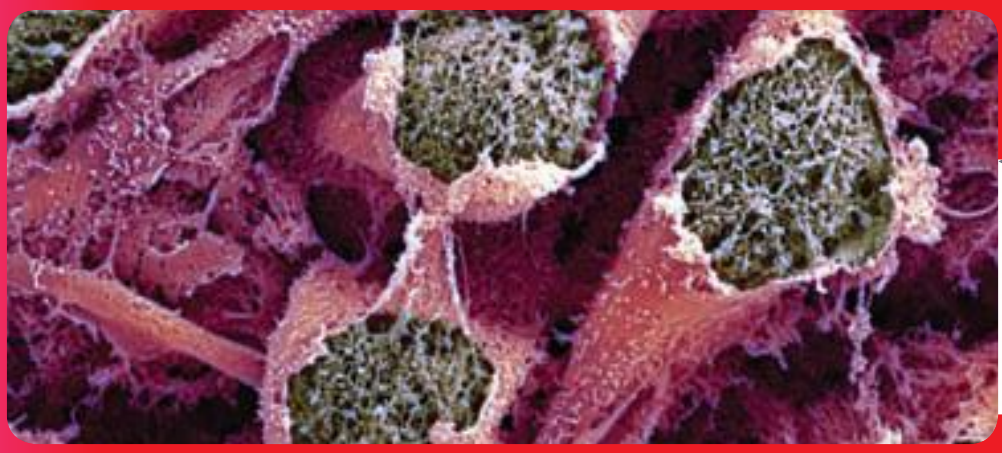


Figure 2.4.14 Stem cells seen under a scanning electron microscope

Stem cells extracted from the hair root are grown in culture for about two weeks. They are completely surrounded by liquid and divide, forming small masses of cells. After two weeks the upper surface of the cell mass is exposed to the air. This is the trigger for the stem cells to turn into skin cells and skin like that in Figure 2.4.15.

The skin is then grafted onto the wound. Within a few days, doctors will know if the graft is going to work. A successful skin graft will look just like your old skin within 10 weeks.

In traditional skin grafts, healthy skin is taken from another part of your body to put over a wound. You then end up with two scars. Which way would you prefer—the traditional method of cell culture or the latest technology?



Figure 2.4.15 A strip of skin is held above the culture medium.

## Growing organs

Scientists hope that in the future complete organs can be grown for transplant. This is becoming closer to reality.

There are children in the USA who have new bladders that were grown from their own cells. These children were born with defective bladders. Doctors took two types of cells from the child's own bladder—cells from the lining of the bladder, and muscle cells from the outside. These cells were grown in culture solution and when there were enough cells they were placed on a bladder-shaped shell made from a biodegradable material. The lining cells went on the inside of the shell and the muscle cells on the outside. The new bladder continued to grow in culture for another seven weeks. After that it was sutured (stitched) into the body of the patients where the new bladders continued to grow and remain healthy.



Figure 2.4.16 The ear on the back of this mouse was grown from cartilage cells from a cow implanted on a mould in the shape of an ear. The experiment suggests that replacement body parts may be able to be grown in the future.

2.8

# 2.4 Unit review

## Remembering

1 **List** these words in order from simplest structure to most complex.
- tissue
- system
- cell
- organ

2 **Name** four different organs in the body.

3 **List** two types of tissues found in the human body.

4 **List** three systems in the human body.

5 **Name** the type of cell division that makes new cells in your body.

## Understanding

6 **Describe** what is meant by the term *organ system*.

7 **Explain** why skin is an organ rather than a tissue.

8 The contraction of muscle tissue can cause your arm to bend, whereas contraction of a single muscle cell would have no effect. **Explain** why.

## Applying

9 Sketch diagrams to **demonstrate** the difference between cells, tissues and organs.

## Analysing

10 **Contrast**:
- a a cell and a tissue
- b an organ and a system.

11 Imagine what it would be like without some of your tissues. **Compare** the way your body works now with how you think it would work if you did not have:
- a nerve tissues
- b connective tissue in the form of tendons and ligaments.

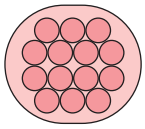
12 **Compare** cardiac muscle and skeletal muscle.

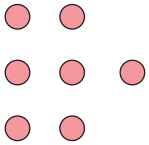
## Evaluating

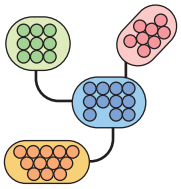
13 In the Science4fun activity on page 65, vinegar (an acid) slowly removed calcium from chicken bones.
- a **Propose** what might happen to bones that have lost calcium.
- b **Predict** what could happen if you do not have enough calcium in your diet.

14 In the diagrams A–D each small circle represents a cell. **Select** the diagram that best represents:
- a individual cells
- b a body system
- c an organ.

A 

B 

C 

D 

15 **Propose** reasons why the muscles of your legs get tired when you have been running fast.

## Creating

16 **Construct** a drawing showing the organisation of muscles, tendons and bones in the arm and how they work together to bend and straighten the arm.

## Inquiring

1 Research information about one of the systems of your body. Present a report to your class.

2 Research the parts of a flower. Identify the organs it contains and the part each plays in plant reproduction.

# 2.4 Practical activities

## 1 Muscles get tired

### Purpose
To find out what contributes to muscle fatigue.

### Materials
- soft foam or rubber ball
- stop watch

### Procedure

#### Part A: Arm relaxed

1 Work in pairs. Squeeze the ball as many times as you can in 30 seconds. Your partner should time you as you count.

2 Rest for 10 seconds.

3 Repeat steps 1 and 2 until you have completed 10 trials. Record your results in a table, showing the number of squeezes per trial.

#### Part B: Arm raised

4 Repeat steps 1–3 but this time hold your arm above your head.

5 Do not lower your arm during the resting time.

### Results

1 Record your results in a table like this.

| Trial | Number of squeezes | |
|---|---|---|
| | Part A | Part B |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |

2 Graph your results by constructing a line graph for each part. You can have two graph lines on the same axes.

### Discussion

1 **Analyse** your results for Parts A and B. Was there any evidence that your muscles were becoming tired (fatigued)? **Explain** why.

2 **Compare** the two graphs. What can you say about the amount of fatigue experienced by the arm?

3 **Describe** any effect that raising your arm would have on the:
- **a** blood supply to your arm
- **b** oxygen supply to your arm.

4 **Explain** why oxygen and blood are important to muscles that are working.

5 **Propose** links between the results shown in the graphs and what could be happening in your arm.

6 **Summarise** the results of this activity.

## 2 Where in my body?

### Purpose
To find out what you know about organs in your body.

### Materials
- large piece of butcher's paper—you need to be able to lie on it and draw round your body
- felt pen

### Procedure

1 Work in pairs. One person lies on the paper and the other person draws an outline of their body.

2 Make a list of all the parts you know are inside your body.

3 Think about the position in the body and size of the organs. Start drawing the organs into the outline of the body.

4 When you have finished all you can do, share your ideas with another pair.

5 Discuss any differences you have and make any changes you want to your drawing.

6 Share your drawing with the rest of the class.

### Discussion

1 **Assess** your knowledge of the body by giving it a rating out of ten.

2 **Discuss** why it is important that we know about the structures inside our bodies. Do you think you need more information?

# 2 Chapter review

## Remembering

1 Draw a table with two columns.
   a In the first column, **list** the parts of an animal cell that can be seen under a light microscope.
   b In the second column, **list** the parts of a plant cell.

2 **Name** the lens of the microscope that:
   a you look through.
   b is closest to the specimen.

3 **Name** the process that occurs in chloroplasts.

4 **State** what is different between unicellular and multicellular organisms.

## Understanding

5 **Outline** the function of the following cell parts.
   a plant cell wall
   b cell membrane
   c nucleus

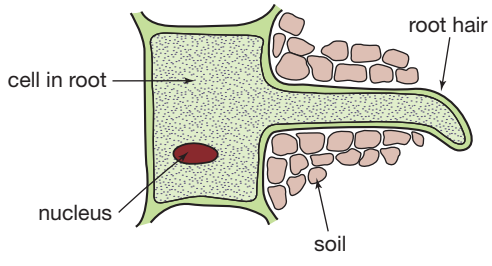
6 **Explain** the difference between a specimen and an image when using a microscope.

7 **Describe** what happens to the field of view when a microscope is changed from low power to high power.

8 **Predict** what will happen to the field of view when a ×10 objective lens is replaced by a ×4 objective lens.

9 When focusing a microscope, you are supposed to look from the side as you bring the stage and objective lens close together. **Predict** what could happen if you were looking through the ocular lens as you did this.

10 Study the diagram below, which shows a root hair cell.
   a **Describe** the function of the root hair cell.
   b **Explain** how the shape of this cell helps it to carry out its function.




11 **Explain** why muscle cells need to have large numbers of mitochondria.

## Applying

12 **Use** diagrams to **demonstrate** the differences between plant, animal and fungal cells.

13 The term *organelle* means little organ. Organs and organelles are very different. **Use** words and diagrams to **demonstrate** why organelle is an appropriate name for these structures.

14 **Calculate** the magnifications to fill in the blanks in this table.

| Ocular lens | Objective lens | Total magnification |
|---|---|---|
| ×4 | | ×40 |
| | ×10 | ×100 |
| ×4 | ×100 | |
| ×10 | ×40 | |
| ×10 | | ×1000 |

15 The field of view of a microscope was measured and found to be 3 mm using a magnification of ×10.

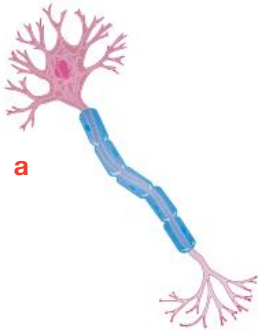
**Calculate** the diameter of the field of view at the following different magnifications and using the two different units.

| Magnification | ×10 | ×100 | ×1000 |
|---|---|---|---|
| Diameter of field of view (mm) | 3 | | |
| Diameter of field of view (μm) | | | |

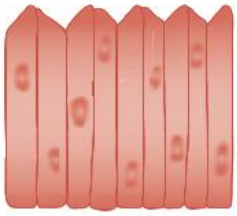
# 2 Chapter review

**16** **Identify** the types of cells represented in these diagrams.

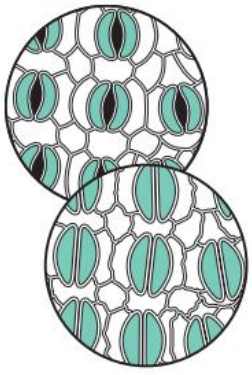
**a**



**c**



**b**



**d**



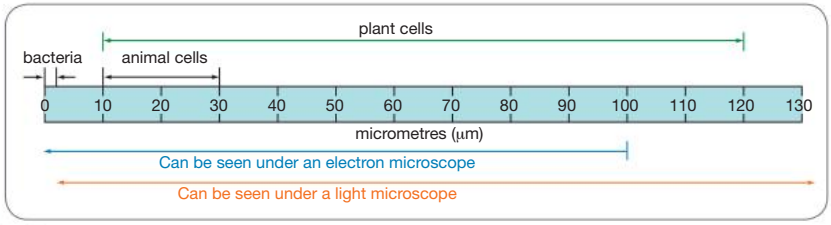



Figure 2.5.1

## Analysing

**17** **Classify** each of the following cell types as plant or animal cells.

- **a** guard cells
- **b** nerve cells
- **c** muscle cells
- **d** photosynthetic cells
- **e** root hair cells

**18** **Compare** the outer layer of plant cells and:

- **a** animal cells
- **b** fungal cells.

## Evaluating

**19** **Select** information from Figure 2.5.1 to use in your responses.

- **a** **Compare** the size of plant cells and animal cells.
- **b** **Suggest** a reason for plant cells being the first ones to be seen.
- **c** Bacteria were not discovered until long after plant cells. **Suggest** why this was so.

**20** **Select** the correct statements from the following list.

- **A** A structure made up of different types of tissues is an organ.
- **B** When cells of the same type are grouped together they form a system.
- **C** There are many different organs in a tissue.
- **D** Tissues are groups of cells of the same type.
- **E** In a system many organs work together.

**21** Look back at Figure 2.3.6 on page 59, showing cardiac muscle. The fibres of cardiac muscle are arranged in a network. **Propose** a benefit to you of having the fibres interlocking in this way.

## Creating

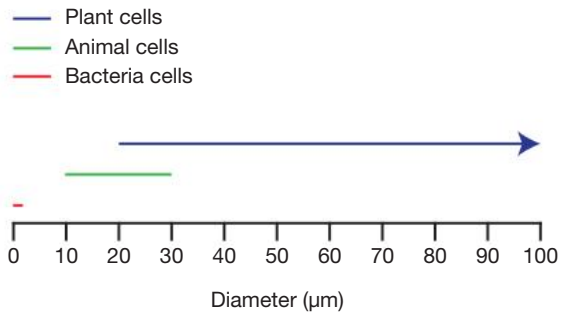
**22** **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

cell
plant
animal
unicellular organism
multicellular organism
tissue
organ
organ system
specialised cell
microscopic



# Thinking scientifically

**Q1** Four cells were viewed under a microscope and their diameter was measured. Use the information in the diagram to decide which one was most likely to be a cell from an animal.

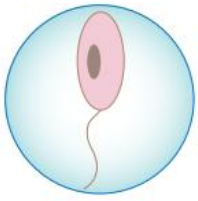



**A** 100 μm **B** 2 μm
**C** 15 μm **D** 45 μm

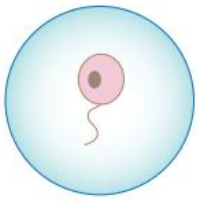
**Q2** The unicellular organism shown was viewed under a microscope with a magnification of ×2. Which diagram represents the image you would see?



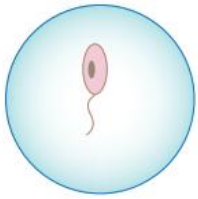
**A**



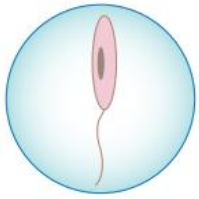
**B**



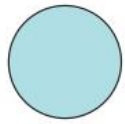
**C**



**D**



**Q3** When a cell was cut from a section of a plant stem and viewed under a microscope, it appeared as a circle as shown.

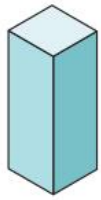


Which one of the following could *not* be the three-dimensional shape of the cell?

**A**



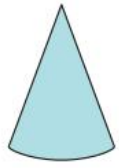
**B**



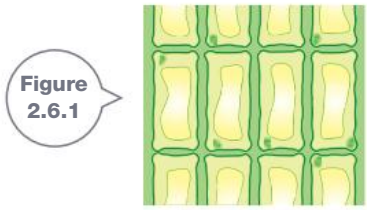
**C**



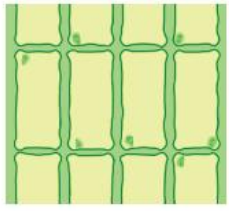
**D**



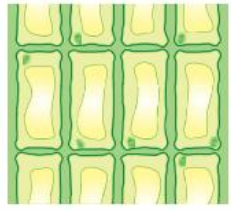
**Q4** Figure 2.6.1 shows a normal plant cell. What would the cell look like if the plant it came from had no water for 3 days?




**A**



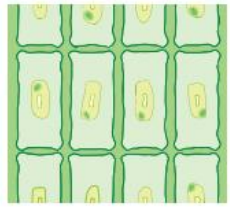
**B**



**C**

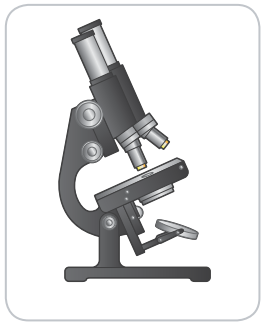


**D**



# Glossary

## Unit 2.1



Binocular microscope

**Binocular microscope:** a light microscope that has two ocular lenses

**Dissection:** when a scientist cuts apart a dead plant or animal to study it

**Electron microscope:** microscope that uses beams of electrons to magnify up to a million times. There are two types of electron microscopes: transmission electron microscopes (TEM) and scanning electron microscopes (SEM)

**Field of view:** the amount of the specimen seen through a microscope

**Image:** what is seen using the microscope

**Light microscope:** a microscope that uses light to reveal the image

**Magnification:** the amount by which the image is magnified (made bigger) compared to the real object (specimen)

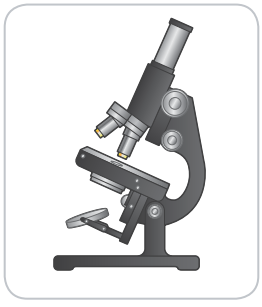
**Magnified:** made bigger

**Micrometre:** one-thousandth of a millimetre, or one-millionth of a metre

**Microscope:** instrument used to make very small things look bigger

**Microscopic:** describes objects that can only be seen using a microscope

**Monocular microscope:** a light microscope that has only one ocular lens



Monocular microscope

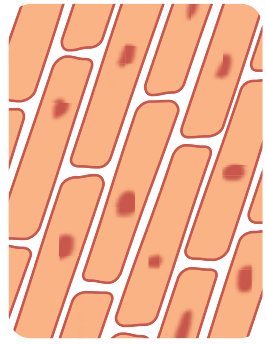
**Objective lens:** the lens of the microscope closest to the stage

**Ocular lens:** the lens of the microscope closest to your eye

**Specimen:** the object being looked at through a microscope

**Stereo microscope:** a binocular microscope that creates a three-dimensional image

## Unit 2.2



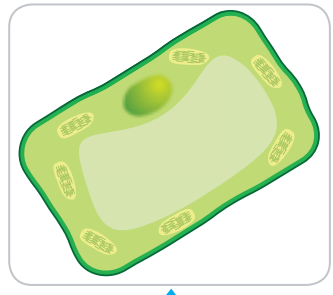
Cell

**Cells:** the building blocks of all living things

**Cell membrane:** the 'skin' that holds the cell together. It controls what comes into and leaves the cell

**Cell wall:** the skeleton of the plant

**Chloroplast:** organelle within the cell where photosynthesis takes place



Chloroplast

**Cytoplasm:** a watery, jelly-like mixture that contains many smaller parts where the work of the cell takes place

**Endoplasmic reticulum:** pathways along which materials move through a cell

**Lysosomes:** organelles that get rid of wastes from cells

**Mitochondria:** the powerhouses of the cell where the energy is released from food

**Nucleus:** the control centre of a cell

**Organelles:** the smaller parts of a cell

**Photosynthesis:** process used by plants to make food from water and carbon dioxide using energy from the Sun

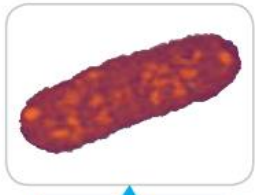
**Ribosomes:** organelles that produce proteins

**Vacuole:** small structure in animal cells that may contain wastes or chemicals, or large sap-filled structure in plant cells that stores water, wastes and nutrients

## Unit 2.3

**Axon:** long fibres that extend from nerve cells and carry messages over long distances

**Bacteria:** very simple unicellular organisms that lack a nucleus and other organelles



Bacteria

**Chlorophyll:** the green chemical in chloroplasts that traps the Sun's energy for photosynthesis

**Guard cells:** cells that work in pairs to open and close the stomata

**Multicellular organisms:** living things made of many cells

**Nerve cells:** cells that carry information in the body

**Protists:** a group of unicellular organisms often found in ponds and soil

**Red blood cells:** cells that carry oxygen from the lungs around the body

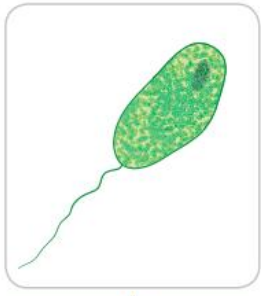
**Root hairs:** extensions on the outer surface of some root cells

**Specialised cells:** cells that have a special job to do in the body and have a structure that makes them better able to do their job

**Stomata:** very tiny pores in leaves

**Unicellular organisms:** living things made up of only one cell

**White blood cells:** part of the immune system; helps the body to fight infection



Unicellular organism

## Unit 2.4

**Cell culture:** growing cells separately from organisms in the laboratory

**Connective tissue:** adds support and structure to the body, e.g. fat, bone, cartilage, blood tendon and ligament



Mitosis

**Epithelium:** skin

**Mitosis:** cell division that produces two identical cells

**Muscle tissue:** specialised tissue that can contract



Muscle tissue

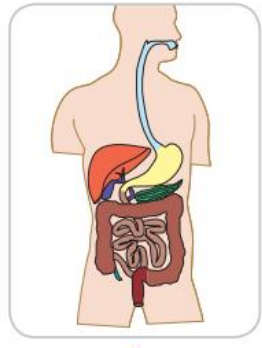
**Nerve tissue:** many nerve cells grouped together

**Organ:** a structure that contains at least two different types of tissues that work together to complete a task

**Organ system:** two or more different organs that work together

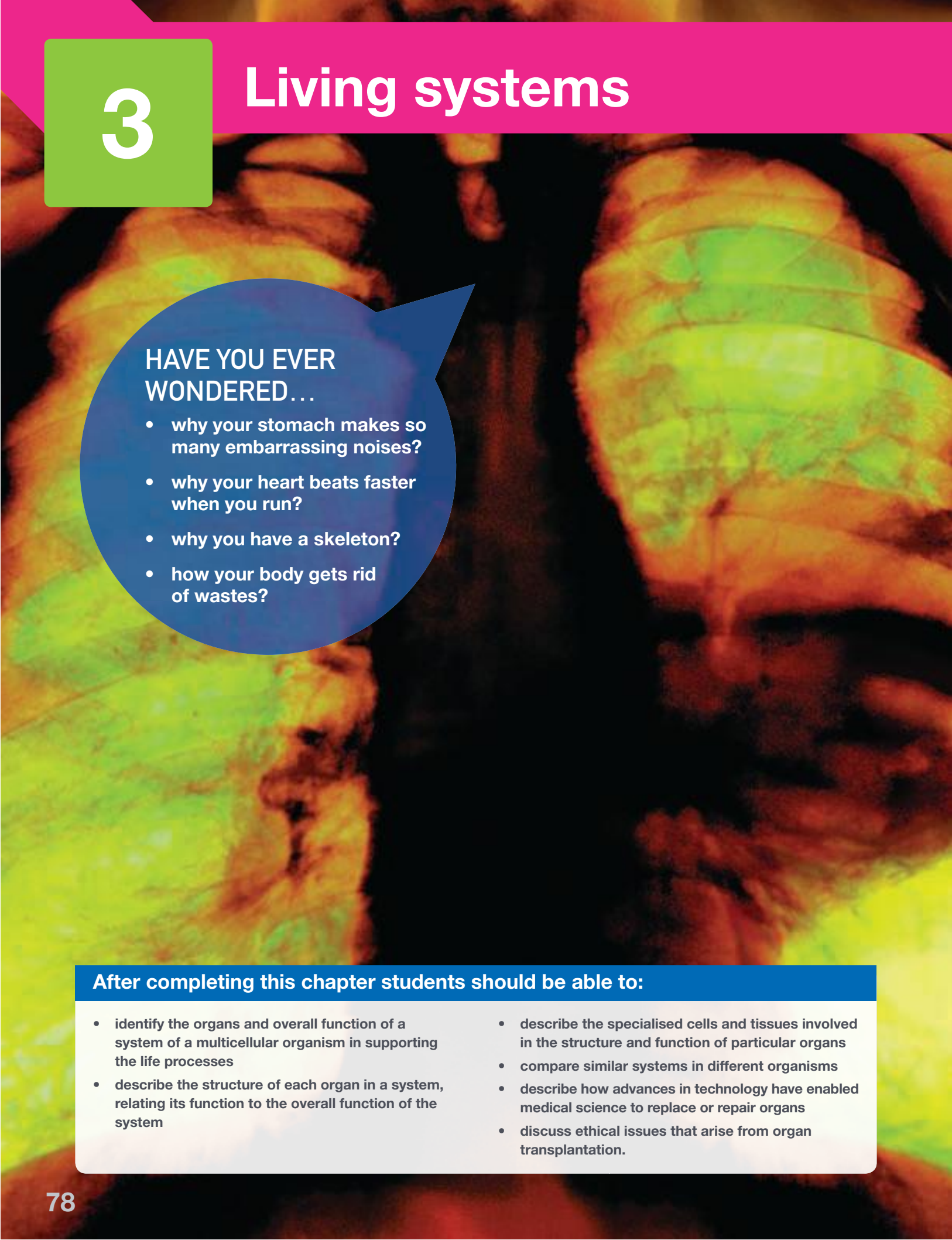
**Tissue:** groups of cells that perform the same function in the body

**Stem cells:** cells that can become different types of cells under specific conditions



Organ system

# 3 Living systems



## HAVE YOU EVER WONDERED…

- why your stomach makes so many embarrassing noises?
- why your heart beats faster when you run?
- why you have a skeleton?
- how your body gets rid of wastes?

## After completing this chapter students should be able to:

- identify the organs and overall function of a system of a multicellular organism in supporting the life processes
- describe the structure of each organ in a system, relating its function to the overall function of the system
- describe the specialised cells and tissues involved in the structure and function of particular organs
- compare similar systems in different organisms
- describe how advances in technology have enabled medical science to replace or repair organs
- discuss ethical issues that arise from organ transplantation.

# 3.1 Digestion



Food is something you probably think about often during the day. You look forward to eating some foods, and hope that your favourite foods are served up for dinner. Food provides your body with all its building materials and the energy you need for all your activities. However, you cannot use food until after your digestive system has been to work on it.

## The need for body systems

Your body is made up of trillions of tiny building blocks called **cells**. These are so small that you cannot see them without the help of a microscope. Your cells are where most of your body's work is carried out. Cells need raw materials to work with. Your body is organised in a way that makes sure that the cells are supplied with the raw materials they need.

In your body there are different levels of organisation. Cells come in many types, such as skin cells and muscle cells. Cells of the same type that carry out the same job in the body are grouped together to form **tissues**, such as muscles and nerves. At the next level of organisation, tissues are grouped to form organs, such as the stomach or brain. An **organ** is a structure that contains at least two different types of tissue that work together to complete a task. Organs are arranged into organ systems that have two or more different organs that work together (Figure 3.1.1).

The systems of your body all have their own jobs to do.

- The respiratory system takes in oxygen.
- The digestive system makes food available in a form the body can use.
- The circulatory system carries the food and oxygen to the cells where it is needed.
- The excretory system gets rid of the wastes.
- The skeletal system supports the body and enables it to move.



**Figure 3.1.1** In both the jockey and the horse, cells are organised into tissues, tissues into organs, and organs into systems.

# The digestive system

The food you eat tastes good but is not in a form that can be used by your cells. Bread, meat, fruit and vegetables, like those in the bun in Figure 3.1.2, are made of complex chemicals. These have to be broken down, or digested, into simple, soluble chemicals that can be used by your cells. Your body needs the chemicals in food for energy, growth and repair. These chemicals are known as nutrients. **Digestion** is the process of breaking down food into a useable form and making the nutrients available.



Figure 3.1.2 The bun looks good and probably tastes good, but it has to be digested before you can use the nutrients it contains.

Digestion takes place in your **digestive system**. Your digestive system consists of:

- a digestive tract, the pathway that the food takes though a series of organs. The first part of the digestive tract is the mouth.
- organs off to the side of the digestive tract that produce chemicals that assist with digestion.

The human digestion system is shown in Figure 3.1.3.

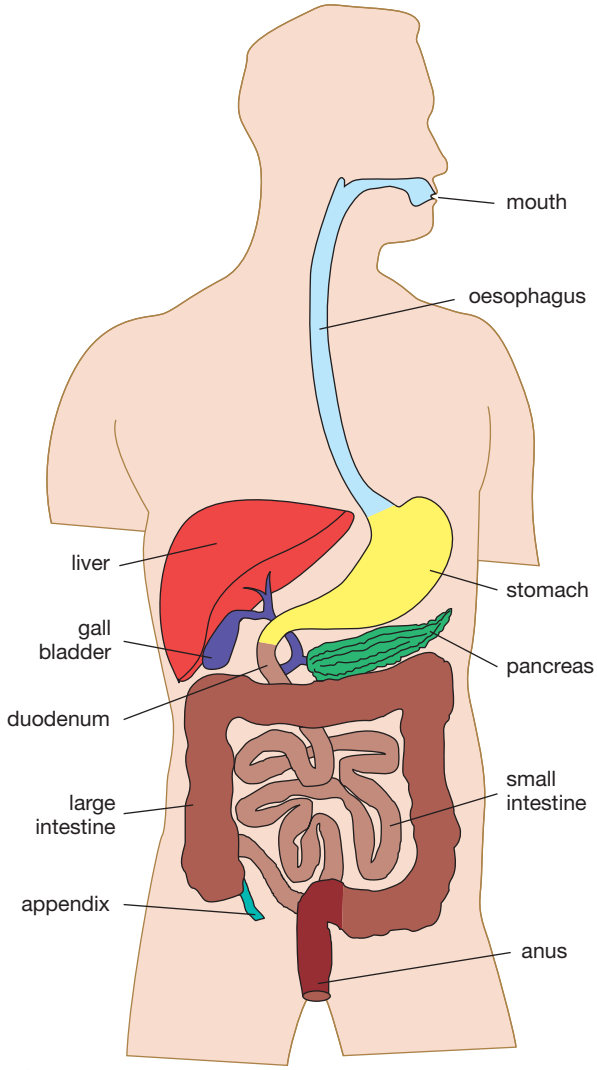



Figure 3.1.3 The human digestive system

3.1

## Types of digestion

There are two different types of digestion: mechanical digestion and chemical digestion. Mechanical digestion is when the food is broken down into smaller pieces, as shown in Figure 3.1.4. It is like cutting a slice of bread or piece of meat into smaller pieces. Mechanical digestion is a physical change because no new substances are made.

science 4 fun

## Where's the sugar?

Is there sugar in bread?

Yes

### Collect this…

- 3 cm x 3 cm piece of bread or water cracker biscuit (not a sweet biscuit)

### Do this…

1. Chew the bread or biscuit so that it is broken up and well moistened with saliva.
2. Keep it in your mouth for about a minute—don't swallow it.

### Record this…

**Describe** any change you observed in the tastes.
**Explain** why you think this happened.

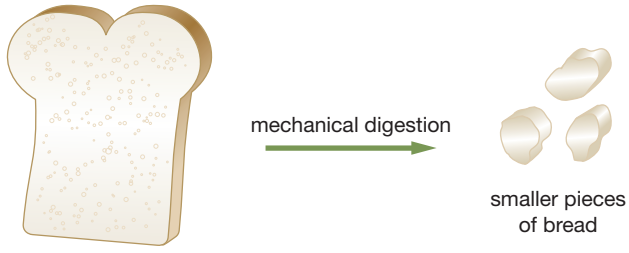



**Figure 3.1.4** Mechanical digestion happens when you tear and chew food with your teeth.

In chemical digestion the large, complex substances in the food are broken down into simpler chemicals. You can see this in Figure 3.1.5. This produces new, smaller chemicals that the body can absorb. Chemical digestion is a chemical change because new substances are produced.

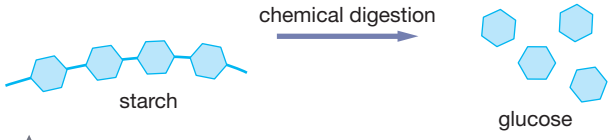



**Figure 3.1.5** Chemical digestion happens when saliva in your mouth and gastric juice in your stomach break down your food.

3.2

## In the mouth

The process of digestion starts with your teeth. You have four types of teeth: incisors, canines, premolars and molars. These are shown in Figure 3.1.6. The incisors are the four pairs of teeth at the front and their job is to bite off pieces small enough to chew. The tongue then pushes the food back to the premolars and molars. These teeth grind the food into smaller and smaller pieces as you chew.

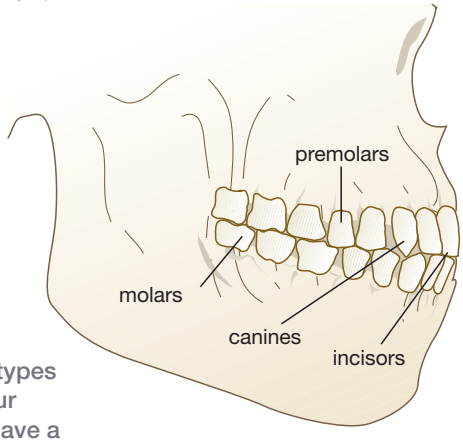



**Figure 3.1.6** The different types of teeth in your mouth each have a specific job to do.

In humans, the canine teeth do not have a significant function or job. However, in animals such as lions or wolves that catch live prey, the long canines are used to hold onto the food as it is torn apart.

Biting and chewing food is a form of mechanical digestion but chemical digestion also takes place in the mouth. As the food is being digested mechanically, it is mixed with saliva. Saliva is a watery liquid produced by your salivary glands. Saliva contains a chemical that starts to change any starch (a complex sugar) in the food into glucose (a simple and easily absorbed sugar). Saliva also moistens the food, making it slippery, slimy and easy to swallow. The tongue rolls the food into a ball (called a **bolus**), which is pushed down into the next part of the system, the oesophagus.

## Swallowing

SciFile

**Tongue tied**

The tongue is the only muscle in the human body that is attached at only one end.

Your **oesophagus** is a long muscular tube that has the mouth at one end and the stomach at its other end. The muscles of the oesophagus push the ball of food down the tube by contracting behind the ball. The muscles then relax. This process is called **peristalsis**. It is as though you are trying to push the air into the end of a long thin balloon. Persistalsis can be seen in Figure 3.1.7.

A flap of skin called the **epiglottis** closes the end of the windpipe as you swallow. This makes sure that the food goes into your stomach and not into your lungs via the windpipe. If food does get into the windpipe, you start to choke. You then cough to force the food back up into your mouth so that it can be swallowed correctly.

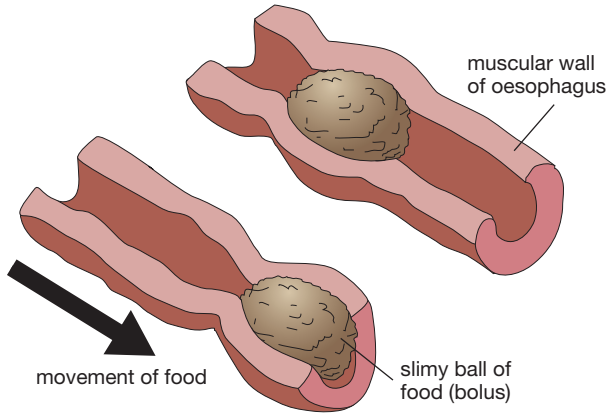



**Figure 3.1.7** Peristalsis is the rhythmic contracting and relaxing of the muscles of the oesophagus that keeps food moving through the oesophagus and other parts of the digestive system.

A circle of muscle (called a **sphincter**) separates the oesophagus from the stomach. The sphincter opens and the food passes into the stomach. It then closes to stop food or stomach juices from flowing back up.

## Stomach

The stomach is shaped like a bag. It is the big red shape in the middle of Figure 3.1.8. Food is stored in the stomach for 1–6 hours. Once in the stomach, the food really begins to change. The muscular walls of the stomach contract and relax, churning up the food. This further digests the food mechanically as well as mixing it with gastric juice. It is this churning of food as the muscles in the stomach wall contract and relax that creates the gurgling noises in your stomach.

**Gastric juice** is produced by special cells in the stomach wall. Gastric juice contains:

- hydrochloric acid—a strong acid that kills many of the bacteria that may have entered the body with the food
- mucus—creates a layer on the lining of the stomach and prevents the stomach digesting itself
- digestive juices—contains chemicals that start the digestion of protein, the main nutrient found in meat.

1 p87

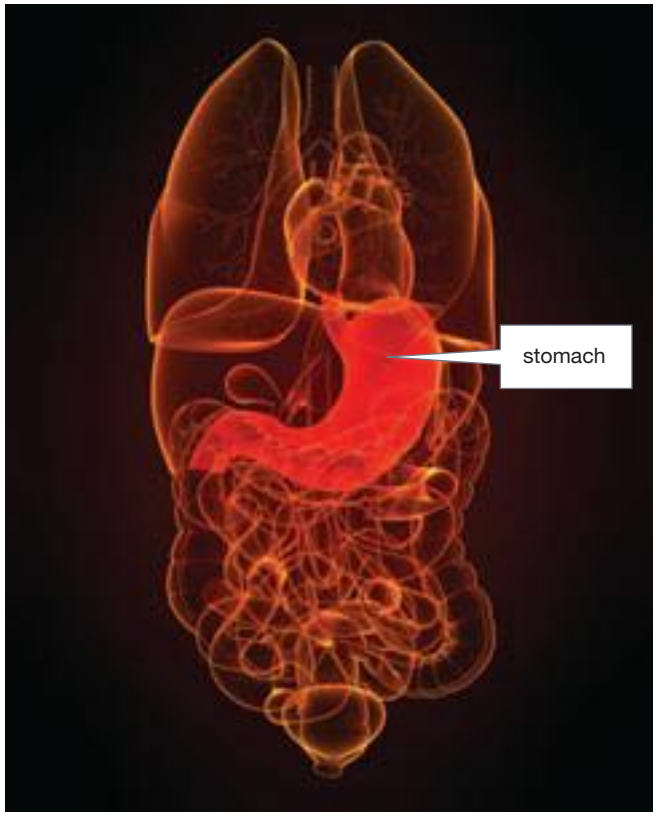



**Figure 3.1.8** In the stomach, food is digested both mechanically and chemically. The food is turned into a thick, acidic soup.

## Small intestine

The **duodenum** is the first part of your small intestine. Two tubes entering the duodenum carry chemicals important for digestion. These tubes come from the pancreas and the liver.

The **pancreas** is not part of the digestive tract. It is an organ that is connected to it that produces pancreatic juice. Pancreatic juice contains chemicals that help digest carbohydrates (starches and sugars), fats and protein.

The **liver** is the body's largest internal organ and performs over 500 different chemical processes. It is a vital organ, meaning that you cannot survive without it. The process in the liver that is important for digestion is the production of bile. **Bile** is a greenish liquid responsible for chemical digestion of fats. It acts in a similar way to dishwashing detergent. In the washing up water, detergents break the fats and oils on dishes into tiny droplets that can easily be washed away. Bile causes large pieces of fat in the food to be broken down into tiny pieces so that they can be digested more easily. Figure 3.1.9 shows the liver and adjacent organs.

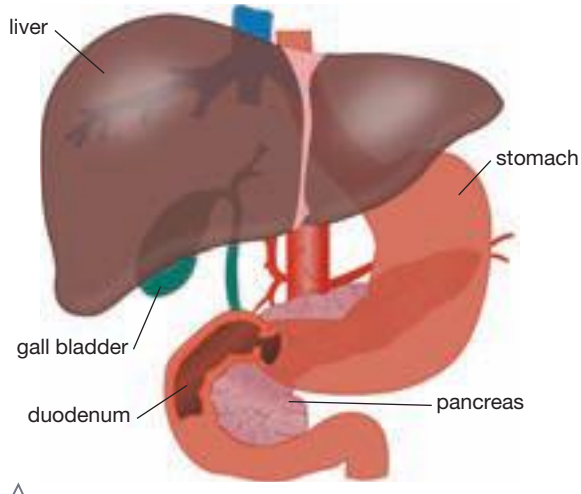



**Figure 3.1.9** Blood carrying nutrients from the digestive system travels to the liver before it goes anywhere else. The liver removes toxins such as alcohol from the blood and also acts as a short-term store for glucose. Glucose is a simple sugar produced by the digestion of carbohydrates.

The walls of the duodenum are muscular. They continue to squeeze and churn the food, breaking it down and making sure that the digestive chemicals are mixed through. The digestive chemicals change the remaining foods into forms that can be used by the body. When it passes into the lower part of the small intestine, the food is in the form of very tiny particles that can be absorbed by (taken into) the body.

The part of the **small intestine** after the duodenum is a very long, narrow tube. It is the longest part of your digestive tract—up to 6 metres long. The 'small' intestine gets its name because of its diameter, which is only 3 cm.

It is in this part of the small intestine that the digested food is absorbed into the body. On the inner lining of the small intestine are **villi** (singular: villus). These are microscopic 'fingers' that greatly increase the surface area of the intestine wall and through which the nutrients can pass. Within the villi are tiny blood vessels called capillaries. The walls of the villi and the walls of the capillaries are only one cell thick. This means that the nutrients have to travel a very tiny distance (about one-hundred-thousandth of the diameter of a full stop) as they move from the digestive system into the blood system. Figure 3.1.10 shows the detailed structure of villi.

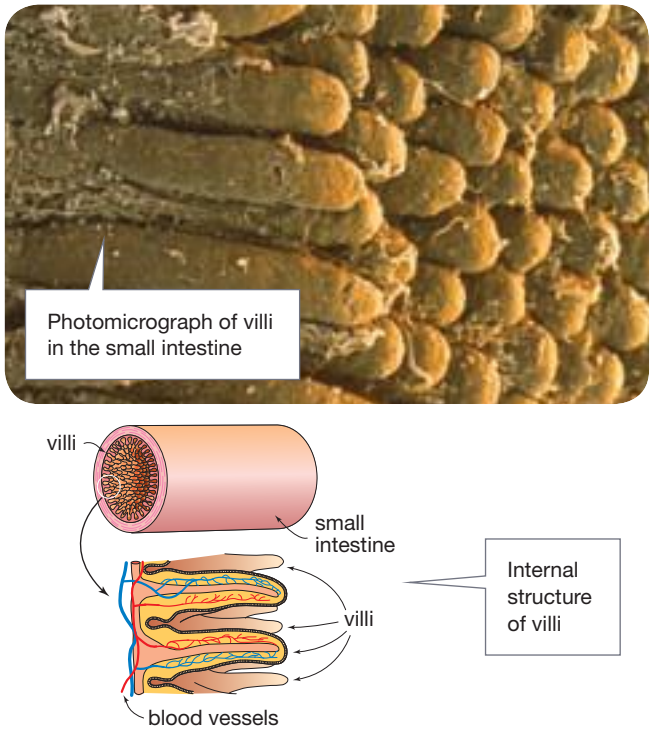



**Figure 3.1.10** Villi greatly increase the surface area through which nutrients can be absorbed from the small intestine.

3/3

The nutrients that pass from the small intestine are:

- fatty acids and glycerol produced from digestion of fats
- amino acids from the digestion of proteins
- glucose from the digestion of carbohydrates.

Your body uses glucose as its main source of energy. Figure 3.1.11 summarises the major changes that occur in the digestive system.

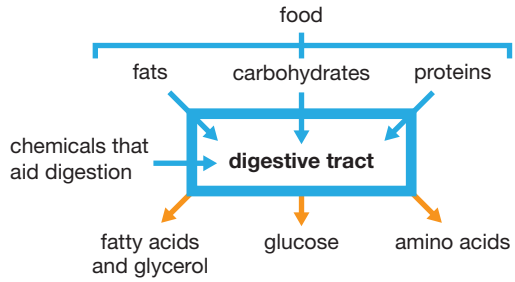



**Figure 3.1.11** A lot of different things happen to food in the digestive system.

2 p88

## Large intestine

The **large intestine** is the final section of your digestive tract. At 1.5 metres, it is shorter than the small intestine, but it is wider, being 6–7 cm in diameter. The large intestine can be seen in red in Figure 3.1.12. In the large intestine, water is reabsorbed into the body from what is left of the food, along with any remaining nutrients. The waste forms lumps of faeces (known as stools). These are later expelled from the body through the **anus**—a sphincter muscle at the end of the digestive tract. As Figure 3.1.13 on page 84 shows, about one-third of the solid material in faeces is bacteria from the intestine. Most of these helped your body digest the food but they are passed out and contribute to the smell of the faeces.

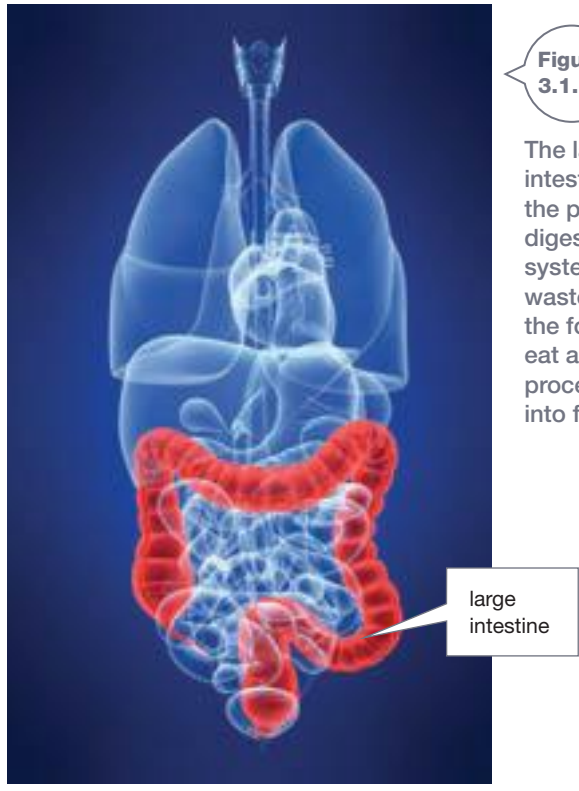



**Figure 3.1.12** The large intestine is the part of the digestive system where wastes from the food you eat are processed into faeces.

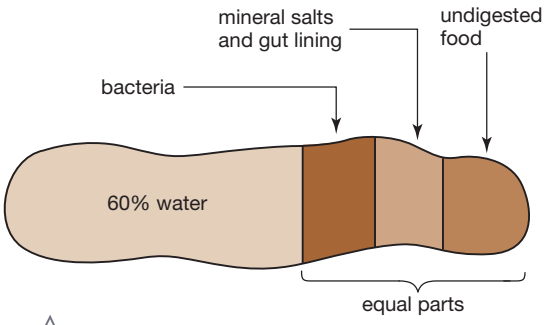



**Figure 3.1.13** A large percentage of faeces is water. If the proportion of water decreases too much, then stools become dry, very firm and difficult to expel from the body.

# Digestive disorders

## Vomiting

Vomiting is a quick way of getting rid of unwanted bacteria in the digestive tract. Stress or infections such as gastroenteritis can cause the muscular wall of the stomach and small intestine to contract. The sphincters at the top and bottom of the stomach open, and the contents of the stomach are forced along the oesophagus and out of the mouth. Vomit is partly digested food mixed with stomach acid and bile.

## Diarrhoea

Diarrhoea is another quick way of getting rid of harmful bacteria and viruses. These cause the lining of the small intestine to become inflamed so that it can no longer absorb water from the faeces. Instead of a firm stool passing through the anus, the faeces are loose and watery. The body is at risk of dehydration so people with diarrhoea should drink plenty of fluids to replace what is being lost.

## Heartburn

Heartburn is a burning sensation that rises up the oesophagus from your stomach. Peristalsis pushes food down your oesophagus to your stomach. Pressure on the stomach wall can cause the stomach contents to be pushed back up. Lying down or bending over can cause this type of pressure.

Unlike the stomach, your oesophagus does not have mucus protecting the lining from stomach acids. The burning sensation of heartburn is the acid attacking the lining of the oesophagus.

## Appendicitis

The appendix is a blind-ended tube connected to the large intestine. If the opening into the appendix is blocked, then the appendix fills with mucus. It becomes inflamed and swollen, causing the pain of appendicitis. The only treatment is an operation to remove the appendix before it bursts and causes even more severe infection.

**SciFile**

### The appendix

It was once thought that the appendix had no function in humans but now it is believed that the appendix may house useful bacteria and be important in the development of the immune system in babies. It is your immune system that helps you fight disease.

# Comparing digestion

Humans, dogs and cows eat different food and they also have a different pattern of eating. Working dogs are very active for a large part of the day and may spend only 10–15 minutes each day eating. The food they eat is mostly meat. In contrast, cows spend a very large part of their day chewing and eating grass. Humans eat both plants and meat. We spend about one and a half hours eating each day.

The teeth and digestive systems of these three animals are different to suit their different diets. Most of a cow's teeth are designed to grind up grass and other plant material. It takes more time to digest plant material than meat. A cow's intestines are much longer than those of a dog. The teeth at the front of a dog's mouth are designed to hold meat and tear it into small pieces. Dogs do not chew their food. The teeth at the back of their mouths are designed for cutting rather than chewing. These different types of teeth can be seen in Figure 3.1.14.



**Figure 3.1.14** The dog has long canine teeth for holding prey. The teeth at the back have sharp edges that can cut though meat. They are not designed for grinding and chewing.

The human digestive system is shorter than that of a cow and longer than that of a dog. Humans eat both plants and meat. Human teeth are designed for both cutting and chewing.

3.4

# 3.1 Unit review

## Remembering

1 **List** the organs of the digestive tract in order from the start to the finish.

2 a **List** the organs that are part of the digestive system but not part of the digestive tract.
b **State** how each organ contributes to digestion.

3 **Name** three disorders of the digestive system.

## Understanding

4 **Describe** the process of peristalsis and how it keeps food moving through the digestive tract.

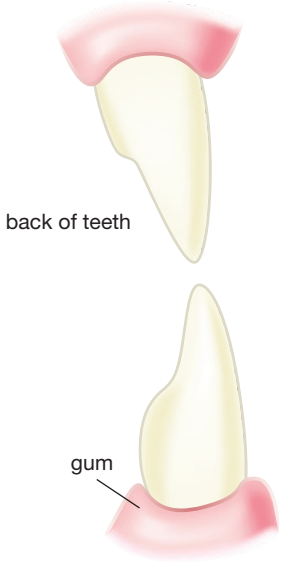
5 **Explain** how the structure of the following organs makes them well suited for the job they do.
a stomach
b small intestine

6 **Explain** what happens to most of the harmful bacteria that enter the digestive system.

7 **Describe** what can happen if too many harmful bacteria enter the system.

8 Figure 3.1.15 illustrates the shape of the incisor teeth.

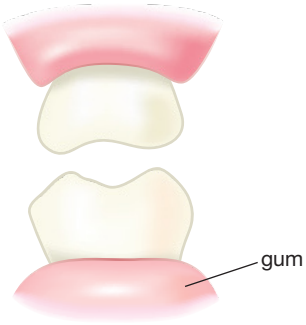
Figure 3.1.15




a **Describe** the shape of the teeth.
b **Explain** why this is an ideal shape to bite off small pieces of food.

9 Figure 3.1.16 illustrates the shape of the molars.

Figure 3.1.16




a **Describe** the shape of the teeth.
b **Explain** why this is an ideal shape for grinding food.

10 **Explain** why it is important that you keep your teeth strong and healthy.

## Applying

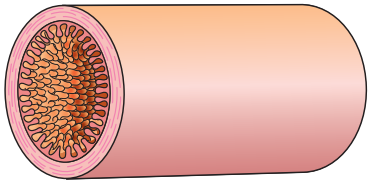
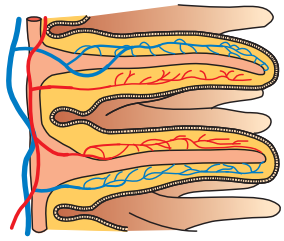


Figure 3.1.17



11 a **Identify** the part of the digestive system shown in Figure 3.1.17.
b Use the diagram to **demonstrate** by how much these structures increase surface area.

# 3.1 Unit review

## Analysing

12 **Compare** mechanical digestion and chemical digestion.

13 **Classify** these descriptions of digestion as mechanical or chemical.

- a The slices of apple were ground to a pulp by his back teeth.
- b Adding the digestive juice caused the mass of oil to break up into tiny droplets.
- c At the end of the experiment we tested the food for the complex compound starch and didn't find any. A test for the simple sugar glucose showed that it was present. There was no glucose at the beginning of the experiment.
- d She nibbled at the biscuit.

## Evaluating

14 **Propose** what would happen if the length of the small intestine was halved.

15 Figure 3.1.18 shows the digestive system of a snake.

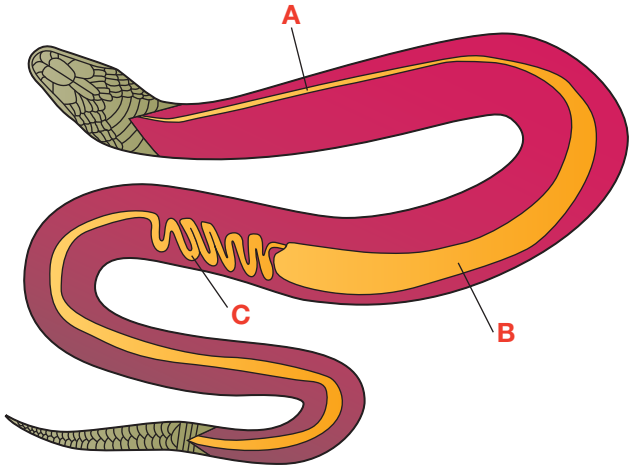



Figure 3.1.18

- a Using the human digestive system as a model, **propose** the names of the parts labelled A, B and C.
- b **Justify** your answer.

## Creating

16
- a **Construct** a diagram of the digestive system.
- b Label the parts and **identify** the function of each part.

17 Imagine that you have been miniaturised and placed in a capsule that has been swallowed. You are in the human stomach. **Construct** an annotated diagram or write a short paragraph describing the conditions around you.

18 Digestive enzymes can be purchased for use in experiments. Write a method for a prac that would **demonstrate** that mechanical digestion makes chemical digestion more efficient.



## Inquiring

1 Research what effect the eating disorder bulimia has on the digestive system.

2 Before modern technology, scientists had great difficulty finding out what happened inside the body. Alexis St Martin contributed a great deal of knowledge of the human digestive system. Research his work.

3 Investigate the structure of teeth and why problems develop if plaque is allowed to build up on them.



Figure 3.1.19 Plaque can lead to tooth decay. Plaque-disclosing tablets from a pharmacy will show you if you are cleaning the plaque off your teeth.

# 3.1 Practical activities

## 1 Breaking down fats and oils

A model is a way of demonstrating how a real system works.

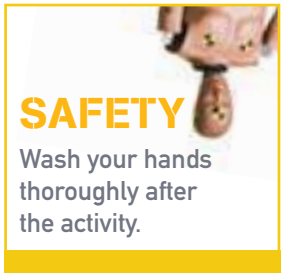
### Purpose

To model the effect of bile.

### Materials

- 4 × 250 mL beakers
- 10 mL vegetable oil
- 1 $cm^3$ block of animal fat
- 20 mL detergent
- warm water at about 38°C
- 10 mL measuring cylinder
- 200 mL measuring cylinder
- 4 stirrers
- 4 labels






### Method

1. Label the beakers 'Fat', 'Fat and detergent', 'Oil', and 'Oil and detergent'.
2. Cut the block of animal fat in half and add one piece to each of the beakers labelled 'Fat' and 'Fat and detergent'.
3. Using the 10 mL measuring cylinder, add 5 mL of oil to each of the beakers labelled 'Oil' and 'Oil and detergent'.
4. Wash the measuring cylinder carefully or use a clean cylinder to add 10 mL of detergent to each of the beakers labelled 'Fat and detergent' and 'Oil and detergent'.
5. Using the 200 mL measuring cylinder, add 150 mL of warm water to all four beakers.
6. Using a clean stirrer for each beaker, stir the contents gently to mix them together.
7. Stop stirring and after 3 minutes observe any changes in the beakers.

### Results

Copy the following table into your workbook. Record all your observations in it.

| Beaker contents | Observations after 3 minutes |
|---|---|
| Oil | |
| Oil and detergent | |
| Fat | |
| Fat and detergent | |

### Discussion

1. **Explain** why the temperature of the water used was close to 38°C.
2. **Compare** the changes in the two beakers containing vegetable oil.
3. **Compare** the changes in the two beakers containing fat.
4. **Compare** the changes to the fat and oil in the beakers also containing detergent.
5. Based on the observations you made, **propose** what happened to the fat and oil.

## 2 A model intestine

Tes-Tape tests for the presence of glucose in a solution.

### Purpose

To investigate how the small intestine works.

### Materials

- 2 × 500 mL beakers
- 2 × 20 cm lengths of dialysis tubing
- 2 × 10 cm lengths of thin string
- starch solution
- glucose solution
- iodine solution
- Tes-Tape
- water



**SAFETY**

Iodine stains. Avoid contact with skin and clothes.

### Procedure

1. Two-thirds fill both of the beakers with water.
2. Add 10 mL of iodine solution to one beaker. Label this beaker 'Starch'.
3. Label the other beaker 'Glucose'. Test the water in this beaker with Tes-Tape to demonstrate that there is no glucose present.
4. Run both pieces of dialysis tubing under the tap to soften them.
5. Tie a knot in one end of each tube and rub the other end to open up the tube.
6. Fill one tube with starch solution and tie the open end firmly with string. Carefully rinse the outside of the dialysis tubing to ensure that there is no starch solution on the outside. Place this tube into the beaker labelled 'Starch'. This is summarised in Figure 3.1.20.
7. Fill the other tube with glucose solution and tie the open end firmly with string. Carefully rinse the outside of the dialysis tubing to ensure that there is no glucose solution on the outside. Place this tube into the beaker labelled 'Glucose'.

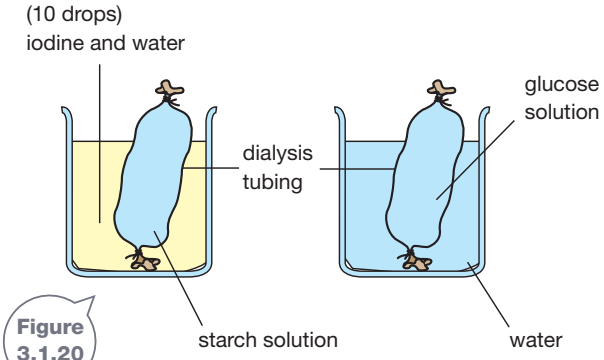



Figure 3.1.20

### Results

1. After 15 minutes, observe the beakers and record any changes.
2. Test the water in the 'Glucose' beaker with Tes-Tape. Record the result.

### Discussion

1. **Explain** how you know when starch is present in a solution.
2. **Explain** how you know when glucose is present in a solution.
3. **Describe** the changes that took place in the beaker labelled 'Starch'. **Infer** what happened to cause the changes.
4. **Describe** the changes that took place in the beaker labelled 'Glucose'. **Infer** what happened to cause the changes.
5. **Compare** what happened in this experiment with what happens in the small intestine.
6. **Explain** why starch cannot be used by the body until it has been digested.

# 3.2 Breathing and respiration

You need food and oxygen to make energy available in your cells. Your digestive system processes food to provide glucose, the main source of the chemical energy your cells need. Your respiratory system supplies the oxygen needed by your cells and gets rid of the carbon dioxide produced by them as waste.

## Respiration

**Respiration** refers to the series of chemical changes that take place in cells to release energy. For humans and many other animals, breathing is the process by which the body takes in and lets out air.

The system of organs and tissues that takes the air into the body and ultimately makes the oxygen available to the cells is the **respiratory system**.

## Respiratory system

Your respiratory system takes in air and extracts oxygen from it. It allows oxygen to pass into your bloodstream to be distributed to the cells for respiration. Figure 3.2.1 shows the structure of your respiratory system.

### Where the air goes

When you breathe in, some air may come in through your mouth but most of it comes in through your nose. Within the nasal cavity, the air is warmed and moistened. Large dust particles are filtered out as the air passes through the hairs inside your nostrils. Glands in the skin lining the nose produce sticky mucus. The mucus helps tiny hairs called cilia lining the nose to trap fine particles.

The mucus with the trapped particles then moves to the back of the nose and into the **pharynx**. It is then swallowed. You swallow about 600 mL of mucus every day without being aware of it.

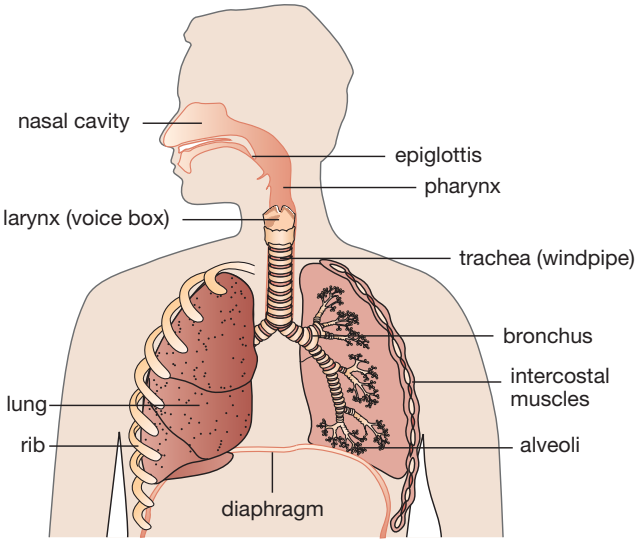



Figure 3.2.1 Structure of the human respiratory system

The warm, moist air then passes down the **trachea** (windpipe). The thin walls of the trachea are reinforced with rings of a firm elastic material called cartilage that keep your trachea from collapsing as you breathe in. You can feel these rings as ridges on the front of your throat. They are shown in Figure 3.2.2. The trachea divides into two **bronchi** (singular: bronchus), which divide and divide into ever smaller tubes (**bronchioles**), eventually ending in a cluster of sacs called **alveoli** in the lungs (singular: **alveolus**).



**Figure 3.2.2** Ridges of stiff flexible cartilage can be seen clearly in this photograph of a trachea.

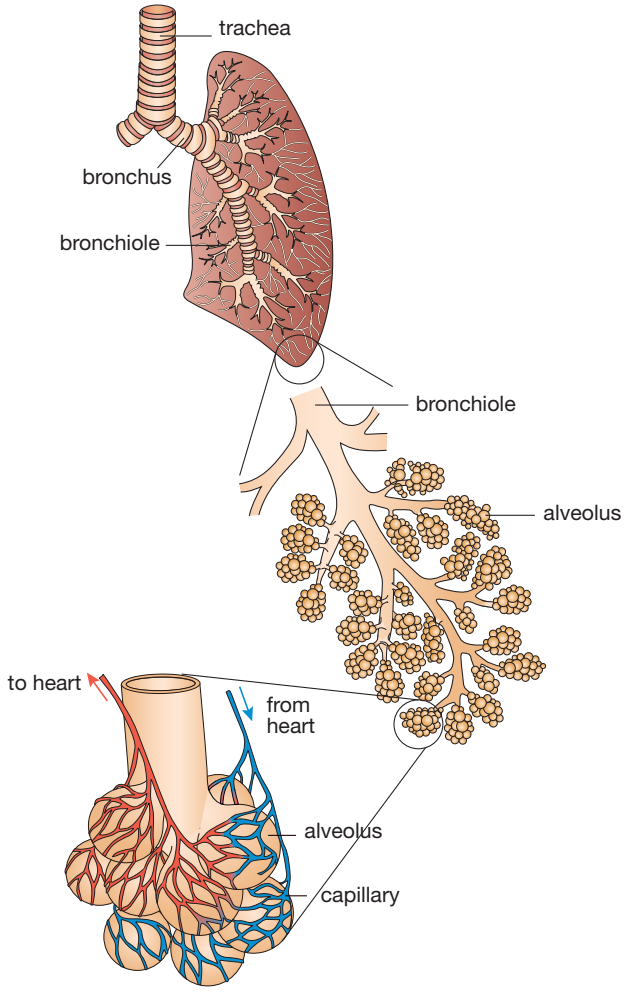



**Figure 3.2.3** The air follows a path that starts with the trachea, a tube about the same diameter as a garden hose, and finishes in a microscopic sac called an alveolus.

Alveoli are microscopic and about 500 million of them make up your lungs. The alveoli provide a very large surface area, allowing gas to be easily exchanged between the lungs and bloodstream. Figure 3.2.3 shows the alveoli in a section of a lung. Figure 3.2.4 shows a magnified view of lung tissue.

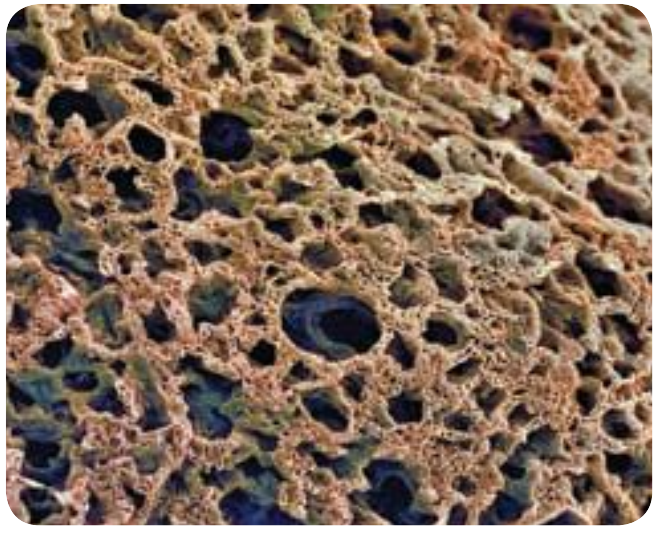


**Figure 3.2.4** The alveoli within the lung are closely packed, making the lung like a sponge.

**SciFile**

## Breathing space

In each of an adult's lungs, there are about 300 million alveoli. If they could be spread out, they would cover an area about the same size as a tennis court (about 160 $m^2$). This is about 80 times the area of your skin.

INQUIRY science 4 fun

## How big?




The lungs have a large surface area, but what does that mean?

### Collect this…

- 20 cm length of plastic tubing (such as garden hose) at least 1 cm in diameter
- ball of string
- measuring tape

### Do this…

1. Thread the string through the plastic tubing without twisting or folding it.
2. Measure the length of the string.
3. Twist and fold the string to find out how much string can be fitted inside the tubing.
4. When you cannot get any more string in, mark the end or cut off the string.
5. Unravel the string from the tubing and measure the length of the string you were able to fit inside.




### Record this…

**Describe** the difference between the two lengths of string.

**Explain** which of the pieces of string has the largest surface area and how this relates to the working of the lungs.

## Gas exchange

The walls of the alveoli are only one cell thick and they are surrounded by tiny blood vessels called capillaries. Oxygen dissolves in the moist surface of the alveoli and moves by a process called diffusion across the short distance from the space inside an alveolus to the blood. Figure 3.2.5 illustrates this process.

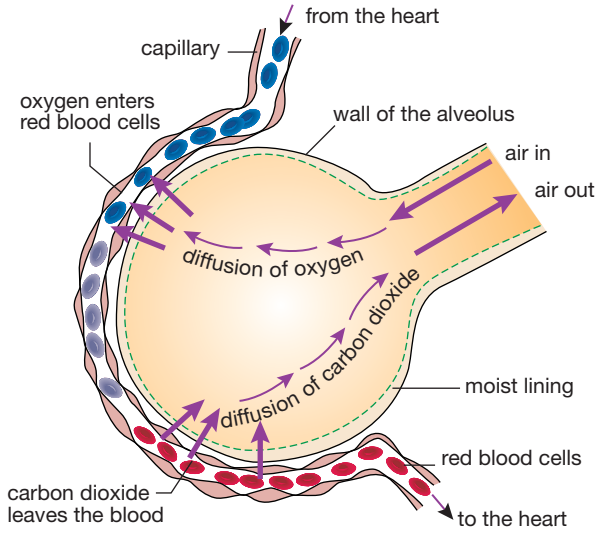



**Figure 3.2.5** The walls of the alveoli are only one cell thick. So are the walls of the blood capillaries. Gases are exchanged where the surface of the alveolus and the blood capillary are in contact.

Once in the blood, the oxygen enters the red blood cells, and the flow of blood carries the oxygen to the cells where it is needed. The blood flowing from the lungs is therefore rich in oxygen and is bright red.

The cells use the oxygen to release energy from food. As they do this, carbon dioxide is produced. Carbon dioxide is a waste product that would harm your body if you did not get rid of it. Carbon dioxide moves from your cells into the blood and from your blood into the alveolus, where it mixes with the remaining air. It then leaves the body with the next outward breath.

Table 3.2.1 compares the air you breathe in (inhale) with the air you breathe out (exhale). The role of the respiratory system is summarised in Figure 3.2.6.

**Table 3.2.1 Comparison of the composition of air when it is breathed in and breathed out**

| Gas | Percentage (%) | |
|---|---|---|
| | Inhaled air | Exhaled air |
| Nitrogen | 78 | 78 |
| Oxygen | 21 | 17 |
| Other gases | 1 | 1 |
| Carbon dioxide | 0.04 | 4 |
| Water vapour | little | carries all it can hold |

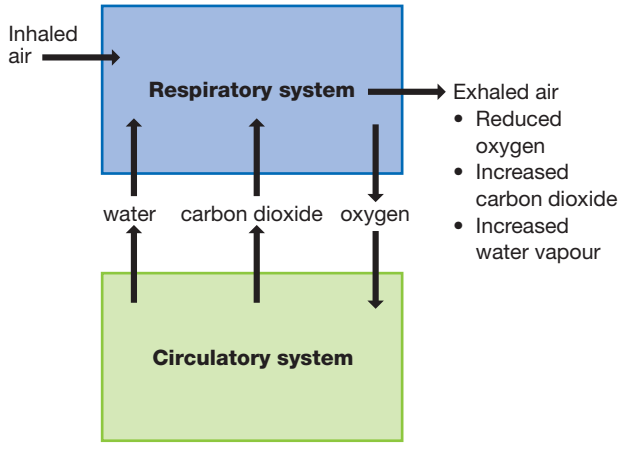



**Figure 3.2.6** Summary of what happens in the respiratory system

1 p96

## Breathing

The air in the alveoli is constantly replaced when you breathe. Breathing is involuntary. Although you can force yourself to stop breathing for a while, breathing is something you do without thinking, all day, every day.

As you breathe in, the muscles between your ribs contract. This pulls the rib cage up and out. At the same time the **diaphragm**—a sheet of muscle that separates the chest from the abdomen—contracts and flattens. This situation is shown in Figure 3.2.7.

These changes increase the volume of the space inside your chest. Your lungs expand, which causes the air pressure in them to decrease. Air is sucked in through the nose (and mouth) to fill up the extra space. This makes the air pressure inside your lungs equal to the air pressure outside the body.

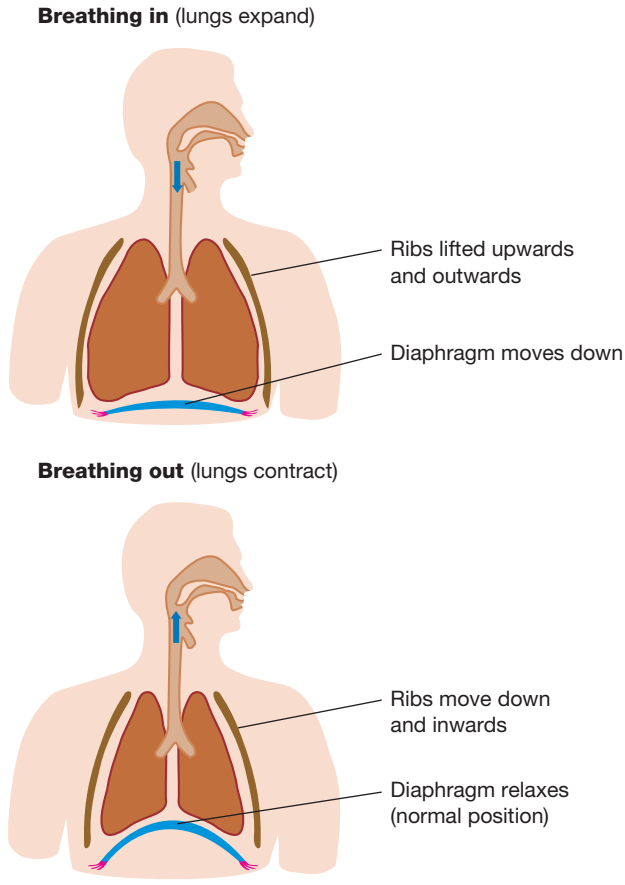



**Figure 3.2.7** Your diaphragm flattens and your lungs expand when you breathe in. The opposite happens when you breathe out.

When you exhale, the opposite happens. All the muscles relax. The ribs therefore move down and in, and the diaphragm arches upwards. The volume inside the chest returns to its normal size and the air pressure increases. Air is therefore forced out of the lungs through the nose (and mouth).

# In the cells

Respiration begins once the oxygen and glucose are together in the cells. The two chemicals react together. Carbon dioxide and water are produced in the reaction, and energy is released. It is this energy your body uses for all its activities (Figure 3.2.8).

The chemical reaction for respiration can be represented by a word equation.

**oxygen + glucose → carbon dioxide + water + energy**

The more energy your body requires, the faster this reaction has to take place, and therefore more oxygen and glucose are required.

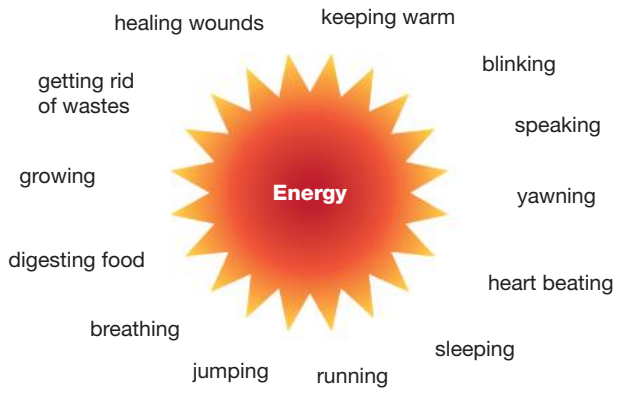



**Figure 3.2.8** Just a few of the ways you use energy



## Chemical equations

A chemical equation is one way of recording what happens when substances react together. On one side are the substances that react together. These are known as the reactants.

On the other side are the substances that are produced. These are known as the products.

Between the reactants and products is an arrow indicating the direction of the change. The substances to which the arrow is pointing are the products. For example in the equation:

$$A + B \rightarrow C + D$$

the arrow is pointing to the C and D. Therefore they are the products.

Because the names of the chemicals are used in the following chemical equation it is known as a word equation.

The reaction of respiration is represented by the word equation:

oxygen + glucose → carbon dioxide + water + energy

Oxygen and glucose are the reactants. Carbon dioxide and water are the products, along with the energy, that are released.

2 p97

3.6

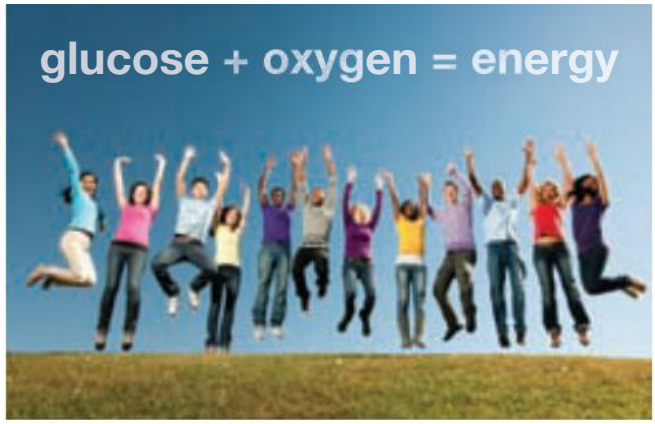



**Figure 3.2.9** Glucose and oxygen are both required to provide the energy your body needs.

## Energy and oxygen

The amount of energy you consume in your food needs to balance the amount of energy you use (Figure 3.2.9). When you consume more energy than your body requires, the excess nutrients are converted to fat and stored in a layer under your skin and around your internal organs. Your mass increases, and over a long period of consuming too much you could become overweight or obese. Becoming overweight may cause health problems because your joints have to support too much mass, your heart has to work a lot harder, and your blood vessels may become blocked by a build-up of a fatty substance called cholesterol.

If you take in less energy in your food than your body requires, you use up any fat stores (stores of energy) and lose mass. This is not a problem if you have extra mass to lose, but if you do not have stores of fat, then your body starts to get energy by using muscle tissue, including heart muscle. The muscles of your arms and legs become weak and your heart is weakened.

To get more oxygen into your cells you have to breathe more quickly or more deeply. You then have to move the oxygen more quickly around the body. To achieve this, you need to build up your heart muscles and the muscles associated with breathing. Just as your arms and leg muscles get stronger with exercise, the muscles of your heart get stronger when it is made to work harder. Strong heart muscles mean that the heart is able to pump more blood out of the heart with each beat.

SciFile

### Couch potato!

You sometimes use more energy sleeping than you do watching TV! While sleeping, you use about 250 kilojoules per hour. While watching TV, you can use as little as 200 kilojoules per hour.

# 3.2 Unit review

## Remembering

1 **State** the word equation for respiration.

2 **List** in order the parts of the respiratory system that air would pass through as it was breathed out.

3 **Name** the part of the respiratory system where gas exchange takes place.

4 **Name** the gas that is taken into the body and used by the cells.

## Understanding

5 **Explain** the advantage of having lungs with many small alveoli compared to having lungs like balloons that have no alveoli.

6 Air rich in oxygen that is breathed in enters the alveoli. Air rich in carbon dioxide is breathed out of the body. **Describe** the events that occur at the surface of the alveoli between these two events.

7 **Describe** the function of the diaphragm in the breathing process.

8 **Explain** why humans die within a few minutes if they cannot breathe, but can live for a few days without water and for a longer time without food.

9 a **Describe** what happens to your breathing rate as you walk along, and then start to run, run faster, and then stop running.

b **Explain** why this would happen.

## Applying

10 a Adult lungs are capable of holding about 6 litres of air. However, only about 500 mL is breathed in and out in a normal breath. **Calculate** the percentage of the lungs that is used for normal breathing.

b **Use** the table below to **calculate** the volume of oxygen that enters the blood from each inhalation.

| Gas | Percentage (%) | |
|---|---|---|
| | Inhaled air | Exhaled air |
| Nitrogen | 78 | 78 |
| Oxygen | 21 | 17 |
| Other gases | 1 | 1 |
| Carbon dioxide | 0.04 | 4 |
| Water vapour | little | carries all it can hold |

11 **Identify** each of the parts labelled A–E in Figure 3.2.10.

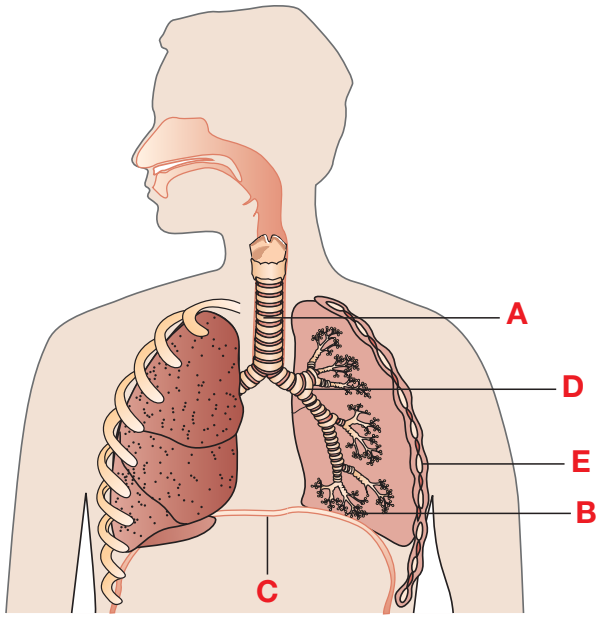



Figure 3.2.10

## Analysing

12 **Contrast** breathing and respiration.

13 Figure 3.2.11 represents the lungs of a frog.

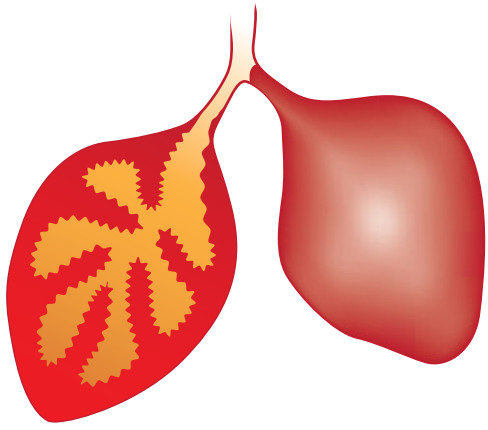


Figure 3.2.11

a **Compare** the structure of the frog's lung with the structure of the human lung.

b **Compare** the effectiveness of each in terms of gas exchange.

## Evaluating

14 a Limewater is a clear liquid that turns milky when carbon dioxide is added to it. **Deduce** what would happen to limewater if:
   i air that you breathe in was bubbled through it
   ii you blew air into it through a straw.
   b **Justify** your answers to part a.

15 **Propose** the advantage to the functioning of your body of having many blood capillaries surrounding the alveoli.

16 Some lung infections cause a build-up of fluid in the lungs and the infected person is short of breath. **Propose** a reason for this symptom.

17 **Propose** which part of the respiratory system is affected by bronchitis.

## Creating

18 **Design** an experiment to test the effect of exercise on breathing rate.

19 Figure 3.2.12 shows a model that is often used to show how the lungs work.

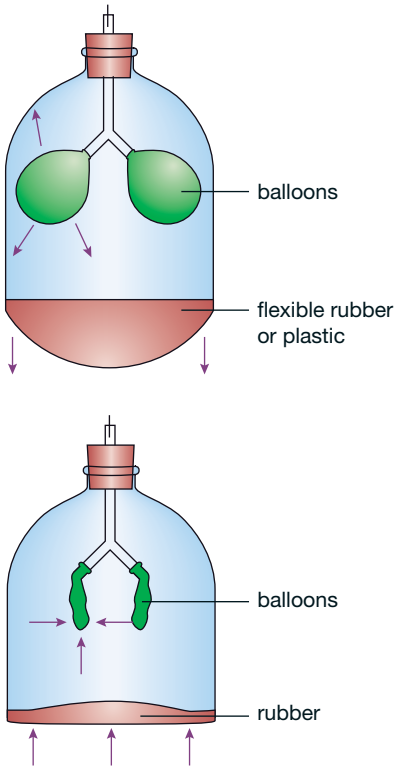



Figure 3.2.12

   a **Use** Figure 3.2.12 as a guide and materials found around the home to **construct** a working model of the respiratory system.
   b For each part of the model **state** the part of the respiratory system it represents.
   c **Compare** the working model and the respiratory system.

## Inquiring

1 Research to find out what hiccups are and what causes them.

2 Research to find out what would happen to you if you did not get rid of the carbon dioxide your body produces.

3 a Research to find out what happens in the lungs when a person has an asthma attack.
   b Find out what asthma inhalers such as Ventolin® do.



Figure 3.2.13 Inhalers like this one can be used to control asthma.

# 3.2 Practical activities

## 1 Changing air

### Purpose

To compare inhaled and exhaled air.

### Materials

- bromothymol blue
- disposable straw
- flasks or large test-tubes and glassware as shown in Figure 3.2.14
- rubber tubing
- digital camera or mobile phone with video function (optional)



**SAFETY**

Ask your teacher or lab technician to check your set-up before you start.

Do not swallow any of the liquid.

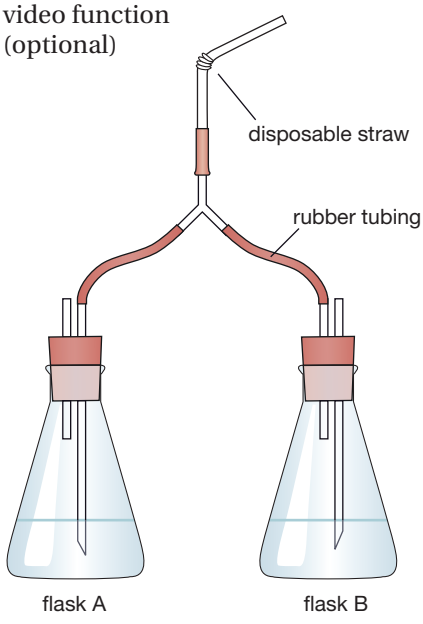



Figure 3.2.14

### Procedure

1. Set up the equipment exactly as shown in Figure 3.2.14. Only one tube in each flask should extend below the level of the liquid. All the joins should be airtight.
2. Add a few drops of bromothymol blue to the water in each flask.
3. Ask your teacher to check your set-up before proceeding.
4. Place your lips over the disposable straw and breathe in and out continuously for a few minutes. You could use your mobile phone or digital camera to video what happens.

### Results

1. Construct a diagram of the apparatus. Add arrows that show the passage of air as you breathed in and out.
2. On this diagram, record any changes to the colour of the liquid in the flasks.

### Discussion

1. **Identify** the flask in which any colour change occurred. Was it the flask through which air was inhaled or exhaled?
2. Bromothymol blue is an indicator that changes from blue to yellow-green in the presence of carbon dioxide. **Explain** the cause of any colour change in the flasks.
3. **Explain** how the results of this activity relate to the changes that take place in the respiratory system.

## 2 Energy production

Heat is a form of energy and is produced as a by-product of respiration.

### Purpose

To record evidence that energy is released in respiration.

### Materials

- 2 wide-mouthed thermos flasks
- 2 thermometers
- cotton wool
- 40 germinating pea or bean seeds
- boiling water
- mild disinfectant
- 2 × 250 mL beakers



**SAFETY**

Take care with boiling water.

Pour it carefully so that it doesn't splash.

### Procedure

1. Label the two flasks 'Live seeds' and 'Killed seeds'.
2. Divide the germinating seeds into two equal groups.
3. Place one group of seeds in a beaker and add boiling water. Leave it for 1–2 minutes to kill the seeds.
4. Allow the beaker and killed seeds to cool, pour off the cooled water and add cold tap water to return their temperature to room temperature.
5. Soak the killed seeds in disinfectant, and then place them into the flask labelled 'Killed seeds'.
6. Place the other group of seeds into the flask labelled 'Live seeds'.
7. Set the two flasks up as shown in Figure 3.2.15.
8. Record the temperature in both the flasks at the start of the experiment and then another three or four times in the next 24 hours.

### Results

Record the temperatures in a table like the one below.

| Time (h) | Temperature (°C) | |
|---|---|---|
| | Live seeds | Killed seeds |
| | | |
| | | |
| | | |

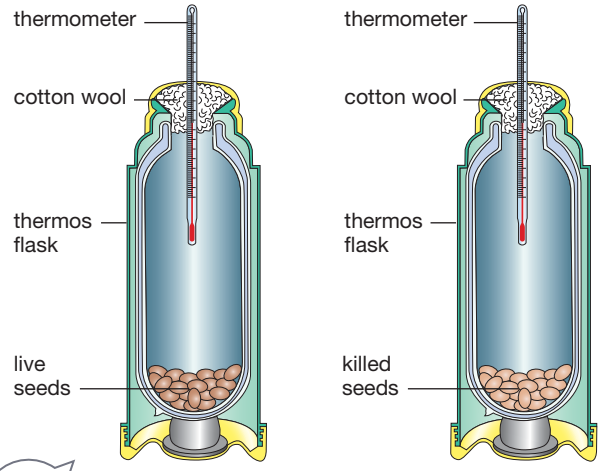



Figure 3.2.15

### Discussion

1. **Explain** why a change in temperature in the flasks can be used as evidence of energy release.
2. **Compare** any change in temperature in the two flasks.
3. **Explain** any differences in the changes in temperature.
4. **Explain** why the flask with the killed seeds was included in the experiment.
5. **Explain** why the killed seeds were soaked in disinfectant and what could have occurred if this was not done.
6. **Explain** how the results of this experiment relate to respiration in human cells and the uses made of energy.

# 3.3 Circulation

The circulatory system is the transport system that makes sure everything gets to where it is needed in your body. This system carries nutrients and oxygen to the cells, carries wastes to where they can be disposed of, and distributes heat (a by-product of respiration) throughout your body.

## The circulatory system

Your **circulatory system** consists of your heart, blood vessels and blood. The heart is the engine room of the circulatory system. It pumps continuously to keep the blood moving. The blood carries all the materials needed by the body through the blood vessels. The blood vessels are the motorways, main roads and side streets along which the blood flows and are shown in Figure 3.3.1.



**Figure 3.3.1** The blood vessels of your body are like motorways. Instead of cars and trucks transporting goods, it is blood and blood cells that carry materials to their destination.

# Blood vessels

In your body there are three types of blood vessels: arteries, veins and capillaries.

## Arteries

**Arteries** carry blood away from the heart. When the heart beats, blood moves along the arteries under pressure. To be able to withstand the pressure, the walls of the arteries (shown in Figure 3.3.2) need to be tough and elastic, bouncing back into shape after each beat. If an artery is cut, then the high pressure within it causes blood to spurt out very quickly. Within a very short time, most of the blood would be lost from the body. All major arteries are protected deep in the body. In a few places, the regular expansion and contraction of the arteries in response to the heartbeat can be felt. This is your pulse. You can feel it most easily in your neck and wrist.




**Figure 3.3.2** The walls of arteries have thick layers of muscle and elastic tissue. The thick-walled artery is a sharp contrast to the vein beside it.

**SciFile**

**Where does it fit?**

There are about 97 000 km of blood vessels in the body of a child and 161 000 km in the body of an adult. End to end they would go round the Earth about four times!

## Capillaries

As they extend through the body, arteries branch into smaller and smaller blood vessels. Eventually the very finest of the blood vessels, called capillaries, reach nearly every cell of the body. **Capillary** walls are only one cell thick. This allows dissolved materials to pass through them. Materials needed by the cell pass out of the capillary and into the cell, and waste materials from the cell pass into the capillary. The blood then carries the wastes back towards the heart. The capillaries join together to form larger and larger blood vessels called veins. This is shown in Figure 3.3.3.

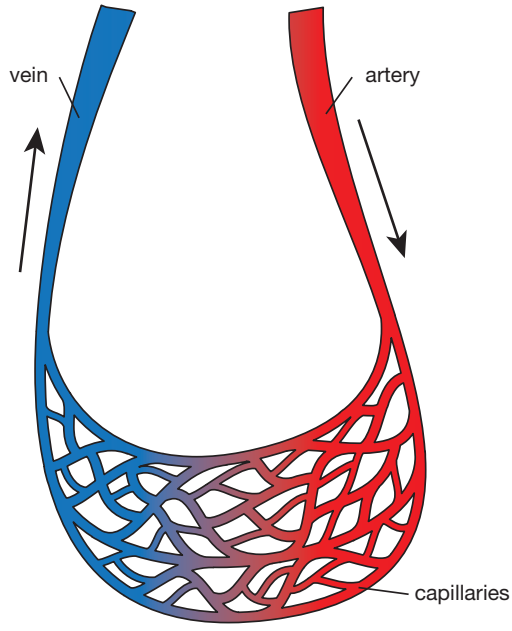



**Figure 3.3.3** The capillaries are a network that joins the arteries and veins, allowing blood to flow continuously.

## Veins

**Veins** carry blood back to the heart. The pressure of the heartbeat is lost as the blood flows through the very narrow capillaries, so the veins do not need thick muscular walls like the arteries do.

Blood is pushed back up to the heart by the contraction of the muscles of your body pressing against the veins. To make sure that the blood flows in one direction only, there are valves along the length of veins. The valves open when the blood is flowing upwards and close if the blood flows downwards. This is shown in Figure 3.3.4 on page 100. If you sit still for very long periods of time, then the flow of blood in the veins slows and blood can 'pool' in the veins. The blood may thicken and form a dangerous blood clot called a thrombosis.

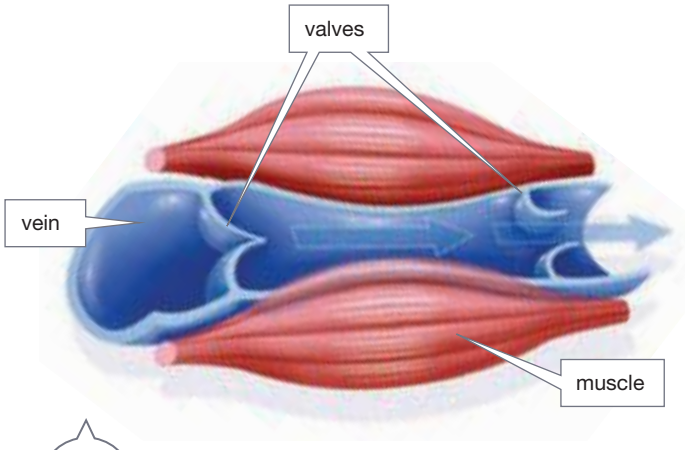



Figure 3.3.4 Blood flowing along the vein towards the heart forces the valves against the vein wall and the blood can flow freely. The valves close preventing blood flow in the opposite direction.

## Bruises

When you bump yourself hard, some of the tiny capillaries near the skin burst and the blood leaks out into the surrounding tissue. Immediately after the injury, an angry red mark appears where blood has leaked into the tissue. Gradually the bruise fades to purple and then yellow as the blood is broken down and cleared away by the body.

# The heart

Your heart is about the size of your fist and is situated in the middle of your chest behind the breastbone. This is shown in Figure 3.3.5. The heart is made of a special type of muscle called **cardiac muscle**. Cardiac muscle does not get tired like the muscles of your legs and arms do. Cardiac muscle works continuously in response to signals from an area of the heart called the pacemaker. A dissected view of the heart is shown in Figure 3.3.6.

The human circulatory system is referred to as a double system because there are two separate circuits through which the blood flows. As can be seen in Figure 3.3.7, both circuits start with the heart. In one circuit, the blood flows from the heart to the body and back to the heart. This circuit carries nutrients and oxygen to the cells. At the cells, it collects wastes, including carbon dioxide. The other circuit goes from the heart to the lungs. In the lungs, carbon dioxide passes out of the blood and oxygen passes into the blood. The blood rich in oxygen then returns to the heart to be pumped around the body.

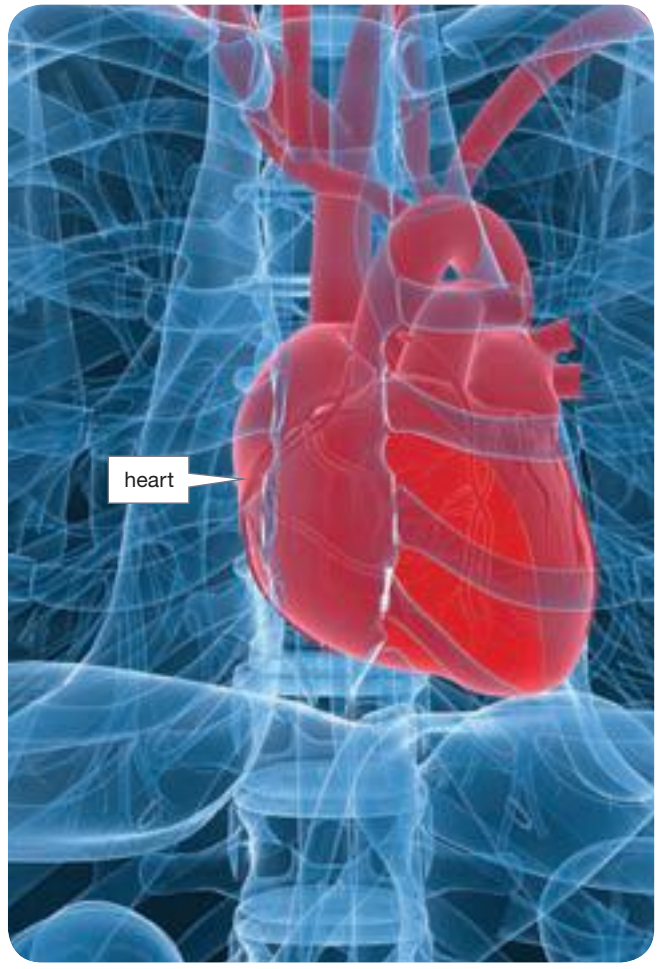



Figure 3.3.5 Your heart lies within your chest protected by your breastbone, ribs and vertebral column (spine).

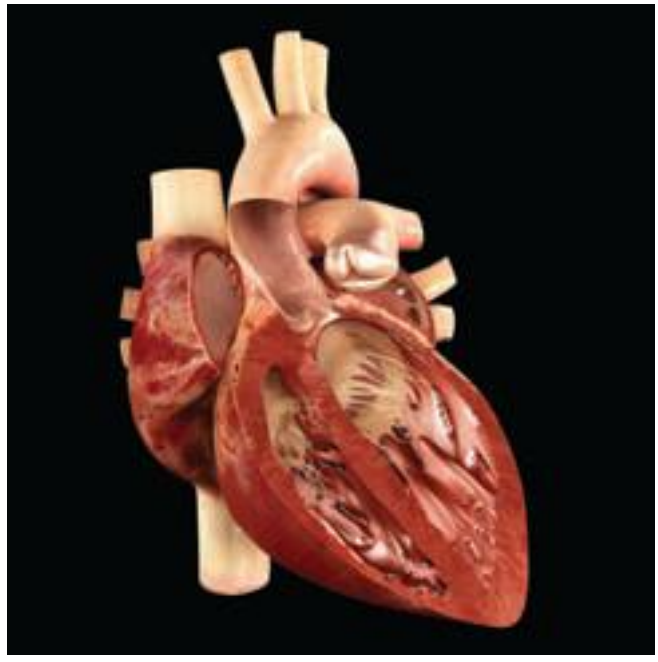


Figure 3.3.6 A model of a human heart

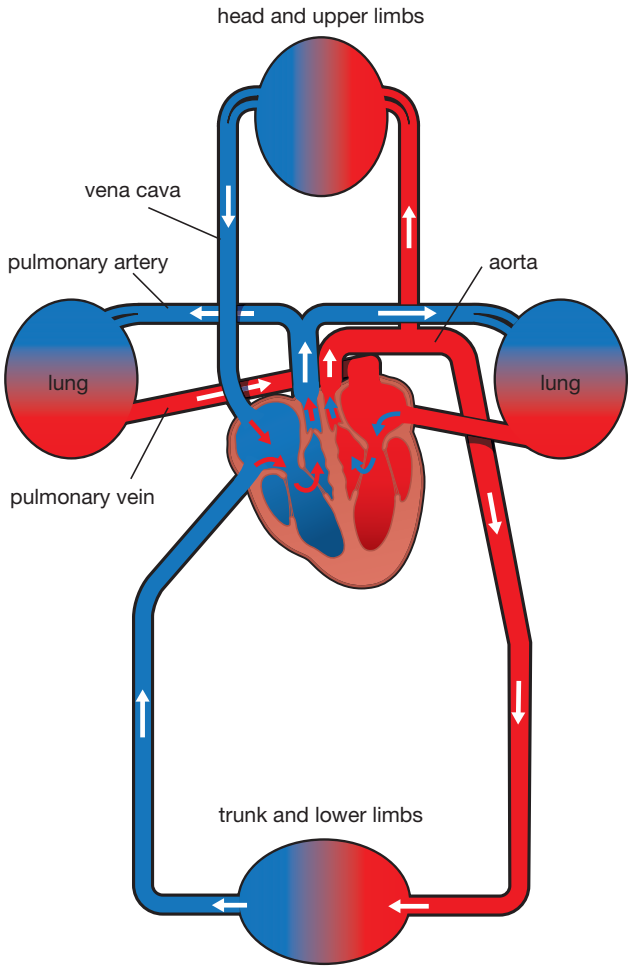



**Figure 3.3.7** Your blood follows two separate pathways in your body. One pathway is from the heart to the body and back to the heart. The other pathway is from the heart to the lungs and back to the heart again.

For the circulatory system to work, the blood rich in oxygen (**oxygenated blood**) and the blood with carbon dioxide (**deoxygenated blood**) must be kept separate where the two systems meet in the heart. The heart has four chambers. Two of the chambers collect blood from the lungs and pump it round the body. The other two chambers collect blood from the body and pump it to the lungs. Figure 3.3.8 shows these four chambers.

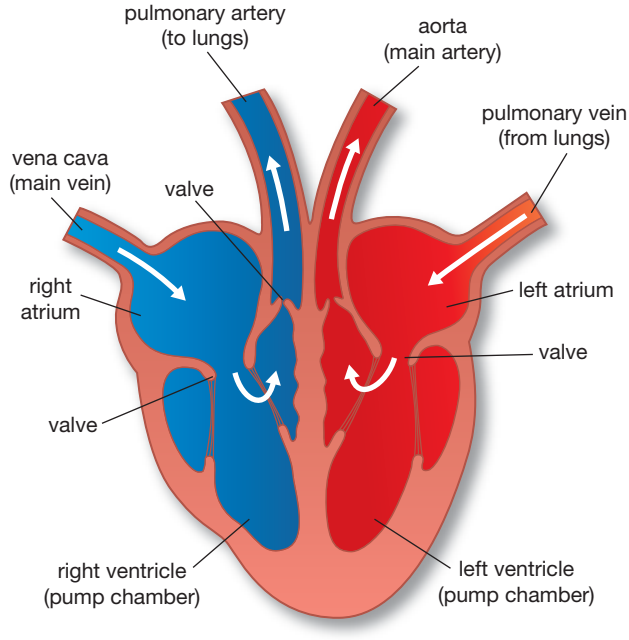



**Figure 3.3.8** One side of the heart collects and pumps out deoxygenated blood (shown here in blue). The other side of the heart is completely separate. It collects and pumps out oxygenated blood (red).

3.7

INQUIRY science 4 fun

## No blood

Can you make the blood stop flowing in your veins?

Yes

### Do this …

1 Hold your hand out and turn it over so that the inside of the wrist is facing you.

2 You should be able to see veins as blue lines coming from the base of your palm and your thumb into your arm.

3 Place the index finger of your other hand on the vein coming from the middle of your palm. Firmly but gently move your finger along the vein back towards the hand. The blood should empty from the vein.



### Record this …

**Describe** what happened.
**Explain** why you think this happened.

## Heartbeat

There are three main phases of a heartbeat.

- The two atria (plural of atrium) contract, pushing blood down into the ventricles.
- The ventricles contract, forcing blood out of the heart to the body and lungs.
- The heart muscle relaxes and the atria fill with blood.

When the atria or ventricles are contracting, valves open or close to make sure that the blood flows in the correct direction. An electronic recording of a heartbeat is shown in Figure 3.3.9.



**Figure 3.3.9** An electronic recording of a heartbeat. Contraction of the atria creates a small peak followed by a large peak as the strong muscles of the ventricles contract. Between the contractions, the heart is resting.

3.8 1 p106 2 p108

## Heart disease

**Cholesterol** is a type of fat that is part of all animal cells. It is essential for health, but can block arteries if it builds up in them. If you have too much fatty food in your diet, cholesterol will eventually start to build up. This can be seen in Figure 3.3.10. Coronary arteries supply the muscles of the heart with blood. When cholesterol builds up in coronary arteries, blood flow to the heart muscles is reduced. Since blood carries oxygen, reduced blood flow also means that oxygen supply is reduced.

A lack of oxygen to the heart muscle causes a condition known as **angina**. A person suffering an angina attack experiences severe chest pain.

If the arteries become completely blocked, then the part of the heart they normally supply with oxygen dies and the person has a heart attack. If a large area of the heart is affected, then the heart attack is severe.

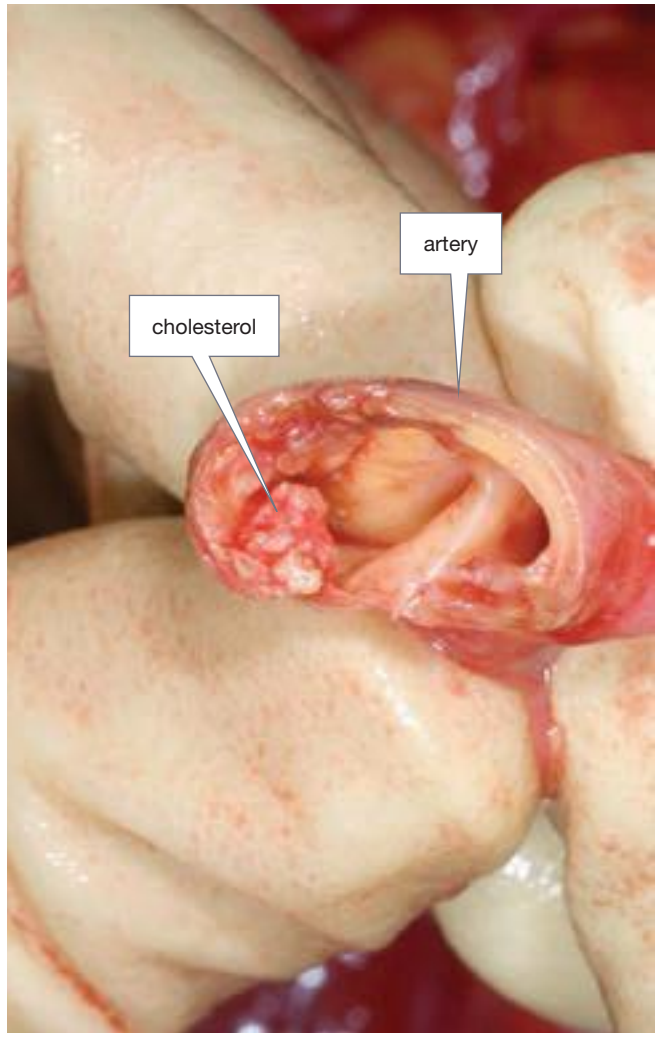



**Figure 3.3.10** A surgeon's gloved hands hold an artery partly blocked by cholesterol.

# Blood

Blood is the only organ of the body that exists as a liquid. The average-sized adult has about 5 litres of blood. Blood carries oxygen, nutrients and water to the cells and carries carbon dioxide and other wastes away from the cells. Blood also helps maintain your body temperature by spreading the heat around. In blood, there are red blood cells, white blood cells, platelets and plasma.

**SciFile**

### That's hot!

It would be possible to boil 30 litres of water with the heat generated by the average human adult in one day!

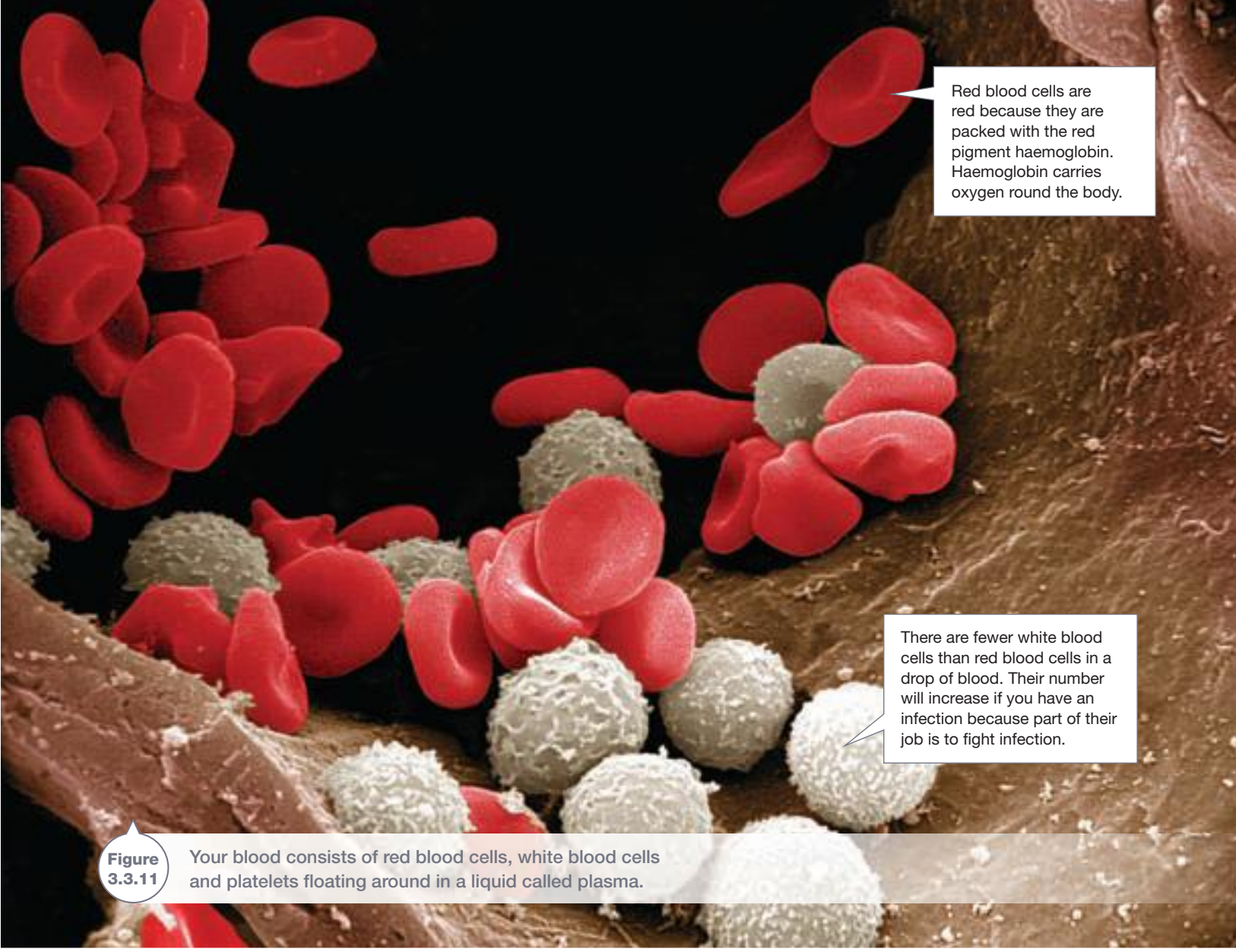



**Figure 3.3.11** Your blood consists of red blood cells, white blood cells and platelets floating around in a liquid called plasma.

## Red blood cells

Red blood cells are made in the bone marrow of long bones such as the femur (the thigh bone) and ribs. They contain the chemical **haemoglobin**. Haemoglobin is a pigment that gives the cells their red colour. Haemoglobin contains iron, and its job is to carry oxygen around the body. When it is carrying oxygen, haemoglobin is a bright red. Oxygen is carried to cells as oxyhaemoglobin. There are about 300 million red blood cells in one drop of blood. Some red blood cells can be seen in Figure 3.3.11.

## White blood cells

White blood cells are bigger than red cells. There are only about 400 000 in a drop of blood. White blood cells are part of the immune system that helps fight disease.

## Platelets

Platelets are broken up bits of cells produced in the bone marrow. They help blood to clot. If you do not have enough platelets, then you could bleed excessively. However, too many platelets can cause blood to clot in the blood vessels. A blood clot in the blood vessels of the heart can cause angina and a heart attack. A blood clot in the brain can cause a stroke, where a part of the brain is starved of oxygen and dies.

## Plasma

Plasma is a clear yellowish liquid that is 90% water. The other 10% is dissolved materials such as nutrients and wastes. Red blood cells, white blood cells and platelets are suspended in plasma.

# SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

## Transplants



This kidney has been cooled and the blood has been flushed from it to prepare it for transplant. **Figure 3.3.12**

An organ transplant is when a diseased organ in one person is replaced with a healthy one from someone else. There are stories that are over 200 years old of early doctors performing transplants. We do not know if they were successful. However, it is likely that the immune system caused problems.

A person's immune system fights disease by attacking and destroying bacteria and viruses. It responds to transplanted organs in the same way—by destroying transplanted organs in a process called rejection. Anti-rejection drugs developed in the 1980s made transplanting organs less risky and transplantation surgery is now relatively common. The person who provides the organ is called the donor. The person who receives the organ is called the recipient.

### Living donors

Tissues and organs that can regrow can be donated by living donors. Blood and bone marrow are easily replaced by the body if only small amounts are taken. We have two kidneys. One can be given as a live donation. The one that remains will grow larger and take over the function of the one that was donated.

### Deceased donors

Most organs for transplant are taken from people who have died, but only if the person has registered as an organ donor or their family agrees. Death is usually declared when the heart stops beating and cannot be restarted. With no blood (and therefore no oxygen), the organs start to break down. Within 40 minutes many are unsuitable for transplantation. However, if hearts can be recovered from the body and stored correctly, they can be kept for 4 hours before transplantation. Kidneys can be stored for about 24 hours. This gives the transplant teams a little time to find and prepare a suitable recipient who is waiting for a new organ.

### The removal procedure

When organs are removed, all the blood has to be flushed out to prevent blood clots forming in the tiny capillaries. Clots would prevent the recipient's blood reaching those parts of the organ and it would die. The organ is cooled to about 4°C and all the veins and arteries are filled with preservatives. This is why the kidney in Figure 3.3.12 looks so pale.

### Implanting an organ

Transplanted hearts and lungs are placed in the correct position in the body. However, transplanted kidneys are often placed inside the pelvis where they are attached to blood vessels and the urinary tract. The recipient's kidneys are not usually removed unless they are so diseased that they could become a health risk.

Once the transplant is completed, the recipient will take a large variety of medicines to prevent rejection of the new organ by their body.

# 3.3 Unit review

## Remembering

1 **Name** the three different types of blood vessels found in the human body.

2 **Name** the four chambers of the heart.

3 **State** what the difference is between oxygenated and deoxygenated blood.

4 **Name** the part of the blood that helps with clotting.

5 **List** three things carried by the blood.

## Understanding

6 **Describe** the characteristics of capillaries that suit them to their function.

7 **Outline** the flow of blood around the body, starting and finishing with the right atrium.

8 **Explain** the importance of keeping the oxygenated and deoxygenated blood separate in the heart.

9 **Describe** the double circulation system of the human body.

## Applying

10 **Identify** the labelled parts of the heart in Figure 3.3.13.

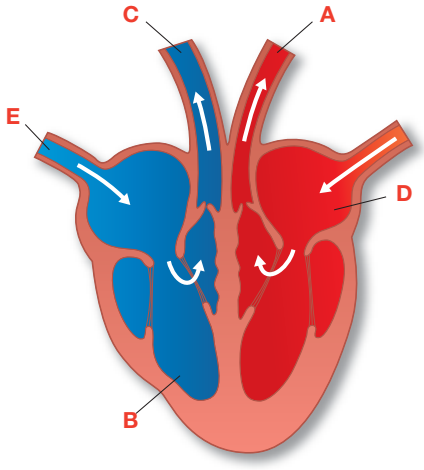



Figure 3.3.13

## Analysing

11 **Compare** by listing their similarities and differences:
- a an atrium with a ventricle
- b a heart attack with a stroke.

12 **Contrast** the right and left ventricles.

13 a Refer to page 107 and then **calculate** the pulse rate for the students listed in the table below.

| Student | Beats counted | Time (s) |
|---|---|---|
| Jo | 15 | 10 |
| Karl | 22 | 15 |
| Jack | 12 | 5 |

- b **Analyse** the data and **identify** which student was most likely to be the one who had just finished playing soccer.
- c **Identify** which results would provide the most accurate measure of pulse rate.
- d **Justify** your response.

## Evaluating

14 Figure 3.3.14 is a graph of a person's pulse rate. **Deduce** from the graph the person's physical activity levels at times A, B and C.

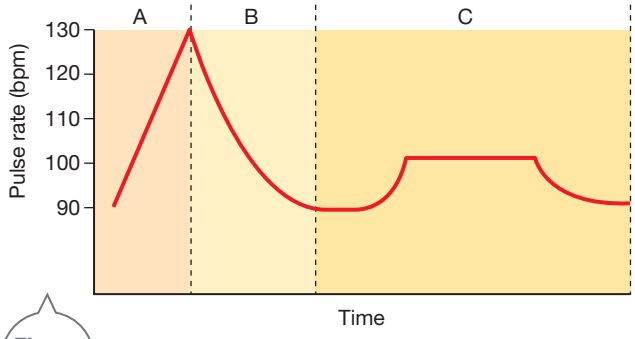



Figure 3.3.14

## Inquiring

1 Research to find out about heart transplants in Australia and the famous heart surgeon Victor Chang.

2 Research to find out what deep vein thromboses are and why people taking long plane flights are given advice on how to avoid them.

3 Some children are born with a hole in their heart. Research to find out what this is and why it is a problem.

# 3.3 Practical activities

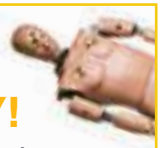
## 1 Heart dissection

### Purpose

To investigate the structure of the heart.

### Materials

- scalpel
- tweezers
- blunt probe
- disposable gloves
- dissection board
- sheep or bullock heart



**SAFETY!**

Take care with sharp instruments.

Wear disposable gloves when handling the heart.

Wash your hands thoroughly after you have completed the dissection.

### Procedure

1. Place the heart on the dissecting board as shown in Figure 3.3.15.
2. Identify as many of the external features as you can: right and left atria, right and left ventricles, aorta, vena cava, pulmonary arteries and veins.
3. Use the blunt probe to investigate which chamber of the heart the blood vessels enter or leave. Use the scalpel to make cut 1 as shown in Figure 3.3.15. Cut with the blade pointing upwards and away from you.
4. Observe the thickness of the wall of the right ventricle.
5. Open out the ventricle.
6. Observe the tendons (thread-like structures) and the valves (flaps of tissue) to which they are attached.
7. Work out how the valves work to control blood flow.
8. Observe the flaps of skin at the base of the pulmonary artery. These are the semilunar valves.
9. Make cut 2 to open up the left ventricle. Continue the cut up into the aorta.
10. Observe the thickness of the wall of the left ventricle.
11. Find the position of the semilunar valves at the end of the aorta.
12. Just above the semilunar valves you should be able to find two small openings from the aorta. These are the branches of the coronary arteries. Use the probe to find out where they go.

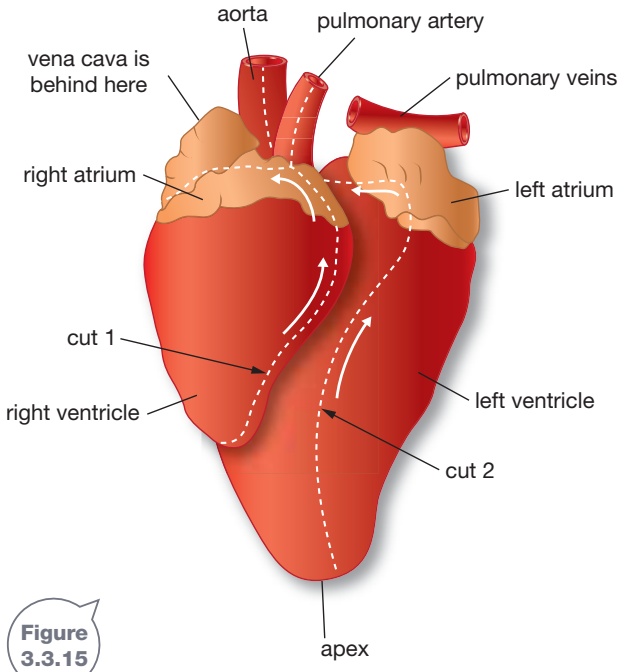



Figure 3.3.15

### Discussion

1. **Compare** the thickness and texture of the aorta and vena cava.
2. **Use** diagrams to **explain** how the valves between the atria and ventricles control the direction of blood flow.
3. a **Use** diagrams to **explain** how semilunar valves work.
   b **Propose** a reason why these values are known as *semilunar*.
4. a **Compare** the thickness of the walls of the right and left ventricles.
   b **Propose** a reason for the difference.
5. a **Describe** where the coronary arteries go.
   b **Propose** a reason why this organ is supplied with fully oxygenated blood.
6. **Construct** a diagram of the heart and use arrows to show the path of blood flow through the heart.

## Measuring your pulse

Your pulse is a measure of your heart rate—the number of times your heart beats per minute. Two of the easiest places to feel your pulse are at the wrist and neck, as shown in Figure 3.3.16. The pulse on your wrist is known as the radial pulse. The pulse in your neck is the carotid pulse.





**Figure 3.3.16** Your pulse can be felt on your wrist or neck.

To take your pulse you need a stopwatch, a digital watch or a watch with a second hand.

To measure the radial pulse:

1. Turn your hand so that the palm is facing upwards.
2. Place your index and middle fingers of your opposite hand on your wrist, approximately 2.5 cm below the base of your thumb.
3. Gently but firmly press your fingers in the area between the tendons of the wrist and the outside bone. You should feel a throbbing which is your pulse.
4. Count the number of beats for 15 seconds, then multiply this number by 4. This will give you your heart rate for one minute.

For example, if you count 18 beats in the span of 15 seconds, then multiply $18 \times 4 = 72$. This means your pulse rate is 72 and your heart rate is 72 beats per minute.

To measure the carotid pulse:

1. Place your fingertips gently on one side of your neck, below your jawbone and halfway between the large neck muscle behind your ear and your windpipe.
2. Count the number of beats and calculate the pulse rate in the same way.

When taking a resting pulse rate—your pulse rate when you have been sitting still for some time—the longer you count the pulse the more accurate the measurement will be. In that situation, count the pulse for 20 or even 30 seconds. If you count the pulse for 20 seconds, then you would multiply the number of beats by 3 to get beats per minute. Counting for 30 seconds means you multiply by 2.

Ten seconds is long enough if you are taking your pulse directly after exercise when it could be changing rapidly. In this instance, you would multiply the number of beats by 6 to get the heart rate.

## 2 Heart rate and exercise

### Purpose

To investigate the effect of exercise on heart rate.

### Materials

- stopwatch or timer
- graph paper
- ruler and pencil



**SAFETY**

Do not run or jog if you have been ill recently or if you have asthma or a heart condition.

### Procedure

1. When you are sitting quietly, find your resting pulse rate (the number of beats per minute). Do this by finding your pulse on your wrist or at the side of your neck and counting the number of pulses for 15 seconds. Multiply this number by 4. For more advice on taking your pulse, see the Skill builder on page 107.
2. Repeat this step twice more and calculate an average by adding up the results and dividing by 3.
3. Run or jog on the spot for 3 minutes.
4. When you stop, immediately take your pulse rate again.
5. Sit down and take your pulse rate every minute until it does not get any lower.

### Results

1. Record all your results in tables like the ones shown.

**Resting pulse rate**

| Trial | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| Resting pulse rate | | | | |

**Pulse rate following activity**

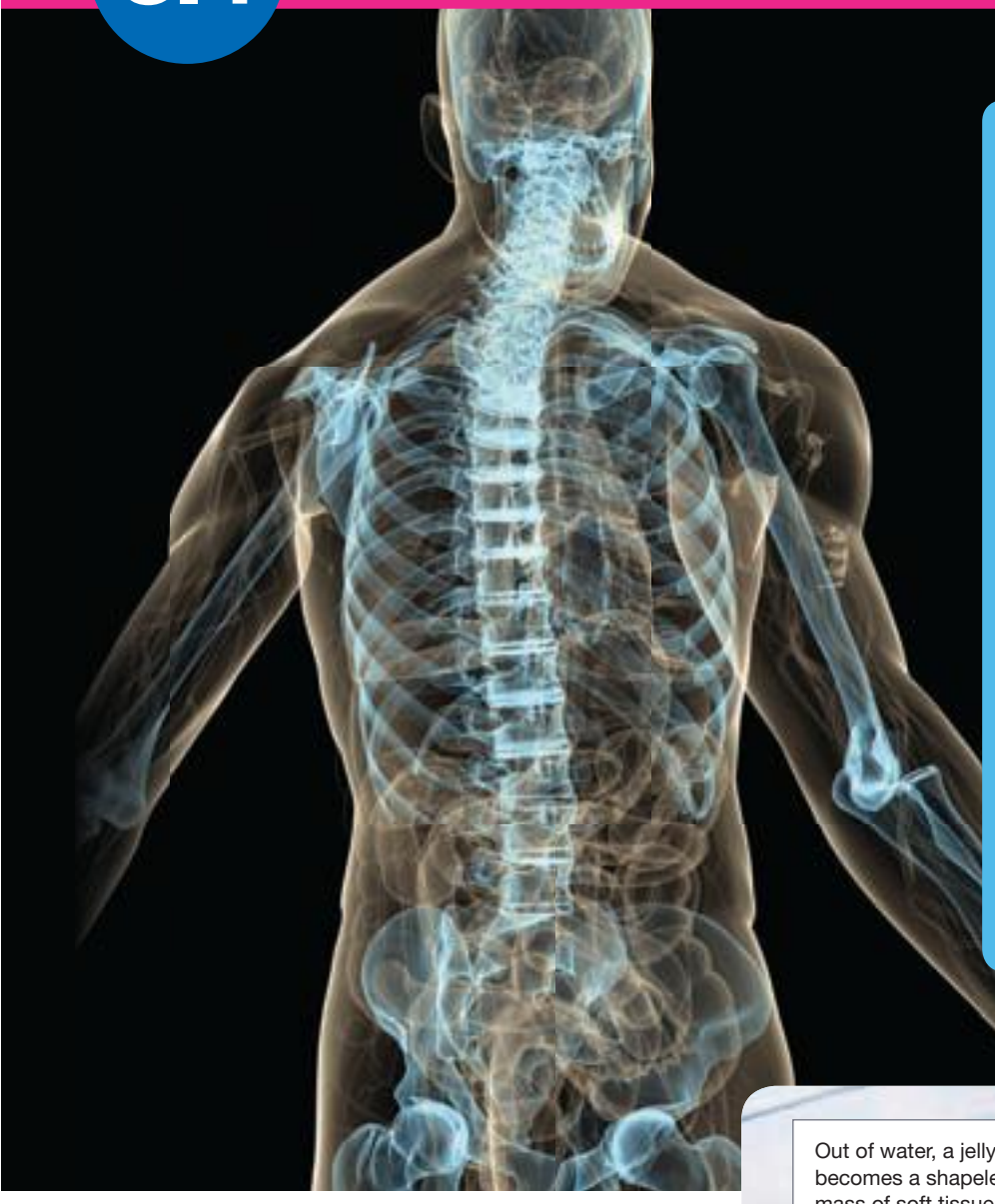
| Time after end of jog (min) | Pulse rate (per minute) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |

2. Construct a line graph from the results in the second table.

### Discussion

1. **State** what happened to your pulse rate when you started exercising.
2. **Propose** reasons for this change.
3. **Describe** the change in your pulse rate after you stopped exercising.
4. **Propose** reasons for these changes.
5. **Compare** your results with those from other members of the class.
6. **Account** for differences in the results.
7. **Predict** from these results what changes would be expected if you:
   - a ran a lot faster for 3 minutes
   - b ran faster and for a longer period of time
   - c walked slowly round the room.

# 3.4 Muscles and bones



Buildings such as houses have a frame that supports the roof and keeps the walls upright. Your body also has a supporting frame—your skeleton. Without a skeleton you would not be able to stand upright, you would not be able to move, and important organs such as your heart and brain would have no protection. Your skeleton works with your muscles to give you shape, protect your insides and allow you to move.

## The skeleton

Your **skeleton** is your body's frame. It is made up of **bones**. The skeleton has three main functions.

- Support for your soft tissues. Without a skeleton, your skin and the organs inside your body would collapse to resemble a jellyfish stranded on the beach (Figure 3.4.1). A jellyfish does not have a skeleton and is supported by the water in which it lives (Figure 3.4.1). You live on land and are surrounded by air. Air does not provide the same support as water; therefore, you need a skeleton.




**Figure 3.4.1** A jellyfish has no skeleton and needs water to support it.

- Protection for your organs. This is the main role of your **axial skeleton**, which is made up of 80 bones. It includes your skull (which protects your brain), vertebral column (which protects your spinal cord), and ribs and breastbone (which protect your lungs and heart). Your axial skeleton is shown in yellow in Figure 3.4.2.
- To allow movement. This is the main role of your **appendicular skeleton**, which is constructed from 126 bones. It includes your shoulder blades and the bones in your arms and legs. It is coloured blue in Figure 3.4.2. Joints within the skeleton allow your body to move.

## Bones

The main bones of your body are shown in Figure 3.4.3. Bones need to be strong so that they do not snap or crumble during normal activity. Compression forces squash bones and tension forces stretch them. Your leg bones experience compression forces when you are standing. Your neck is usually under compression too, especially when carrying a load on your head like the woman in Figure 3.4.4. Your arms experience tension forces whenever you carry shopping bags or when you hang off a bar like the gymnast in Figure 3.4.4.

Bones also need to be slightly elastic. They must be able to flex and twist a little and then return to their original shape and size when the force is removed from them.

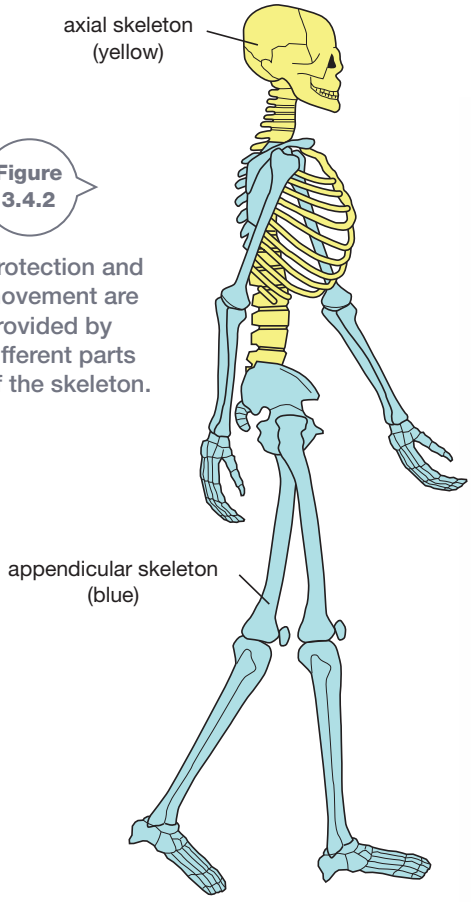



**Figure 3.4.2** Protection and movement are provided by different parts of the skeleton.

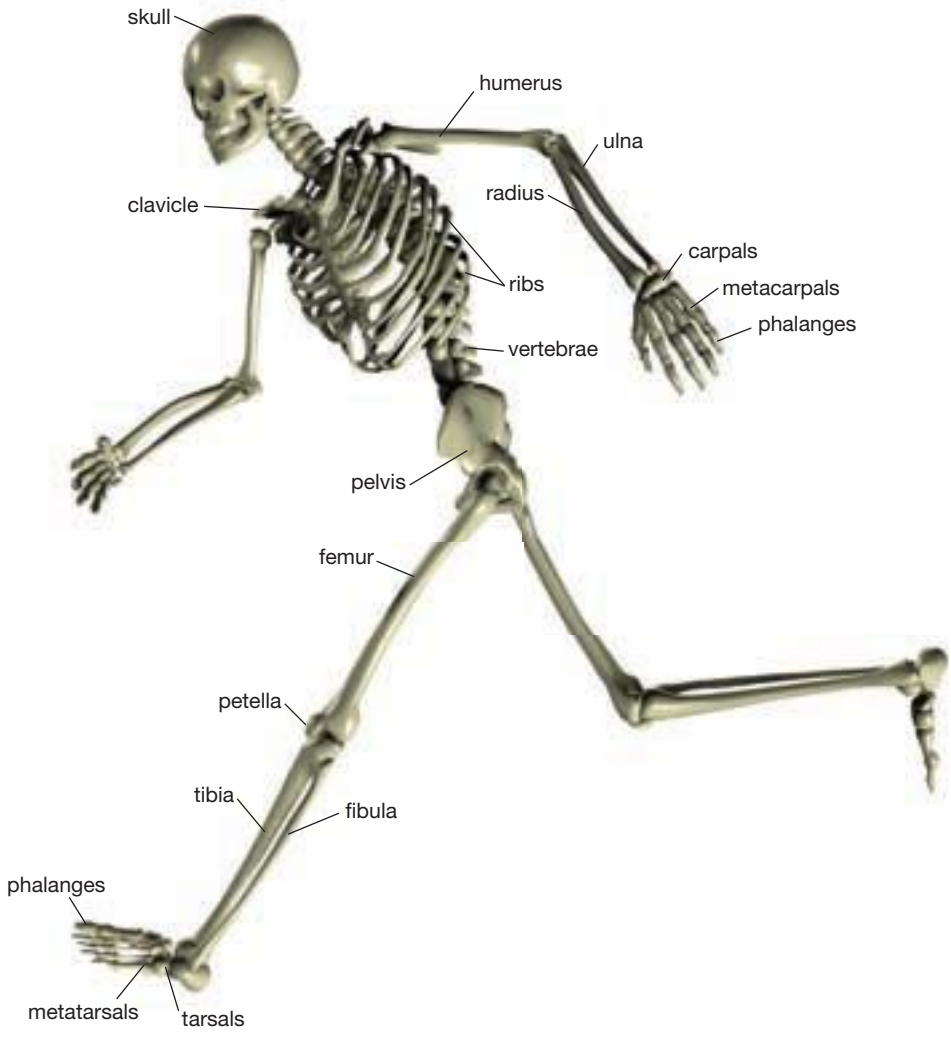



**Figure 3.4.3** Your skeleton and its joints allow you to be active, relax and stand upright.

### Sexist bones!

SciFile

Men usually have bulkier and heavier muscles than women and so a man's bones need to be a little larger and heavier to support them. Some bones, such as the pelvis, also have a different shape. Forensic scientists can use these facts to determine the sex of a skeleton.

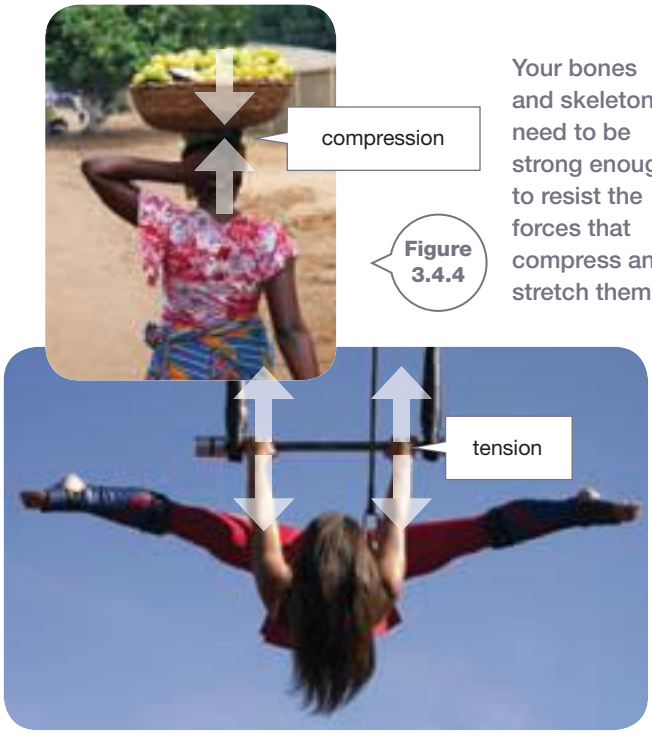



Figure 3.4.4 Your bones and skeleton need to be strong enough to resist the forces that compress and stretch them.

Bones must also be light enough for your muscles to move. The strength and lightness of bones comes from their structure. Bone tissue has two different forms.

- **Compact bone** makes up the outer layer of the bone. Compact bone is dense and heavy and gives the bone much of its strength.
- **Spongy bone** resembles honeycomb. It is light yet provides a strong inner structure to the bone. Gaps in spongy bone are filled with a fatty, jelly-like material called bone marrow. Red blood cells and platelets are made in **bone marrow** along with some of your white blood cells.

Bones are living tissues. They contain living cells that are surrounded by calcium phosphate, a substance that makes the bone hard. They also contain collagen, a material that provides elasticity. Blood vessels supply bone with the nutrients it requires. Because they are living, bones are able to repair themselves and replace worn-out cells. The structure of a typical bone is shown in Figure 3.4.5.

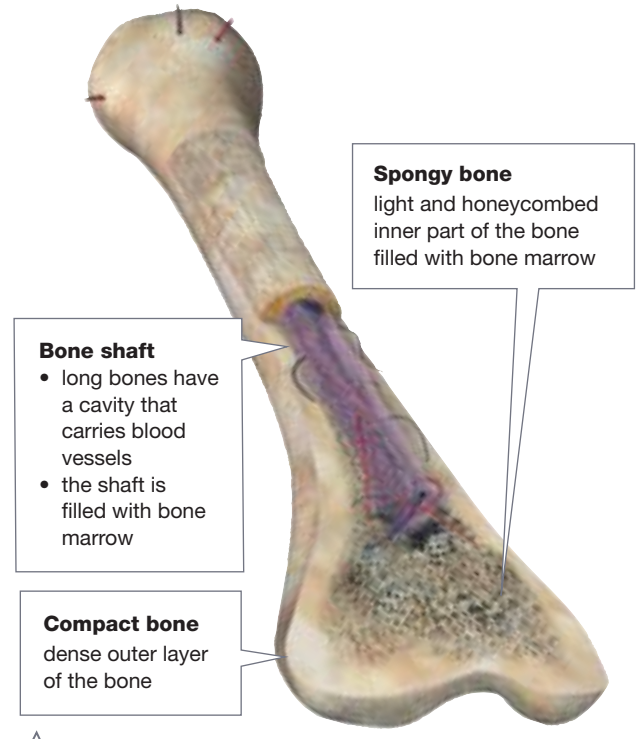



Figure 3.4.5 Bones are lightweight and living. This makes them easy enough for your muscles to move and allows them to renew and repair themselves.

## Joints

A **joint** is a place in the body where two bones come together. Most joints allow movement and the type of joint determines the range of movement of the bones. Bone moving against bone would cause pain and the bone would wear down.

To protect your bones from wear, joints have:

- **cartilage**, a smooth and slippery material that covers the ends of bones that are moving against each other. It helps to cushion the impact of movement
- **synovial fluid**, which lubricates the bone ends and allows them to slide over each other freely.

These are both shown in Figure 3.4.6.

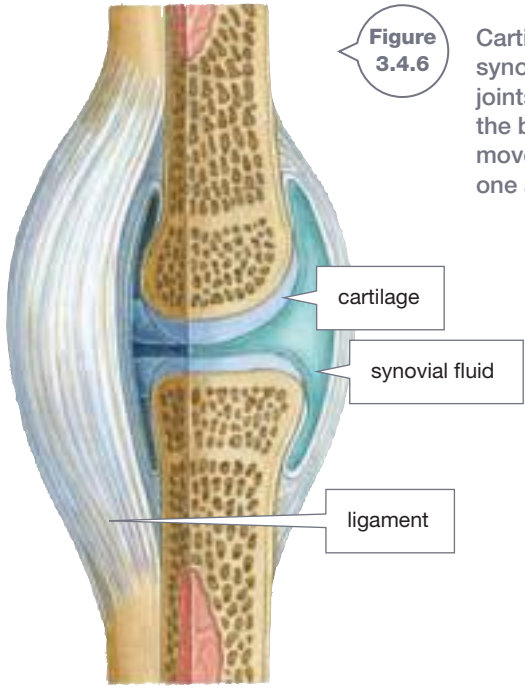


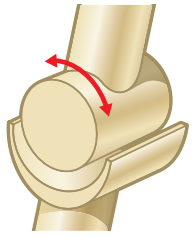

Figure 3.4.6 Cartilage and synovial fluid in joints ensure that the bones can move freely over one another.

# Types of joints

When you are sitting on a chair, your lower leg can move only forwards or backwards. The joint at the knee does not allow the lower leg to move from side to side. Using the hip joint, you can move your leg to make a complete circle with your toes. This is because the joints in your hip and knee are different types of joints.

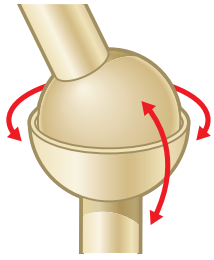
## Hinge joint

In a **hinge joint** the ends of the bones are shaped so that movement is allowed in only one plane—backwards and forwards like the hinge of a door. There is a hinge joint between the bone of the upper arm (humerus) and the larger bone of the lower arm (ulna). Other examples are the knee joint and joints in your fingers.



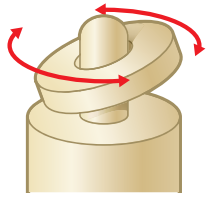
## Ball-and-socket joint

In a **ball-and-socket joint**, one bone has a ball-shaped surface that fits into an area shaped like a cup (socket) in the other bone. The bone with the ball at its end is able to complete all types of movement. Ball-and-socket joints are found in the hip and the shoulder.



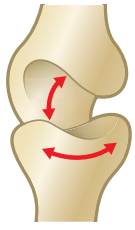
## Pivot joint

A **pivot joint** moves by a ring-shaped bone turning around a bone shaped like a finger. A pivot joint allows a wide range of movement. The joint at the base of your skull that allows you to turn your head is a pivot joint.



## Saddle joint

A **saddle joint** allows movement in two directions but does not allow the same amount of movement as a ball and socket joint. Saddle joints are found in the ankle and base of the thumb.



3.9

1 p116

# Ligaments

**Ligaments** are bands of tough, flexible tissue that hold the bones in a joint together. Ligaments prevent the bones of the joint from moving too far apart. Figure 3.4.7 shows the ligaments in the foot.

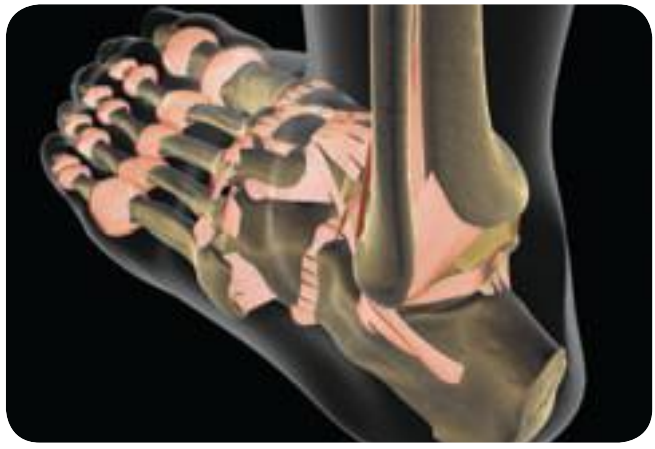


Figure 3.4.7

Ligaments, shown here in pink, hold all the bones of the foot together. Without them the foot would not be able to work as a single unit.

INQUIRY science 4 fun

## Flexing muscles

Can you feel your muscles contract and relax?

Yes

### Do this…

1. Relax your right arm so that it hangs beside you. Wrap your left hand around your lower right arm (below the elbow) and hold onto it. Then clench your right hand into a fist. Unclench and repeat.
2. Wrap your left hand around your upper right arm (above the elbow). Clench your right fist then raise it to your chin. Lower your arm and repeat.
3. Stand near a wall and place your right hand on it. Wrap your left hand around your upper right arm as before and lean into the wall so that your elbow is bent. Lean further in, then straighten up (as though you were doing single-handed push-ups against the wall).

### Record this…

**Describe** what happened.
**Explain** why you think this happened.

# Muscles

It is your **muscles** that move bones. Muscles are tissues that are able to contract and be stretched. You have 640 muscles, regardless of whether you are a couch potato or a body builder. Some of the main muscles are shown in Figure 3.4.8. **Tendons** are tissues that attach muscles to bones and hold the muscles in position. When activated, muscles contract, becoming fatter and shorter. They pull on the bones they are attached to, causing them to move.

Muscles can only pull. They cannot push. Therefore, another muscle is required to return the bone to its original position. For this reason, your muscles are arranged in antagonistic pairs that work in opposition to each other. The biceps and triceps are antagonistic muscles in your upper arm. When activated, the biceps contracts, pulling your forearm up. The biceps then relaxes. To lower the forearm, the triceps contracts. The relaxed biceps is stretched back to its original shape and the arm is straightened. This action is shown in Figure 3.4.9.

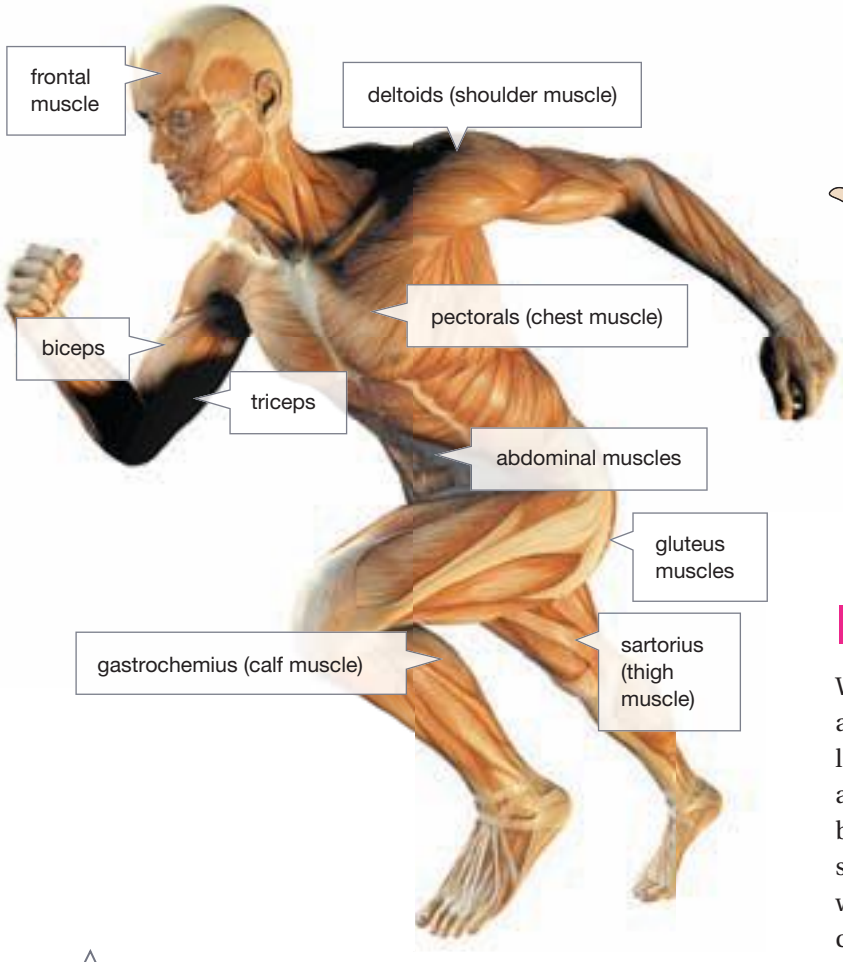



**Figure 3.4.8** The human muscular system. The pale areas are tendons joining muscles to bones.

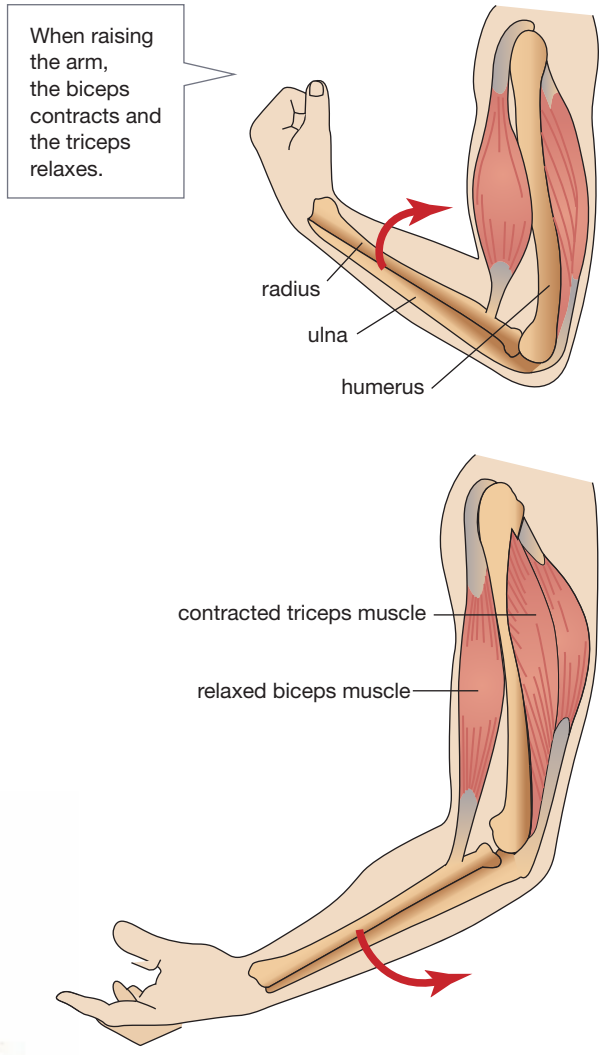



**Figure 3.4.9** Muscles work in antagonistic pairs. The biceps flexes the arm while the triceps straightens it.

2 p116 3 p117

# Injuries

When you are young, your skeleton and muscles are usually able to withstand the forces of normal life. However, the forces involved in sport and accidents are sometimes great enough to cause bones, muscles, tendons and ligaments to split, snap or tear. As you age, your bones and muscles weaken and these types of injuries become more common, even when you are not playing sport!

## Broken bones

Bones can stretch, squash and twist slightly but, like any material, will fracture (break or crack) if too much force is applied to them. Figure 3.4.10 shows what can happen. However, bone is a living material and will eventually mend if broken. This process takes around 6 weeks in adults and a little less in children.

A cast is usually needed to ensure the bones mend in the correct shape and position. This can be made of plaster or fibreglass, or may even be inflatable. Very bad breaks may need additional reinforcing with stainless steel plates or pins, like the ones shown in Figure 3.4.11.



**Figure 3.4.10** Both the bones in the lower leg were broken by the twisting action of a skiing accident.



**Figure 3.4.11** Pins and plates are often used to hold and strengthen bones in serious breaks.

## Sprains and strains

Ligaments are strong but elastic. They hold the bones in place at the joint but allow some movement in different directions. If a ligament is stretched too far, it can tear, causing an injury called a **sprain**. Ligaments in ankles and wrists are commonly sprained by a fall.

A **strain** is an injury to a muscle or tendon. Muscles are made to stretch but if they are stretched too far, or stretched while they are contracting, then either the muscle or the tendon may tear, causing a strain. You hear of footballers and other sports people suffering from torn hamstrings. The hamstring is the muscle running along the rear of the upper leg (connecting the pelvis to the knee).

Repetitive activities may also cause a sprain or strain when the muscles, tendons and ligaments are stretched continuously.

Minor strains and sprains can be treated by the RICE method. RICE stands for **R**est, **I**ce, **C**ompression and **E**levation.

# 3.4 Unit review

## Remembering

1 **State** how many bones there are in the:
   - a axial skeleton
   - b appendicular skeleton
   - c adult human skeleton.

2 **List** the characteristics of bones.

3 **State** the number of muscles found in the human body.

4 a **State** what the RICE method is.
   b **State** what each of the letters in RICE represents.

## Understanding

5 The bones in your arm need to perform well under both compression and tension. **Explain** why.

6 **Predict** what the movement of your head would be like if its pivot joint was replaced with a hinge joint.

7 **Describe** where the following are found and what they do.
   - a ligaments
   - b tendons
   - c cartilage

8 Broken bones need to be kept in a cast for 6 weeks. **Explain** what would happen if they weren't kept in a cast.

## Applying

9 **Identify** the property of cartilage that reduces friction in a joint.

10 **Use** the biceps and triceps to **explain** why muscles need to be arranged in antagonistic pairs.

## Analysing

11 **Contrast**:
   - a the axial and appendicular skeleton
   - b compact with spongy bone.

12 **Compare** the amount and direction of movement allowed by a hinge joint and a:
   - a ball-and-socket joint
   - b saddle joint.

13 **Contrast** a strain and a sprain.

## Evaluating

14 **Propose** reasons why your wrists and ankles have extra ligaments forming 'cuffs' around them.

15 Your spine extends from the base of your skull to the base of your pelvis. It holds your body upright but also allows you to flex and bend. **Propose** how this is achieved.

## Creating

16 **Construct** a diagram showing the position of the muscles of the leg that cause the knee to bend and straighten.

## Inquiring

1 Find out why adults have nearly 100 fewer bones than babies.

2 Research brittle bone disease. Find out what it is, who it affects, what causes it and how it is treated.

3 Search the internet using the keywords *EdHeads* to carry out your own virtual knee and hip replacement surgery.

4 The footballer in Figure 3.4.12 below has torn his hamstring. Find out what a hamstring is, how it is torn and ways of minimising the risk of such tears when playing sport.



Figure 3.4.12

# 3.4 Practical activities

## 1 Model joints

### Purpose

To construct models of the different joints found in the human body.

### Materials

- selection of junk materials

### Procedure

1 Refer to page 112 and decide which joint you are going to build a model of.

2 Analyse the joint, how it is 'strapped' with ligaments, and what materials could represent each part.

3 Construct your model and demonstrate it to the class.

### Discussion

1 **Describe** the movement that this type of joint gives the bones attached to either side of the joint.

2 **Identify** where in your body these types of joints are most likely to be found.

## 2 Dissecting an animal structure

### Purpose

To investigate the structure of a chicken wing.

### Materials

- uncooked chicken wing
- dissecting kit (scalpel, scissors, tweezers/forceps)
- dissecting board
- newspaper
- disinfectant
- access to stereo microscope



**SAFETY!**

Take care with sharp instruments.

Wear disposable gloves while dissecting the chicken wing.

Wash your hands thoroughly after completing the dissection.

### Procedure

1 Cover your workbench with newspaper and then set the dissecting board on top of it.

2 Lightly cut the skin of the wing down its length.

3 Use the tweezers to help you gently peel back the skin to expose the muscles. Record what they look and feel like and how they connect to the bones.

4 Once the muscles are exposed, flex the wing so that it opens and shuts. Record what happens.

5 Cut the muscle and fat off the wing to expose the bone. Record how the different bones of the wing connect to each other.

6 Try to break one of the bones. If successful, carefully look at the inside of the bone or its fragment, perhaps under a stereo microscope. Record what you see.

### Discussion

1 **State** whether or not you saw an antagonistic muscle pair in the wing.

2 **Describe** the function of the muscles in the chicken wing.

3 **Describe** what tendons do.

4 Bird bones are extremely light and much less dense than the bones in most other animals. **Propose** a reason why.

## 3 Muscle fatigue

### Purpose

To test how quickly muscles fatigue (get tired).

### Materials

- springy test-tube clamp or similar
- stopwatch or access to clock or watch with second hand

### Procedure

1. Use the hand you normally write with to hold the test-tube clamp with your thumb and first two fingers.
2. When your prac partner says 'Go', squeeze the test-tube clamp until your thumb meets or touches your fingers. Then relax. Keep squeezing and relaxing. As you go, count out aloud how many complete squeezes you are up to.
3. Your prac partner needs to take note of the time and record how many squeezes you complete every 30 seconds.
4. Keep squeezing and relaxing until you have reached 2½ minutes or have tired out.
5. Swap roles and repeat.

### Results

1. Construct a table in your workbook like the one below to show your results.

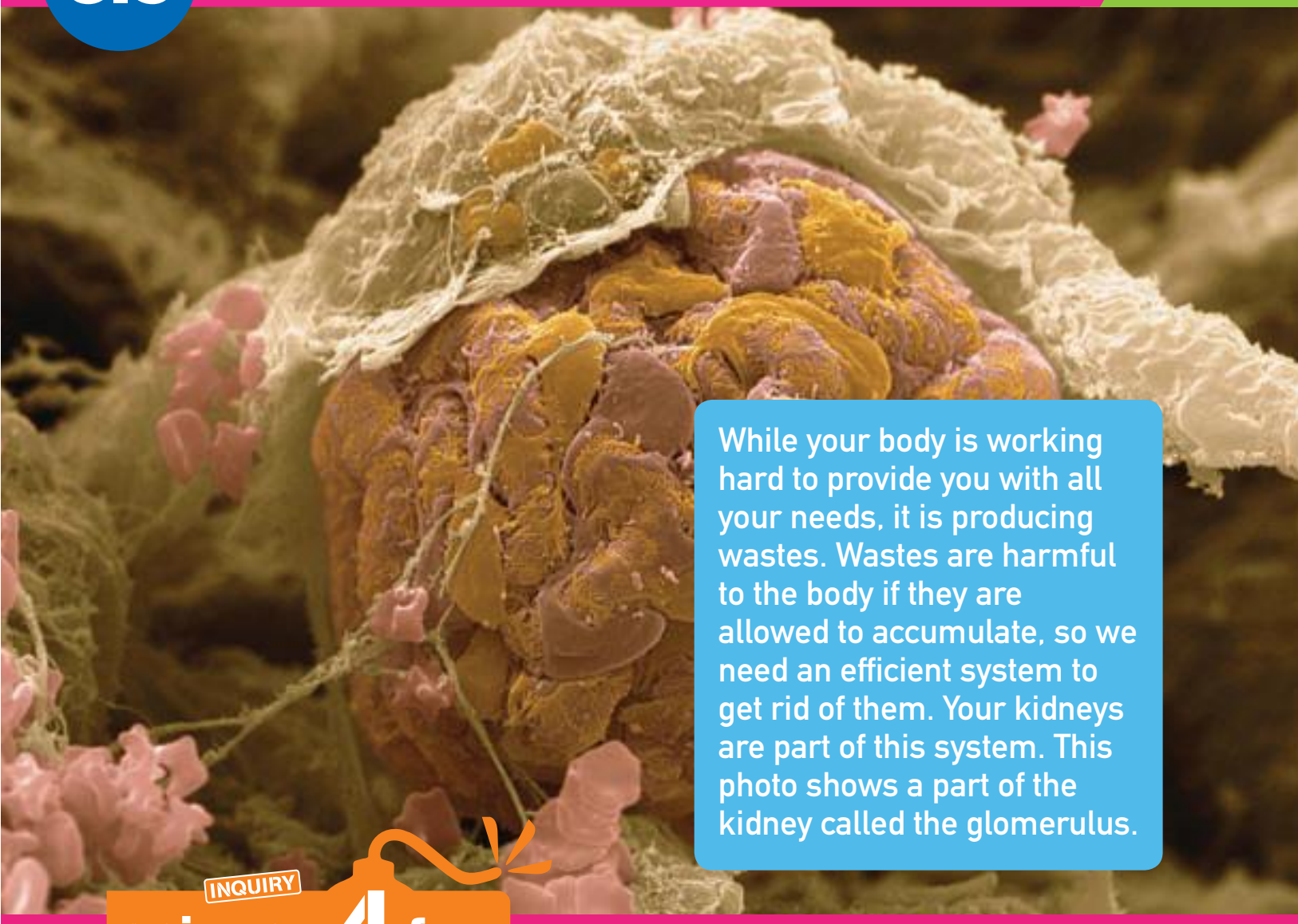
| Time (s) | Number of squeezes completed by me | Number of squeezes completed by my partner |
|---|---|---|
| 30 | | |
| 60 | | |
| 90 | | |
| 120 | | |
| 150 | | |

2. Plot a line graph showing the number of squeezes completed against time. Place the number of squeezes on the vertical axis and time on the horizontal axis.

### Discussion

1. **Describe** what happened as time progressed in this experiment.
2. **Propose** a meaning for the term *muscle fatigue*.
3. **Propose** reasons why some people experience muscle fatigue more quickly than others.

# 3.5 Waste disposal



While your body is working hard to provide you with all your needs, it is producing wastes. Wastes are harmful to the body if they are allowed to accumulate, so we need an efficient system to get rid of them. Your kidneys are part of this system. This photo shows a part of the kidney called the glomerulus.

INQUIRY science 4 fun

## It smells!

Does what you eat affect the smell of your urine?

Yes



### Collect this ...

- tin of asparagus or freshly cooked asparagus

### Do this ...

1. Eat the asparagus.
2. Next time you urinate, pay attention to the smell.

### Record this ...

**Describe** what happened.
**Explain** why you think this happened.

# Defecation

The process of getting rid of solid waste (faeces) from your body is known as **defecation**. Faeces is undigested material that has passed through your digestive tract. It is waste because it is material that your body has not been able to use.

# Excretion

Getting rid of the wastes your body has produced is called **excretion**. It is the function of the **excretory system**. The lungs, skin, liver and kidneys are all involved in excretion.

## Lungs

Respiration produces carbon dioxide and water as waste products. These are carried back to the lungs and breathed out. The lungs are part of the excretory system as well as being part of the respiratory system.

## Liver

Your liver carries out many processes. Some are involved in excretion.

Amino acids are the end products of protein digestion. They are used by your body to make proteins and for growth and repair. Amino acids cannot be stored. If you have more than needed, they are broken down and excreted. The liver breaks amino acids down into a substance called **urea**.

Poisonous substances may enter the body from the digestive tract. These are carried to the liver, where they are broken down into harmless substances. The harmless substances are then returned to the blood and from there they pass to the kidneys.

The liver breaks down old red blood cells. Any unwanted haemoglobin is added to bile and passes with the bile into the intestines.

## Skin

Chemical reactions taking place in your body produce heat as a by-product. Some of this heat is required to maintain your body temperature at 37°C, but you usually produce more than you need. If you did not get rid of the excess heat, then your temperature would rise. This could be fatal. You lose much of your excess heat through your skin by sweating, as shown in Figure 3.5.1. Sweat also contains a very small amount of urea.



Figure 3.5.1 Your body gets rid of excess heat by sweating.

**SciFile**

**Airhead!**

The whole of the human skin weighs twice as much as the brain.

## Kidneys

The kidneys are very important excretory organs. If you place your hands on your hips with your thumbs to the back, then your thumbs will be sitting over your kidneys. They are two bean-shaped organs about the size of a fist. They are filters that process about 50 litres of blood every hour. Figure 3.5.2 shows the position and relative size of the kidneys.

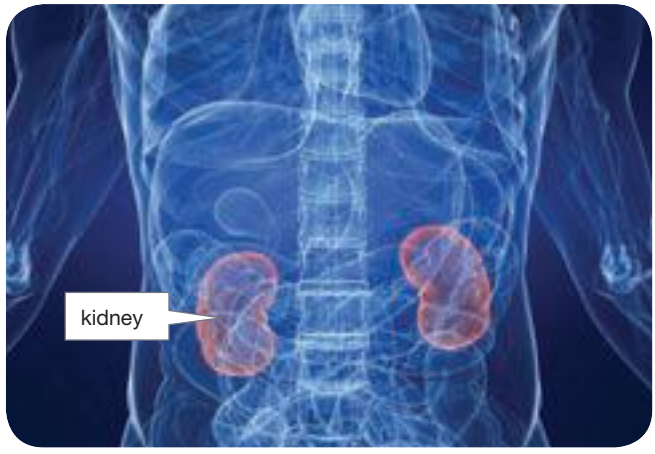



Figure 3.5.2 Although your kidneys are not large, they are very important. About 20% of the blood leaving your heart flows to the kidneys first before continuing its circulation of the body.

The kidneys excrete urea. The kidneys also control the level of water in the body. If you have drunk more than you require, then extra water is taken out of the blood as it is filtered through the kidneys and very dilute urine is produced. If your body is short of water, then the kidneys take out less water and produce more concentrated urine.

Your kidneys also control salt levels in the blood. Too much or too little salt in the blood prevents cells from working correctly. So it is very important that the concentration of salts is controlled. Excess salt is removed in the urine.

Figure 3.5.3 shows the structure of a kidney.

### Urine

Urine is the waste material that has been filtered out of the blood by the kidneys. Urine is 95% water. The other 5% is urea, with small amounts of salts and pigment. The pigment comes from the breakdown of haemoglobin and gives urine its yellow colour.

Urine passes from the kidneys down narrow tubes called **ureters** and into the **bladder**, where it is stored. The bladder is a muscular bag. It can expand to hold about 500 mL of urine.

The **urethra** is a tube that carries the urine to the outside of the body. At the end of the urethra is a sphincter muscle that controls the emptying of the bladder.

Together, the kidneys, bladder, ureters and urethra are called the **urinary tract**.

The male urinary tract system is shown in Figure 3.5.4.

1 p124 2 p125

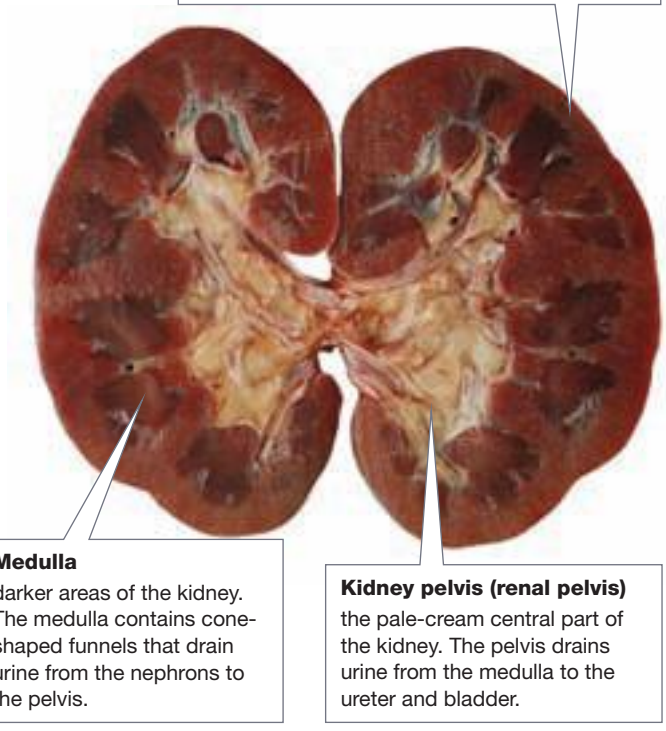



**Figure 3.5.3** A dissected kidney. The image used in the introduction to this unit was of a glomerulus. Glomeruli are part of the nephrons in your kidneys.

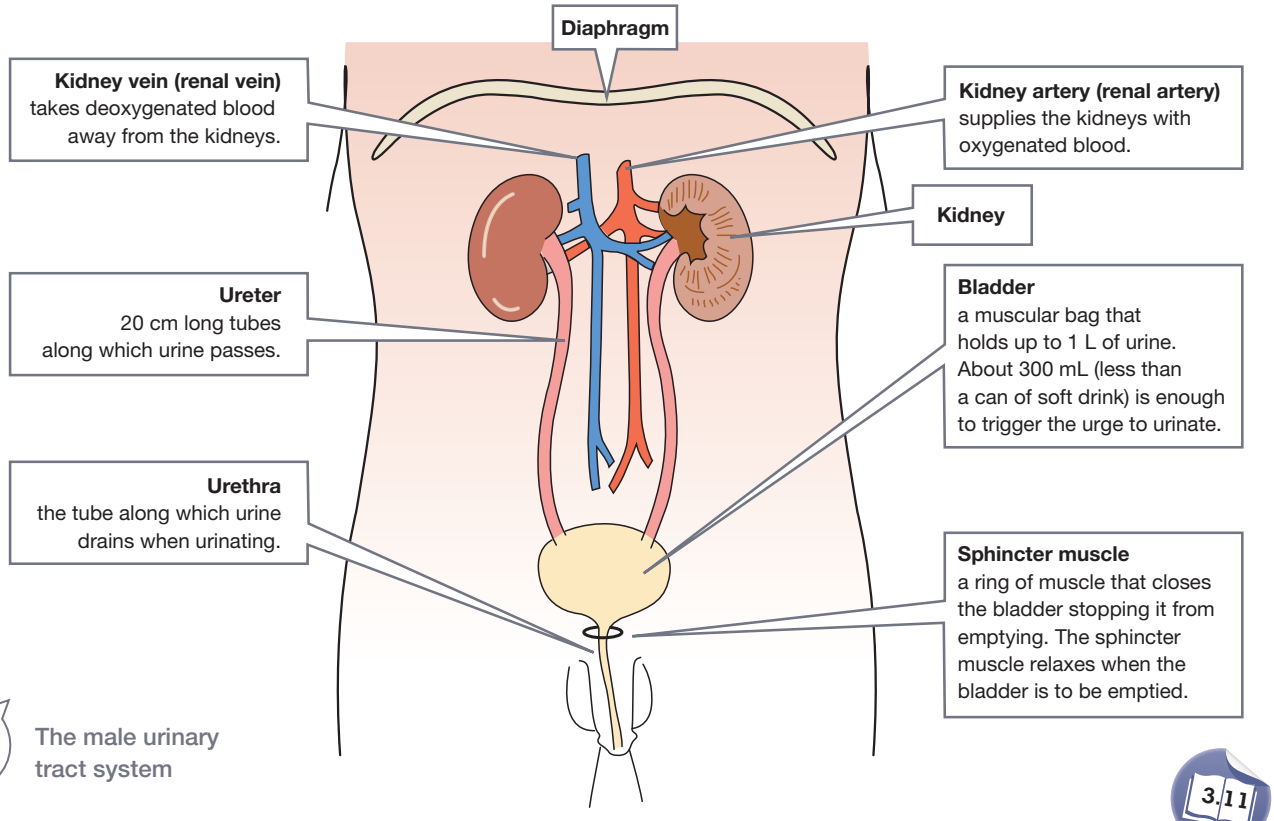



**Figure 3.5.4** The male urinary tract system

3.11

# Kidney disease

More than 500 000 Australians a year consult their doctors about kidney disease and urinary tract infections. High blood pressure, kidney stones and infections are some of the causes.

## High blood pressure

Your blood travels a relatively short distance to your kidneys. Very little pressure from the heartbeat is lost, so blood entering the kidneys is under pressure. This pressure helps the filtering process carried out by the kidneys. However, abnormally high blood pressure can easily damage the capillaries where the blood is filtered. This affects the functioning of the kidneys.

## Kidney stones

Kidney stones occur when chemicals normally present in the urine combine to create hard crystals. If they are small enough, the crystals will pass out of the kidneys with the urine. However, larger stones (like those shown in Figure 3.5.5) can block the fine tubes within the kidney, causing pain and preventing the flow of urine.

Large kidney stones may have to be removed in an operation but more commonly they are shattered into tiny pieces using ultrasound waves. The smaller pieces should then pass naturally from the body.

Substances in the urine usually prevent kidney stones from forming. However, in some people these substances do not work and they suffer the pain and discomfort of this disease.

You can help keep your kidneys healthy by drinking. Water is the best drink (Figure 3.5.6). You should drink enough to produce about 2 litres of urine in every 24-hour period.

## Infections

The structure of the urinary tract prevents any backflow of urine from the bladder to reduce the chance of infections of the kidneys. However, infections of the urinary tract sometimes occur. Most are caused by bacteria.

Urine is normally sterile, so the bacteria have to come from another source. They usually enter through the urethra. Most infections are caused by *Escherichia coli* (*E. coli*), a bacterium common in the digestive tract, which spreads to the urethra from the anus.




**Figure 3.5.5** The red dots in this X-ray are kidney stones.

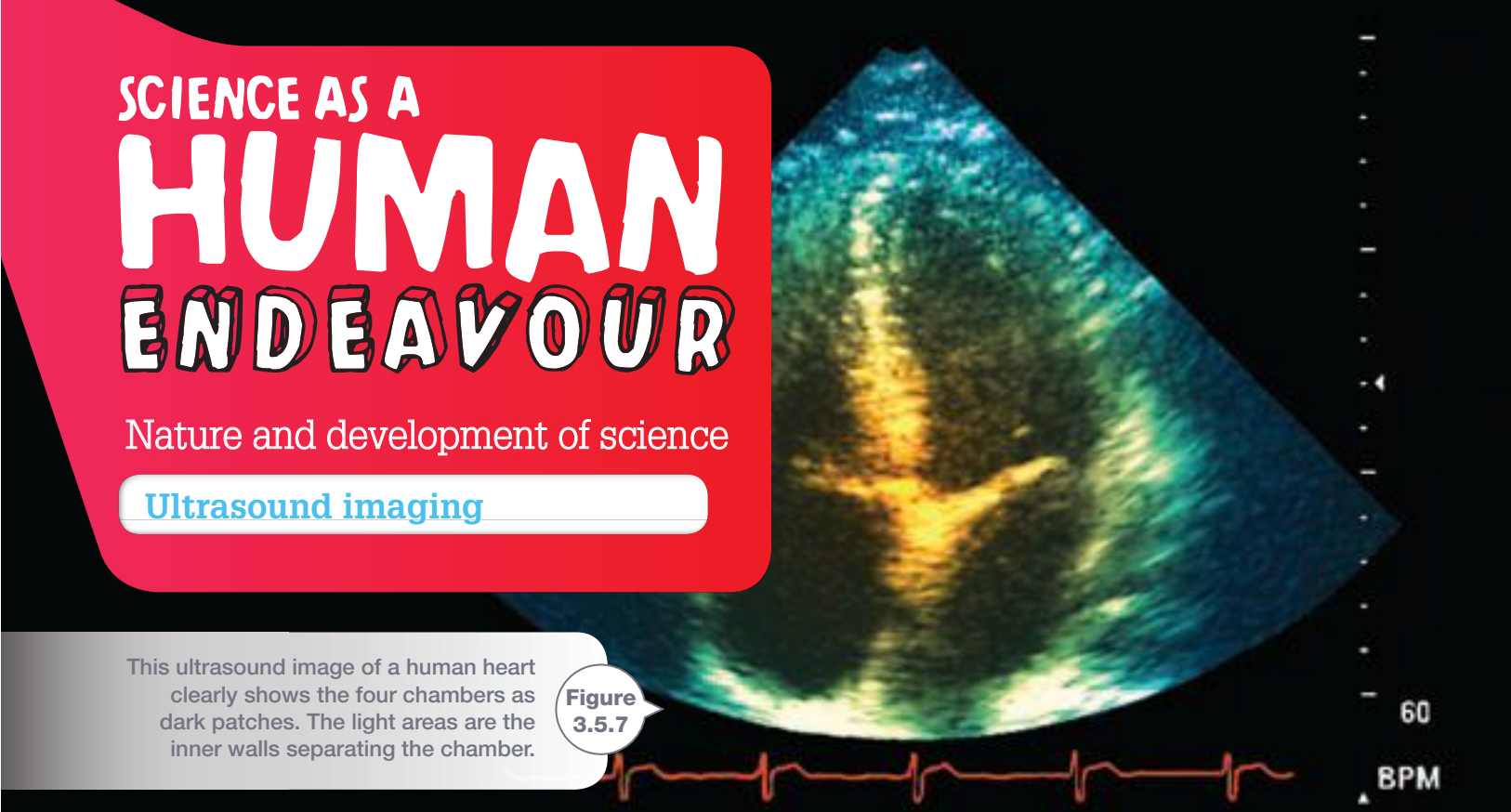


**Figure 3.5.6** Drinking plenty of water helps to keep the kidneys healthy.

# SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

## Ultrasound imaging




This ultrasound image of a human heart clearly shows the four chambers as dark patches. The light areas are the inner walls separating the chamber.

Figure 3.5.7

You will probably have heard of ultrasound imaging and may have seen an ultrasound image of yourself as a baby inside your mother's uterus. The ability of medical practitioners to create ultrasound images is due in part to the work of Australian scientists.



Figure 3.5.8

Ultrasound image of a baby at 12 weeks with its thumb up.

Australians George Kossoff and David Robinson did not invent ultrasound imaging but they made a significant contribution to its development when they introduced 'grey-scaling'. Grey-scale produces images that have many shades of grey ranging from almost black to almost white. Before this innovation, the images produced were in black and white and interpreting the images could be difficult.

When grey-scale was introduced to ultrasounds, such as the one in Figure 3.5.8, the image was improved. It was easier to distinguish between liquid and solid tissues and to see the boundary between them.

In 1970 Kossoff and Robinson published one of the earliest scientific papers relating to the diagnosis of development problems in fetuses, using ultrasound technology.

Grey-scale ultrasound imaging is used for finding cancers in various parts of the body; observation of the direction and speed of blood flow; and checking the internal structure of the eye.

A recent (2010) innovation using ultrasound is in the area of dentistry. David Hsiao-chuan Wang (a PhD student) and his supervisor, Professor Simon Fleming from the Institute of Photonics and Optical Science at the University of Sydney, have developed the dental laser ultrasound. This instrument uses laser-generated sound waves to detect early signs of tooth decay. The technique is painless and replaces potentially harmful X-rays and painful probing with sharp instruments. It may also eliminate the need for surgery.

3.12

# 3.5 Unit review

## Remembering

1 **Recall** the function of the bladder.

2 **List** the wastes produced by respiration.

3 **List** the wastes excreted by the lungs.

4 **List** three functions of the kidneys.

5 **Recall** the missing steps in the pathway followed by urine:

**kidney** → _____ → **bladder** → _____

## Understanding

6 On average, urine is 95% water and 5% urea and salts. **Predict** how the composition of urine would change if you:
- **a** drank very little water on a hot day
- **b** drank very large amounts of water
- **c** ate a diet high in salt.

7 **Explain** the difference between excretion and defecation.

8 **Describe** the involvement of the liver in excretion.

## Applying

9 Kidneys process about 50 L of blood every hour. Your body contains about 5.5 L of blood. **Calculate** how often any drop of blood would pass through the kidneys in:
- **a** 1 hour
- **b** 1 day.

10 Figure 3.5.9 is a diagram of the excretory system. **Identify** the parts labelled A–D.

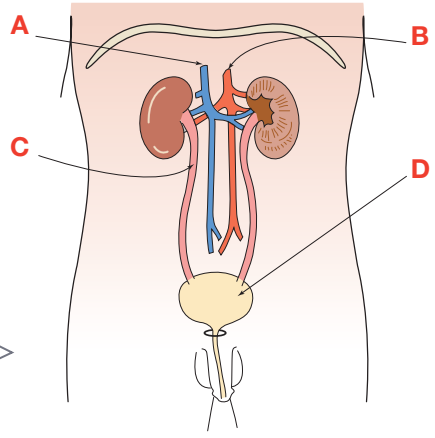



Figure 3.5.9

## Analysing

Questions 11–13 refer to the following table. It compares blood and urine.

| Component | Percentage in blood | Percentage in urine |
|---|---|---|
| Water | 92 | 95 |
| Protein | 7.5 | 0 |
| Glucose | 0.1 | 0 |
| Urea | 0.03 | 2 |
| Salts | 0.37 | 3 |

11 **Compare** the data for blood and urine and **identify** the substances that are:
- **a** more concentrated in the urine
- **b** not excreted by the kidneys.

## Evaluating

12 Decide whether the person from whom the data were collected had adequate water in their body or was dehydrated. **Justify** your response.

13 **Propose** a reason for glucose not being excreted.

14 **Propose** why drinking water should reduce the chance of developing kidney stones.

## Creating

15 **Use** the following eleven key terms to **construct** a concept map.

| | | |
|---|---|---|
| excretion | excretory system | defecation |
| urea | urine | kidneys |
| skin | lungs | ureter |
| bladder | urethra | |

## Inquiring

1 People who have donated a kidney and those who have received a transplant survive with only one kidney. Research to find out how this is possible.

2 Research to find out what changes occur in your body if you become dehydrated and overheated.

# 3.5 Practical activities

## 1 Kidney dissection

### Purpose

To dissect a kidney and look at its structure.

### Materials

- dissecting board
- scalpel
- disposable gloves
- sheep or bullock kidney

**SAFETY!**

Take care with sharp instruments.

Wear disposable gloves when handling the kidney.

Wash your hands thoroughly after you have completed the dissection.

### Procedure

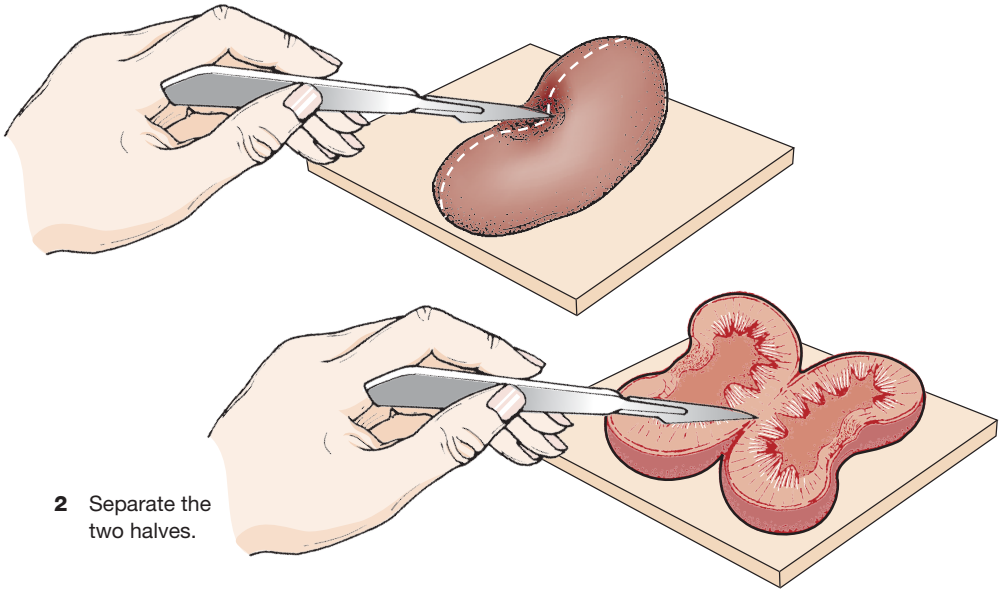
1. Place the whole kidney on the dissecting board and examine it. Look for any tubes entering or leaving the kidney. It may be possible to identify three tubes: ureter, renal artery and renal vein. (*Renal* is a word used in relation to the kidney.)
2. Use the scalpel to cut the kidney in half lengthwise as shown in Figure 3.5.10.
3. Identify the parts of the kidney as shown in Figure 3.5.3 on page 120.

### Results

Draw a labelled diagram of the cut surface of the kidney.

### Discussion

1. **Compare** the texture in the three different areas of the kidney.
2. **Compare** the kidney you have dissected with the human kidney shown in Figure 3.5.3. How similar are the two kidneys?
3. **Use** this comparison to **compare** human excretion with excretion in sheep (or bullocks).
4. **Describe** the function of each part of the kidney.



**1** Cut the kidney lengthwise.

**2** Separate the two halves.

**Figure 3.5.10**

## 2 Water and wee

### Purpose

To gather information about the relationship between drinking and urinating.

### Materials

- notebook and pencil
- graph paper
- liquids that are normally drunk in a day

### Procedure

1. Read through the complete activity. Make a prediction about the relationship between urination and consuming liquids. The prediction could be to do with the amounts or the timing.
2. Construct a table like the one below to record the:
   a. amount that you drink
   b. time the drink was consumed
   c. time you urinated.
3. For a 24-hour period, record the volume of all the drinks you consume and the time that you consumed them.
4. Record the times that you urinated for the same 24-hour period.

### Results

1. Construct a table like the one shown below.

| Time drink consumed | Amount drunk (mL) | Time urinated |
|---|---|---|
| | | |
| | | |
| | | |

2. Construct a bar graph with time along the horizontal axis. Use one colour to show when and how much liquid was consumed.
3. Use a different colour to record when urination took place.

### Discussion

On average, the adult bladder can hold between 500 mL and 1 litre of urine. Assume that your bladder is a little smaller than that of an adult and that it is not filled to capacity when you urinate. Assume that each time you urinate, the volume of urine is 300 mL.

1. **Calculate** the total amount you drank in the 24-hour period.
2. **Calculate** the total amount of urine you produced in the 24-hour period.
3. **Compare** the two amounts. Explain the difference.
4. **Calculate** the length of time between drinking and urinating. Explain any relationship you identified.
5. **Discuss** the idea that not all the water in your body has come from the liquid you have drunk.
6. **Identify** any activities that you engaged in that could have reduced the amount of urine produced. Is there any evidence to support this idea in the data you have collected or other observations you may have made, such as the colour of your urine?

# 3 Chapter review

## Remembering

1 **Name** the system that distributes heat evenly through your body.

2 **State** whether the following statements are true or false.
- a The diaphragm contracts as you inhale.
- b You exhale because the air pressure in the chest cavity has decreased.
- c Mechanical digestion changes food chemically.
- d Arteries carry blood towards the heart.
- e Veins have valves in them to help the flow of blood.
- f In humans there are two separate parts to the circulatory system.

3 **List** these organs in the order food will pass through them in the digestive tract:

small intestine, mouth, stomach, large intestine, duodenum, oesophagus

4 **Name** three things produced in the bone marrow.

5 **Name** three organs in the excretory system.

## Understanding

6 **Explain** why the lungs are included in both the respiratory system and the excretory system.

7 **Explain** why urine is a darker colour on a hot day.

8 **Describe** three situations in the body where a large surface area helps the functioning of a system.

9 Major arteries are a long way from the body surface. **Explain** why.

10 **Explain** the advantage of bone being a living tissue.

11 **Describe** the function of:
- a tendons
- b ligaments
- c joints.

## Applying

12 You take in about 500 mL of air in one breath, and breathe 12 times a minute. **Calculate** how much air you take into your body every hour.

13 **Identify** the organs labelled A–J in Figure 3.6.1.

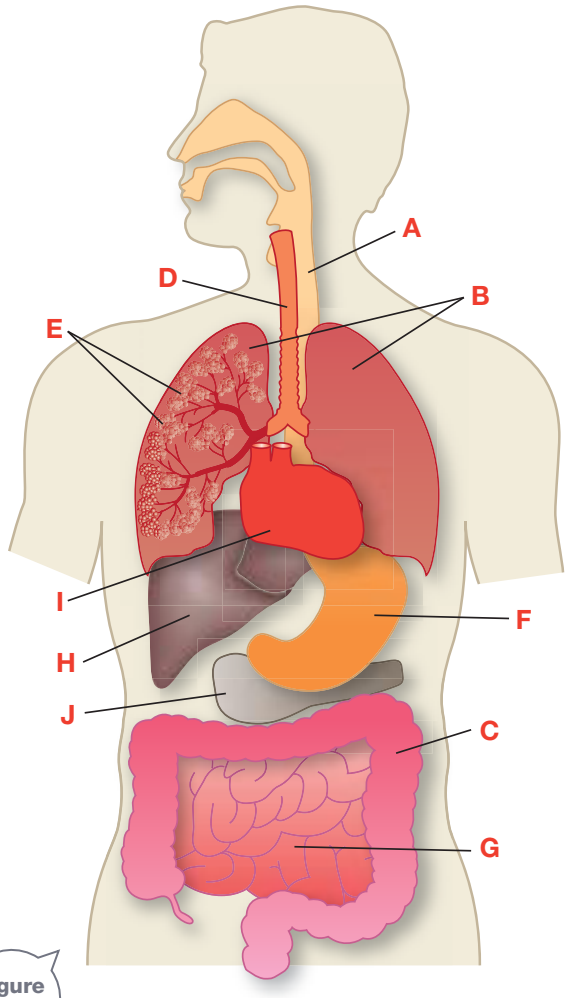



Figure 3.6.1

14 **Identify** each of the following body parts.
- a A slippery elastic tissue found on the ends of bones
- b The structure that carries urine out of the body
- c The joint that allows movement in two directions
- d A tissue that can contract and be stretched but cannot expand

## Analysing

15 a **Use** the information in the table below to **calculate** the amount of oxygen that enters your blood for 1 hour while you are sleeping.

b **Calculate** the amount of carbon dioxide you would breathe out in that time.

c i **Compare** the amount of oxygen and carbon dioxide breathed out during sleep and during exercise.

ii **Account** for any differences.

d i **Compare** the amount of nitrogen breathed in and out.

ii **Account** for any differences.

| Gas | Composition of air (%) | | |
|---|---|---|---|
| | Breathed in | Breathed out during sleep | Breathed out during exercise |
| Nitrogen | 78 | 78 | 78 |
| Oxygen | 21 | 16 | 11 |
| Carbon dioxide | 0.03 | 4 | 9.5 |
| Water vapour | a little | saturated | saturated |

16 **Compare** the part of the lungs where gas exchange takes place with the lining of the small intestine.

## Evaluating

17 a **Interpret** Figure 3.6.2 to identify the organs or parts of systems that are represented in the Aboriginal drawing below.




b **Propose** why Aboriginal Australians would have represented these organs or systems in their art.

18 There have been situations where people have drunk their own urine to survive in the desert when they had run out of water. **Assess** how this would change the composition of the urine they would produce the following day.

19 Some athletes strap their wrists, ankles, knees and shoulders when playing sport. **Propose** reasons why.

20 Birds have hollow bones with very little compact bone. **Propose** an advantage of this characteristic.

21 Dialysis is a process that uses a machine to filter wastes out of blood. The process is used if a person's kidneys stop working efficiently. Dialysis must take place at least three times a week and requires the person to be hooked up to the dialysis machine for 4–6 hours each time.

a **Use** this information to **calculate** the minimum time a person needs to be connected to the dialysis machine each week.

b **Propose** a list of disadvantages of kidney dialysis.

## Creating

22 Some people say that we should drink 2 litres of water every day and that tea or soft drink should not be included in the 2 litres. Others say that any drink is equally good at hydrating the body. **Design** an investigation that would help settle the argument.

23 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

digestion
respiration
excretion
circulatory system
heart
enzymes
diffusion
glucose
oxygen
breathing

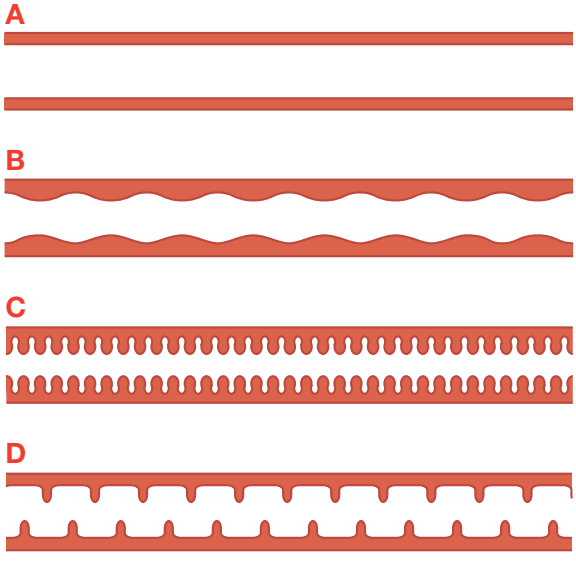
# Thinking scientifically

**Q1** Analyse the information in the table to decide which parts of the body had increased blood flow during exercise.

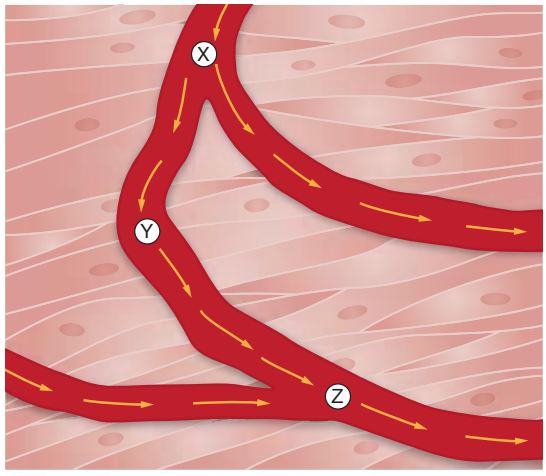
| Part of body | Blood flow (L/min) | | |
|---|---|---|---|
| | At rest | During light exercise | During medium exercise |
| Heart muscle | 250 | 350 | 800 |
| Leg muscle | 1100 | 4600 | 13000 |
| Brain | 750 | 750 | 750 |
| Kidneys | 1000 | 850 | 700 |
| Digestive system | 1300 | 1100 | 550 |
| Skin | 500 | 1500 | 1800 |

**A** heart, brain and skin
**B** leg muscle, heart and skin
**C** gut, brain and kidneys
**D** gut, leg muscle and skin

**Q2** The lining of the small intestines of four animals was examined. These are the diagrams that were produced. The intestines were all the same length. Deduce which of these four animals would be able to absorb most nutrients from its food.




**Q3** The diagram below shows blood flowing through the tiny blood vessels of the muscles of a runner involved in a race. Select the statement about the amount of oxygen in the blood that is most likely to be true.




**A** It is highest at point X.
**B** It is highest at point Y.
**C** It is highest at point Z.
**D** The amount of oxygen present will be the same in all the blood vessels shown.

**Q4** When urine is analysed, it is found to contain many different substances. The following diagram represents a possible analysis.



| Urine | |
|---|---|
| 0.05% | ammonia |
| 0.18% | sulfate |
| 0.12% | phosphate |
| 0.6% | chloride |
| 0.01% | magnesium |
| 0.015% | calcium |
| 0.6% | potassium |
| 0.1% | sodium |
| 0.1% | creatinine |
| 0.03% | uric acid |
| 2% | urea |
| 95% | water |

Identify the substance that is found in the highest concentration in urine.

**A** sulfate
**B** urea
**C** potassium
**D** ammonia

# Glossary

## Unit 3.1

**Anus:** a sphincter muscle at the end of the digestive tract

**Bile:** a greenish liquid responsible for mechanical digestion of fats

**Bolus:** food rolled into a ball by the tongue

**Cells:** the building blocks of all living things

**Digestion:** the process of breaking down food into a useable form

**Digestive system:** the system of the body where digestion takes place

**Duodenum:** the first part of the small intestine

**Epiglottis:** the flap of skin in the oesophagus that stops food entering the windpipe

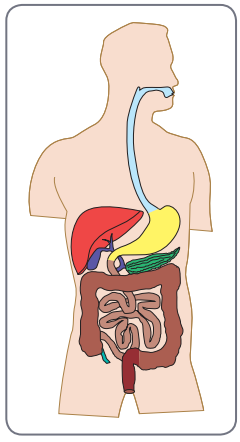
**Gastric juice:** a mixture of chemicals produced by cells in the stomach wall

**Large intestine:** the final section of the digestive tract

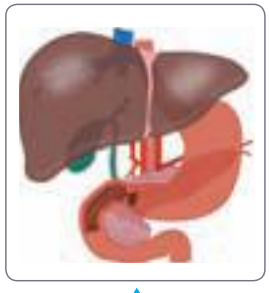
**Liver:** the largest internal organ, it produces bile

**Oesophagus:** the part of the digestive system that connects the mouth to the stomach

**Organ:** a structure that contains at least two different types of tissue that work together to complete a task



Digestive system



Liver

**Peristalsis:** the process of pushing food through the digestive tract by alternating contraction and relaxation of muscles

**Small intestine:** the longest part of the digestive tract

**Sphincter:** a circle of muscle

**Tissue:** a group of cells of the same type that carry out the same job in the body

**Villi:** microscopic 'fingers' that greatly increase the surface area of the wall of the small intestine

## Unit 3.2

**Alveoli:** a cluster of sacs at the end of the bronchioles where gas exchange takes place

**Bronchi:** tubes formed by the division of the trachea

**Bronchioles:** small tubes formed by the division of the bronchi

**Diaphragm:** a sheet of muscle that separates the chest from the abdomen

**Pharynx:** the cavity at the back of the nose, connecting the mouth and nose to the oesophagus

**Respiration:** the series of chemical reactions that takes place in cells to release energy

**Respiratory system:** the system of organs and tissues that takes the air into the body

**Trachea:** the tube that carries air from the nose and mouth into the chest cavity

## Unit 3.3

**Angina:** severe chest pain caused by lack of oxygen being supplied to heart muscle

**Artery:** a blood vessel that carries blood away from the heart

**Capillary:** the narrowest blood vessel that reaches nearly every cell of the body

**Cardiac muscle:** the type of muscle found in the heart

**Cholesterol:** a fatty chemical that can cause blockages in arteries

**Circulatory system:** the system that carries materials around the body; it consists of the heart, blood vessels and blood



Circulatory system

**Deoxygenated blood:** blood with carbon dioxide

**Haemoglobin:** a pigment that gives red blood cells their colour

**Oxygenated blood:** blood rich in oxygen

**Vein:** blood vessel that carries blood back to the heart

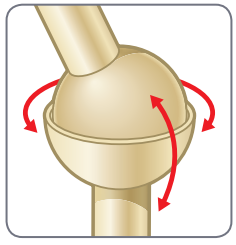
## Unit 3.4

**Antagonistic muscles:** pairs of muscles that work in opposition to each other

**Appendicular skeleton:** bones that allow movement

**Axial skeleton:** bones that protect the organs

**Ball-and-socket joint:** a joint in which one bone has a ball-shaped surface that fits into a cup-shaped socket of another bone. The bone with the ball at its end is able complete all types of movement



Ball-and-socket joint

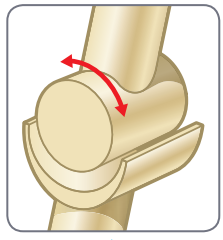
**Bone marrow:** jelly-like material in which new blood cells are made

**Bones:** structures that make up the skeleton

**Cartilage:** tissue with a smooth and slippery surface allowing smooth movement of a joint

**Compact bone:** dense tissue forming the outer layer of a bone

**Joint:** the point where two bones meet



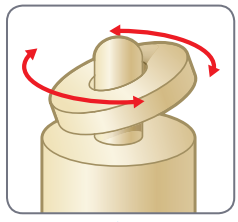
Hinge joint

**Hinge joint:** a joint that allows movement in only one plane.

**Ligaments:** fibrous bands of tissue that hold bones together in a joint

**Muscles:** tissues that can contract and, when attached to bones, cause the bones to move.

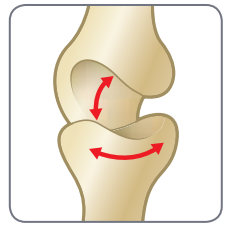
**Pivot joint:** a joint like the one at the base of your skull that allows a wide range of movement.



Pivot joint

**Saddle joint:** a joint that allows movement in two directions

**Skeleton:** bony structure that holds the body upright, protects its organs and allows movement



Saddle joint

**Spongy bone:** honeycombed bone structure, makes up much of the inner structure of a bone

**Sprain:** injury to a ligament

**Strain:** injury to a muscle or tendon

**Synovial fluid:** lubricating liquid in a joint

**Tendons:** elastic tissue that attaches the muscles to the bones

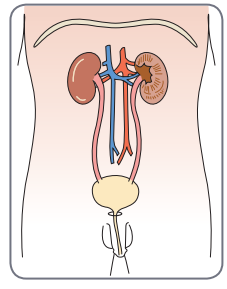
## Unit 3.5

**Bladder:** a muscular bag where urine is stored before it is expelled from the body

**Defecation:** getting rid of solid waste

**Excretion:** getting rid of the wastes that the body has produced

**Excretory system:** the system in the body that gets rid of the wastes that the body has produced



Excretory system

**Urea:** substance formed by the liver when amino acids are destroyed

**Ureters:** narrow tubes that carry urine to the bladder

**Urethra:** a tube that carries the urine to the outside

**Urinary tract:** kidneys, bladder, ureters and urethra

# Growth and reproduction

# 4



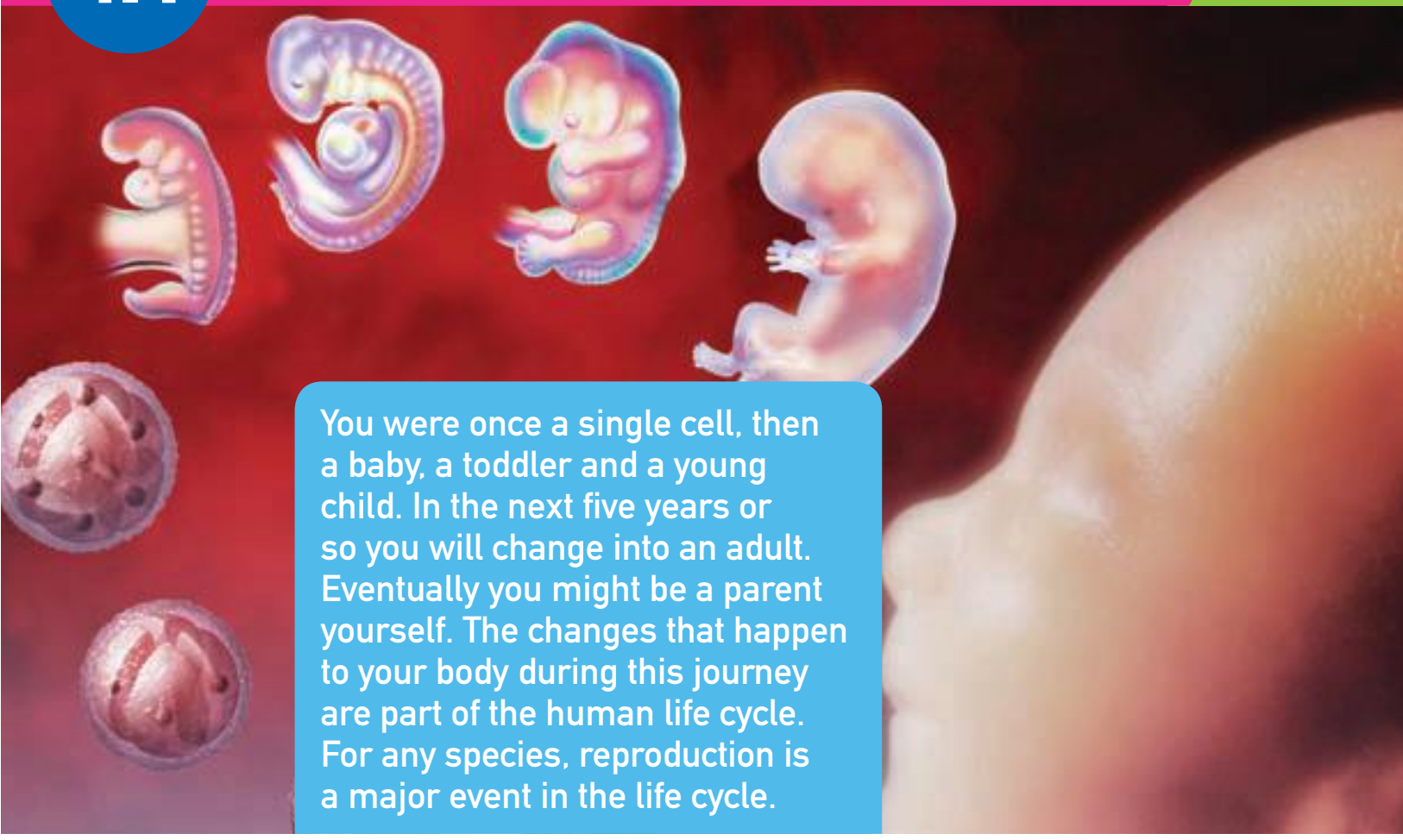
## HAVE YOU EVER WONDERED…

- how babies grow inside their mother?
- why there are so many different types of flowers?
- why animals have different sexes?
- why males and females look different?

## After completing this chapter students should be able to:

- compare reproductive systems of organisms
- distinguish between sexual and asexual reproduction
- identify the organs and overall function of a system of a multicellular organism
- describe the structure of each organ in a system
- recall that cells reproduce via cell division
- research the use of reproductive technologies.

# 4.1 Life cycles



You were once a single cell, then a baby, a toddler and a young child. In the next five years or so you will change into an adult. Eventually you might be a parent yourself. The changes that happen to your body during this journey are part of the human life cycle. For any species, reproduction is a major event in the life cycle.

## What is a life cycle?

A cycle is something that goes around and around, repeating itself. The seasons occur in a cycle, where the weather changes through spring, summer, autumn and winter, and then back to spring again. All organisms go through a cycle in their lives. Organisms change as they grow, but they do not return to their starting point. Instead, the organisms reproduce, and the pattern of growth begins again in their young. **Reproduction** is the process of parents producing new individuals, or offspring. For example, in humans, the **life cycle** goes through the stages of a developing baby, a toddler, a child, an adult and finally a parent.

At each stage the organism might look different and have different roles. For example, when young, an organism may be dependent on its parents. Later in life, the organism may care for its own young. Life cycles can be very different in different types of organisms. For example, the life cycles of insects, frogs and grasses are very different from the life cycle of humans.

## Insect life cycles

The life cycle of the wanderer butterfly is shown in Figure 4.1.1. It starts when an adult male and an adult female mate. Mating results in the female laying an **egg** on a leaf. In the next stage, the egg hatches into a **larva**, which is commonly called a caterpillar. The caterpillar eats steadily and grows bigger. It then changes into a **pupa** (plural: pupae), a life stage where it does not eat. Inside the hard case of the pupa some amazing changes take place. The caterpillar's body completely rearranges and re-forms itself into a butterfly. It grows wings, different eyes, antennae, legs and many other body parts. The butterfly is known as the adult, or **imago** stage. The butterfly breaks out of the pupal case and flies away to find a mate and start the whole cycle again.

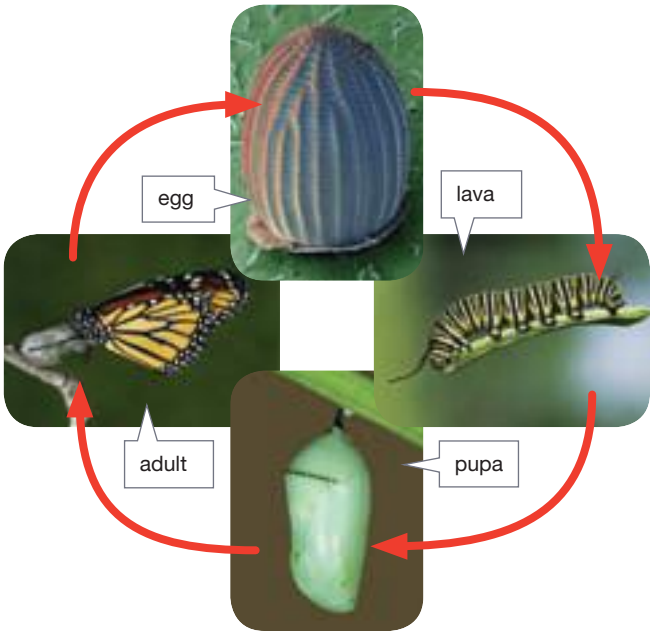



**Figure 4.1.1** The life cycle of the wanderer butterfly shows four different life stages—egg, larva, pupa and adult.

INQUIRY

## science 4 fun

### Garden life cycles

Can you see a life cycle in the garden?

Yes

**Do this…**

1. Search in a garden for insects. Look for evidence of different stages in the life cycle of an insect, such as egg, larva, pupa or adult.
2. Carefully observe the area to see if there are different stages of the life cycle in the same place. You could use your mobile phone or camera to take a photo if you are not sure what you have found and identify it later in class.

**Record this…**

**Describe** what you observed.

**Explain** what happens to the insect in this part of the life cycle.

## Growth and development

The changes in body form and shape in the course of an organism's life are called **development**. Development is different from growth. For an insect, **growth** means becoming larger, whereas development in an insect is about changes such as wings or legs forming. Usually as an organism grows, it also develops.

## Metamorphosis

The life cycle of the wanderer butterfly has four stages—egg, larva, pupa and adult. These stages look very different, and show a metamorphosis. **Metamorphosis** means 'changing form', referring to the changes in structure that happen as an organism develops into an adult.

The butterfly life cycle is known as complete metamorphosis. Most insects have this type of life cycle, including moths, bees, wasps, flies, mosquitoes and beetles.

Other insects have different life cycles. An example is the grasshopper, which has a life cycle called incomplete metamorphosis. You can see in Figure 4.1.2 that grasshoppers have no pupa. The young is called a **nymph**, and looks like a smaller version of the adult but with a few parts still undeveloped. The nymph slowly changes into the adult, developing wings as it matures. Insects such as cockroaches, earwigs, termites, dragonflies and all the true 'bugs' have this type of life cycle.

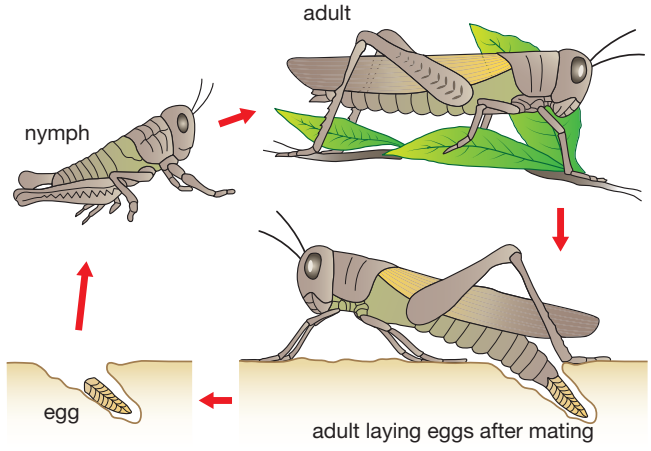



**Figure 4.1.2** The life cycle of the grasshopper shows incomplete metamorphosis, with three stages—egg, nymph and adult.

1 p138

4.1

# Frog life cycle

As you can see in Figure 4.1.4, frog and toad life cycles have four stages—egg, tadpole, metamorph and adult frog. The life cycle begins with two parents mating. During mating the male clings onto the female until she passes her eggs into the water. Then the male sheds (spreads) a fluid over the eggs that contains special cells called sperm. Sperm are special cells involved in reproduction. One sperm cell fertilises the egg. Most frog parents then leave the eggs and give them no parental care. Tiny tadpoles develop inside the fertilised eggs, then break out of the egg and gradually grow larger. As the tadpole grows, it develops legs. It is now known as a metamorph (or froglet). The gills it used for breathing in water are gradually replaced by lungs for breathing air. The metamorph slowly absorbs its tail as its legs grow longer. Eventually it becomes an adult frog and can produce its own offspring.

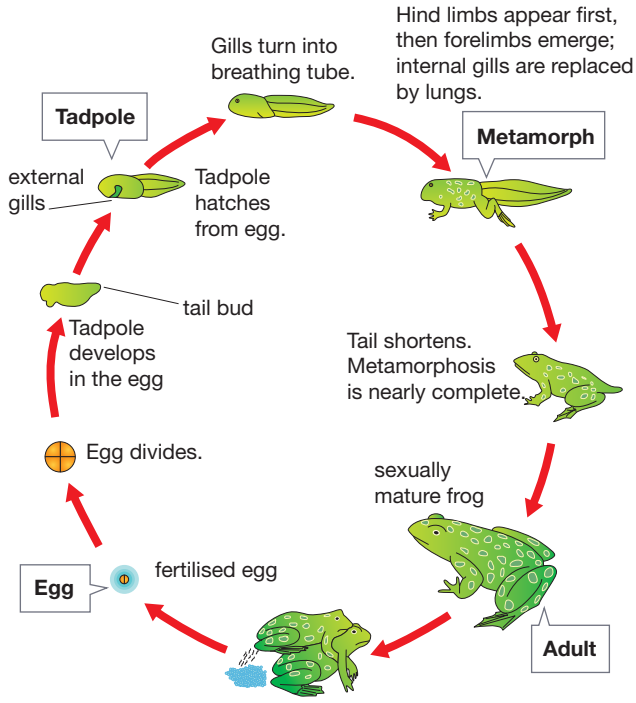



**Figure 4.1.4** The female lays 500–5000 eggs, which the male fertilises.

The life cycle of a frog, showing four main stages: adult, egg, tadpole and metamorph (or froglet)

2 p138 4.2



**Figure 4.1.3** A gastric brooding frog giving birth to its young after raising them in its stomach. The paperclip shows how small this frog is.

**SciFile**

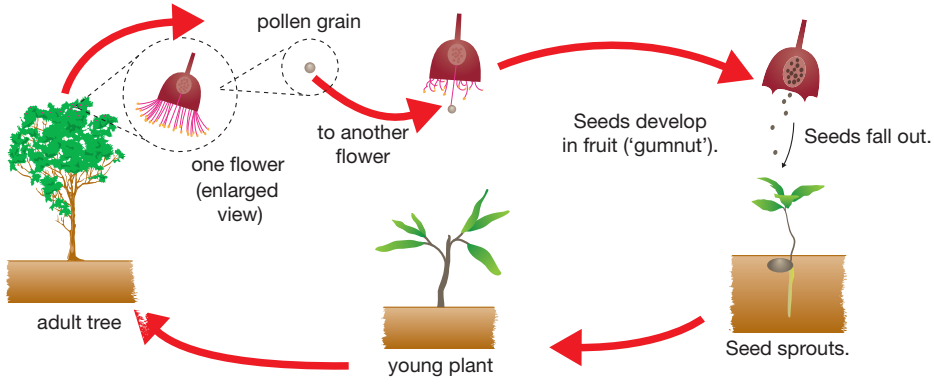
### Stomach breeders

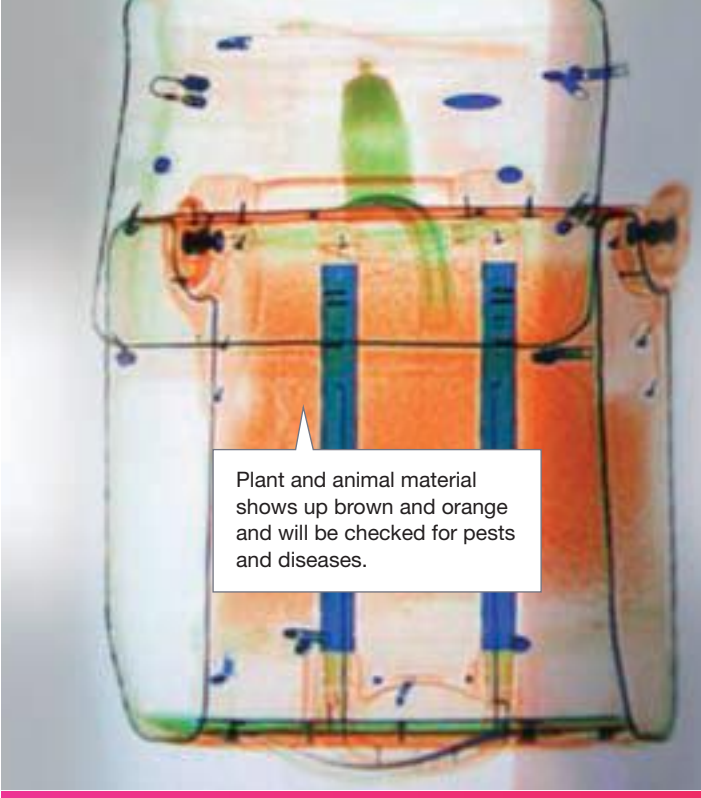
The females of Queensland's gastric brooding frogs protected their young by swallowing their fertilised eggs. The female frogs did not eat while the young frogs developed in their stomach. They gave birth by vomiting out the froglets just when their legs were developing. Gastric breeding frogs haven't been found in the wild for many years and may be extinct.

# Plant life cycles

Plants have many different types of life cycle. In Figure 4.1.5 you can see the life cycle of a eucalyptus tree (gum tree), which is a flowering plant. The tree produces flowers, special structures that make seeds. Flowers produce tiny particles called pollen, which contain a special male reproductive cell called a sperm. This must join with the female egg in a different part of the flower. When these two particles join up, they develop to form a seed. The seed will sprout (germinate) and grow into a new adult tree.

**Figure 4.1.5** The life cycle of a eucalyptus tree






# SCIENCE AS A HUMAN ENDEAVOUR

## Use and influence of science

### Customs and quarantine

**Figure 4.1.6** This is what a quarantine inspector might see when your bag is X-rayed.

At airports and shipping ports, Australian Customs Service officers can be seen inspecting passengers' luggage. Sometimes instead they check X-rays of the luggage. This is shown in Figure 4.1.7. They are not just looking for drugs. They are also looking for items that could accidentally bring serious diseases or pests into Australia that could affect our health or destroy our agriculture and tourism. Preventing the entry of disease-causing organisms and pests into a country is known as **biosecurity**.

Items brought back from overseas can carry live organisms at various stages in their life cycles. For example, the souvenirs you bring home might contain insects as eggs, larvae, pupae or adults. Some may be hard to see, such as insect larvae living inside wood or plants. Pupae can be found inside wood or on leaves. Adult insects, such as weevils, can be found inside seeds. Food can contain microscopic bacteria and viruses and these will be impossible to find on inspection at the airport. Soil can carry all these organisms too.

For these reasons, the following items are not allowed into Australia:

- dairy products (such as cheese)
- uncanned meat (such as salami)
- seeds (such as spices)
- fruits and vegetables
- live animals and plants (some might be hidden inside souvenirs made of wood or cane)
- soil, dirt or mud (some might be trapped in the treads of your shoes).

Sometimes living organisms can be imported under licence. For example, racehorses, dogs and cats can be imported but need to be placed in quarantine (away from other organisms) and observed to make sure they do not have infectious diseases. Non-living items such as wood and cane furniture and souvenirs can be fumigated with chemicals to kill any live insects, worms and bacteria they may contain. A specialist division of the customs service called the Australian Quarantine Inspection Service (AQIS) carries out these tasks. One of their posters is shown in Figure 4.1.8 on page 136.

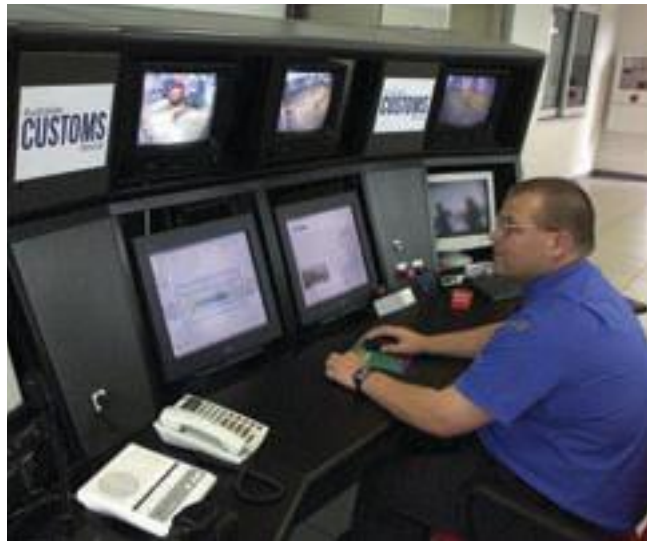



**Figure 4.1.7** A customs officer checking X-ray images for prohibited items in passengers' luggage




**Figure 4.1.8** This poster from the Australian Quarantine Inspection Service (AQIS) shows organisms that pose a threat to our health and industries.




**Figure 4.1.9** Varroa mites on a honey bee

Some of the biosecurity threats to us are shown in Table 4.1.1.

**Table 4.1.1 Biosecurity threats to Australia**

| Threat organism | Where is it found? | What is the threat? |
|---|---|---|
| Red imported fire ant | South America, USA | An insect that is aggressive and has a painful sting that can cause allergic reaction and even death in humans. Will prevent an outdoor lifestyle and can kill native wildlife. |
| Varroa mite (Figure 4.1.9) | Worldwide | A mite that feeds on European honey bee larvae and adults, destroying the colony. Could destroy beekeeping and the orchards and nurseries that depend on bees. |
| Asian longhorn beetle (Figure 4.1.10) | China, Korea, Japan, USA | An insect that burrows into the wood of trees and into timber. Could destroy Australia's forests and timber industry. |
| Guava rust | North and South America | A fungus that affects eucalypts, corymbias, bottlebrushes and paperbarks and other plants in the myrtle family. Can kill young trees and seriously slow the growth of adult trees. |
| Rabies virus | Most of the world except Australia, New Zealand, UK | A virus that infects animals such as dogs, foxes and humans, causing death in about four days. Can be treated, but about 40 000 people die each year from it. |
| Bird flu virus | Worldwide, though rarely in Australia | A virus that infects and often kills birds. Some strains can infect humans and some deaths have occurred. |



**Figure 4.1.10** Asian longhorn beetles burrow into the wood of trees

# 4.1 Unit review

## Remembering

1 **Name** the process by which parents produce offspring.

2 **List** the four stages in the life cycle of a butterfly.

3 **List** the three stages of an incomplete metamorphosis life cycle in insects.

4 **Recall** what happens inside a butterfly pupa.

5 **List** five types of item that are not allowed to be brought into Australia.

## Understanding

6 **Explain** why reproduction is a necessary part of a life cycle.

7 **Describe** some structural changes that occur when a tadpole becomes a frog.

8 **Describe** some structural changes that occur as a grasshopper nymph becomes an adult.

9 **Define** the following terms.

- **a** reproduction
- **b** life cycle
- **c** growth
- **d** development
- **e** biosecurity

10 **Explain** the role of the Australian Customs Service and AQIS.

11 If you move overseas and take your dog with you, it may have to stay in isolation at a quarantine area for several months. **Explain** why quarantine is necessary.

## Applying

12 **Identify** the following stages in the life cycle of a mosquito, which undergoes complete metamorphosis.

- **a** This stage lives in water and feeds on microscopic plants.
- **b** This stage breaks out of its skin at the water surface and flies away.
- **c** These are laid by the parent in water.
- **d** This stage does not feed at all, but develops wings, different eyes and long legs.

13 A person arrives by plane in Australia with some plant seeds, honey and dried flowers in their luggage. **Identify** possible problems they might have with Customs.

## Analysing

14 **Compare** the life cycles of a grasshopper and a frog.

15 **Compare** the life cycles of a butterfly and a grasshopper.

16 Refer to the life cycle of the wanderer butterfly to help you **compare** growth with development.

## Evaluating

17 The gastric brooding frog protected its young in the mother's stomach. A biologist claims this gave the young a greater chance of surviving than the young of other frogs. **Justify** this claim.

18 The larvae of houseflies are called maggots. They feed on decaying plant and animal matter. Understanding the life cycle of the housefly could help home owners to control houseflies. **Propose** how.

## Creating

19 **Construct** a pamphlet for airline travellers about the dangers of bringing banned substances into Australia from overseas.

## Inquiring

1 Research how Aboriginal people survived by observing the life cycles of plants and animals that they hunted or harvested. In your answer give relevant examples of a plant and an animal.

2 Research how methods in agricultural science, farming or fishing have improved through knowing about life cycles of plants and animals. Choose one plant and one animal. Some plants you could research are crops, introduced weeds and poisonous native plants. Animals you could research include livestock and native animals.

3 Life cycles such as that of a butterfly puzzled biologists for a long time. Research and report on the advantages to the insect of having very different stages in its life cycle.

# 4.1 Practical activities

## 1 Animal life cycles

### Purpose
To compare different animal life cycles.

### Materials
- live or dead specimens from the life cycle of animals such as fruit flies, mosquitoes, houseflies or silkworms
- information sheets on each animal
- glass jars
- cotton wool
- food scraps
- hand lenses or stereo microscopes

### Procedure
Move around the room from one animal to another. Observe each and decide on the order in which the stages occur in the life cycle.

### Results
1. Draw each stage in a simple outline diagram. Name the animal, label each stage and connect the stages with arrows.
2. Write on your diagram any additional information that may be on an information sheet near the specimens.

### Discussion
**Compare** the life cycles of the animals you observed.

## 2 Plant life cycles

### Purpose
To compare different plant life cycles.

### Materials
- specimens or diagrams from the life cycle of plants such as flowering plants, moss, ferns, conifers and cycads
- hand lenses or stereo microscopes

### Procedure
Move from one plant specimen to another. Observe each and decide on the order in which the stages occur in the life cycle.

### Results
1. Draw each stage in a simple outline diagram. Name the plant, label each stage and connect the stages with arrows.
2. Write on your diagram any additional information that may be on an information sheet near the specimens.

### Discussion
**Compare** the life cycles of the plants you observed.



**Figure 4.1.11** Both the wild chicory plant and the bee have life cycles but each is very different.

# 4.2 Reproduction and survival

Nothing lives forever. An insect may live for only a few weeks. A tree may last thousands of years. Since every individual will eventually die, there must be a way of producing new individuals or the species will become extinct. This production of new individuals by parents is called reproduction. It is one of the most amazing processes in nature.



INQUIRY science 4 fun

## Flowers

What is in a flower?

No

### Collect this…

- 2 different garden flowers (make sure they are not poisonous)
- pair of tweezers
- knife or fine pair of scissors

### Do this…

1. Look at each flower and identify parts of the two flowers that look similar.
2. Carefully pull each flower apart and place its different parts into separate piles. Each pile should have parts that look similar.
3. Try to find some seeds.
4. Think about the function (role) of the different parts of the flower.

### Record this…

**Describe** what you observed.

**Explain** how each part might contribute to the life of the flower.

## Methods of reproduction

Unless you have an identical twin, no one else is like you. However, all the plants in a crop of potatoes can be identical. This is because humans and potatoes reproduce in different ways.

There are two basic methods of reproduction:

- sexual (needing two parents)
- asexual (needing only one parent). 'Asexual' means 'without sex'.

Although most plants and animals use only one of these methods, some can use both.

## Sexual reproduction

**Sexual reproduction** happens when a sperm (from a male) and an egg (from a female) join together in a process called **fertilisation**. Sperm and eggs are special reproductive cells, called gametes. The male sex cell is sperm and the female sex cell is the egg. Fertilisation results in a new cell (called a **zygote**), which then grows by dividing to form many copies of itself. The zygote eventually grows and develops into a new individual. In Figure 4.2.1 on page 140 you can see many human sperm around a single egg.

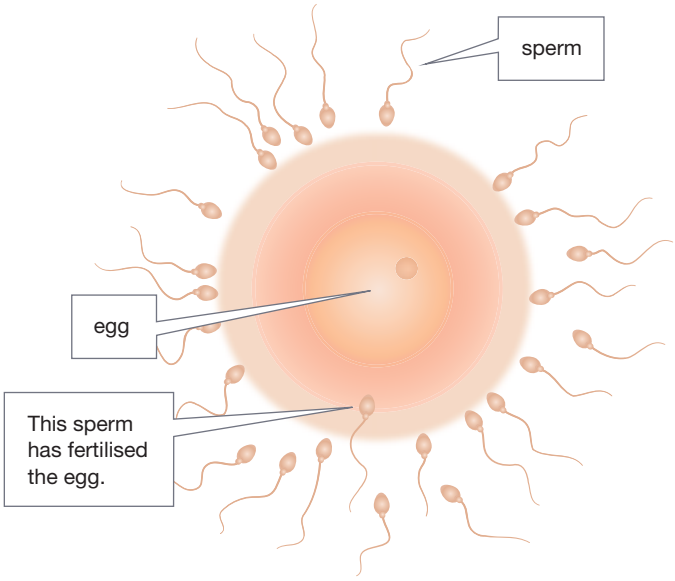
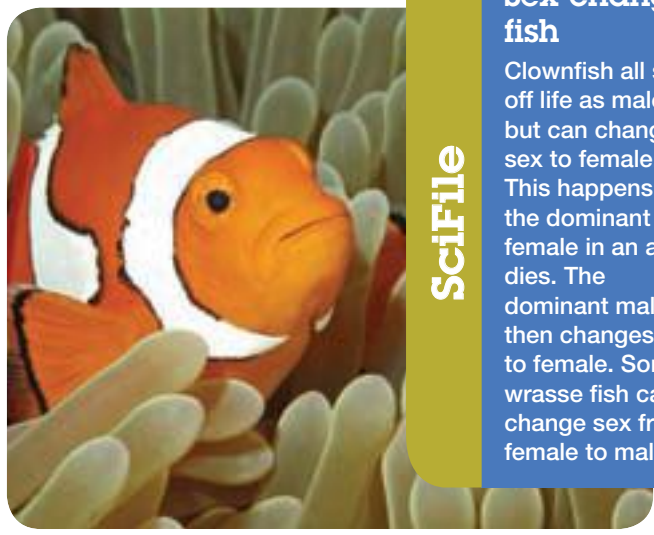



**Figure 4.2.1** Human sperm and an egg. Sperm have a tail to help them swim. During fertilisation only one sperm enters the egg.

Humans, dogs, cattle, birds and kangaroos undergo sexual reproduction and need two parents, one male and one female.

A few species like tapeworms have individuals that have both male and female sex organs. They can therefore produce both sperm and eggs. Individuals with both sex organs are known as **hermaphrodites**. In Figure 4.2.2 you can see a flatworm, which is a hermaphrodite. The ovaries make the female gametes and the testes make the male gametes.



**SciFile**

### Sex-change fish

Clownfish all start off life as males, but can change sex to female. This happens if the dominant female in an area dies. The dominant male then changes sex to female. Some wrasse fish can change sex from female to male.

## Sexual reproduction in flowering plants

**Flowers** are reproductive structures in plants that produce the gametes and allow fertilisation to occur. This results in a seed. You can see a typical flower in Figure 4.2.3.

To form a seed, the pollen produced in the **anther** needs to be deposited on the **stigma**. The transfer of pollen to the stigma is known as **pollination**. The pollen grain develops into a long tube called the pollen tube that grows through the **style**. The pollen tube grows down to the ovary and into the egg. In flowering plants, the egg is inside a structure known as the ovule. During this process, the male gamete passes down the pollen tube to join the female gamete in the ovule. After this joining of male and female gametes, a seed gradually develops.

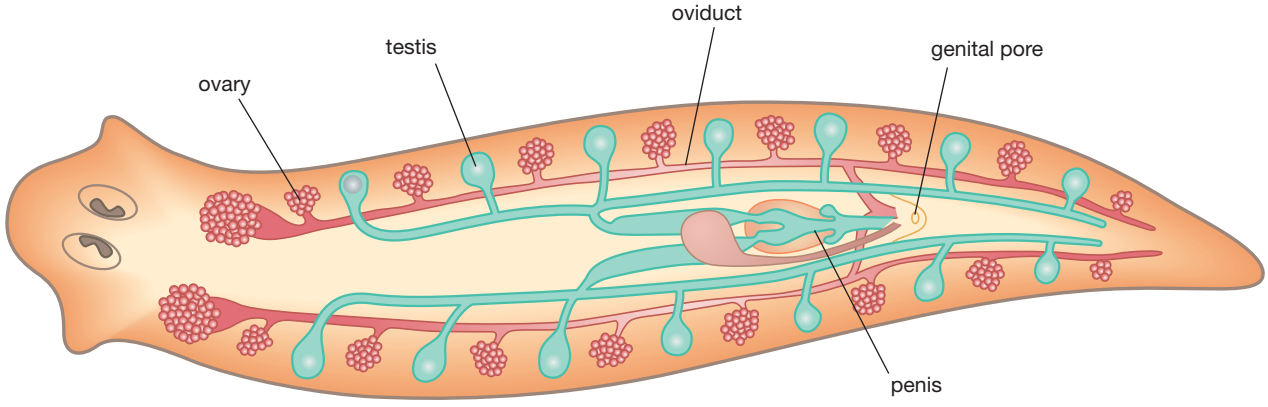



**Figure 4.2.2** This flatworm is a hermaphrodite, with both male sex organs (shaded blue) and female sex organs (pink). The penis passes sperm to another flatworm through a small tube called the genital pore. The oviduct is a tube for the egg to move to the genital pore.

Seeds develop in a structure in plants called the fruit. A **fruit** is the remains of the ovary, plus all the seeds it contains. In some plants, fruit will appear as seed cases or pods. This means that fruit range from very juicy (like an apple) to hard and dry seed cases like a gumnut.

A seed is a capsule containing a new plant, called an **embryo**. The embryo is at a very early stage of its development, supported by a food supply inside the seed. You can see a seed in Figure 4.2.4.

The embryo in a seed is dehydrated (dried out) and requires water and warmth before it will grow. The seed swells up by absorbing water, and this triggers the growth of the embryo.

The embryo then sprouts out of the seed in a process called **germination**. The embryo uses the stored food in the seed and begins to grow. It will begin making its own food when it reaches the sunlight above the ground.

1 p148 2 p149 4.3

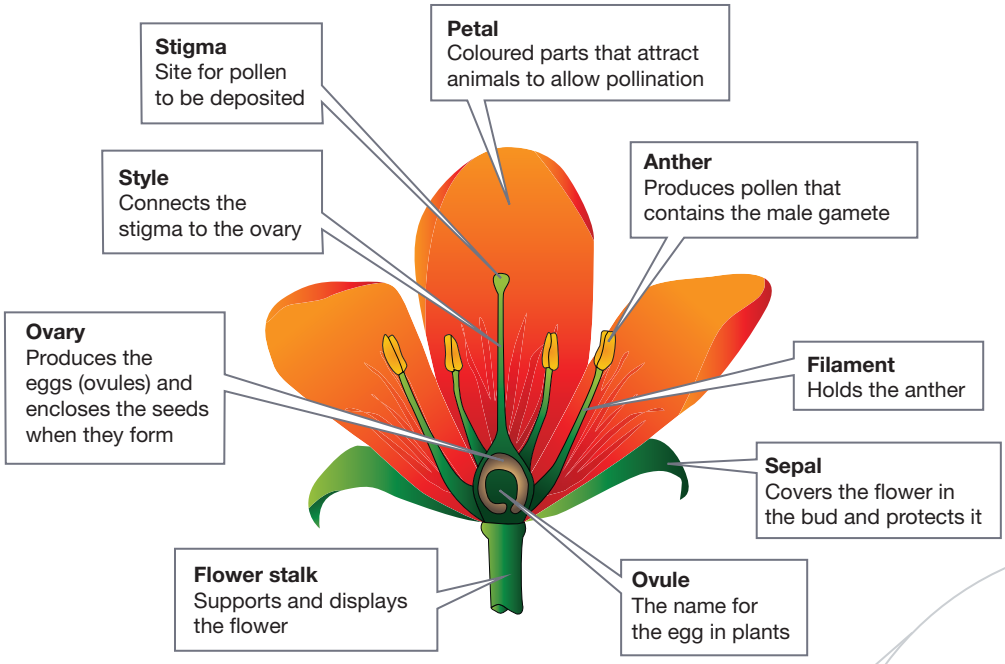



**Figure 4.2.3** A flower is a reproductive structure.

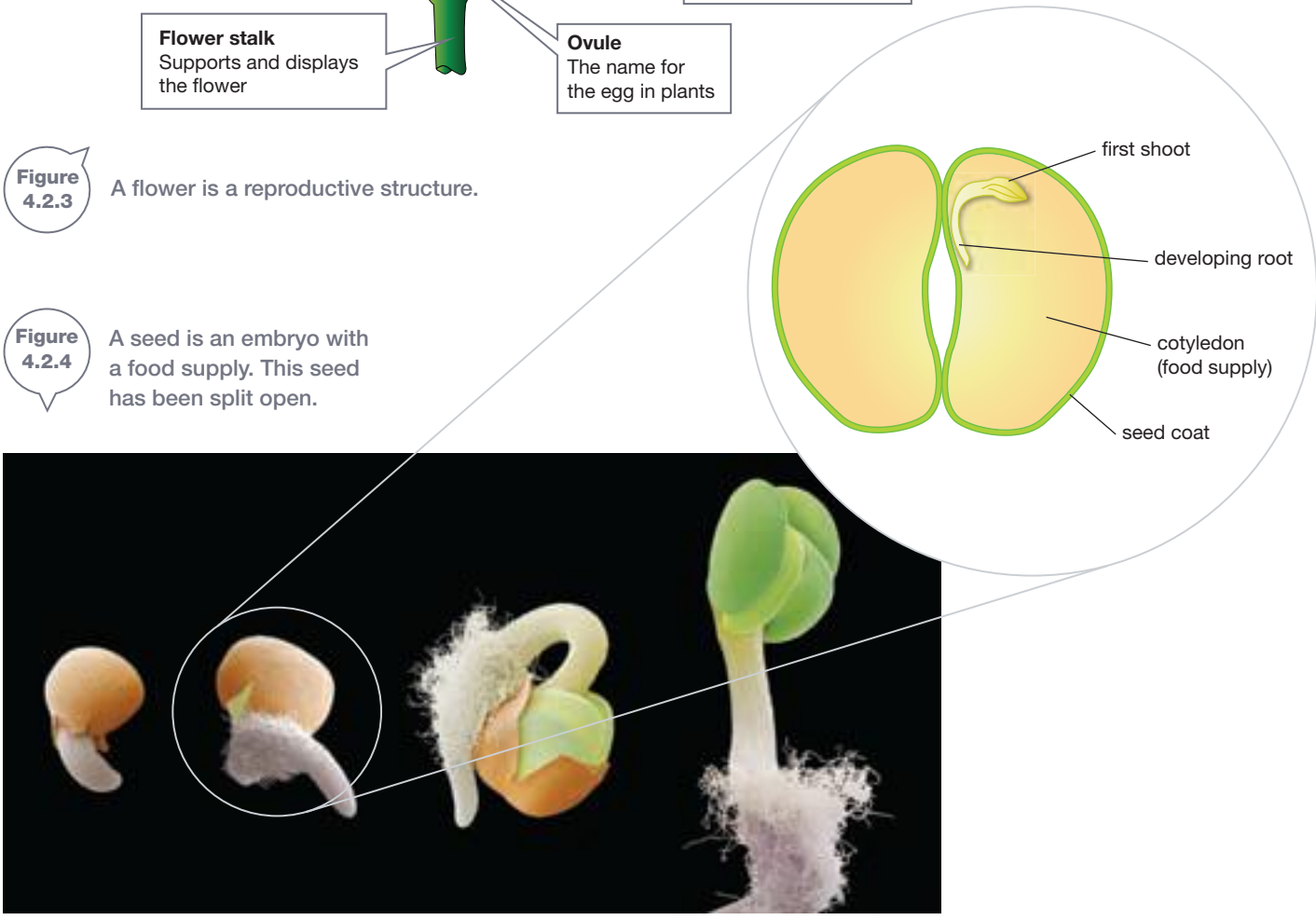



**Figure 4.2.4** A seed is an embryo with a food supply. This seed has been split open.

Plants other than flowering plants have different methods of sexual reproduction. Conifers such as pine trees also make seeds, but they do not have flowers. They produce seeds in a cone. Ferns and mosses do not make seeds, but they still produce embryos. But all plant groups show the basic feature of producing male and female gametes that then join to form a new individual.

## Sexual reproduction in animals

Sexual reproduction can be very different in different animals. The differences are:

- how and where fertilisation occurs
- where the young develop
- the amount of parental care.

### Site of fertilisation

Fertilisation takes place outside or inside the body, depending on the animal involved.

External fertilisation happens outside the body. Figure 4.2.5 shows fish fertilising eggs in the water. The sperm are also shed into the water and swim through it to reach the eggs. Frogs and most fish do this, and so do sea urchins and jellyfish. The water stops the sperm from drying out and they can swim through it.

Internal fertilisation happens inside the body. All land animals use internal fertilisation, as do some water-based (aquatic) species.

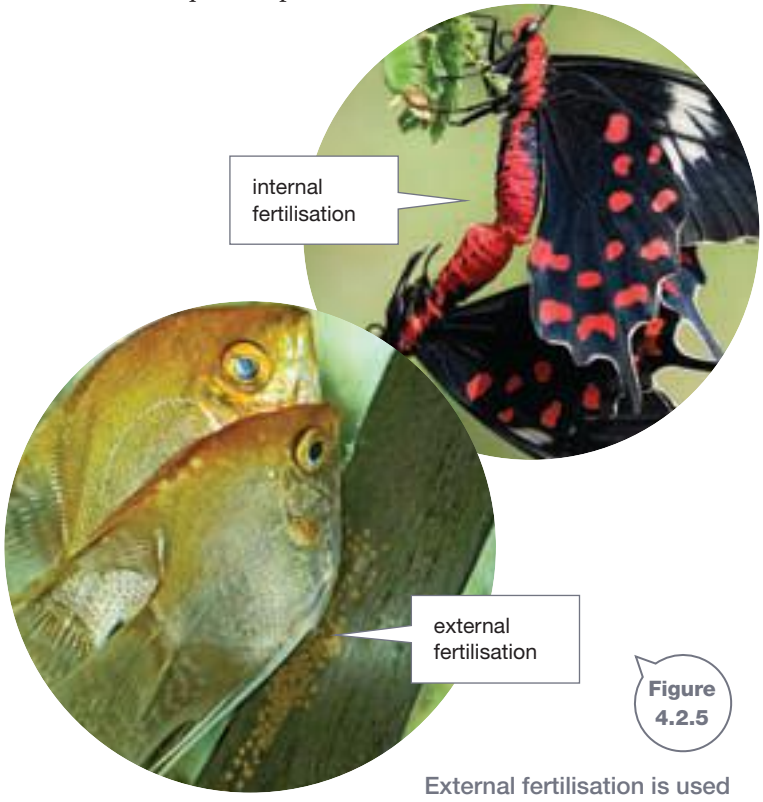



**Figure 4.2.5** External fertilisation is used mainly by water animals like fish, and internal fertilisation is used mainly by land animals such as insects.

Internal fertilisation is better for land environments because sperm shed into the air may dry out and die. The act of joining together of the male and female to transfer sperm is called **copulation**. There are many different ways this happens. In dogs, the male inserts his penis into the female. In the octopus, the male transfers sperm with one of his tentacles.

### Development

**Development** is the process in which the new individual changes to look like others of its type. The young can develop inside or outside the parent's body. Most mammals (animals that feed their young on milk) have internal development—the young develop inside the mother's body. Marsupials such as kangaroos have part internal and part external development. Most other animals, such as spiders, amphibians, birds and most reptiles and fish have external development. For example, birds lay eggs and the young develop inside the egg until they hatch. This is happening in Figure 4.2.6. Most aquatic animals also have external development.

### Parental care

Parental care is common in animals such as mammals and birds. These animals have relatively large brains that need time to develop.

A human baby stays with its parents until it is mature enough to live independently. Birds also show a period of parental care. Most other animals show little or no parental care, especially once the eggs hatch. The general rule is that more complex animals need more parental care. As a human, you are a very complex animal and require a lot of parental care.

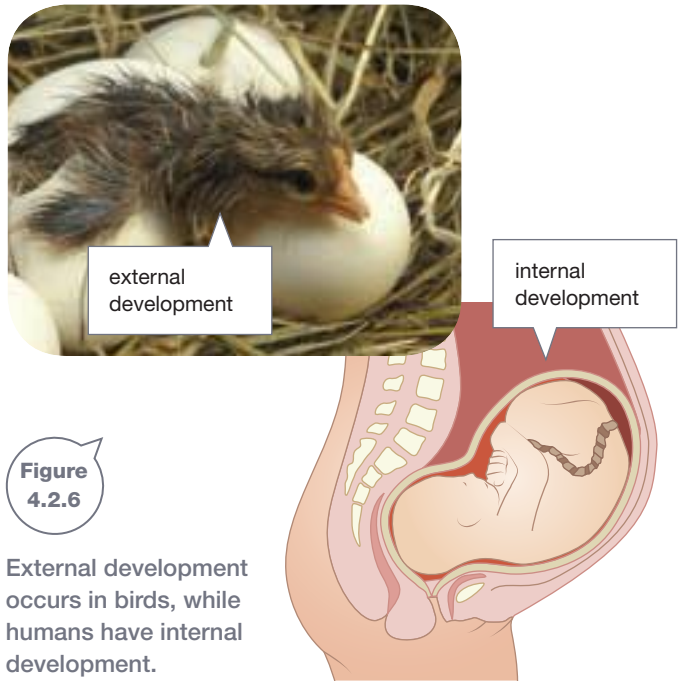



**Figure 4.2.6** External development occurs in birds, while humans have internal development.

# Asexual reproduction

**Asexual reproduction** requires only one parent. It occurs when a new individual grows from part of the parent's body. It does not involve sperm or eggs. An example is the freshwater animals called hydra. Hydra are relatives of jellyfish, and can reproduce both sexually and asexually. Figure 4.2.7 shows a young hydra growing from its parent. The young one was formed by asexual reproduction. It will break off the parent and lead a separate life.

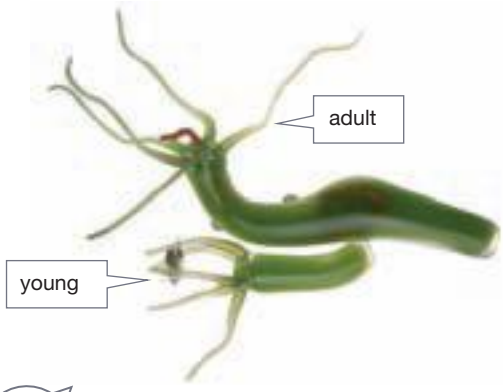



**Figure 4.2.7** This adult hydra has a young hydra that was produced asexually still attached to it. The young one has caught a small water animal to eat.

INQUIRY science 4 fun

## Hydra breakdown

What grows on a hydra?




### Collect this…

- a live budding hydra in cavity slide without a coverslip (or a prepared microscope slide)
- hand lens

### Do this…

Use the hand lens to observe your hydra carefully. Search its whole body looking for a bud.

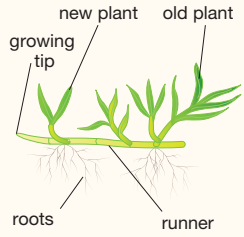
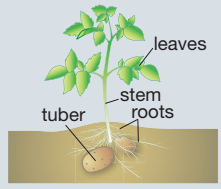
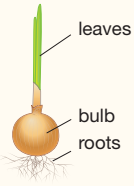
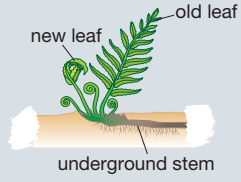
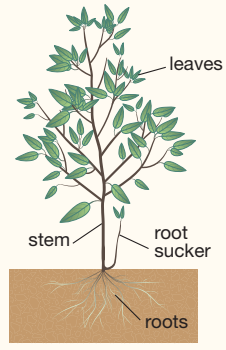
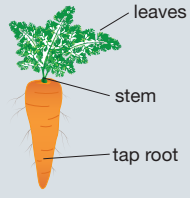
### Record this…

**Describe** what you observed.
**Explain** what its function is.

## Asexual reproduction in plants

In plants, asexual reproduction can occur by vegetative reproduction or by spores. Vegetative reproduction in plants is shown in the Table 4.2.1.

**Table 4.2.1 Methods of vegetative reproduction**

| Vegetative reproduction method | Plants that show this | Structures involved | |
|---|---|---|---|
| Runners | Many grasses, strawberries, ivy, violets | Stems run along the ground surface. They send down roots at intervals. |   |
| Stem tuber | Potato, yam | Swellings called tubers are attached to the stem underground and full of stored food. |   |
| Bulbs | Onions, tulips, daffodils | Underground 'leaves' are full of stored food. |   |
| Underground stem | Bamboo, bracken | Stems run along underground and send up leaves at intervals. |   |
| Root suckers | Some eucalypts | Roots send up stems where they come near the surface. |   |
| Tap root | Carrot, beetroot | Swollen roots are full of stored food. |   |

Fungi and plants such as ferns and mosses use spores to asexually reproduce. A spore is a microscopic single cell. Spores are used by plants and fungi to help them spread to many other places. This spread is called dispersal. Spores have a protective wall around them but are very light and easily carried by wind or water. They can also be carried by animals. You can see some places where spores are produced in Figure 4.2.8.

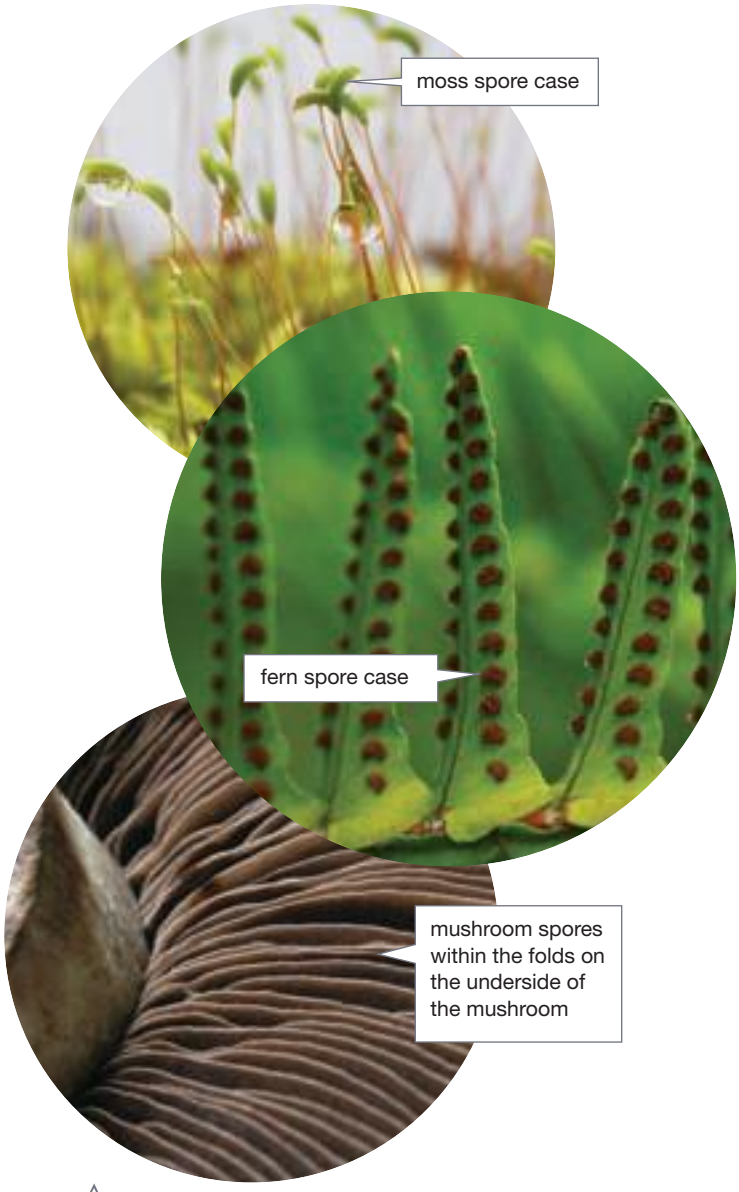



**Figure 4.2.8** Plants such as ferns and mosses produce spores, as do fungi.

## Asexual reproduction in simple organisms

Many simple organisms have bodies made of only one cell. One such group of single-celled organisms is the protozoa. Protozoa reproduce by dividing in two in a process called fission. You can see this in Figure 4.2.9.

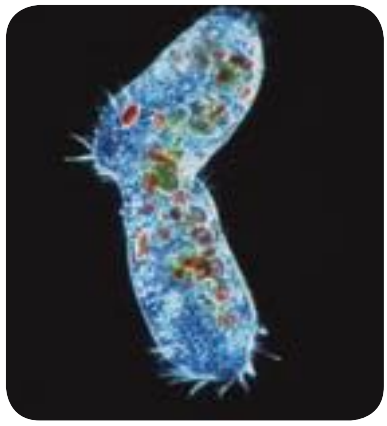


**Figure 4.2.9** This protozoa has nearly completed the process of dividing into two.

## Asexual reproduction in animals

Few animals reproduce asexually. One that does is the hydra. Budding is the name for the process of asexual reproduction in the hydra, shown in Figure 4.2.7 on page 143. Another type of asexual reproduction is called **parthenogenesis**, where offspring develop from eggs that have not been fertilised by a male gamete. Parthenogenesis happens in water fleas, aphids, some bees, and a small number of reptiles and fish.

3 p150

# Reproduction and the environment

Each type of reproduction, sexual and asexual, has advantages and disadvantages. The type of reproduction an organism uses is related to its environment.

## Asexual reproduction and the environment

In some environments, asexual reproduction is an effective method of reproduction, particularly for:

- organisms that live a long way from others of their kind—they are able to reproduce without having to find a mate
- organisms that cannot move very far—they do not have to find a mate
- environments that do not change much—the offspring will all be identical and therefore all will be suited to surviving in the environment.

However, asexual reproduction can have disadvantages. The major problem is if the environment changes in some way. Then the problem is that all the individuals in a species that uses asexual reproduction are identical. Imagine if a new disease swept through a population. If every individual is identical, then they will all be vulnerable to the disease and they could all die. You can see an example of this in Figure 4.2.10. In this way, a species could become extinct.



Figure 4.2.10

Disease can easily wipe out a whole crop of plants if all the plants are similar. This is a fungus attacking a grass lawn and killing almost every plant.

## Sexual reproduction and the environment

Sexual reproduction produces offspring that are all different from each other. This helps a species survive in a changing environment.

The survival of a species depends on some individuals being different enough to survive any changes in their environment. When a change occurs, there are likely to be some individuals that are able to cope with the new conditions. They can then breed and continue the species. So having differences means a greater chance of survival for the species.

An example of some individuals surviving because they are different occurred during the Great Plague. In 1346 in England and some other parts of Europe, a disease commonly called the Black Death killed up to half of the population of some towns. But not everyone who was exposed to the disease died. Some people had a natural resistance to the bacteria that caused it. Their bodies could fight the bacteria. Being different gave them a survival advantage.

# Sex and differences

Snails are unusual animals. They are hermaphrodites with both male and female sex organs on the one individual. However, they do not fertilise themselves. They mate with another snail, each passing sperm to the other and each having its eggs fertilised by the other. Cross-fertilising is what is happening in Figure 4.2.11. This process is called **cross-fertilisation**.

Cross-fertilisation is also common in flowering plants. Most species have flowers that are both male and female. But the pollen rarely ends up on the stigma of the same flower. Occasionally it may be carried to another flower on the same plant. Usually it is



Figure 4.2.11

Cross-fertilisation in snails

transferred to a different plant. The flowers avoid **self-fertilisation** by having the stigma mature at a different time from the anthers. So the pollen cannot stick to the stigma of the same flower or even flowers on the same bush. An example is the geranium in Figure 4.2.12.

Cross-fertilisation is important for the survival of a species that uses it. This is because it produces greater differences in the offspring than with self-fertilisation. This is the same reason why sexual reproduction is an advantage to species in a changing environment—because it can produce greater differences in the offspring than asexual reproduction can.

4.4

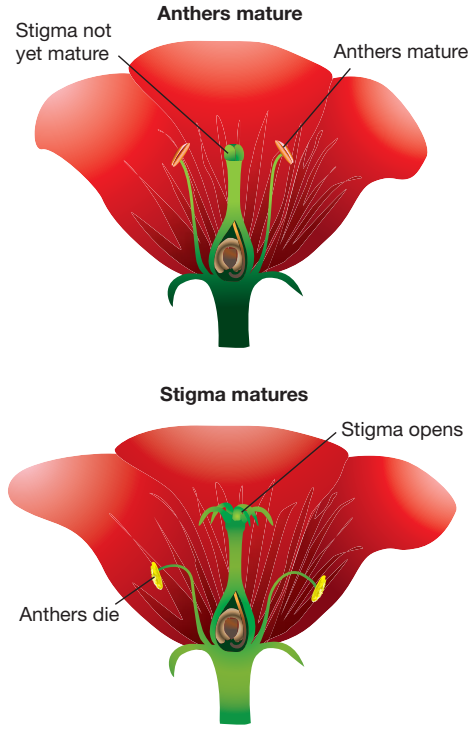



Figure 4.2.12

This geranium avoids self-fertilisation because the anthers and stigma mature at different times.

# 4.2 Unit review

## Remembering

1 **Name** the two main types of reproduction.

2 a **List** five different ways that plants reproduce asexually.
b For each way **identify** one plant reproducing that way.

3 **Name** two methods of asexual reproduction in animals and for each give an example of an animal that uses the method.

4 **Name** the parts of the flower that have the following functions.
a produce pollen
b attract pollinators to the flower
c produce female gametes
d hold the seeds as they form

5 **State** where fertilisation takes place in:
a flowering plants
b frogs
c dogs.

6 **State** the type of reproduction that made you.

## Understanding

7 **Explain** what is meant by reproduction and why it is necessary.

8 If you were told an animal was produced by sexual reproduction, **discuss** whether you could identify how many parents it had.

9 **Define** the following terms.
a fertilisation
b copulation
c embryo
d internal fertilisation
e external development
f hermaphrodite

10 **Explain** some advantages of asexual reproduction.

11 **Explain** some disadvantages of asexual reproduction.

## Applying

12 **Identify** whether each of the following is cross-fertilisation or self-fertilisation and give a reason for your answer.
a A worker bee is produced from a queen that had mated with a male.
b A flatworm individual lives alone in a cow intestine for years and keeps reproducing.
c Platypus are mammals and are male or female. However, they lay eggs that have already been fertilised before they are laid. The young platypus hatches from the egg and is cared for by the parents.
d An Australian pea plant grown nowhere near others of its species flowered and produced seed in England.

## Analysing

13 **Compare** the processes of sexual and asexual reproduction.

14 **Compare** the processes of copulation and fertilisation.

15 **Compare** the processes of internal and external development.

16 **Compare** the suitability of sexual and asexual reproduction for the survival of a species in a changing environment.

## Evaluating

17 Honeyeaters are birds that drink sugary nectar made by plants such as eucalypts and banksias. They are attracted to the bright colours of the flowers. **Propose** why these birds are important to these flowering plants.



Figure 4.2.13 Honeyeaters have long thin beaks that allow them to get to the nectar inside the flowers.

18 **Propose** whether internal development is more likely to occur in animals that are internally fertilised or externally fertilised. **Justify** your answer.

19 Animals such as frogs produce hundreds of fertilised eggs and usually give them no parental care. Humans usually produce one at a time and give it lots of care. **Propose** a reason why there is such a large difference in the number of fertilised eggs produced by frogs and humans.

20 Whales are mammals that had ancestors that lived on land millions of years ago. The way they reproduce still shows this relationship to their land ancestors. **Propose** whether whales have:
- a internal or external fertilisation
- b internal or external development.

21 **Propose** what advantage there could be to a species that uses sexual reproduction to produce many offspring in an environment that is changing rapidly.

22 Asexual reproduction is more commonly found in water environments than terrestrial (land) environments. **Propose** reasons why this may be so.

23 Consider the following situations and **classify** them from those producing the most differences among the offspring to those producing the fewest differences. **Justify** your answer.
- a Bamboo plants connected to one underground stem
- b Plants from the seeds of one flower that was pollinated from another flower on the same bush
- c Plants from the seeds of one flower that was pollinated from a flower from a different bush
- d Plants from the seeds of a self-pollinated pea plant
- e Grass plants in a lawn grown from stem cuttings from three different gardens

## Creating

24 **Construct** a table summarising some differences between animals in:
- a where the gametes are produced
- b how and where fertilisation occurs
- c where the young develop.

## Inquiring

1 Research reproduction in the platypus and echidna, explaining why they are so unusual.

2 Research how temperature affects the proportion of male and female crocodiles hatched.

3 Research how plants are grown from cuttings. Design experiments that will test the suitability of several different plants for propagation by cuttings. Ask your teacher if you can try your experiments.

4 Research the impact of plant cloning techniques in agriculture, such as horticulture, fruit production and vineyards.

5 Research the amazing life cycle of aphids, which can reproduce by sexual reproduction and another process called parthogenesis. Use your research to explain why the aphid uses the different methods of reproduction in different seasons.

6 Research examples of animals that can change sex once they are born (this is known scientifically by the term *sequential hermaphroditism*).



Figure 4.2.14 All barramundi under 3–5 years old are male. They then all turn into females!

# 4.2 Practical activities

## 1 Flower structure and pollination

### Purpose

To compare the structure of different flowers and to propose the method of pollination of each.

### Materials

- blade and forceps
- hand lens or stereomicroscope
- selection of flowers




### Procedure

Carefully observe the structure of each flower. To do this you may have to:



- use a stereo microscope or hand lens to study them
- dissect the flowers carefully using the forceps and blade.

### Results

1. Construct a quick sketch of the basic shape of the flowers. Do not draw in fine detail. Write the name of the plant species on your diagram.
2. Identify all the flower parts and label these on your diagram.
3. On your diagram, write down the general features of the flower, such as its size and colour.
4. Using the table below, decide which method of pollination the flower may have.

### Discussion

For each flower, **justify** your choice of the method of pollination.

| Method of pollination | Flower structure/colour/size | Anther/stamens | Stigma/style |
|---|---|---|---|
| Wind | Often small but many flowers in one head, often no petals, not brightly coloured, no nectar, no scent | Long stamens with large anthers exposed | Long style with exposed stigma, stigma has large surface area—often look like brushes |
| Insect | Usually small, some with many flowers in one head, brightly coloured petals especially blues and yellows, small amounts of nectar, strong scent, often strongly marked with 'landing guides' | Often has short stamens and small anthers, which are close to nectar source in most flowers, sticky pollen | Short style, small stigma close to nectar source |
| Bird | Large strong flowers, some have petals but many don't, lots of nectar, often red | Often has long, strong stamens and large anthers a long way from the nectar source | Long style, smallish stigma, a long way from the nectar source |
| Mammal | Large strong flower heads, much nectar, often not brightly coloured and hidden in plant, nectar produced at night | Strong and rigid | Strong and rigid |

## 2 Germination

### Purpose

To find out what factors affect the germination of seeds.

### Materials

- 5 test-tubes
- 25 wheat seeds
- cotton wool
- labels or waterproof pens
- 1 mL (cool) boiled vegetable oil
- 10 mL (cool) boiled water
- 100°C thermometer
- lamp
- access to dark cupboard and fridge
- digital camera or mobile phone with camera function (optional)

### Procedure

The test-tubes will have the following conditions:

| Test-tube | Conditions |
|---|---|
| A | Light, moisture, oxygen, warmth |
| B | Dark, moisture, oxygen, warmth |
| C | Dark, no moisture, oxygen, warmth |
| D | Dark, moisture, no oxygen, warmth |
| E | Dark, moisture, oxygen, cold |

1. Label the test-tubes with your name and the correct letter A to E.
2. Put a centimetre of cotton wool in the bottom of test-tubes A to E as shown in Figure 4.2.15.
3. Add about 1 mL of tap water to test-tubes A, B and E.
4. Add five seeds to each of test-tubes A to E.
5. Add about 10 mL of boiled (but cooled) water to test-tube D. Add the boiled (but cooled) oil to this test-tube.
6. Put a loose cotton wool plug in the mouth of each test-tube.
7. Place test-tube A under a fluorescent lamp. Your teacher will place a thermometer next to the test-tubes to check the temperature. Place test-tubes B, C and D in a dark cupboard. Place test-tube E in a fridge.
8. Observe or photograph the experiment each day for about 5 days. Record the results in a table.

### Discussion

1. **List** which test-tubes had seeds that germinated, and the conditions in those test-tubes.
2. **Deduce** the conditions necessary for germination.
3. **Explain** which test-tubes you compared to form this conclusion.
4. **Explain** the result in test-tubes C, D and E.

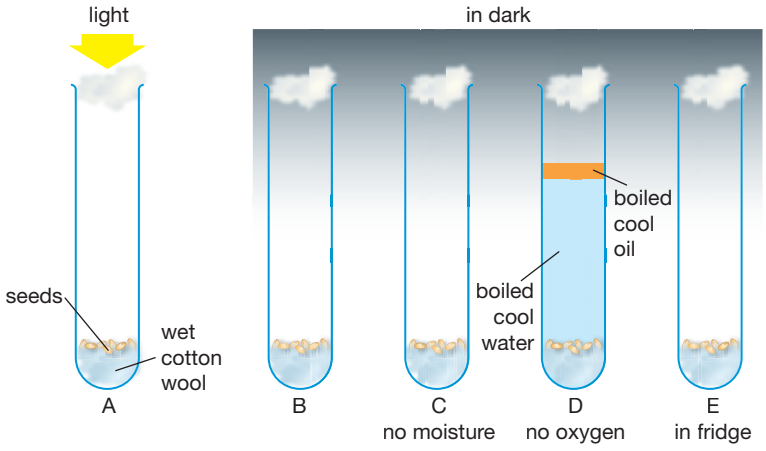



Figure 4.2.15

## 3 Asexual reproduction

### Purpose

To observe examples of asexual reproduction.

### Materials

- onion, garlic, potato, African violet or tree of life (Bryophyllum), geranium, grass, bamboo or bracken
- glass jars
- soil
- toothpicks
- glass slides
- ice-cream containers
- stereo microscope
- digital camera or mobile phone with camera function (optional)

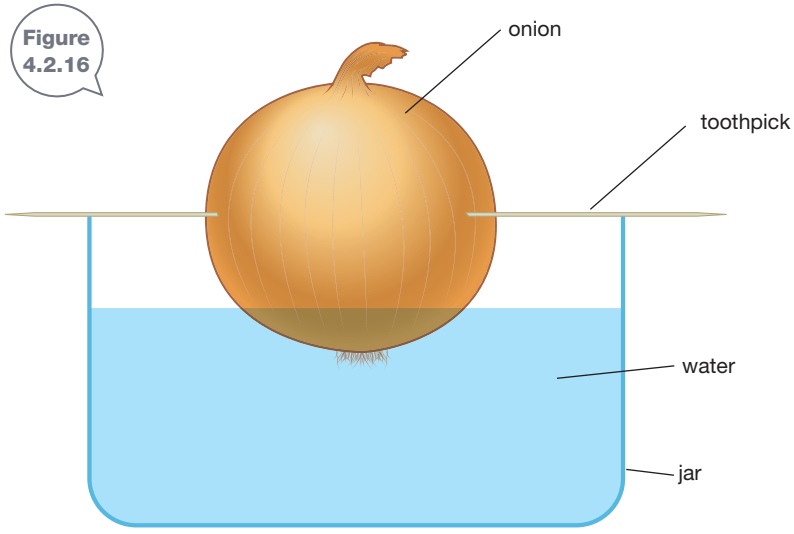
### Procedure

1. Take an onion, a piece of garlic and a potato. Stick some toothpicks in them so that they can be supported on top of a jar of water and just touch the water at the bottom. Figure 4.2.16 shows how to do this using an onion. Fill each jar with water and place them away in a cupboard somewhere. You will check them over the next few weeks.
2. Place a leaf from a tree of life or a geranium on some soil in an ice-cream container. Place a glass slide over the top of the leaf to keep it pressed against the soil. Water the soil. Put the container in a cupboard and check it over the next few weeks. Keep the soil moist.
3. If you are provided with African violets, place the leaf stalk in a jar of water. When roots appear, plant it in soil.
4. Cut a piece of geranium stem about 10 cm long. Strip the leaves off. Stick it in soil, leaving a few centimetres above the soil and then water it.
5. If you have some bamboo stem or bracken stem, break about 10 cm off it and cover it in soil, watering it well.

### Discussion

1. After several weeks, observe or photograph your experiment. **Describe** the appearance of the plant parts.
2. **Identify** the method of reproduction for each of the specimens you studied.

Figure 4.2.16



# 4.3 Human reproduction and growth

The human reproductive system enables us to produce offspring. Its structure suits that function, but it also affects how humans function as an organism. Chemicals from your reproductive organs affect your behaviour, the way you grow, your appearance and how your body works.



## The female reproductive system

The female reproductive system has the role of producing a baby. All of its parts shown in Figures 4.3.1 and 4.3.2 cooperate in achieving this.

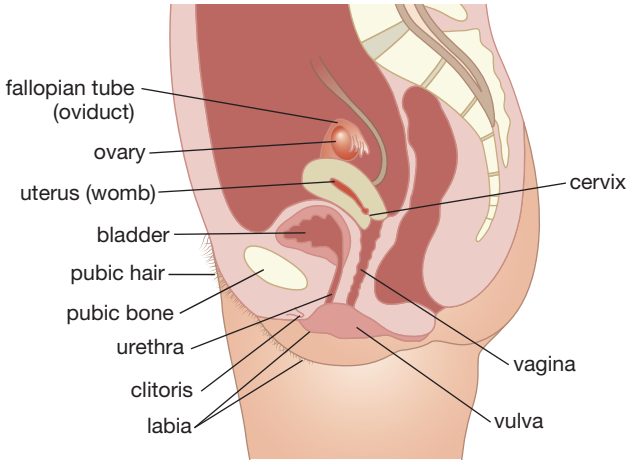



**Figure 4.3.1** A side view of the human female reproductive system

The eggs, or ova, are produced in the **ovaries**. The ovaries are similar in size to an olive. They usually release only one ovum (a single egg) each month, alternating between left and right ovaries. The egg forms in a capsule called a follicle.The egg then bursts out of the follicle.

The **fallopian tubes**, or **oviducts**, are tubes down which the egg passes on its way to the uterus. If the egg meets a sperm and becomes fertilised, it is usually in this tube.

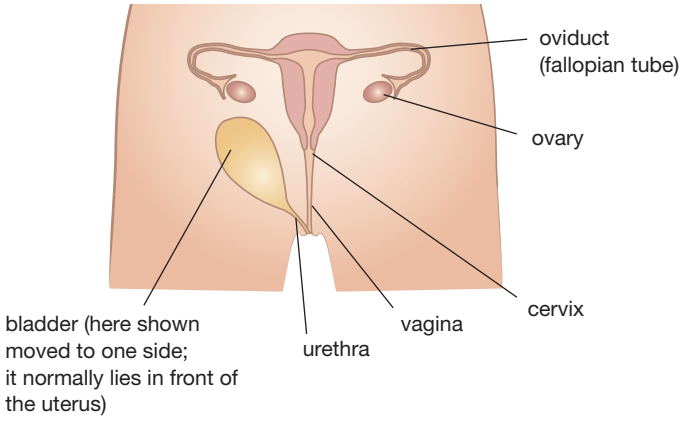



**Figure 4.3.2** A front view of the human female reproductive system

The **uterus** (or **womb**) is a thick-walled muscular organ in the female reproductive system that is about 7 cm long and 5 cm wide. It has a lining called the endometrium that can change and become rich in blood vessels. The fertilised egg enters the uterus and burrows into the endometrium. This process is called **implantation**. The baby grows and develops in the uterus until birth. The uterus can swell up to many times its normal size to allow the baby room to grow. If the egg was not fertilised, then it passes out of the uterus through the lower end.

At the lower part of the uterus is a ring of muscle called the **cervix**. The cervix has the job of contracting tightly to hold the uterus closed while the baby is developing. This protects the baby in the womb. The cervix opens up when the baby is about to be born.

The role of the **vagina** is to allow the male penis to be inserted to deposit the sperm inside the female body. It is also the birth canal down which the baby passes.

## The menstrual cycle

Reproduction in females is controlled by chemicals called **hormones** that are produced in the female body and travel around in the bloodstream. One hormone (known as FSH) causes the follicles to mature. A follicle is shown in Figure 4.3.3. Another hormone (known as LH) makes the egg burst out of the follicle. This is called **ovulation**.

A third hormone called estrogen (also spelled oestrogen) makes the lining of the uterus grow thicker and develop an increased blood supply. Estrogen comes from the follicles in the ovaries. There are other hormones involved as well. The amounts of these hormones change in a cycle over a month. These changes in the body over the month are called the **menstrual cycle**. The menstrual cycle is shown in Figure 4.3.4.

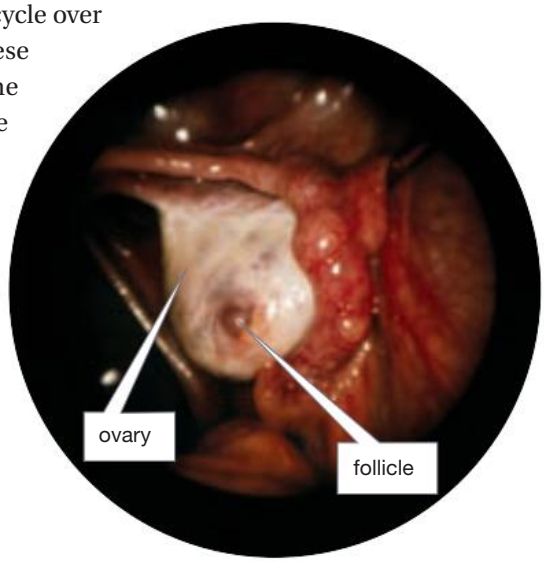



**Figure 4.3.3** A photo inside a woman showing the ovary (the whitish area), and a follicle (red) starting to swell

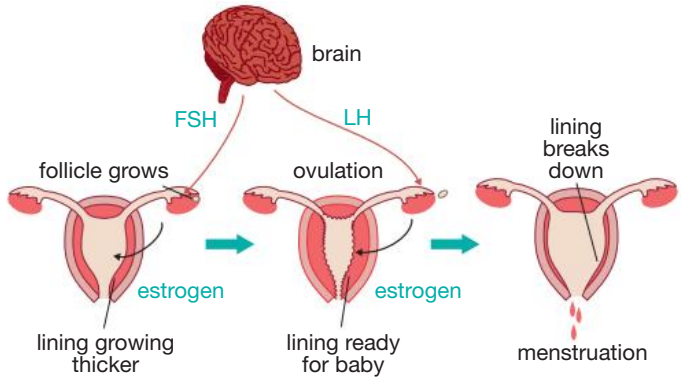



**Figure 4.3.4** The menstrual cycle is controlled by hormones.

If the egg is not fertilised and implanted, the thickened lining of the uterus breaks down. Over the next few days some blood, along with much of the lining of the uterus, passes out of the body. These events are called a **period** or **menstruation**.




### Menstrual cycles

Menstrual cycles can vary greatly in length, especially when they first begin. A typical menstrual cycle is about 28 days once it becomes fairly regular. In a typical 28-day cycle, the first day of menstruation (bleeding) is counted as day 1, and typically lasts 3–7 days. Ovulation occurs at day 14 of the cycle.

You can see this in Figure 4.3.5. In some cycles, ovulation can occur as early as day 9, while in others it may be after day 20. The part of the cycle that stays the same is the time from ovulation to the start of menstruation. This is always 14 days.

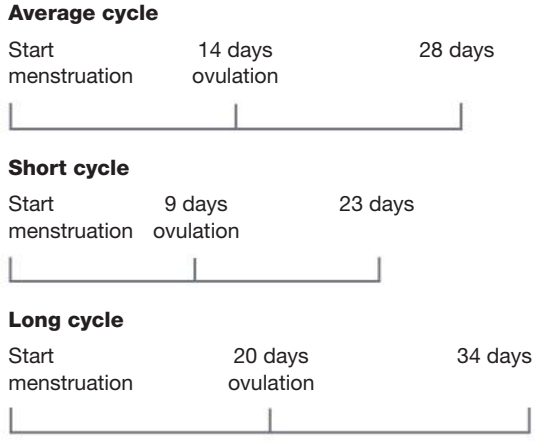



**Figure 4.3.5** The menstrual cycle can vary in length.

WORKED EXAMPLE

## Time of ovulation

### Problem

In a 25-day cycle, on what day would ovulation occur?

### Solution

Time from ovulation to menstruation is always 14 days.

Therefore 25 – 14 = 11 days

So ovulation would have been on day 11 of the 25-day cycle.

# Male reproductive system

The role of the male reproductive system is to produce and deliver sperm. All of its parts cooperate in achieving this. The main parts are shown in Figures 4.3.6 and 4.3.7.

The sperm are produced in the **testes**. There are two testes (singular: testis), each about the size of a golf ball. Testes are also known as testicles. They hang outside the male abdominal cavity in a sac called the scrotum. This is because sperm are killed or deformed if they become too hot and it is cooler in the scrotum than inside the abdomen. The sperm are produced in tubes inside the testes. Then they are squeezed into a coiled tube called the epididymis. There is one on the outside of each testis. There the sperm mature.

To get to the outside of the body, sperm are squeezed by muscles lining the epididymis. They are pushed into a hollow tube about 45 cm long called the **sperm duct**, or **vas deferens**. This tube has muscles in its walls that squeeze the sperm along. On the way, fluid is added to the sperm from glands called seminal vesicles. This fluid contains various chemicals such as sugars that provide an energy source for the sperm. There is also fluid added to the sperm by the prostate gland and Cowper's glands. This mixture of sperm and other fluid is called **semen**. Semen passes out of the penis through the urethra, the same tube through which urine flows. However, urine cannot pass through at the same time as semen.

1 p157

**SciFile**

## Acidic women and basic men

The vagina produces acid to kill infectious organisms like fungi. This acid would kill sperm if the fluid carrying it (semen) did not contain a chemical called a base. This destroys the acid and allows the sperm to survive.

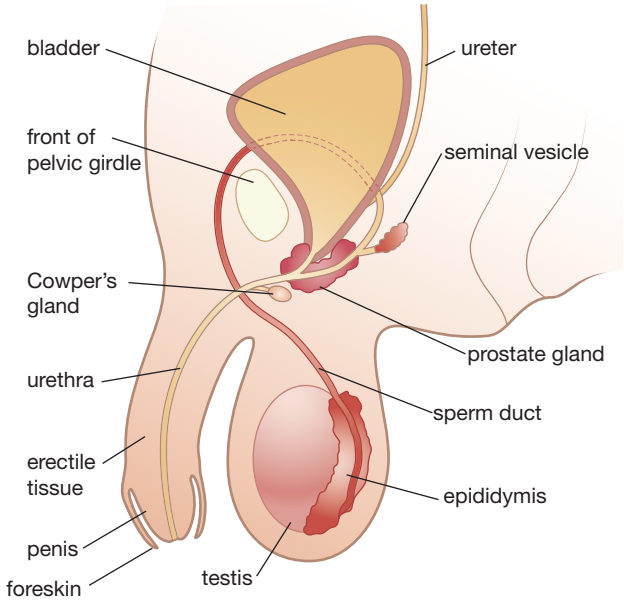



**Figure 4.3.6** A side view of the human male reproductive system

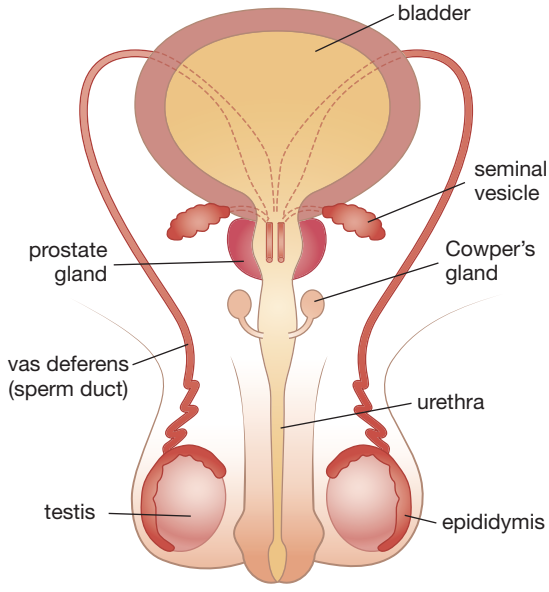



**Figure 4.3.7** A front view of the human male reproductive system

4.5

# Puberty

**Puberty** refers to the time in a person's life when they become able to reproduce. Puberty involves physical changes that bring sexual maturity. The physical changes of puberty take several years to complete. For boys, puberty is when fertile sperm are able to be produced. For girls, it is when the first ovulation occurs.

The time in the life cycle when puberty begins varies greatly. In Australia, girls begin puberty on average around 12 years of age, while boys are generally about 13, but it is not unusual to differ from this. Every person is different, and reaches puberty when their body is ready.

## Changes in males

The early changes of puberty in males are increased levels of some hormones such as testosterone. These lead to some changes you can observe, such as:

- enlargement of the testes
- sperm formation by the testes
- growth of the penis
- the voice 'breaking' to become deeper
- hair growth on the face, arms, chest and groin
- increased muscle and bone growth and strength
- sudden increase in height and chest capacity.

You can see these changes in Figure 4.3.8.

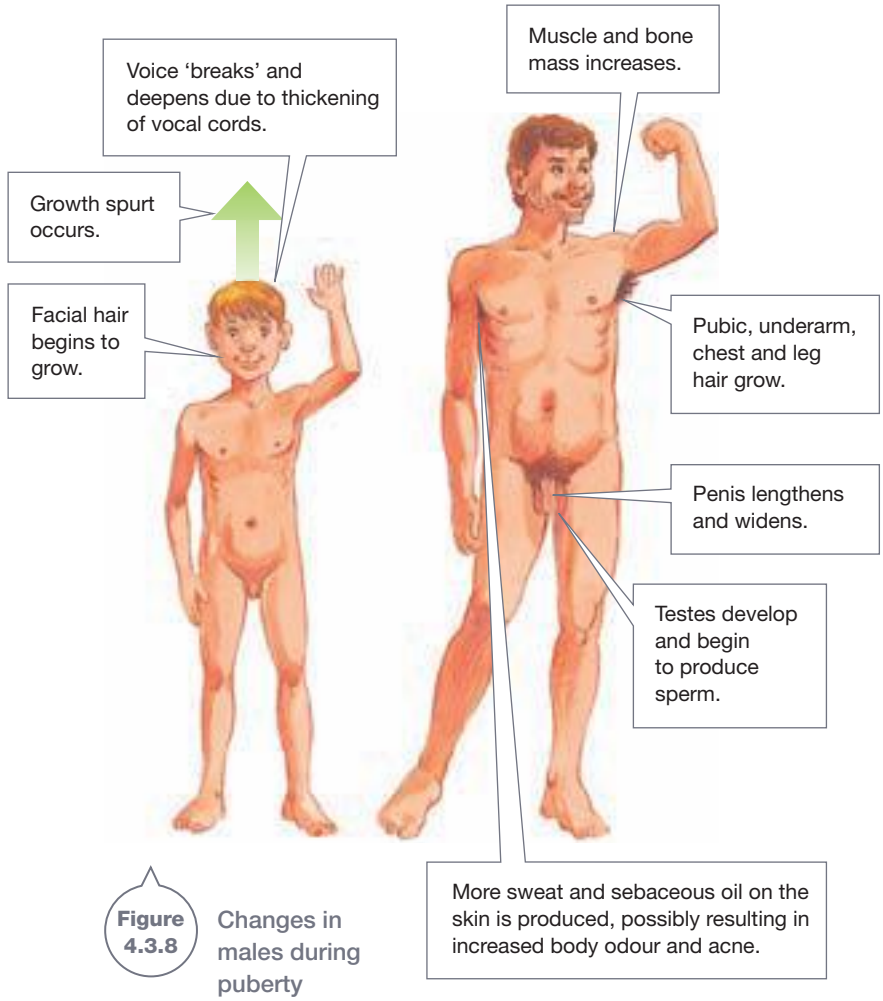


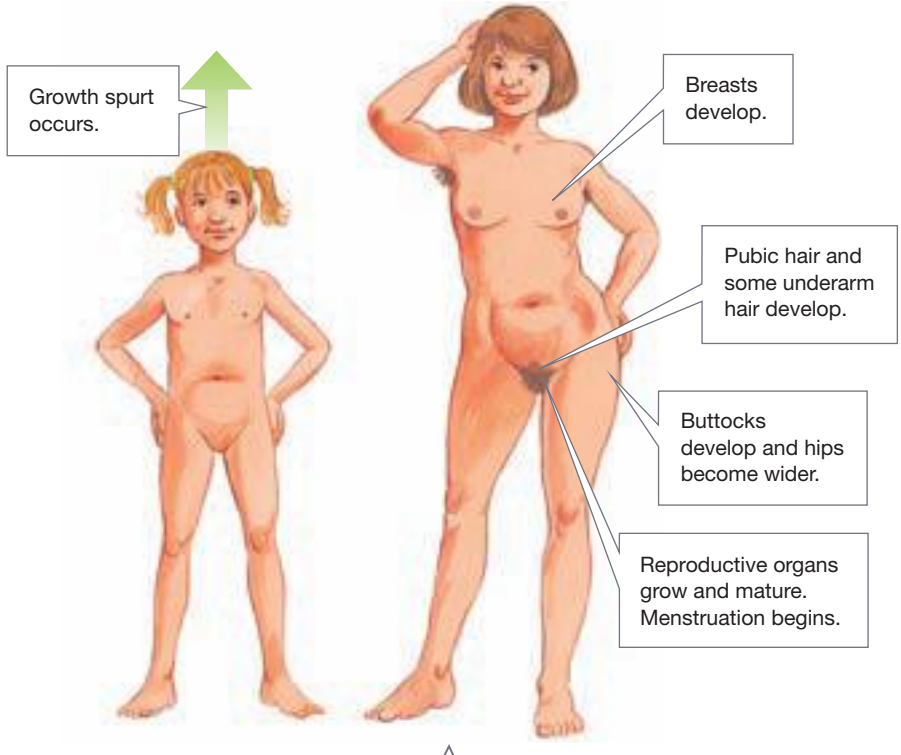

**Figure 4.3.8** Changes in males during puberty

## Changes in females

In girls, the early changes are increased levels of hormones such as FSH and LH. These hormones cause an increase in estrogen. These hormonal changes result in observable changes such as:

- the breasts begin to enlarge—generally the first sign of puberty
- hair grows on the armpits and groin
- a sudden growth spurt
- the first period
- widening of the hips
- more fat deposited in the hips.

You can see these changes in Figure 4.3.9.




2 p157

4.6

**Figure 4.3.9** Changes in females during puberty

# 4.3 Unit review

## Remembering

1 **Name** the parts of the female reproductive system that have the following functions.
   - a Produces eggs
   - b Keeps the uterus closed during pregnancy
   - c Carries the egg to the uterus
   - d Where the baby grows and develops until birth
   - e Site of fertilisation

2 **Name** the parts of the male reproductive system that have the following functions.
   - a Produces sperm
   - b Carries sperm to the penis
   - c Holds the testes
   - d Places sperm in the vagina
   - e Gland beginning with 'p' that adds chemicals to the semen

3 **Name** the female cycle that shows regular changes in hormonal levels.

4 **Name** the female hormones that have the following functions.
   - a Triggers ovulation
   - b Starts eggs maturing each month
   - c Causes the lining of the uterus to thicken

5 **List** the changes in males during puberty.

6 **List** the changes in females during puberty.

7 **Recall** on what day of a 28-day menstrual cycle a woman would ovulate.

## Understanding

8 **Explain** why the lining of the uterus is important in reproduction.

9 **Explain** the role of hormones in the menstrual cycle.

10 **Define** the following terms.
   - a ovulation
   - b period
   - c puberty

11 **Explain** the importance of the testes being held in a sac outside the abdomen.

12
   - a **Name** two components of semen.
   - b **Explain** the function of these components.

## Applying

13 If a woman reaches puberty at age 12 and produces one egg each a month from puberty until she is 50 years of age, **calculate** how many eggs she releases in her lifetime.

14 **Identify** the male reproductive part that has functions in both the reproductive and excretory systems, and describe its role in each.

15 Figure 4.3.10 shows how the proportions of a human body change as they grow.

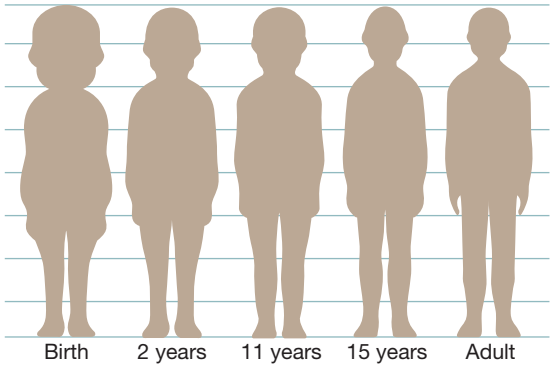



Figure 4.3.10

   - a **Calculate** the fraction of a newborn body taken up by the head.
   - b **Calculate** the fraction of an adult body taken up by the head.
   - c **Identify** the area of the body that appears to have grown fastest in the womb.

16 If ovulation occurs at day 23 in a particular cycle, **calculate** when menstruation occurs.

17 **Calculate** the time from menstruation to ovulation in a 36-day cycle.

# 4.3 Unit review

## Analysing

18 **Compare** ova, ovulation and oviduct.

19 **Compare** oviducts and sperm ducts.

20 **Compare** ovaries and testes in:
- a their position
- b number of gametes produced.

## Evaluating

21 **Propose** why there are millions of sperm in a single ejaculation, but usually only one egg is produced in each menstrual cycle.

22 Study a diagram of the male reproductive system and then **propose** why swelling of the prostate gland could cause difficulty in urinating.

## Creating

23 **Construct** a diagram of the female reproductive system from the front. Next to each organ write its function.

24 **Construct** a diagram of the male reproductive system from the front. Next to each organ write its function.

## Inquiring

Research how twins are formed. Find out what the differences are between:
- identical twins
- fraternal twins
- conjoined twins.



**SciFile**

### Unisex

While in the womb everyone has the same basic reproductive parts up to about the first eight weeks of development. Then these are reshaped and turn into male or female organs.



# 4.3 Practical activities

## 1 Reproduction models

### Purpose
To construct models representing the structure of the male and female reproductive systems.

### Materials
Choose from the different materials provided by the teacher, such as cardboard, scissors, felt-tip pens, sticky tape, modelling clay, string.

### Procedure
1. Make a model of the male or female reproductive system. Use the materials provided. Your model should be 3D, and can have cutaway sections to show what the insides of different parts look like. The aim is to make a model that teaches people about the structure of the reproductive system.
2. You can either suspend the model from string or cotton, or have it on a stand.
3. When all the models are complete, display them around the room.
4. Observe the other models and decide which ones you think are the best.

### Discussion
1. **Justify** why you chose a particular model as the best.
2. **Evaluate** your model and suggest improvements you could have made to produce a better teaching model.

## 2 My changing body

### Purpose
To identify the changes that occur in the human body at puberty and to discuss why these changes occur.

### Materials
- A3 sheet of paper or roll of butcher's paper
- coloured sticky note
- sticky tape, Blu-Tack or similar

### Procedure
1. Choose a partner. Trace or draw an outline of your bodies on separate sheets of paper.
2. On your outline, add labels to each part of your body that changes as you go through puberty. Describe the changes that occur to each body part as puberty proceeds.
3. At the bottom of your page, demonstrate in a sentence or two that you understand what causes these changes. Be as specific as possible, giving correct terms if possible.
4. Swap outlines with your partner and read their page. Identify any differences with yours. Discuss differences with your partner and combine the information onto one of the outlines and stick it up on the wall to create a gallery with the other students.
5. When all the outlines in the class are up, wander around the gallery. Read all the posters and then place a sticker on the one you think best represents all the changes that occur during puberty.
6. Your teacher will ask the class what was good about the poster that won. Listen carefully and remember what is said so that you can answer the questions below.

### Discussion
1. **Justify** why the class chose a particular outline as being the best representative of changes during puberty.
2. **Evaluate** your page and suggest improvements you could make to it.
3. **Summarise** in 25 words what causes the changes during puberty.

# 4.4 Pregnancy

Pregnancy and birth are often described by people as the most amazing experiences of their lives, reducing many parents to tears. They are overwhelmed by the realisation that they have created a life. You are in the womb for close to 9 months before you are born. A lot happens in those 9 months!



## Copulation

**Copulation** is the term for two individuals joining together for sexual reproduction. In humans it is also called **sexual intercourse**. In sexual intercourse, the penis becomes stiff and erect. It is then inserted into the vagina. Stimulation causes sperm to be squeezed out of the penis in a process called **ejaculation**.

Ejaculation deposits several hundred million sperm near the cervix. Sperm can swim, propelled by their tail. Their energy source is sugar in the semen. However, not all sperm are healthy. Some have two tails and some have deformed tails. There are many different ways a sperm can be defective, as you can see in Figure 4.4.1.

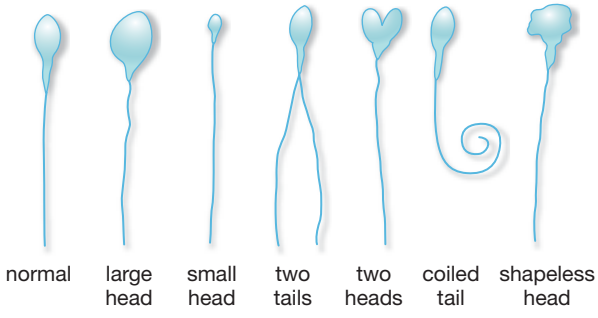



**Figure 4.4.1** Sperm can swim, but defective sperm are poor swimmers.

Sperm enter the uterus (womb) through the cervix. They swim through the uterus and into the fallopian tube. Most sperm die along the way, leaving a few hundred healthy sperm to make it to the upper fallopian tube to meet the egg. When they encounter the egg, the sperm swarm over its surface (Figure 4.4.2). One sperm manages to bury its head into the egg, and the tail breaks off. The egg surface changes as soon as one sperm head makes it through to ensure that no more sperm can enter the egg.

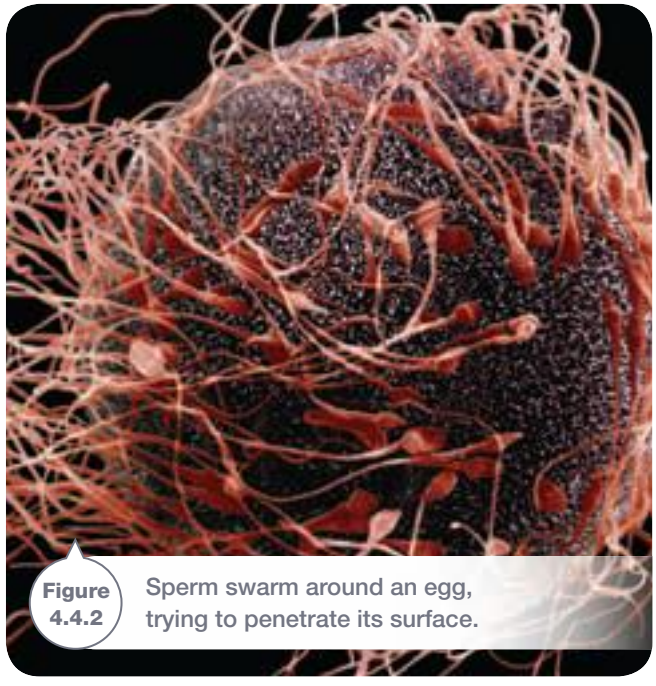


**Figure 4.4.2** Sperm swarm around an egg, trying to penetrate its surface.

# Implantation

When the egg is fertilised, the first cell of the new individual is called a zygote. The zygote begins to divide as it continues its journey down the oviduct. You can see this in Figure 4.4.3. The zygote keeps dividing until it forms a hollow ball of cells called a blastocyst. About five days after fertilisation, the **blastocyst** reaches the uterus. Then the blastocyst burrows into the wall in a process called implantation. Now it is correct to say the woman is pregnant.

# Embryonic development

A baby takes about 38 weeks to develop from fertilisation to birth. The first 8 weeks are called the embryonic period and the developing baby is referred to as an **embryo**. During this time, all the different types of cells, such as nerve, muscle and bone, are developing. These are being built into the different organs and systems of the body. In this critical period of development, the baby can be severely affected by many things. This means that smoking, alcohol and some drugs (legal and illegal) have the potential to cause damage. So, too, do some illnesses, such as rubella. These can cause deformities such as missing limbs and can also cause brain damage. Any chemical that can affect cells could damage the embryo. In Figure 4.4.4 you can see an embryo.

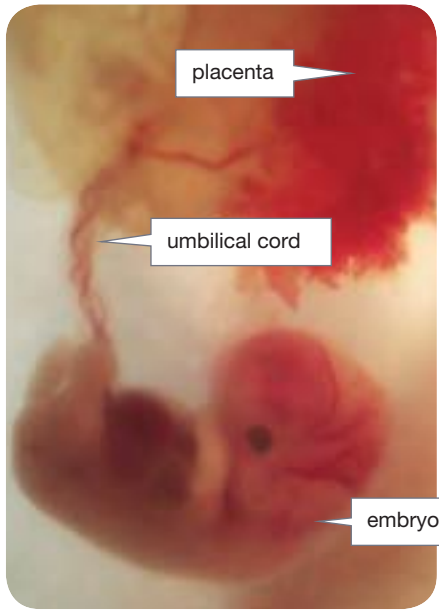



**Figure 4.4.4** Major tissues, organs and systems form during the early development of the embryo.

**SciFile**

## A fast but brief life

The fastest sperm take about 15 minutes to make their journey to the fallopian tube. Sperm can live for up to 2 days and fertilisation is possible if the egg encounters the sperm in this time. This means that intercourse up to two days before ovulation can result in pregnancy.

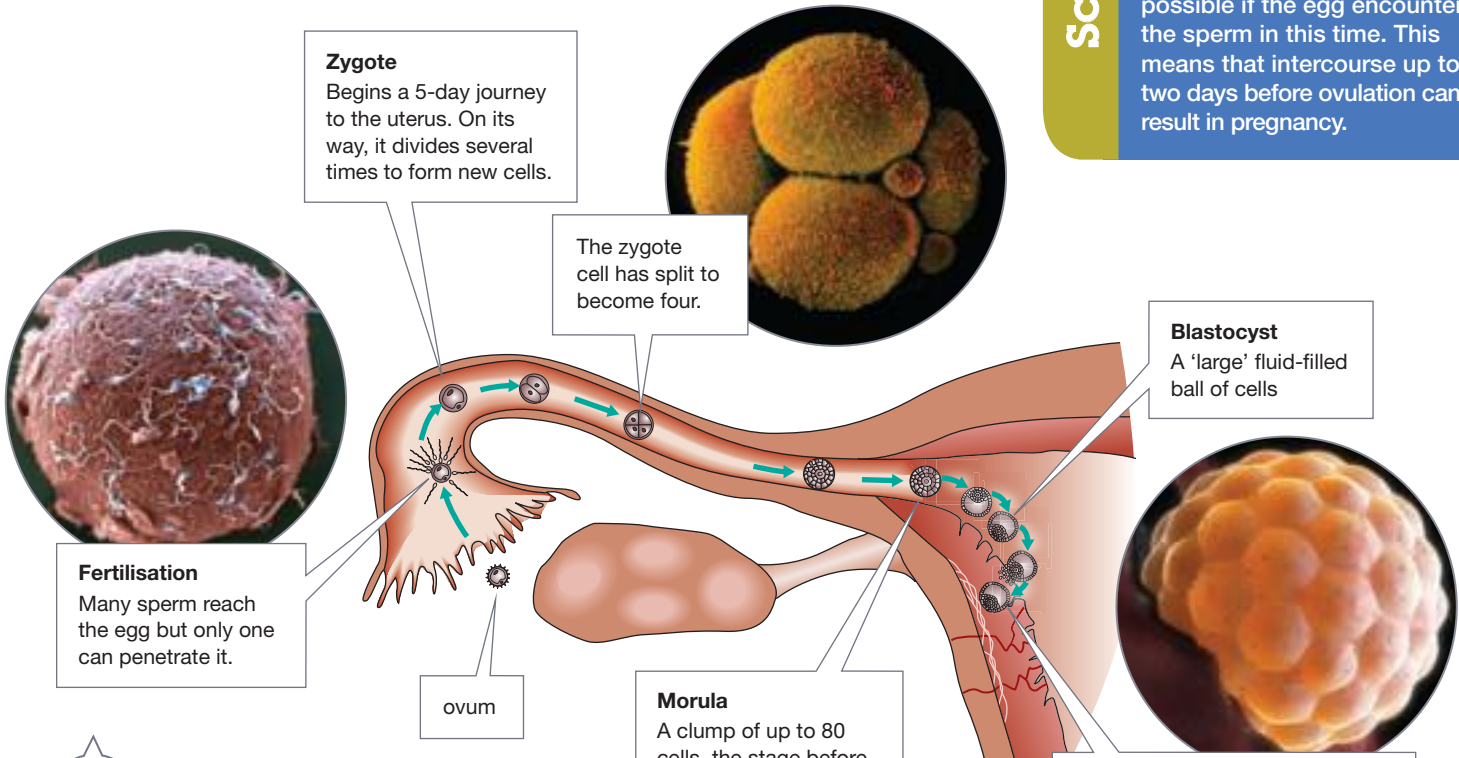



**Figure 4.4.3** The sequence of steps from ovulation to implantation takes about 5 days.

## Amniotic fluid

The embryo floats in a fluid enclosed in a 'balloon' or membrane (thin layer of living tissue) called the amnion. The **amniotic fluid** acts as a shock absorber, protecting the embryo from bumps. It also helps keep the embryo's temperature constant.

## The placenta

In its early development, the embryo is fed from the yolk sac and secretions (fluids) from the lining of the uterus. The yolk sac is similar to the yolk in a chicken egg. Later, another structure called the placenta develops. The placenta develops from branching structures called villi, which are on the outside of the blastocyst. You can see these in Figure 4.4.5. The **placenta** is a highly folded series of membranes and blood vessels. It allows nutrients and oxygen from the mother to enter the baby. It also allows the embryo's waste materials such as carbon dioxide to enter the mother's blood so her body can remove it.

### SciFile

**Belly buttons**

The umbilical cord joins the embryo in its abdomen. Your 'belly button' is where your umbilical cord joined you to your mother in the womb.

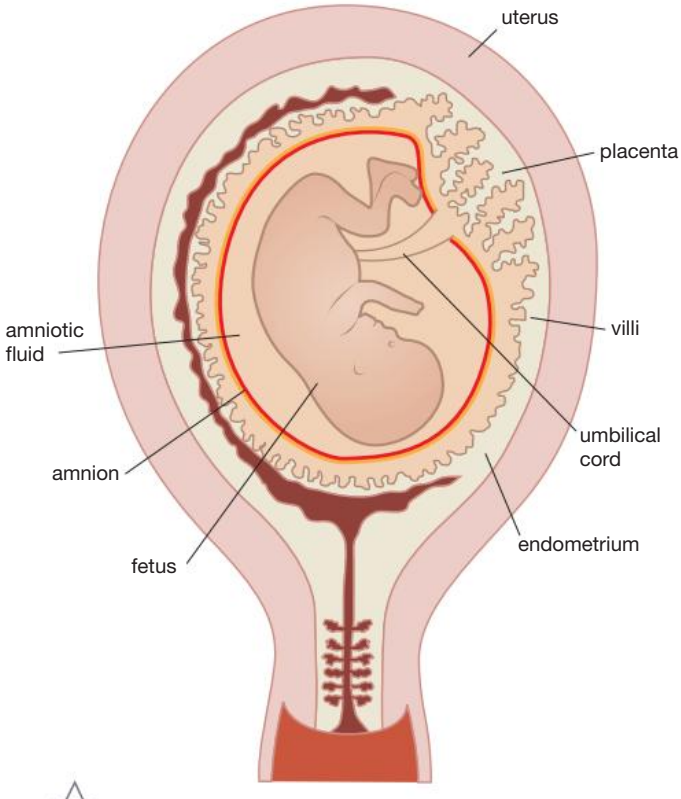



**Figure 4.4.5** The umbilical cord connects the baby to the placenta.

Figure 4.4.6 shows how the placenta is connected to the embryo by the umbilical cord. This contains blood vessels from the embryo. The blood supplies of the mother and embryo do not mix together. They are kept apart by a membrane. The materials to be exchanged between the mother and embryo pass across this membrane.

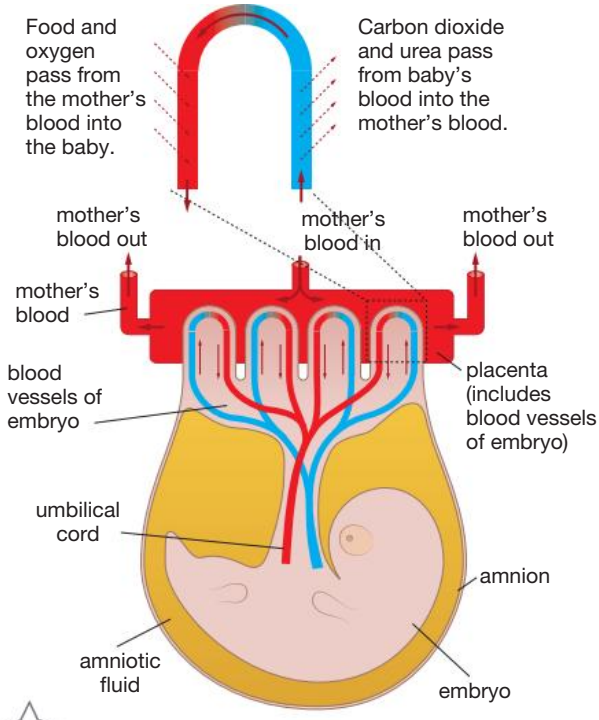



**Figure 4.4.6** The placenta allows exchange of materials between the mother and the developing baby.




### Weeks pregnant

The period during which the baby develops in the uterus is known as the **gestation** period.

A baby develops for about 266 days (38 weeks) from fertilisation to birth. However, doctors can't be sure when ovulation actually occurred in a cycle, because cycles can vary in length. So, they usually talk about 'weeks pregnant', counted from the start of the last menstrual cycle. Since this is usually about 14 days before fertilisation, birth is at '40 weeks', or 280 days, from the last menstruation. So a doctor talking about 'weeks pregnant', is probably referring to the weeks since the last menstrual period. But the actual time it took for the baby to develop was really 38 weeks, or 266 days.



# Fetal development

Most of the major organs and systems have been formed when the embryo reaches about 9 weeks old. The external appearance looks more human-like. The developing baby is now classified as a **fetus** (also spelled foetus.) During the fetal period, the developing baby increases in size and the organs mature so they can function at birth.

# Birth

Birth is part of the process called **labour**, which can last for a few hours to a day or more. The first sign of labour is pain in the abdomen. This is due to the uterus contracting and relaxing. The pains come and go. These gradually get stronger and more painful and come closer together. When the pains are regularly a few minutes apart, birth is not far away. The cervix relaxes and widens. This process is called dilation. The amniotic sac usually bursts, and then the baby's head begins to pass through the cervix. Usually the head goes through first, as you can see in Figure 4.4.7. Then the baby is born. This may take from 10 minutes to a few hours. The umbilical cord is cut and tied. A short time after the baby is born the placenta is expelled from the mother. This is called the **afterbirth**.

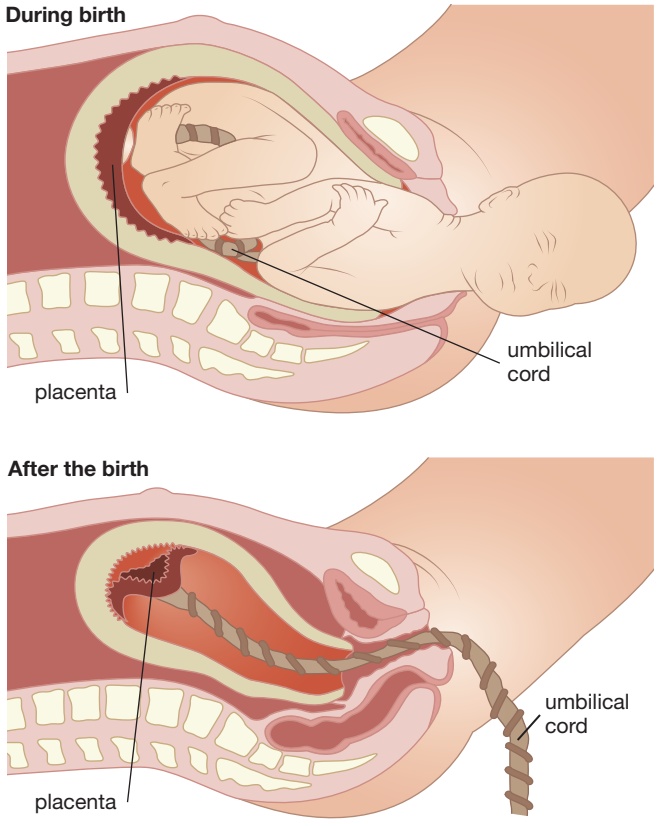



**Figure 4.4.7** Labour involves birth of the baby and expulsion of the afterbirth.



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### Big baby

The largest baby on record was born to Anna Bates, in Canada in 1879. The baby boy had a mass of 10.77 kg, about three times as heavy as the average baby born in Australia. He survived for only about 9 hours. Both his parents were over 2.2 metres tall.

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### Pregnancy tests

The blastocyst produces a hormone known as HCG. This keeps the lining of the uterus thick to support the blastocyst. HCG is detected in pregnancy tests of the mother's urine.

SCIENCE AS A

# HUMAN ENDEAVOUR

Use and influence of science

## Drugs and pregnancy



**Scientists have known for over 50 years that some drugs can damage the developing baby.**

**Figure 4.4.8** Alcohol and smoking can do great harm to a developing fetus.

One of the earliest examples of drugs doing damage to babies was discovered by the Australian scientist Dr William McBride in the 1960s. He identified a drug called thalidomide as the cause of deformities in babies. Many pregnant women experience morning sickness, a feeling of wanting to vomit that is particularly strong in the morning, and the drug was taken by mothers as a sedative to help relieve these symptoms. Thalidomide crossed the placenta and entered the developing embryo. It affected cell development, resulting in missing or deformed limbs. Thalidomide is now banned for use by pregnant women, but it is still used to treat many diseases in people who aren't pregnant.

### Alcohol and pregnancy

Drinking alcohol while pregnant can also have consequences for the baby. Alcohol crosses the placenta, which means the baby has the same blood alcohol level as the mother. If the mother is drunk, the baby is too, and can be damaged.

High alcohol intake may cause a condition known as fetal alcohol syndrome (FAS). Some signs of FAS are:

- low birth weight
- smaller head
- small eyes and flattened face and nose
- heart defects.

The children are affected for life and cannot be cured.

Some serious effects are:

- low intelligence, poor memory and learning difficulties (because the growing brain is damaged)
- behaviour problems, for example ADHD (attention deficit hyperactivity disorder)
- increased risk of mental illness
- increased risk of alcohol and drug misuse.

### Smoking and pregnancy

Smoking during pregnancy damages both the mother and the baby. Effects can include:

- death of the fetus in the womb
- miscarriage—bleeding and expulsion of the fetus
- premature birth
- retarded growth and development
- increased risk of facial deformities such as cleft lip and cleft palate
- lower birth weight
- twice the risk of sudden infant death syndrome (SIDS).

Smoking damage can cause health problems in the baby for years to come once it is born. Effects may include:

- decreased lung function
- higher incidence of asthma
- increased risk of developing behavioural problems, such as antisocial behaviour.

1 p164

4.7

# 4.4 Unit review

## Remembering

1 **Name** the following.
   - a The cell formed by fertilisation
   - b Both terms for the place where fertilisation occurs
   - c The site of implantation
   - d The fluid that surrounds the embryo
   - e The connection between the embryo and the placenta
   - f The time period from fertilisation to birth

2 **List** the major events from fertilisation to implantation.

3 **List** the signs that labour is occurring.

4 **List** some events in childbirth after dilation of the cervix.

## Understanding

5 **Explain** the function of the amniotic fluid.

6 **Explain** the function of the placenta.

7 **Define** the following terms.
   - a copulation
   - b ejaculation
   - c implantation
   - d blastocyst
   - e placenta
   - f labour

8 **Explain** what prevents mixing of the blood supply of the mother and the fetus.

## Applying

9 If a woman last had a period on 1 January, and is clearly pregnant, **calculate** the date when her baby should be born.

10 If a zygote was definitely formed on 1 January, **calculate** the date when the baby should be born.

## Analysing

11 **Compare** the major features of an embryo and a fetus.

12 **Distinguish** between the placenta and umbilical cord.

13 **Compare** the meaning of labour and birth.

14 **Distinguish** between fertilisation, implantation and pregnancy.

## Evaluating

15 A pregnant woman complains that she is feeling sick every morning. She wants to use a natural remedy that a friend suggested. What would you **recommend** she do, and why?

16 A baby's skull bones do not lock together to make the skull rigid until well after birth. **Propose** why this is an advantage in childbirth.

17 To induce labour (to make it happen), a chemical called oxytocin can be injected into the mother. **Propose** what effect the chemical would have on the uterus.

## Creating

18 **Construct** a diagram of a developing fetus and the uterus. Next to each part on the diagram, write its function in reproduction.

19 **Create** a pamphlet for pregnant women to warn them how drugs might hurt their unborn baby.

## Inquiring

1 Research the use of the following in prenatal diagnosis (checking the health of the developing baby).
   - a ultrasound
   - b amniocentesis
   - c chorionic villus sampling

2 Research dietary advice for pregnant women, particularly the recommended type and amount of food (for example, should they eat soft cheeses and 'cured' raw meat products?).

3 Research how in-vitro fertilisation can help with infertility problems.

4 Research the effect and treatment of the condition called incompetent cervix.

5 Research the condition called placenta previa and the problems it can cause.

6 Research the condition called eclampsia, particularly the threat it poses to the mother and baby.

# 4.4 Practical activities

## 1 Interview a mother

### Purpose

To interview a mother to discover her experiences of pregnancy and the advice she received.

### Materials

- paper
- pen
- tape recorder if available

### Procedure

1 You are going to interview a woman who has been a mother—either your own mother, or someone you know who is keen to help. It is important that the woman agrees to participate freely. If your mum does not want to do it, ask someone else. The aim is to find out what advice they received about pregnancy and birth before they occurred, and what they think of their experiences.

The first step is to think about the questions you should ask them, and write these down. Some examples follow:

- What changes did you think having a baby would make to your life?
- What changes did you find you had to make to your life after having a baby?
- What advice were you given about diet during pregnancy?
- What did you know about the possible effects of alcohol and smoking?
- What advice were you given about exercise?
- What care did you take during the pregnancy?

2 After compiling your list of questions, discuss them with another student to get their opinion on them. Check with your teacher if you are not sure.

3 Show the questions to the mother and ask her if she could help you. Tell her that her name will not appear in the report and that her answers will not be shown to anyone else other than the teacher. It would be best if you could actually talk to her and write out what she says. If she doesn't want to talk about it, but would be happy to write out some answers, then accept the offer. Don't hassle her to tell you things. Some things may be personal.

4 Obtain the answers to your questions by interview or in writing from the person. Make sure that you keep your promises about her privacy.

### Discussion

**Assess** what you learnt in this activity, including any lessons that could help if you become a parent.



# 4 Chapter review

## Remembering

1 **Name** the following:
   - a the type of insect life cycle with four stages
   - b changes in body form and shape in an organism's life
   - c sex cells that must join together in sexual reproduction
   - d the human organ that produces male gametes
   - e the human organ that produces female gametes.

2 **State** the following times:
   - a the length of human gestation in weeks and days
   - b the average age for the start of puberty in girls and boys
   - c how long a sperm can live in the oviduct
   - d when ovulation occurs in a typical 28-day menstrual cycle
   - e when a blastocyst implants after fertilisation.

3 **List** five different methods of asexual reproduction and for each name an organism reproducing that way.

## Understanding

4 **Discuss** the advantages of:
   - a sexual reproduction
   - b asexual reproduction.

5 **Discuss** the role of hormones in human reproduction.

6 **Explain** the important role of the lining of the uterus in human reproduction.

## Applying

7 **Identify** the following:
   - a a structure in a pregnant woman that allows the embryo's carbon dioxide to enter the mother's circulation
   - b a drug that can affect the fetus and cause brain damage, behavioural problems, reduced brain size, and learning difficulties for life.

8 Animals such as humans, dogs, sheep and horses are classified into a group called placental mammals. The echidna and platypus are classified into a different mammal group called monotremes because they lay eggs. **Identify** the key difference between these two mammal groups.

## Analysing

9 **Compare** the life cycles of a human, a butterfly and a frog, discussing the main stages and processes.

10 **Compare** the processes of sexual reproduction in plants and animals.

11 **Compare** the structures involved in sexual reproduction in plants and animals.

12 **Contrast** between sexual and asexual reproduction.

13 **Compare** cross-fertilisation and self-fertilisation.

14 **Compare** the effects of alcohol and smoking on the developing fetus.

15 **Compare** the changes in male and female bodies during puberty.

## Evaluating

16 *Sexual reproduction is superior to asexual reproduction if the environment is changing.* **Justify** this statement.

17 **Justify** the argument that illegal drugs should not be taken during pregnancy.

## Creating

18 Make flash cards about the male and female reproductive systems. Each card can be either a word or a diagram. Do some as words and some as diagrams. Write the answer on the back without your partner seeing it. Use the flash cards to test a partner. If you flash a word, they must tell you the function or meaning. If you flash a diagram, they must tell you the name. Take turns testing each other with your flash cards.

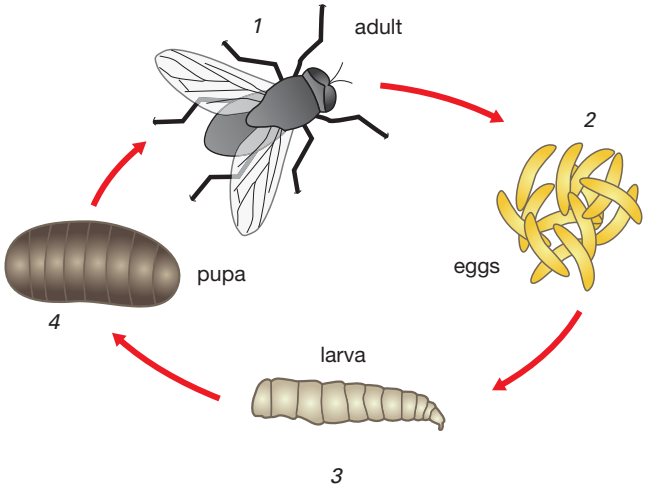
19 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

| | |
|---|---|
| life cycle | development |
| sexual | asexual |
| plant | animal |
| reproductive structure | reproductive process |
| fertilisation | placenta |



# Thinking scientifically

Questions 1 and 2 refer to the following diagram of the life cycle of a housefly.




**Q1** Between which two stages does fertilisation occur?

**A** 1 and 2 **B** 2 and 3
**C** 3 and 4 **D** 4 and 1

**Q2** Between which two stages is this cycle most similar to the stage in the life cycle of a flowering plant when the seed germinates (the plant breaks out of the seed)?

**A** 1 and 2 **B** 2 and 3
**C** 3 and 4 **D** 4 and 1

**Q3** Bats are placental mammals. Which of the following should occur in the life cycle of a bat?

**A** Bats would lay eggs in nests, like birds.
**B** Bats would give birth to live young and carry them in a pouch like marsupials.
**C** Bats would give birth to babies that go through a metamorphosis like butterflies.
**D** Bats would develop in a uterus with the fetus connected to the mother by an umbilical cord.

Questions 4 and 5 refer to the following table listing some reproductive structures in a human and a flowering plant.

| Pair number | Human part | Flowering plant part |
|---|---|---|
| 1 | testis | stigma |
| 2 | uterus | seed |
| 3 | sperm | pollen |
| 4 | egg | anther |
| 5 | fetus | ovule |
| 6 | fallopian tube | fruit |

**Q4** Which of the following pairs in the table names parts that have the same role in human reproduction as they do in plant reproduction?

**A** pair 1 **B** pair 2
**C** pair 3 **D** pair 6

**Q5** Which of the following pairs in the table names parts found in the female human and the female part of the flower?

**A** pair 1 **B** pair 3
**C** pair 4 **D** pair 5

**Q6** The methods of reproduction of several species are shown below.

| Organism | Method of reproduction |
|---|---|
| Pea | Self-fertilisation |
| Bracken fern | Underground stem, spores, sexually—mostly self-fertilisation |
| Amoeba | Asexually by fission |
| Dog | Cross-fertilisation |

Which of the following species would probably show the greatest variation in its offspring?

**A** pea **B** amoeba
**C** bracken fern **D** dog

# Glossary

## Unit 4.1

**Biosecurity:** preventing pest and disease organisms from entering our country

**Development:** changes in body form and shape in an organism's life

**Egg:** female cell that must be fertilised to start a life cycle

**Growth:** an increase in body size

**Imago:** the adult stage in an insect life cycle (complete metamorphosis)

**Larva:** the second stage in an insect life cycle (complete metamorphosis)

**Life cycle:** the changes that happen to an individual from its formation until it has produced offspring similar to it



Larva

**Metamorphosis:** the changes in structure that happen as an organism develops into an adult

**Nymph:** the stage of an insect life cycle that gradually develops into the adult without becoming a pupa (incomplete metamorphosis)

**Pupa:** the stage in an insect life cycle when the larva changes into an imago (complete metamorphosis)

**Reproduction:** the process of parents producing new individuals, or offspring

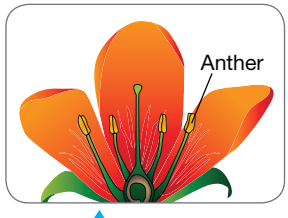


Pupa

## Unit 4.2

**Anther:** the part of the flower that produces the pollen

**Asexual reproduction:** a new individual growing from part of its one parent's body with no joining of gametes




Anther

**Copulation:** two individuals joining to allow gametes to become fertilised

**Cross-fertilisation:** when gametes from two separate individulas join together



Asexual reproduction

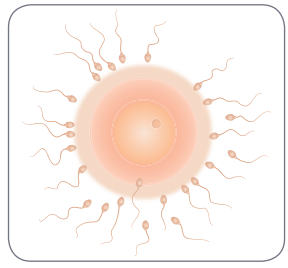
**Development:** the process by which the cell formed by fertilisation divides and develops to begin to look like an adult

**Embryo:** a developing offspring at a very early stage of development

**Fertilisation:** the joining of gametes

**Flower:** the reproductive structure in plants that makes male sex cells and female sex cells

**Fruit:** the structure that the ovary of a flowering plant turns into as the seeds ripen



Fertilisation

**Germination:** when the young growing plant sprouts out of the seed

**Hermaphrodite:** an individual with both male and female sex organs

**Parthenogenesis:** where offspring develop from eggs that have not been fertilised by a male gamete. A form of asexual reproduction

**Pollination:** transfer of pollen from the anther to the stigma

**Self-fertilisation:** when gamates from the same individual join together

**Sexual reproduction:** the process of a sperm and an egg joining together and then growing into a new individual

**Stigma:** the flower part that receives the pollen

**Style:** connects the stigma to the ovary

**Zygote:** the first cell of the new individual after fertilisation

# Glossary

## Unit 4.3

**Cervix:** part of the uterus that keeps it closed while the baby is developing

**Fallopian tubes (oviducts):** tubes down which the egg passes and where fertilisation occurs

**Hormones:** chemicals made in the body to control reproduction and physical characteristics

**Implantation:** process of the blastocyst burrowing into the lining of the uterus

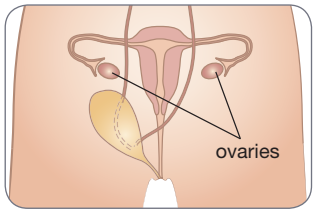
**Menstrual cycle:** regular monthly changes in the hormones and reproductive organs of adult females

**Menstruation:** blood and tissue loss from the lining of the uterus at the start of a menstrual cycle

**Ovaries:** organs that produce the eggs or ova

**Ovulation:** the egg bursting out of the follicle

**Period:** shedding of blood and dead tissue from the the lining of the uterus



Ovaries

**Puberty:** the time in life when physical changes bring sexual maturity

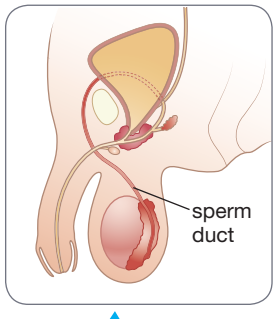
**Semen:** a mixture of sperm and other fluid released from the penis

**Sperm duct (vas deferens):** tube carrying sperm from the testes to the urethra

**Testes:** male organs that produce the sperm

**Uterus (womb):** organ in which the fetus grows and develops

**Vagina:** organ that allows the male penis to be inserted to deposit the sperm and also acts as the birth canal down which the baby passes



Sperm duct

## Unit 4.4

**Afterbirth:** placenta expelled from the mother after birth

**Amniotic fluid:** fluid surrounding the embryo that acts as a shock absorber and helps to maintain a constant temperature

**Blastocyst:** a hollow ball of cells that becomes an embryo


Blastocyst

**Copulation:** two individuals joining together for sexual reproduction

**Ejaculation:** process of sperm being squeezed out of the penis

**Embryo:** early stages of development before the major organ systems are formed

**Fetal alcohol syndrome (FAS):** damage caused by alcohol in pregnancy where the baby is small, has a small head, unusual facial features, and heart defects

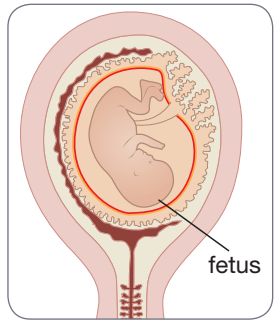
**Fetus (foetus):** stage of development when most of the major organs and systems are present

**Gestation:** the time period from fertilisation to birth

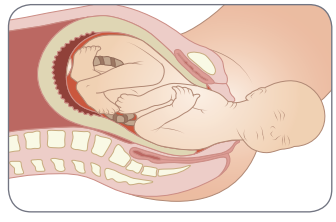
**Labour:** process leading to birth, from first contractions of the uterus to expulsion of the afterbirth

**Placenta:** membranes of the fetus and mother that allow nutrients and oxygen to be exchanged and waste to be removed

**Sexual intercourse:** a male and female copulating



Fetus


Labour

SCIENCE TAKES YOU PLACES

# Look who is using science

## HAIRDRESSER



**My name is Aldijana Petovic and I am a hairdresser at a salon called Stylistic.**

My job is to colour, cut and style clients' hair. I have a ten-minute meeting with clients to discuss what look they're trying to achieve. During this consultation I check the condition and colour of the client's hair. Then I know what type and strength of coloured dye or peroxide I need to use to give them the colour they're after. Peroxide is a chemical used in salons that bleaches (removes) the colour from the hair. If the client hasn't used our brand before, then I do a skin test, where I apply a small amount of the dye behind the ear. If the person is allergic to it, they will feel a burning sensation on the test spot and the skin will redden. When using chemicals, I wear gloves so that I won't get colour stains on my skin or burns from the peroxide.

## CHIROPRACTOR



**My name is Dr James Nicola and I'm a chiropractor at The Parker Clinic.**

Damage to the joints of your skeleton can cause pain and affect your general health. It's my job to use the science I've learnt to work out what has happened to these joints and how they can be fixed.

The adult human skeleton consists of 206 bones that are very different from any non-living bones you may have seen in a museum. Living bone is like a green branch on a tree; it's strong yet flexible. Dead bone becomes like a dried-up dead branch. While still quite strong, dead bone loses its flexibility, making it more brittle (easy to break). Your spine is particularly remarkable because it allows a significant amount of movement while still protecting the body's most vital and delicate organs, the brain and spinal cord.

## PROSTHETIST



**My name is Amy Emons and I am a prosthetist, which means I fit artificial limbs for people who have lost all or part of their arm or leg.**

I meet with patients who have lost a limb through accident or disease, or who have been born with a limb missing. First, I complete a full physical and biomechanical assessment of the patient's motion. Then I make a cast from the patient's remaining limb and construct an artificial replacement, which is called a prosthesis, to suit the needs and lifestyle of the patient. I try to select the most appropriate prosthetic foot, ankle and knee joint components to build into the prosthesis.

Some components are now controlled using computer microprocessors. The prosthesis has a soft gel or foam part to fit onto the patient's skin and a hard outer covering of fibreglass or carbon fibre. I make sure that the prosthesis fits the patient comfortably and I assist the patient with learning to use it. I enjoy my work because I love helping my patients get back to the lifestyle they once had and I enjoy working with developing technology.

# 5 Using energy



## HAVE YOU EVER WONDERED…

- why you get hot when you run?
- what the energy stars on refrigerators and televisions mean?
- how a hybrid car works?

## After completing this chapter students should be able to:

- recall that kinetic energy is the energy possessed by moving bodies
- describe different forms of potential energy, such as gravitational, chemical and elastic
- identify different forms of energy based on their effects
- recall that heat energy is often a by-product of energy transfer
- use flow diagrams to illustrate changes between different forms of energy
- discuss how energy-efficient design can reduce energy consumption
- outline the development of vehicles over time, including the science used in solar-powered vehicles.

# 5.1 Energy around you



As a roller-coaster speeds downwards, the wheels of the rolling cart heat up. As a passenger, you feel the wind rushing past you, your hair flies around and you probably scream! Energy is needed to make all these things happen. Energy exists in many different forms, from electrical energy to sound, light and heat energy. Energy can change forms, but it is never lost.

INQUIRY

## science 4 fun

### Making spiders

Can you release energy by mixing two substances together?

**SAFETY!**
Do not eat food prepared in the science laboratory.

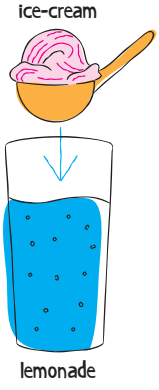
**Collect this…**

- lemonade
- ice-cream
- spoon

Yes

**Do this…**

1. Half-fill a glass with lemonade.
2. Add a scoop of ice-cream.
3. Give it a stir.




**Record this…**

**Describe** what happened.
**Explain** why you think this happened.

## What does energy do?

On a typical day, many things happen around you. People walk and drive around in cars, birds chirp, leaves fall from trees, clothes dry on the clothesline and music comes out of an iPod®. Each of these activities needs **energy**. It is hard to explain what energy is, because you can't see it or weigh it. Instead, you can observe what energy does. Energy is needed to move or heat something, to make a noise, or to change an object's shape. Energy makes things happen.

**Work** is the name given to the effects of using energy. Whenever an object is shifted or forced to change shape, then work has been done.




## Measuring energy

Energy is measured using a unit called the joule (symbol J). You use one joule of energy when you lift a 1 kg bag of potatoes 10 cm off the floor. Lifting 1 kg of potatoes isn't too hard, which shows that a joule is a small amount of energy. In fact, a joule is so small that energy is often measured in batches of 1000 joules. A batch of 1000 joules is known as a kilojoule (kJ). If you lifted 1 kg of potatoes 10 cm with 1 J of energy, then you could lift them 100 metres with 1 kJ of energy!

Food energy is commonly measured in kilojoules (kJ). Even larger amounts of energy, such as electrical energy, are measured in megajoules (MJ).

1 kJ = 1000 J

1 MJ = 1 000 000 J

## Counting calories

SciFile

You may have heard of a unit of energy called the calorie. This unit is used in some countries of the world, particularly to measure food energy. One calorie (cal) is the amount of energy needed to raise the temperature of 1 gram of water by 1°C. This is about 4.2 joules.

WORKED EXAMPLE

### Calculating energy

#### Problem 1

**Calculate** how many joules of energy are contained in:

**a** 2 kJ

**b** 3.5 MJ

#### Solution

**a** 2 kJ = 2 × 1000 = 2000 J

**b** 3.5 MJ = 3.5 × 1 000 000 = 3 500 000 J

#### Problem 2

**Calculate** how many megajoules of energy are contained in:

**a** 4 800 000 J

**b** 5 700 000 000 J

#### Solution

**a** 4 800 000 J = 4 800 000 ÷ 1 000 000 = 4.8 MJ

**b** 5 700 000 000 J = 5 700 000 000 ÷ 1 000 000
= 5700 MJ

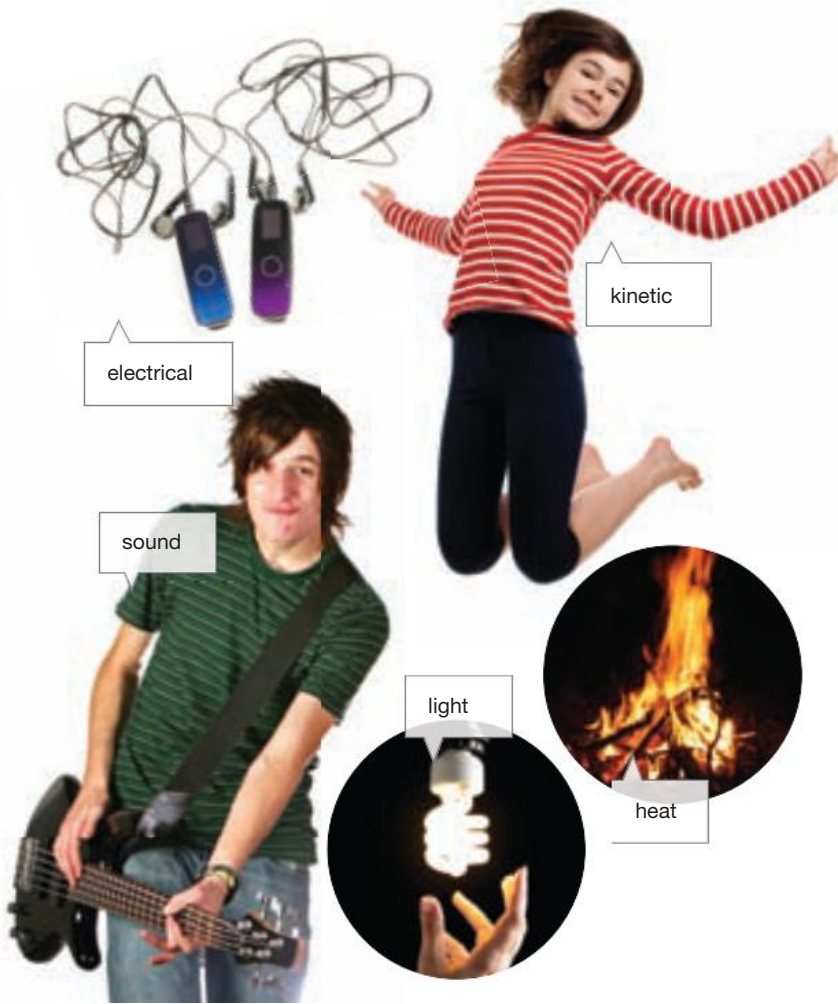
# Forms of energy

There are many different forms of energy, as shown in Figure 5.1.1.

- **Kinetic energy** is the energy of movement. Anything that moves has kinetic energy. The faster an object moves, the more kinetic energy it has. In a collision, kinetic energy is quickly changed into other forms.
- **Heat energy** can come from the Sun, flames, chemical reactions, electrical devices or even from a person or animal. Heat warms, burns, dries, melts, and makes hot-air balloons rise.
- **Light energy** comes from the Sun, light globes, fires and animals such as glow-worms. Without light energy, the world would be a very dark place.
- **Sound energy** is the energy that air has when it is vibrating. Your ears and brain interpret the vibrating of air as sounds. Sound comes from your voice, musical instruments, cars and power tools.
- **Electrical energy** comes from power stations, solar cells, batteries, and sparks such as lightning. Electrical energy powers your TV, computer, microwave and toaster.

1 p177

Figure 5.1.1 Here are five different and common forms of energy. All these forms of energy make things happen.



INQUIRY

science 4 fun

## Creepy crawly

What happens when you twist a rubber band?

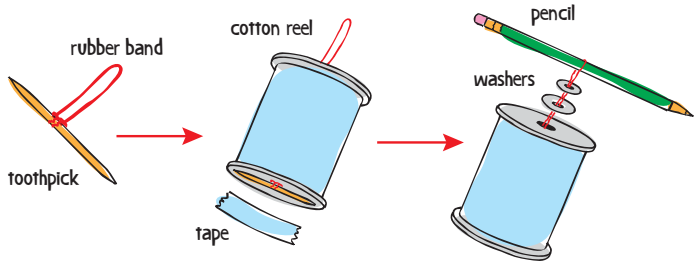
Yes

### Collect this...

- rubber band
- cotton reel
- part of a toothpick or match smaller than the diameter of the cotton reel
- masking tape
- 2 metal washers
- a pencil or a piece of dowel longer than the diameter of the cotton reel

### Do this...

1. Loop a rubber band around the toothpick and through the cotton reel as shown. Tape the toothpick to the cotton reel.
2. Insert the rubber band through the metal washers and loop the end around the pencil.
3. Twist the pencil to wind up your creepy crawly.
4. Place it on a smooth surface and let it go!




### Record this...

**Describe** what happened.

**Explain** why you think this happened.

## Stored energy

Not all forms of energy are as obvious as those discussed so far. Many of the objects around you have stored energy or **potential energy**. Petrol in a car's fuel tank and books on a shelf both have potential energy. They are not using energy at the moment but have stored energy. Stored energy gives objects the potential to make things happen: the books can fall off the shelf and the petrol can burn.

One form of potential energy is the chemical energy your body gains from eating food. This energy enables you to run, play sport, heat your body and keep your heart beating. The foods that you eat originally obtained energy from the Sun. Plants capture light from the Sun and convert it into chemical energy in the form of simple sugars. This happens in a process called **photosynthesis**. Plants such as wheat make sugars and then convert them into starch for storage. When you eat the plants, their seeds, nuts or grains (or eat animals that have eaten them), your body uses the chemical energy from these simple sugars and starch as your energy source. Figure 5.1.2 shows the energy content available from one type of breakfast cereal.

**NUTRITION INFORMATION (Average)**

SERVING SIZE: 30G (APPROX. 1 CUP) SERVINGS PER PACKAGE: 16

| | PER SERVE | PER 100g | 30g with 2/3 cup (170mL) Whole Milk | 30g with 2/3 cup (170mL) So Good™ |
|---|---|---|---|---|
| Energy (kJ) | 459 | 1530 | 930 | 920 |
| (Cal) | 110 | 366 | 222 | 220 |
| Protein (g) | 2.3 | 7.6 | 7.9 | 8.1 |
| Fat - Total (g) | 0.1 | 0.4 | 6.6 | 5.9 |
| - Saturated (g) | <0.1 | 0.2 | 4.3 | 0.7 |
| Cholesterol (mg) | 0.0 | 0.0 | 22.1 | 0.0 |
| Carbohydrate | | | | |
| - Total (g) | 24.0 | 80.0 | 32.0 | 33.0 |
| - Sugars (g) | 2.8 | 9.3 | 10.8 | 6.0 |
| Dietary Fibre (g) | 0.9 | 3.1 | 0.9 | 0.9 |
| Sodium (mg) | 234 | 780 | 304 | 311 |
| Potassium (mg) | 41 | 136 | 299 | 327 |
| Thiamin (mg) | 0.55 (50%)* | 1.83 | 0.58 | 0.65 |
| Riboflavin (mg) | 0.42 (25%)* | 1.42 | 0.76 | 0.72 |
| Niacin (mg) | 2.5 (25%)* | 8.3 | 2.5 | 2.5 |
| Folate (µg)** | 100 (50%)* | 333 | 108 | 105 |
| Iron (mg) | 3.0 (25%)* | 10.0 | 3.0 | 3.9 |

*=Percentage of Recommended Dietary Intake (RDI)

Figure 5.1.2 The nutritional information listed on this cereal box states that a serving contains 459 kJ of energy. For a healthy lifestyle, the energy you put into your body from food should be about the same as the energy you require for your body to function.

Figure 5.1.3 shows four different types of potential energy:

- **Gravitational potential energy** is energy stored in an object when it is above the ground. The greater the height, the more gravitational potential energy an object has. For example, the higher a water slide, the more gravitational potential energy you have at the top and the more kinetic energy you will have on the way down!
- **Chemical energy** is energy stored in substances. This energy is released by your body when you digest food, and by cars when fuel is burnt. Wood, paper, apples, petrol and batteries all contain chemical energy.
- **Elastic potential energy** is energy stored in a stretched or squashed spring. Stretched rubber bands also store elastic potential energy, which is released when they are let go.
- **Nuclear energy** is energy stored inside the small particles that make up all matter. Nuclear energy is released in a nuclear power plant, in a nuclear bomb explosion, and inside the Sun. Nuclear reactions produce heat and light.

2 p178

5.1

SciFile

## The blade runner

Oscar Pistorius is a sprinter from South Africa who is missing the lower part of both his legs. Some people argued that his prosthetic running blades could give him an unfair advantage over able-bodied athletes. Pistorius was able to enter the qualifying races for the 2008 Beijing Olympics after a court decided that there was not enough evidence to prove that his blades gave him any advantage.



Figure 5.1.4 A prosthetic running blade stores elastic potential energy as it flexes. This energy is then released as the athlete runs.




Figure 5.1.3 Objects that have any of these forms of stored potential energy may release the energy in different forms at a later time. When stored energy is released, things happen.

# 5.1 Unit review

## Remembering

1 **Name** the unit used to measure energy.

2 **List** five different forms of energy.

3 **Recall** what you know about energy by matching the following types with their descriptions.

- a kinetic energy
- b sound energy
- c elastic potential energy
- d gravitational potential energy
- e light energy

- i in vibrating air particles
- ii in a stretched or squashed spring
- iii in objects positioned above the ground
- iv released from glow-worms
- v in a moving object

## Understanding

4 **Explain** why the energy in food is usually stated in kilojoules rather than joules.

5 **Explain** why sound energy could be considered a type of kinetic energy.

6 Petrol, kerosene and oil are all types of fuel. **Clarify** which type of energy these fuels possess.

7 **Describe** situations in which kinetic energy could cause damage.

## Applying

8 **Calculate** how many joules of energy are in:

- a 3 MJ
- b 7500 kJ

9 **Calculate** how many megajoules would be in these quantities:

- a 2 500 000 J
- b 5000 kJ

10 **Identify** the types of energy that caused the changes in the:

- a 'Making spiders' activity on page 171
- b 'Creepy crawly' activity on page 173.

11 Your body needs a source of energy. **Use** Figure 5.1.5 to **list** four different ways that the chemical energy in food can be used by your body.

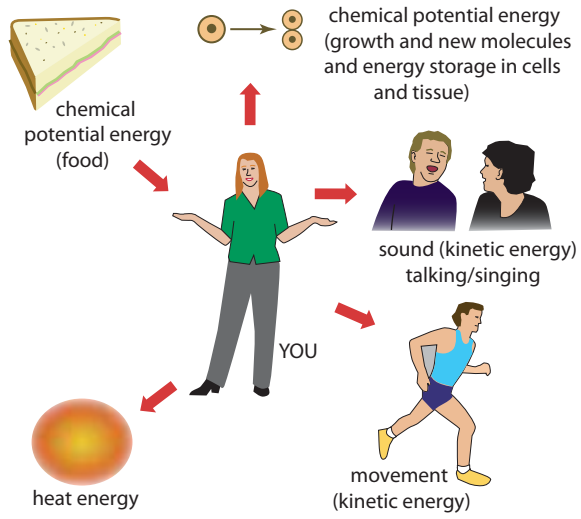



Figure 5.1.5

12 **Identify** the key type of energy possessed by a:

- a seatbelt buckle that has been in the sun all day
- b shopping trolley rolling across the floor
- c marshmallow
- d golf ball hit along the ground
- e lawnmower filled up with petrol
- f bird resting in its nest on a tree branch.

13 a Ben burns about 30 kJ per minute while he's dancing. **Calculate** the number of kilojoules he would use if he danced for an hour.

b **Calculate** how many servings of the breakfast cereal in Figure 5.1.2 on page 173 Ben would need to supply this energy.

c When Ben dances, he moves his arms and legs, he sings and he gets hot. **List** three types of energy that are present when Ben dances.

# 5.1 Unit review

## Analysing

**14** The following objects have potential energy. **Classify** each one as an example of gravitational potential energy, chemical potential energy or elastic potential energy.

- **a** A piece of chocolate cake
- **b** A stretched spring
- **c** A glass of cola
- **d** An empty coffee mug on a table
- **e** A teaspoon of sugar
- **f** A cardboard box
- **g** A 9-volt battery
- **h** A painter at the top of a ladder
- **i** A banana
- **j** A squashed tennis ball

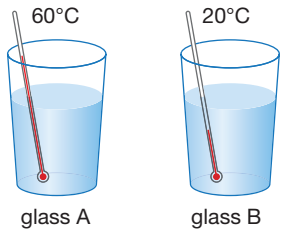
## Evaluating

**15** Aisha lifts a 10 kg bag of onions 10 cm off the ground. **Propose** a different task in which she would do the same amount of work.

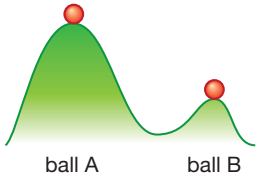
**16** For each pair of objects shown in Figure 5.1.6:

- **i** **identify** which (A or B) has more energy
- **ii** **justify** your response.

**a**




**b**




**c**

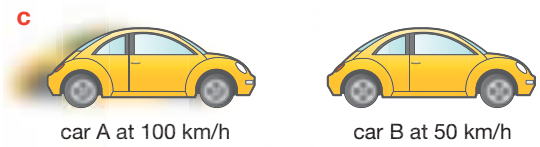



Figure 5.1.6

## Inquiring

**1** **a** Research the approximate number of joules of energy contained in a:

- **i** litre of full-cream milk
- **ii** litre of petrol
- **iii** litre of oil
- **iv** kilogram of coal
- **v** kilogram of wood.

**b** Construct a column graph to show the energy content of these substances.

**2** Investigate the energy content of a range of fast foods. Link a typical meal from one fast food restaurant with activities required to use up an equivalent amount of energy.

**3** Research Oscar Pistorius on the internet. Outline his life story.

**4** Some animals can produce their own light. This process is called bioluminescence. Research five animals that can produce their own light.

# 5.1 Practical activities

## 1 Making a spinning snake

### Purpose

To observe how heat can cause a change.

### Materials

- square of aluminium foil
- 15 cm length of string
- retort stand and clamp
- Bunsen burner and bench mat
- matches



**SAFETY**

Be careful not to touch the spiral just after it has been heated.



### Procedure

1. If your aluminium foil is thin, then fold over a piece to double its thickness.
2. Cut a spiral shape from your piece of foil about 8 cm in diameter, as shown in Figure 5.1.7.

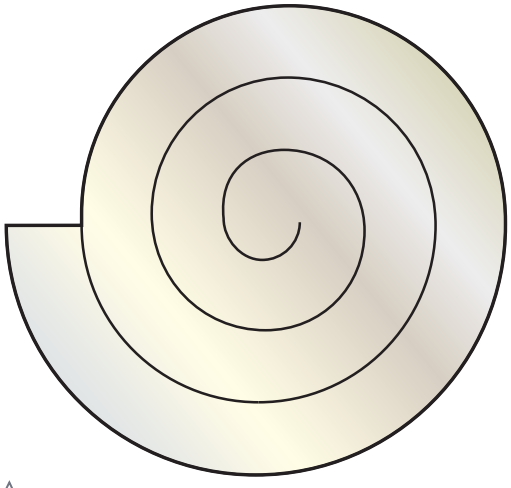


Figure 5.1.7

3. Make a small hole in the tip of your spiral and tie a piece of string from the tip to a clamp as shown in Figure 5.1.8.

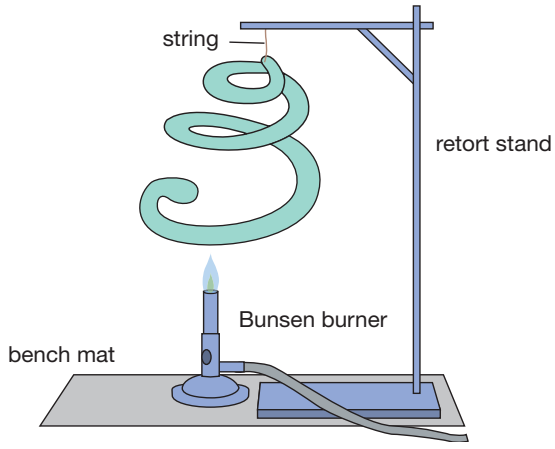



Figure 5.1.8

4. Position a Bunsen burner underneath the spiral. Make sure that the flame will not touch the spiral.
5. Light the Bunsen burner and adjust it to produce the blue flame.
6. Observe the spiral.

### Results

List changes that happened to your foil spiral.

### Discussion

1. **Identify** which source of energy caused these changes to occur.
2. **Propose** how you think this energy might have caused the change you observed.
3. **Propose** why the spiral was made from aluminium foil instead of paper.
4. The circulating air that caused this change is called a convection current. **Propose** situations in which convection currents might occur.

## 2 Energy makes things happen

### Purpose

To observe how different types of energy can cause a change.

### Materials

- sparkler
- soil in a beaker
- matches
- torch
- tennis ball
- slinky spring
- damp piece of cloth
- peg
- coat hanger
- hair dryer



**SAFETY**

Do not touch the sparkler while it is burning. Allow it to cool before cleaning up.

Do not operate the hair dryer near water.



### Procedure

1. Copy the table shown in the results section into your workbook. As you complete each task, record your observations in the table.
2. Stand a sparkler in a beaker of soil. Light the sparkler and observe until it goes out.
3. Turn on a torch and see what happens. Switch the torch off.
4. Drop a tennis ball off the edge of a bench and observe how it moves.
5. Compress a slinky spring on a bench and then let it go. Describe what happens.
6. Peg a damp piece of cloth to a coat hanger. Blow warm air from a hair dryer over the cloth.

### Results

Copy the following table into your workbook.

| Situation | Type of energy that caused the change | Changes you observed |
|---|---|---|
| A sparkler burns. | | |
| A torch is turned on. | | |
| A tennis ball falls. | | |
| A slinky spring is compressed and released. | | |
| Warm air is blown over a damp cloth. | | |

### Discussion

1 a The sparkler, the torch, the tennis ball and the slinky spring all had potential energy before you completed each activity. **Identify** which type of potential energy each object possessed.

b **Explain** whether each of these four objects still had potential energy once the experiment was completed.

2 The warm air blown from the hair dryer produced a change in the damp cloth. **Identify** three examples in which heat is used to produce a similar change.

# 5.2 Energy changes



Sometimes energy is passed from one object to another. If you hit a tennis ball with a racquet, then some of the kinetic energy of the racquet is transferred to the ball. At other times, one form of energy changes into other forms of energy. For example, a television is powered by electrical energy, which is changed into light, sound and heat energy. A car travelling down the freeway uses the chemical energy in petrol to give it the kinetic energy to keep moving.

INQUIRY science 4 fun

## Energy transfer




How is energy passed on from one object to another?

**Collect this…**

- dominoes

**Do this…**

1. Carefully stand each domino vertically with only a centimetre or so between each one.
2. Give the first domino a gentle push.

**Record this…**

**Describe** what happened to the other dominoes.

**Explain** why you think this happened.

## Energy transfer

Energy can be passed from one object to another. This is known as **energy transfer**. If you stand in front of a heater, then heat energy is transferred from the heater to you, warming you up. As Figure 5.2.1 shows, when you kick a ball, kinetic energy from your foot is transferred to the ball, causing the ball to move.

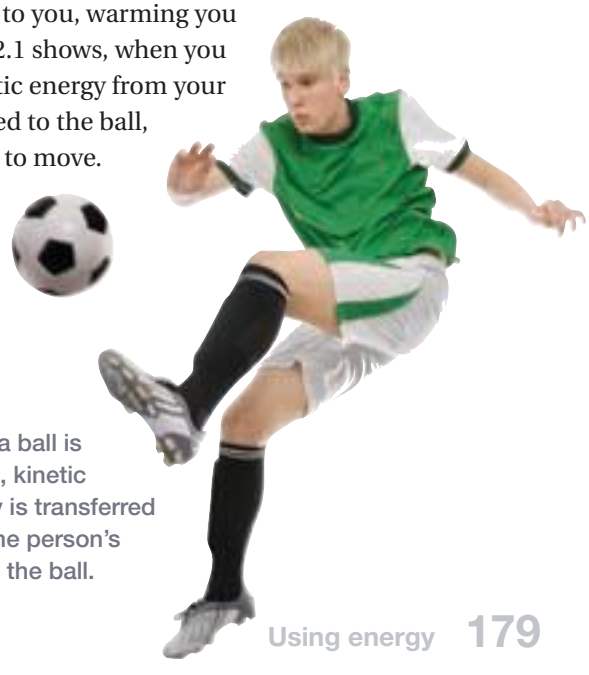


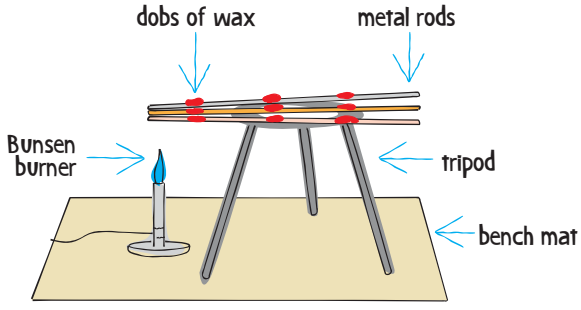
Figure 5.2.1 When a ball is kicked, kinetic energy is transferred from the person's foot to the ball.

INQUIRY science 4 fun

## Heat transfer

How is heat energy transferred?

No




### Collect this…

- three rods of different metals (e.g. iron, copper and steel)
- Bunsen burner, tripod and bench mat
- candle
- timer
- matches

### Do this…

1. Place a tripod on a bench mat.
2. Lie the three metal rods on top of the tripod as shown.
2. Place the Bunsen burner just below the ends of the rods.
3. Light the candle and drip dobs of wax onto each rod as shown.
4. Heat the ends of the rods using the blue flame of the Bunsen burner. Time how long each dob of wax takes to melt.
   *Note:* Do not touch the metal rods until they have cooled down.
   If a dob of wax has not melted after 10 minutes, turn off the Bunsen burner.
5. From your observations, identify the rod that was best at transferring heat.

### Record this…

**Describe** what happened.

**Explain** why you think this happened.

1 p187

# Energy transformation

Energy can be transferred from one object to another. Energy can also be changed, or transformed, from one type of energy into another type of energy. Whenever you watch TV, listen to music or play on a games console, you are relying on **energy transformation**. Computers, TVs and MP3 players convert electrical energy into sound, light and heat energy. Figure 5.2.2 shows some energy transformations using an **energy flow diagram**.

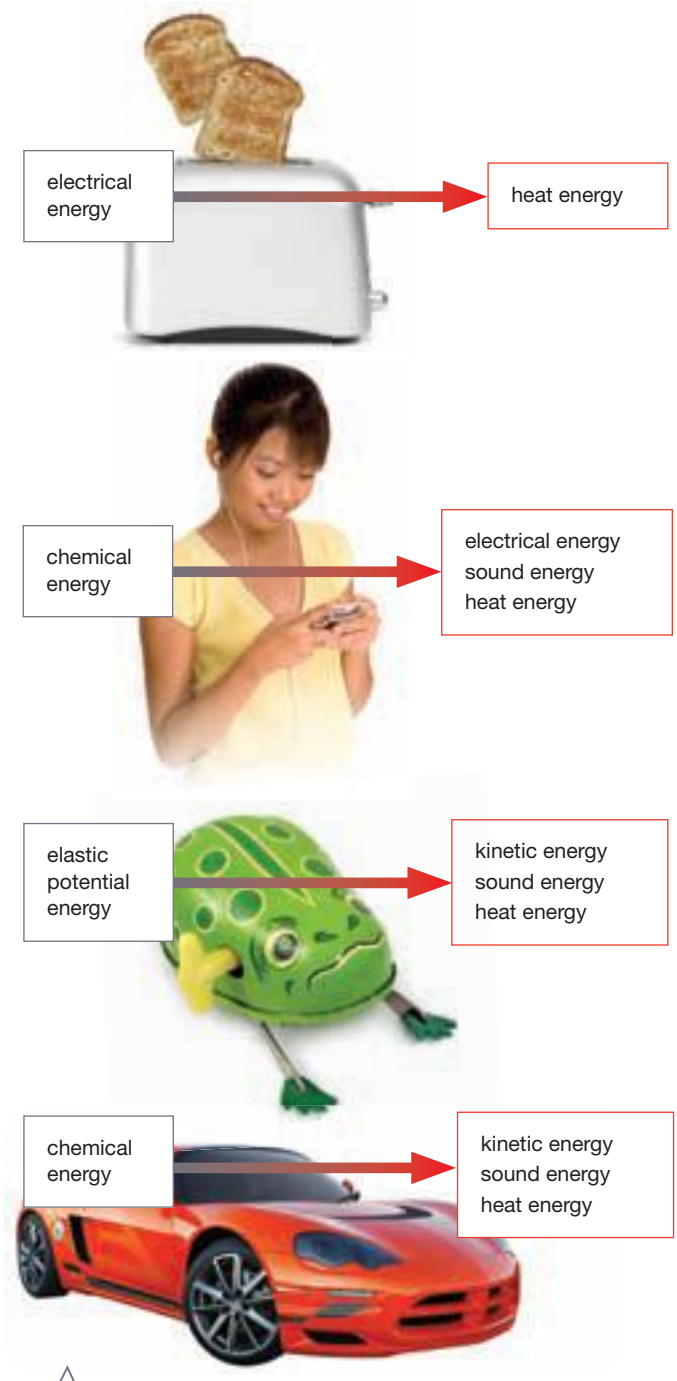



**Figure 5.2.2** Energy transformations are shown using an arrow. Here are some energy transformations that occur when using a toaster, an MP3 player, a wind-up toy and a car.

Sometimes a number of different energy changes happen all at once. Imagine that you accidentally knock a glass off a table. The glass falls and smashes on the floor below. The glass initially has gravitational potential energy. When it is falling, this energy is changed into kinetic energy and some heat energy. When it hits the floor, some of the kinetic energy is transferred to the pieces of glass that break and fly off in all directions. Some kinetic energy is converted into sound and heat energy. Figure 5.2.3 describes these changes in a flow diagram.

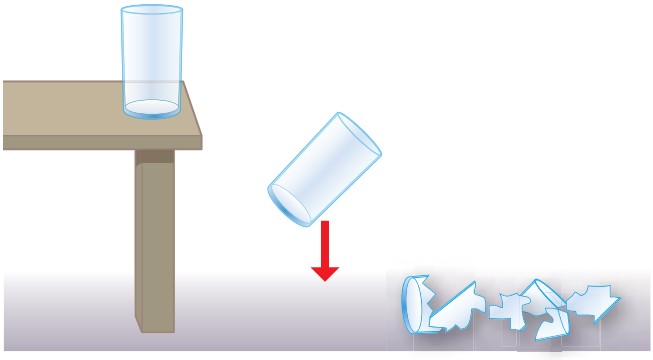



**Figure 5.2.3** There are many energy changes happening when a glass falls off the table.

A solar cell converts light energy into electrical energy. This energy can then be converted into many different types of energy. Figure 5.2.4 shows an energy flow diagram for the energy changes involved in using a solar fan.

## The law of conservation of energy

Sometimes it looks as though energy disappears. For example, when you kick a ball, the kinetic energy you give the ball seems to be lost when the ball stops moving. Actually, this kinetic energy has been converted into other forms of energy, such as heat and sound energy.

The **law of conservation of energy** states that energy can never be created or destroyed. It can only be converted from one form to another.

This means that:

- energy might be passed on or wasted, but it is never lost
- if one object wastes energy, then it is always gained by another object, usually as heat.

2 p188 5.2 5.3

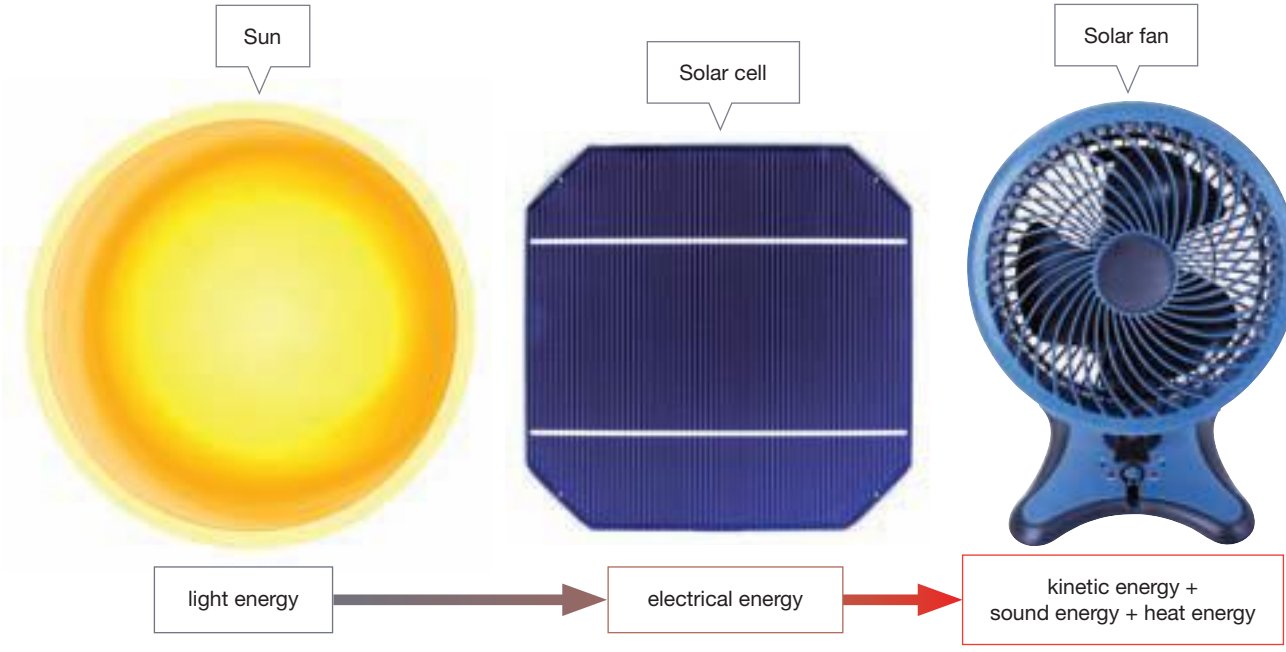



**Figure 5.2.4** A solar cell converts light energy from the Sun directly into electrical energy. This electrical energy is converted into the kinetic energy of the blades, as well as sound and heat energy produced by the solar fan.

# Useful and wasted energy

Any object that moves, or has moving parts, has kinetic energy. A child pushing a toy car gives the car kinetic energy. When the child stops pushing, the car keeps moving along the ground. However, friction between its wheels and the ground produces heat energy. Eventually, the car will stop moving because all of its kinetic energy has been converted into heat energy. This heat energy is wasted energy. The energy has been transformed into a form that is not useful.

INQUIRY science 4 fun

## Hot stuff!

Does friction produce heat?

Yes

### Collect this…

- hose or needle attachment that fits the bike tyre or ball
- bike tyre or inflatable ball
- pump

### Do this…

1. Fit the hose to the bike tyre or the needle into the ball.
2. Pump up the tyre or ball. *Note:* Do not over-inflate balls or tyres or they could explode.
3. Undo the hose or needle attachment.
4. Feel the end of the hose or needle.

### Record this…

**Describe** what happened.

**Explain** why you think this happened.



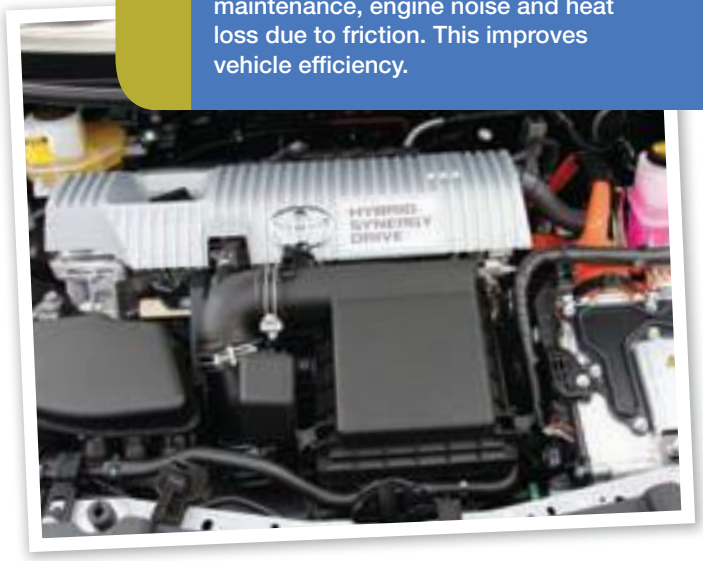
Figure 5.2.5

The useful energy you want from a torch is light energy. The heat released is wasted energy.

SciFile

### Beltless

If you have ever looked at a car engine while it is running, you have probably noticed belts used to transfer energy.
For example, a fan belt is used to turn a fan that cools the engine.
Some new cars now rely on electrical systems to replace the use of belts.
A beltless engine reduces car maintenance, engine noise and heat loss due to friction. This improves vehicle efficiency.



Most energy conversions waste some energy, usually releasing it as heat and perhaps some sound. For example, you can feel unwanted heat coming from computers, TVs and light globes. This heat wastes some of the electrical energy used to operate the appliance, making it more expensive to run. Some examples of energy conversion and wasted energy are shown in Table 5.2.1.

**Table 5.2.1 Examples of energy conversions**

| Example | Initial energy | Useful energy produced | Wasted energy |
|---|---|---|---|
| Using an electric toothbrush | Electrical energy | Kinetic energy | Heat and sound energy |
| Playing cricket | Chemical energy from food digested | Kinetic energy of moving cricket bat and ball | Heat and sound energy |
| Using an MP3 player | Chemical energy from batteries | Sound and light energy | Heat energy |
| Using a torch (Figure 5.2.5) | Chemical energy from batteries | Kinetic energy | Heat energy |

## Energy efficiency

Any device that converts energy, such as a car or a computer, requires some form of energy to make it run. This is its input. Useful energy is its output. As we have seen, unwanted forms of energy are released too, usually as heat. **Energy efficiency** is a measure of how much input energy is converted into useful output energy. The greater proportion of useful output energy, the greater the energy efficiency of the device. If most of the input energy is converted into useful output, then the device is energy efficient. If a lot of the input energy is wasted, then the device is inefficient.

In an electric fan, electrical energy is converted into the kinetic energy of the fan blades, which produces a breeze. If all of the electrical energy was converted into kinetic energy, then the fan would be extremely energy efficient. In reality, an electric fan wastes some of its electrical energy by converting it into sound and heat. This makes it inefficient. Figure 5.2.6 shows one inefficient and one efficient energy conversion.

### Idle energy

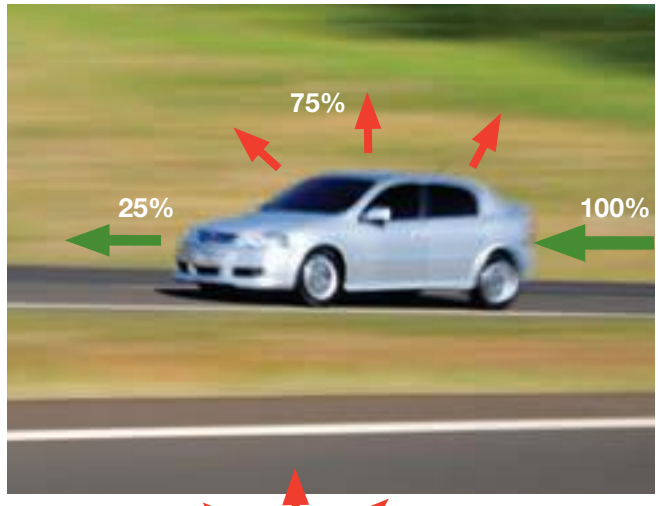
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Long-distance truck drivers often keep their truck's engine running during their rest breaks. This keeps the truck's heating, cooling and other features working, but wastes billions of litres of fuel worldwide each year. Auxiliary power units (APUs) reduce these energy losses. These portable, truck-mounted units provide power and climate control without the need to keep the engine running.



## Renewable energy

Some energy sources are renewable. This means that they are unlimited in supply and can be used over and over again. Examples are solar energy, wind energy and hydroelectric energy. Most of the electrical energy that supplies Australian households comes from burning fossil fuels, such as coal, oil or natural gas. These fossil fuels were formed over millions of years and are known as non-renewable energy sources. Fossil fuels contain chemical potential energy, which is released when the fuel is burnt. Figure 5.2.7 on page 184 shows that only a small fraction of the original chemical potential energy of a fossil fuel is converted into the useful energy needed to operate devices in our homes. This happens because heat energy is lost at each step of generating and delivering the electricity.



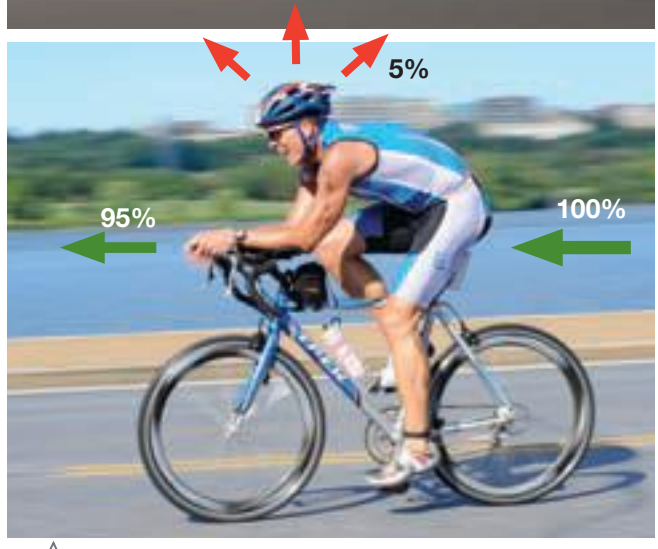




**Figure 5.2.6** Only about one-quarter of the chemical energy supplied to a car goes into making it move. In other words, for every 100 J of chemical energy supplied, only 25 J of kinetic energy is produced. In contrast, when riding a bike, up to 95kJ out of every 100kJ of energy that your muscles supply is converted into the kinetic energy of the bike.

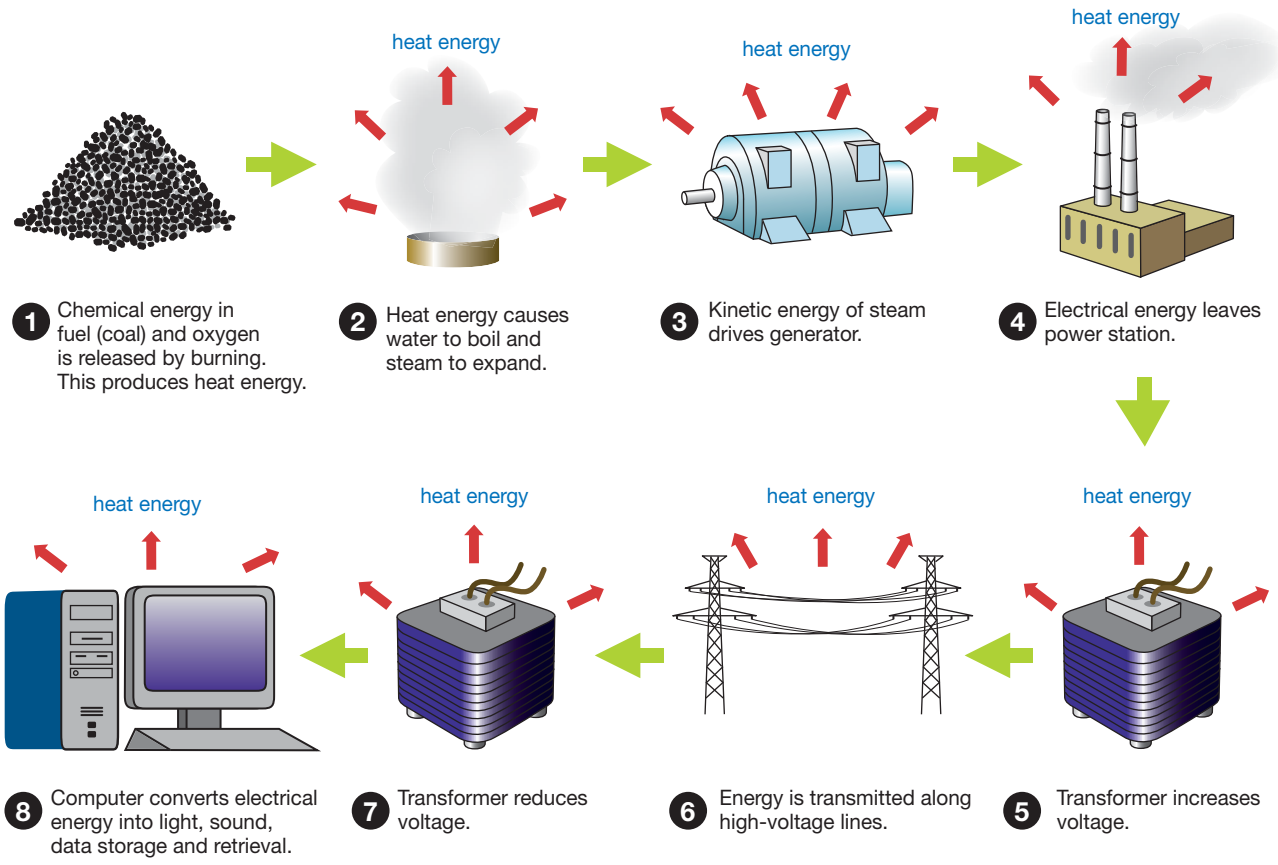



**Figure 5.2.7** There are many steps needed to convert the chemical energy of coal into electrical energy for households. Heat energy is produced at each stage of this process. These losses of heat energy reduce the efficiency of the process.

Table 5.2.2 compares the typical percentage energy efficiencies of some energy converters.

**Table 5.2.2 Energy efficiencies of some energy converters**

| Energy converter | Efficiency (%) |
|---|---|
| Incandescent light globe | 5 |
| Electric motor | 80 |
| Steam engine | 40 |
| Power station | 30 |
| Human | 25 |

5.4 p189

## WORKED EXAMPLE
### Energy efficiency

#### Problem

In 5 minutes, a particular battery-operated remote-controlled car used 1800 J of chemical energy. Of this chemical energy, it converted:

- 450 J into kinetic energy
- 300 J into sound energy
- 1050 J into heat energy.

Given that the useful energy output of this device is kinetic energy, calculate the percentage energy efficiency of the car.

#### Solution

The useful energy output is the 450 J of kinetic energy and the total energy input is the 1800 J of chemical energy supplied by the battery.

$$\text{energy efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

$$= \frac{450}{1800} \times 100$$

$$= 25\%$$

This means that 25% of the energy input is converted into a useful form of energy output, so the car is 25% efficient.

# 5.2 Unit review

## Remembering

1 **Recall** two examples of energy transfer.

2 **Name** the type of energy that is produced by a solar cell.

3 Refer to Table 5.2.1 on page 182 and **list** the wasted forms of energy that occur when you:
   - a listen to an MP3 player
   - b play cricket.

4 Refer to the law of conservation of energy and **state** whether the following statements are true or false.
   - a If energy is wasted, then it is lost altogether.
   - b If energy is lost from one object, then it will be gained by another.
   - c The total amount of energy in the universe is always changing.

5 **Name** the type of energy possessed by fossil fuels.

## Understanding

6 a Use an example to **explain** what is meant by the term *energy transformation*.
   - b **Describe** the energy transformation(s) that take place when you cook rice in a microwave oven.

7 a **State** the law of conservation of energy.
   - b **Explain** what this law means, using an example.

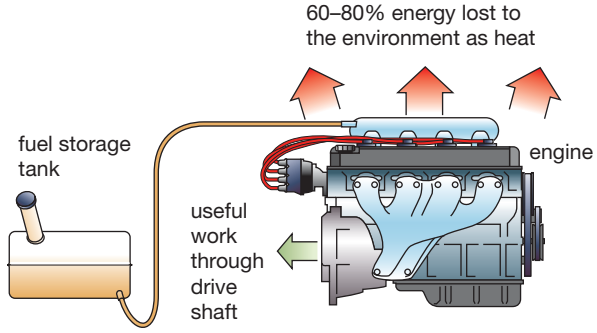
8 **Explain** why any object on Earth that moves will get warmer than if it was not moving.

9 **Define** the term *energy efficiency*.

10 **Describe** how heat losses reduce the efficiency of a device.

11 **Outline** why the process of converting the chemical energy of coal into electrical energy is very inefficient.

## Applying




Efficiency:

| | |
|---|---|
| petrol engine | 25% |
| diesel engine | 35% |
| jet turbine | 30% |
| steam engine | 40% |

Figure 5.2.8

12 a **Use** the information in Figure 5.2.8 to **rank** the different engines from most to least efficient.
   - b If 100 MJ of energy is supplied to a jet turbine, **calculate** the amount of energy that is converted into useful energy required to fly the jet.
   - c **Calculate** the percentage of energy that is wasted in a typical petrol engine.

13 You ride a skateboard down the street.
   - a **Identify** the source of energy input for this activity.
   - b **Identify** the types of energy that are produced.

14 **Use** your knowledge of energy transformations to match the situations a–e below with the appropriate energy transformations i–v.
   - a A girl toboggans down a slope.
   - b You ride a bike.
   - c A wind-up toy car travels across the floor.
   - d A boy swims in a pool.
   - e Wood burns in a fire.
   - i chemical energy → kinetic energy + sound energy + heat energy
   - ii gravitational potential energy → kinetic energy + sound energy + heat energy
   - iii chemical energy → heat energy + light energy + sound energy
   - iv elastic potential energy → kinetic energy + sound energy
   - v chemical energy → kinetic energy + sound energy + heat energy

# 5.2 Unit review

## Analysing

**15** In 10 minutes, a power saw used 6050 J of electrical energy. It converted:

- 1210 J into kinetic energy
- 1520 J into sound energy
- 3320 J into heat energy.

**a** **Identify** useful output energy from the saw.

**b** **Calculate** percentage energy efficiency of the saw.

**16** An iPod dock is supplied with 2000 J of electrical energy. Of this, 900 J is converted into heat energy, 300 J is converted into kinetic energy of the sound system and the remaining energy is converted into sound. **Calculate** the:

**a** number of joules of sound energy produced

**b** percentage efficiency of the device for converting electrical energy into sound energy.

**17** A car is a very inefficient machine.

**a** **List** which forms of wasted energy are produced.

**b** Cars would soon overheat if they didn't have a radiator. **Analyse** what the purpose of a radiator is.

**18** An apple that falls from the top of an apple tree hits the ground at a greater speed than an apple that falls from near the base of the tree. **Analyse** why this happens.

## Creating

**19** **Construct** a flow diagram to show the energy changes that happen when you:

**a** ring a doorbell

**b** light a match

**c** fall over.

**20** **Use** Figure 5.2.9 to **construct** a flow diagram to show the energy changes that occur when you vacuum the floor using electricity from a wind generator.

## Inquiring

**1** Materials differ in how well they transfer heat. If heat travels easily through a material it is called a good conductor of heat. If heat is not easily conducted through a material, it is called an insulator. Research which materials are good conductors of heat and which materials are insulators.

**a** List three conductors and three insulators.

**b** Discuss ways that materials can be used based on how well they transfer heat.

**2** A scramjet is a new type of jet engine that is designed to operate at very high speeds. It has no moving parts, which is necessary to avoid losing energy due to friction at high speeds. Research the scramjet and outline four facts about it.

**3** **a** Using materials such as rubber bands or hat elastic, craft sticks or pieces of dowel, construct a model bungee. Securely fix a weighted bungee-jumper to your bungee and examine changes in speed and motion as the bungee operates.

**b** Construct a flow diagram to describe the energy transformations that occur during a bungee jump.

**c** Propose reason why the bungee will eventually come to a stop.

**4** Does a ball bounce higher if it is warmer? Investigate, using a ball and a hair dryer.

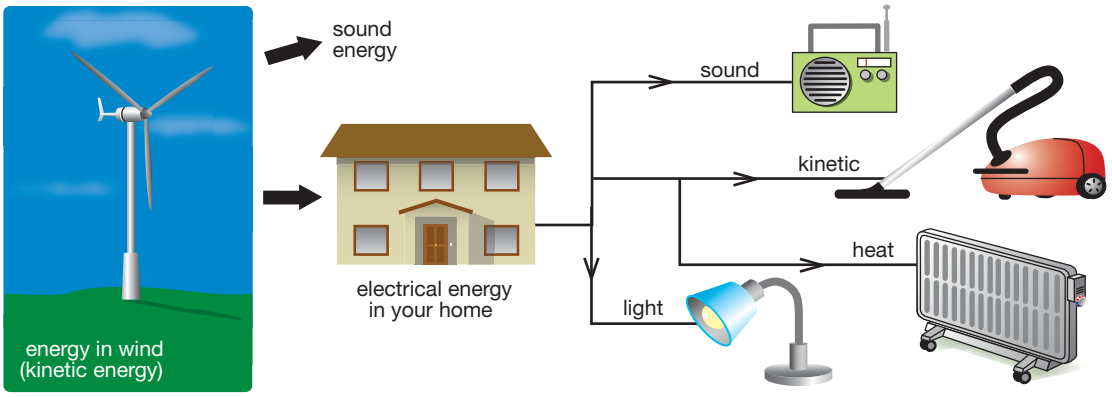



Figure 5.2.9

# 5.2 Practical activities

## 1 Investigating heat

Heat can be transferred in a number of different ways. If two substances are in contact, then the heat of one substance can be transferred to the second substance through a process called conduction. Some materials are better conductors than others.

### Purpose

To compare how effectively different substances conduct heat.

### Materials

- supply of hot water
- polystyrene cup
- metallic mug
- ceramic coffee mug
- thermometer or temperature probe and data logger




### Procedure

1. Copy the results table below into your workbook.
2. Carefully pour 100 mL of hot water into each cup or mug. Make sure that the water poured into each is at the same temperature.
3. Place a temperature probe or thermometer into each cup or mug.
4. Record the starting temperature using the data logger or thermometer and take measurements for 10 minutes.

### Results

Construct a line graph showing the temperature of the water in the cup and mugs over the 10 minutes.

### Discussion

1. To be a fair scientific test, the three containers used in this experiment should be the same thickness and have the same diameter opening at the top. **Explain** why these factors are important.
2. Based on your results, **identify** the material that was the:
   a. best conductor of heat
   b. worst conductor of heat.
3. A pool blanket is used to trap heat within a swimming pool. **Propose** whether the blanket should be made from material that is a good or a poor conductor of heat.

| Time (minutes) | Temperature of water in | | |
|---|---|---|---|
| | Polystyrene cup (°C) | Metallic mug (°C) | Ceramic coffee mug (°C) |
| 0 | | | |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

# 5.2 Practical activities

## 2 Energy changes

### Purpose

To observe and identify different energy changes.

### Materials

**Part A**

- alligator clips
- light globe
- 6 V battery

**Part B**

- steel wool
- bench mat
- alligator clips
- 6 V battery and switch

**Part C**

- tuning fork
- rubber stopper
- beaker of water

**Part D**

- 200 g mass
- modelling clay

**Part E**

- rubber band
- polystyrene ball



**SAFETY**

Wear safety glasses for these tasks.

In part B, do not leave the switch closed as the steel wool could catch fire.

In part E, do not flick polystyrene balls near people.

### Procedure

Copy the results table into your workbook. As you complete each task, fill in your observations in this table.

**Part A**

1 Use two alligator clips to connect a light globe to a battery or power pack as shown in Figure 5.2.10.

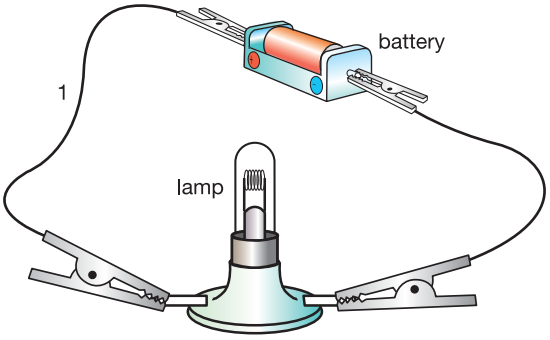



Figure 5.2.10

**Part B**

2 Place the strands of steel wool on a bench mat. Use alligator clips to connect these to a battery and a switch as shown in Figure 5.2.11. Close the switch for a few seconds and watch the steel wool.

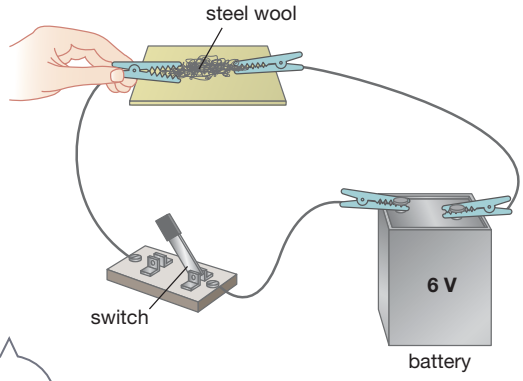



Figure 5.2.11

**Part C**

3 Strike a tuning fork on a rubber stopper. Put the ends of the tuning fork into a beaker of water.

**Part D**

4 Drop the 200 g mass onto a lump of modelling clay from a height of about 30 cm.

**Part E**

5 Place the polystyrene ball on the bench. See if you can make the ball roll along the bench using a stretched rubber band. Figure 5.2.12 shows the method.

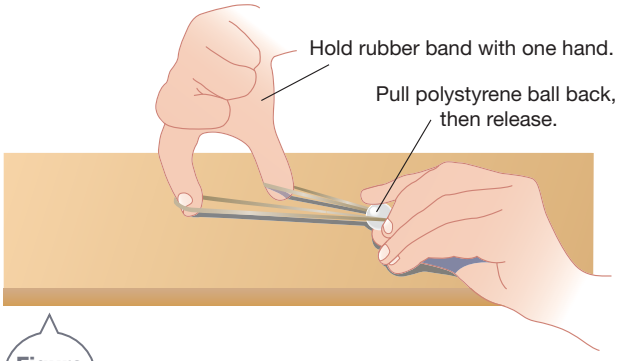



Figure 5.2.12

### Results

1. Copy the table below into your workbook. Use it to record your observations.
2. Next to the observations recorded in your results, list the source of energy in each case, and any forms of energy produced.

### Discussion

1. **Discuss** whether there were any situations in which energy was transferred but not transformed into a different form.
2. **Name** two devices that you have used today. **State** the energy changes that occurred in these devices.

| Prac | Situation | Observations | Energy supplied | Energy produced |
|---|---|---|---|---|
| Part A | Connecting a light globe to a battery | | | |
| Part B | Connecting steel wool to a battery | | | |
| Part C | Striking a tuning fork and dipping its ends into water | | | |
| Part D | Dropping a 200 g mass onto a lump of modelling clay | | | |
| Part E | Propelling a polystyrene ball using a rubber band | | | |

## 3 Investigating the efficiency of bouncing balls

### Purpose

To calculate and compare the efficiency of bouncing balls.



### Materials

- different types of balls
- equipment to measure the height of a bounce (such as a video camera or metre ruler)

### Procedure

When a ball is dropped from a height, its gravitational potential energy is converted to kinetic energy and heat. As the ball rebounds from the floor, some of its kinetic energy is converted back into gravitational potential energy. This process continues until all of the initial gravitational potential energy has been converted into other forms of energy. The efficiency of the first bounce of the ball can be calculated as:

$$\text{Efficiency} = \frac{\text{rebound height of first bounce}}{\text{initial height above ground}} \times 100\%$$

Design an experiment to calculate the percentage efficiency of the first bounce of a range of different types of balls. Use apparatus such as a video camera and metre ruler to assist you in measuring the rebound height.

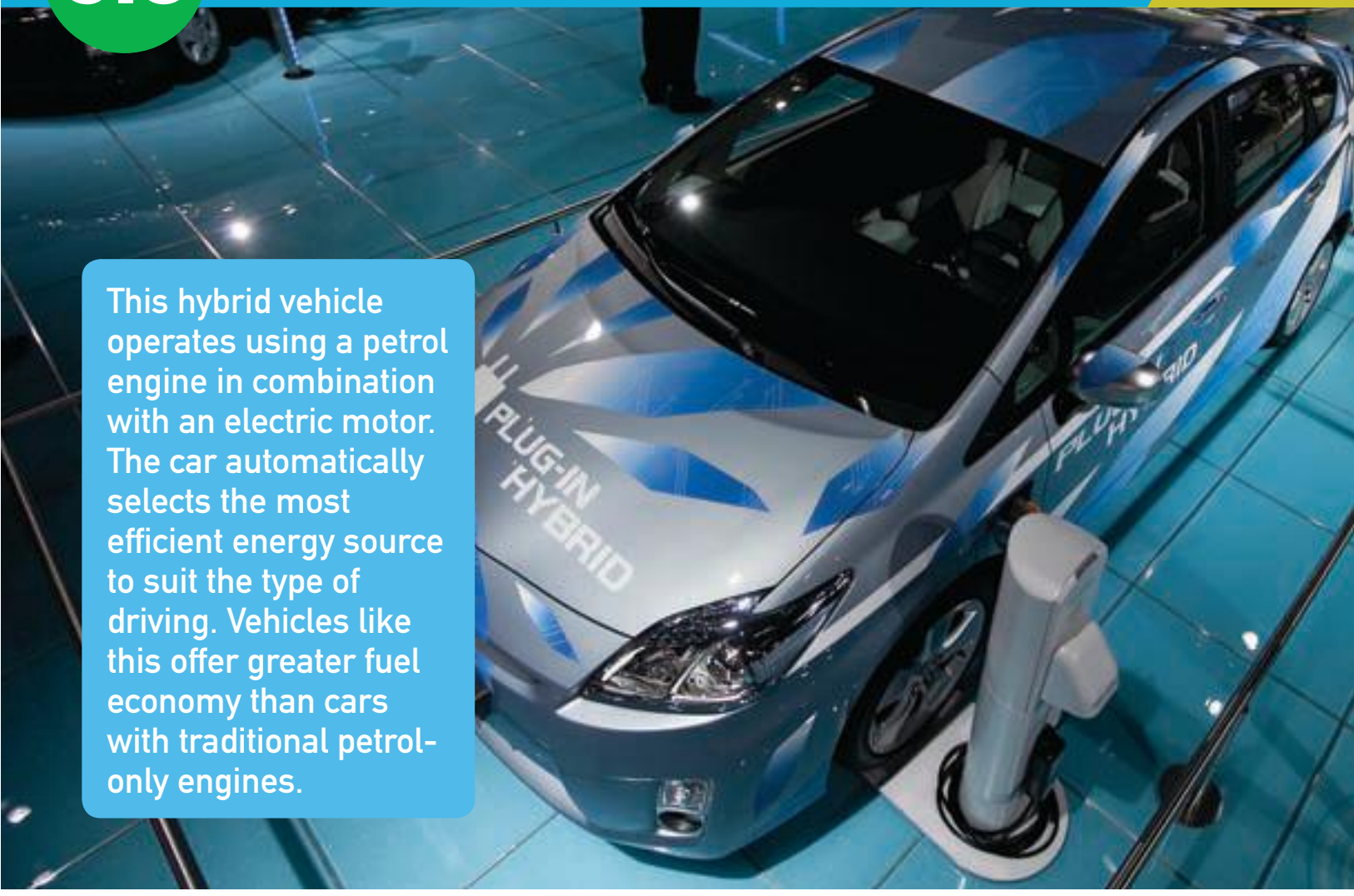
### Results

1. Compare the efficiency of the different balls in your sample.
2. Summarise your aim, materials, procedure, results and discussion in a report.

### Discussion

1. **Propose** ways to improve your experiment design.
2. **Propose** reasons why the balls varied in efficiency.

# 5.3 Energy-efficient design




This hybrid vehicle operates using a petrol engine in combination with an electric motor. The car automatically selects the most efficient energy source to suit the type of driving. Vehicles like this offer greater fuel economy than cars with traditional petrol-only engines.

## Reducing energy consumption

Around the world, the demand for energy has never been greater than it is today. Most of the energy that we rely on to power our cars, heat and cool our homes and run electronic devices is produced from non-renewable sources such as coal, natural gas and oil. These non-renewable energy sources are limited in supply and burning them adds greenhouse gases to the atmosphere. More and more people are realising that these greenhouse gases increase the risk of globing warming and that may cause climate change.

In Australia, climate change is likely to:

- cause more frequent and intense droughts, storms and floods
- assist the spread of diseases, especially mosquito-borne diseases such as dengue fever and Ross River virus
- alter the populations of different species of plants and animals, especially those that live above the snowline in the southern states.

Reducing the amount of energy we use reduces the amount of greenhouse gases put into the atmosphere. We can reduce energy consumption in many ways, such as by switching off lights, computers and televisions when they are not in use. Walking, cycling or using public transport instead of relying on the family car will reduce your household's energy consumption. Replacing highly inefficient incandescent globes with more efficient compact fluorescent globes has already cut the energy bills of most households. Table 5.3.1 compares the efficiencies of incandescent and fluoroescent globes.

5.5
5.6

Table 5.3.1 Comparison of incandescent and compact fluorescent globes

| Power | Approximate balloons of greenhouse gas produced over its lifespan | Purchase price | Expected operating hours | Approximate cost per year |
|---|---|---|---|---|
| 75 watt incandescent  |  3600 | $1.00–1.20 | 1000–2000 | $12.30 |
| 15 watt (75 watt equivalent) fluorescent  |  730 | $4.00–10.00 (cheaper if buying a pack of 2 or 3) | Around 8000 hours | $2.30 |

SciFile

### See the light!

Old-fashioned incandescent light globes converted most of their electricity into heat. The compact fluorescent globes available today use about 80% less electricity to produce the equivalent amount of light.

SciFile

### Comparing labels

The energy rating label was first used in New South Wales and Victoria in 1986. Today, any household refrigerator, freezer, television, washing machine, clothes dryer, single-phase air conditioner or dishwasher sold in Australia must carry an approved energy rating label. It's the law!

# Energy rating labels

Household appliances vary in their energy efficiency. By purchasing appliances that are more efficient, your household will save energy and save on running costs. If you look around shops selling electrical appliances you will see that most large appliances carry a red and yellow **energy rating label**. A sample label is shown in Figure 5.3.1.

1 p198

Energy efficiency is shown by the number of stars on the label. The more stars (usually from 1 to 6) that are shaded on the energy rating label, the greater the energy efficiency of the appliance. You can determine which models are the most energy efficient by comparing the number of stars. The number found on the label provides the customer with an estimate of the amount of energy (usually listed in kilowatt hours per year) needed to operate the appliance for one year. The higher the number, the more energy is needed and the more the appliance will cost to run.

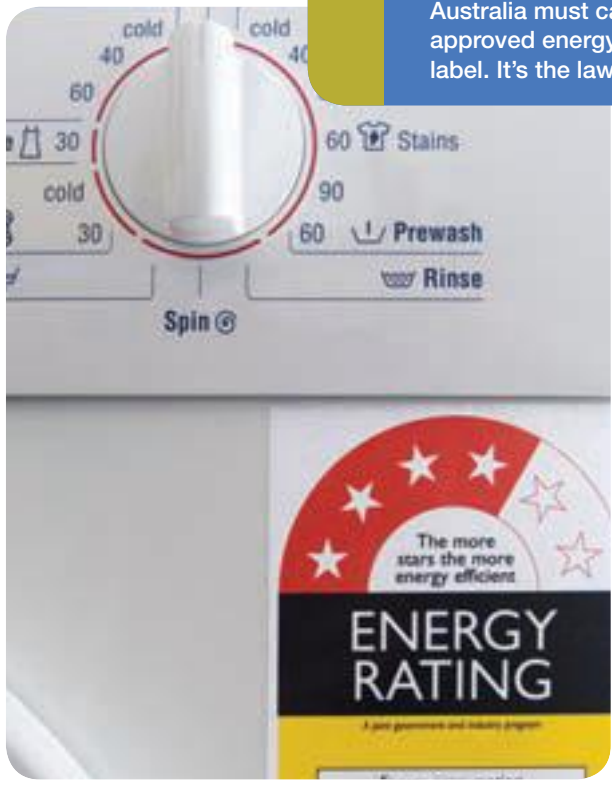



Figure 5.3.1 Appliances are tested under Australian standards to produce an energy rating label. Greater energy efficiency is indicated by more stars (or half stars) out of a possible six stars.

INQUIRY
science 4 fun

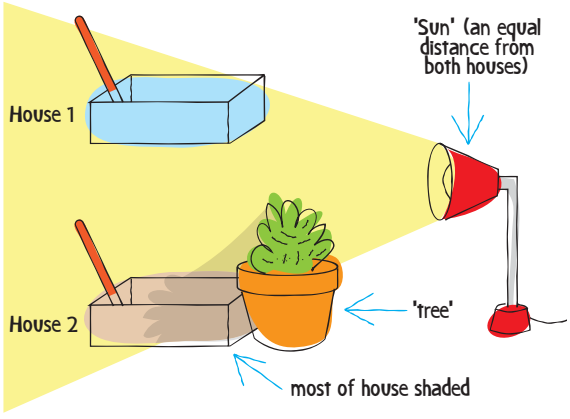
## Shading a house

How much difference does shade make to the temperature inside a house?

### Collect this…

- 2 identical shoeboxes
- incandescent desk lamp (sunlight will do on a warm day)
- pot plant or branch with leaves propped up in a pot with dirt
- 2 thermometers or temperature probes

### Do this…




1. Position the two shoebox 'houses' an equal distance from the desk lamp (or outside in a sunny position).
2. Place the pot plant or branch close to one 'house' so that it is shaded as much as possible.
3. Measure the temperature inside each 'house' every 5 minutes for an hour.

### Record this…

**Describe** what happened.

**Explain** why you think this happened.

SciFile

### How much energy is that?

Energy rating labels display the typical amount of energy an appliance will use over one year. This value is stated in kilowatt hours. One kilowatt hour is equal to 3 600 000 joules of energy. This can also be written as 3.6 megajoules (MJ).

## Efficient housing

Living in an energy-efficient house makes it easier for households to reduce their energy consumption. It is estimated that about half of the energy costs of running a house are to keep it warm in winter and cool in summer. Heat naturally flows from regions of higher temperature to regions of lower temperature. In winter, the warm air from a heater or heating system can flow through any cracks or gaps in the walls to the cool air outside or into the cooler garage. Alternatively, heat can rise up into the roof space. This means that a lot of energy is needed to keep a leaky house warm in winter. Similarly, in summer, the warm air outside will naturally flow into a cool house. To keep the house cool, air-conditioners might be used. However, they use a lot of energy, making them expensive to run. Adding **insulation** to ceilings and between the walls of a home reduces the heat flowing outside in winter and inside in summer. This makes heating and cooling more effective and makes a house more comfortable.



Figure 5.3.2 This zero emissions house has been constructed in a Victorian housing estate. Over the course of a year, solar panels on the roof generate as much energy as the house will use.

The **National House Energy Rating Scheme** uses computer simulations to provide a star rating for the built exterior shell of a house. A rating of zero stars means that the house is poorly designed and does little to protect its occupants from heat in summer and cold in winter. A house rated at 10 stars probably won't need any heating or cooling because it remains at a comfortable temperature all year round.

Improvements in house design can be achieved by:

- considering the orientation of windows—in Australia this usually means placing large windows along the northern and eastern sides of the house, with small or no windows on the hot western side and the cooler southern side
- considering the orientation of the house on the block of land—in Australia, this usually means having living areas facing north and other rooms (such as the bathroom) facing south
- tinting or shading west-facing windows
- including coverings such as eaves, verandas or pergolas over the north- and west-facing windows
- insulating the floor, walls and roof to reduce energy losses.

Building regulations throughout Australia require new homes to be built to specific minimum energy standards. Figure 5.3.3 shows design features that make a house more energy efficient.

## Innovative design

The need to save energy has led to new and innovative designs to increase efficiency. Some of these ideas include regenerative braking, interior cooling in parked cars, magnetic refrigeration, LED lighting, organic photovoltaics and dry washing mashines.

The **regenerative braking** system of a hybrid car captures some of the vehicle's kinetic energy as the car slows down. Stored in a battery, this energy is then used to power the car's electric motor when needed. Elevator (lift) manufacturers are investigating how to use this idea to save the energy used by lifts.

Some luxury cars now incorporate solar cells on the roof of the car. These cells power interior fans that prevent the inside of the car from getting too hot when the car is parked. This reduces the need for air conditioning when the car is being driven.

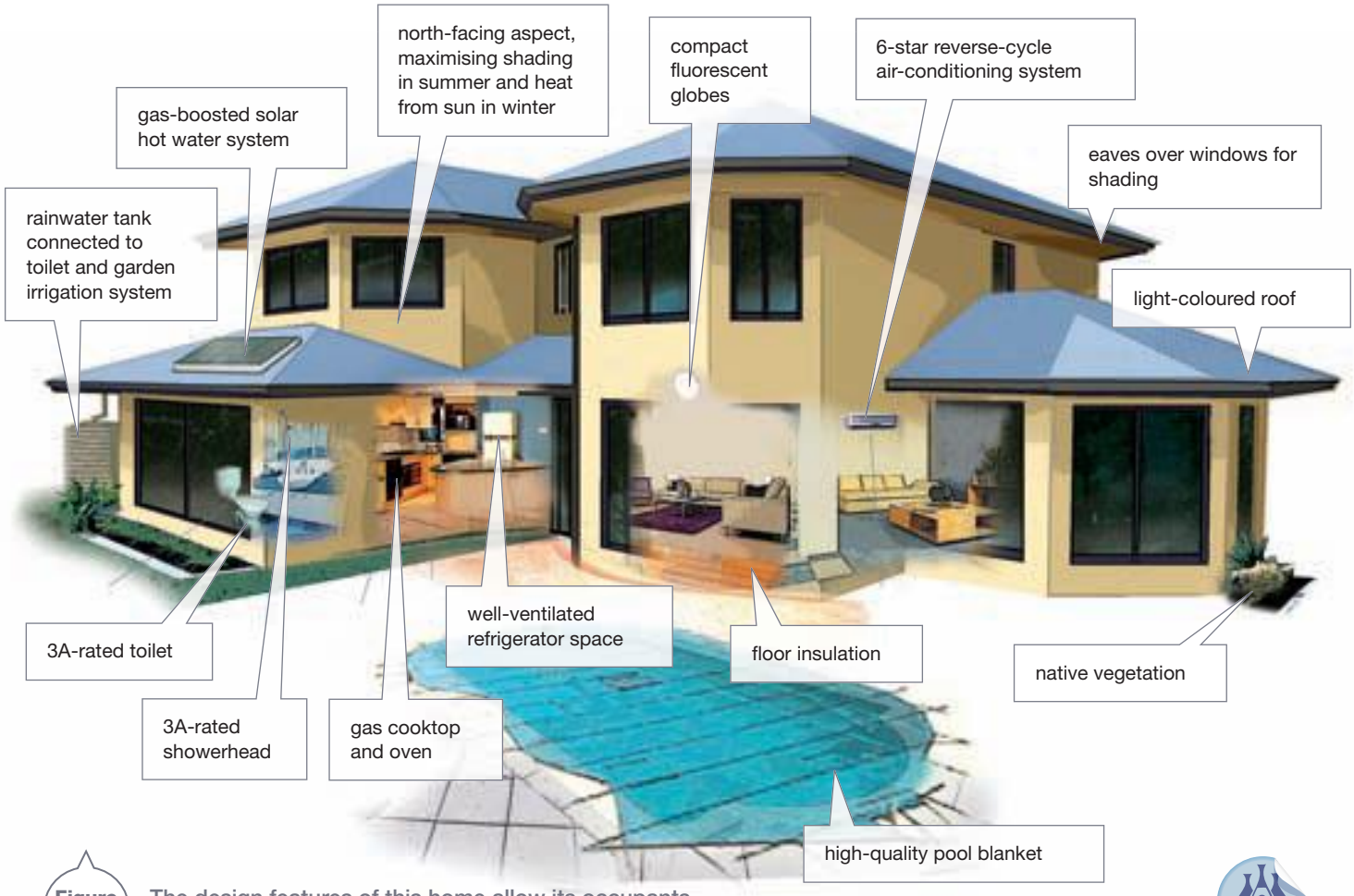



**Figure 5.3.3** The design features of this home allow its occupants to be comfortable while reducing energy consumption. They also include water-saving features.

2 p199

Magnetic refrigeration is a new way of providing cooling using a magnetic field. Once fully developed, this technology could reduce the energy used by refrigerators and air conditioners.

LED (light-emitting diodes) are very bright but use very little energy. Current LEDs produce a cool bluish light, but manufacturers are working on producing LEDs with a warmer colouring so they can be more widely used. Figure 5.3.4 shows the spectacular use of coloured LEDs to light buildings.

Organic photovoltaics are a new generation of flexible and cheap solar cells that are made from carbon-based materials. Researchers are currently trying to increase the efficiency of these solar cells from their current 5% to 15–20% efficiency of a traditional photovoltaic cell. If their efficiency can be improved, these cells have huge potential for widespread use. An organic photovoltaic cell is shown in Figure 5.3.5.

Dry washing machines are currently being developed. These machines clean clothes using thousands of dirt-absorbing nylon beads and use 90% less water than a conventional washing machine. As the dry washing machine only uses a small amount of water, much less energy is required to pump water in or out than in a normal washing machine. Energy is also saved because the water does not need to be heated. Finally, because the clothes that come out are already dry, people who rely on clothes dryers will not need to use them!

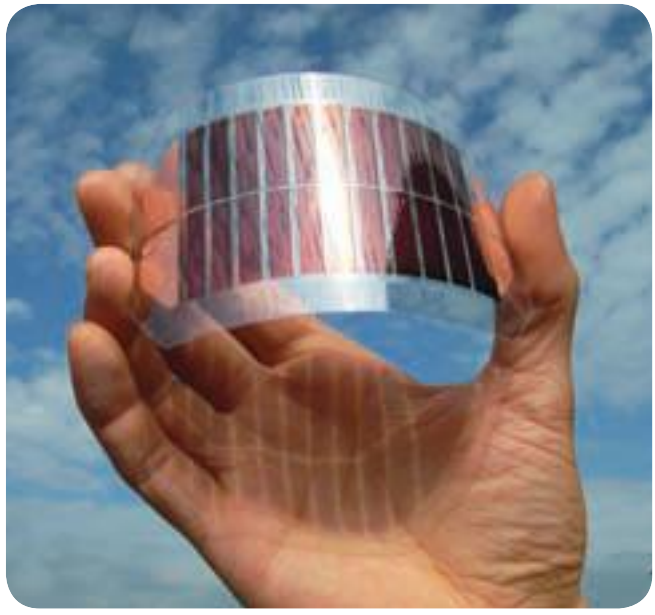


**Figure 5.3.5** Lightweight, flexible and cheap organic solar cells could be attached to bus stops, buildings and even clothing to generate electricity.



**Figure 5.3.4** Over 20 000 LEDs were installed on Council House in the city of Perth. This energy-efficient lighting display is controlled by computer.



Figure 5.3.6 Otto Lilienthal died in 1896 after losing control of a glider like this one in a strong wind.

# SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

## The development of aircraft

Humans have wanted to fly for thousands of years. Some of the important developments that have led to modern aircraft are outlined below.

### 400 BCE

Kites were flown in China.

### 1480 CE

Leonardo da Vinci drew diagrams of a machine with wings—an 'ornithopter'—that he thought could help people fly.

### 1799

British scientist Sir George Cayley (1773–1857) discovered many of the principles of flight. He did this by experimenting with the shape of the wings on a glider that would allow smooth air flow. In 1799 he designed a fixed-wing flying machine with airfoil-shaped wings for lift (the same shape as modern wings), a moveable tail for control and 'flappers' to provide thrust.

### 1891–1896

German engineer Otto Lilienthal (1848–1896) made over 2500 flights in monoplane and biplane gliders he designed. His gliders, such as the one shown in Figure 5.3.7, were the first to travel a long distance.

### 1903

American brothers Orville and Wilbur Wright researched the work of earlier aviation pioneers and tested theories of air flow using kites and balloons. The Wright brothers tested different shapes of aircraft wings in a wind tunnel to assist them in designing their gliders. They later added a gas-powered engine. In 1903, in North Carolina, USA, Orville Wright flew 36.5 metres in the *Flyer*—the first powered, heavier-than-air controlled flight (see Figure 5.3.7). By 1905 they had achieved a flight of 39.4 kilometres.

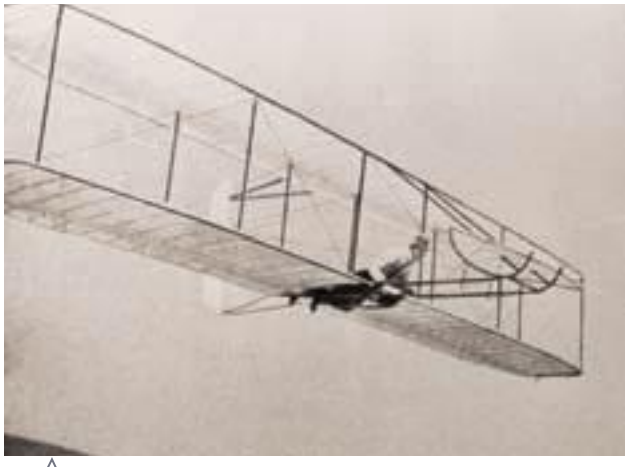


Figure 5.3.7 Orville Wright lying on the lower wing of the *Flyer*

continues on page 196

continued from page 195

## early 1900s

The first few decades of the 1900s were times of great development in aviation. To build faster and more efficient aircraft, the bodies of the aircraft needed to be enclosed to reduce the drag on them when in flight. Aircraft were then made from stronger (but not heavier) materials like aluminium. Figure 5.3.8 shows US aviator Charles Lindbergh, who made the first flight across the Atlantic Ocean in 1927, from New York to Paris. Australian aviator Charles Kingsford Smith made the first flight across the Pacific Ocean between the USA and Australia in 1928.



**Figure 5.3.8** Charles Lindbergh (1902–1974) flew his aircraft *Spirit of St Louis* from New York to Paris in the first solo flight across the Atlantic Ocean.

## 1950s

Aviation boomed following World War 2. Most aircraft were built with piston engines and propellers to provide thrust for flight.

Passenger jets such as the Boeing 707 were manufactured from the 1950s.



**Figure 5.3.10** The use of composite materials such as carbon–fibre reinforced plastic in the structure of this modern aircraft increases fuel efficiency and reduces greenhouse emissions.

## 1937

British pilot Frank Whittle designed the first turbo jet engine, which was used to power an aircraft in 1941. The jet engine shown in Figure 5.3.9 enabled aircraft to travel at high speeds.

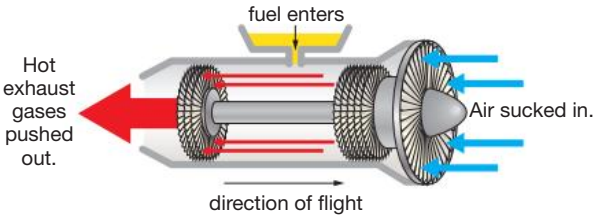



**Figure 5.3.9** A jet engine uses a spinning fan to draw in outside air, which is compressed by a second fan. Fuel is mixed with this compressed air, which burns, expelling hot exhaust gases at high speed. The force produced by releasing the exhaust gases propels the aircraft forward.

## Now

The engines of passenger jets such as the A380 airbus shown in Figure 5.3.10 have become more efficient and the materials used to construct the aircraft are lighter.

Improvements in aircraft design are ongoing. Figure 5.3.11 shows the design of a solar plane called *Solar Impulse* that successfully completed a 26-hour flight in 2010. Its 61-metre wingspan holds the 12 000 solar cells that power its flight. The aircraft carried only one passenger—the pilot. The flight is encouraging for future development of solar technology.

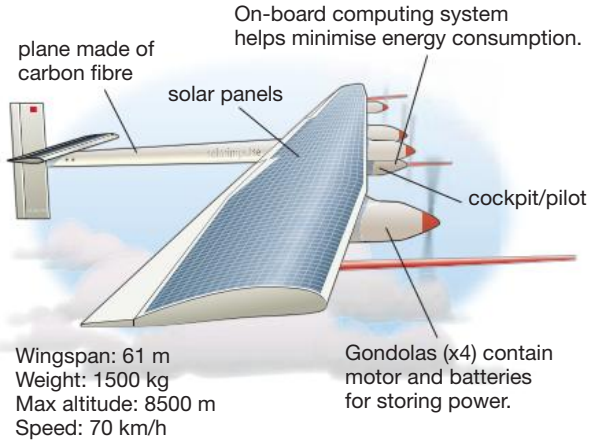



**Figure 5.3.11** *Solar Impulse* is made from lightweight carbon fibre and utilises super-efficient solar cells, batteries and four engines to fly.

5.8

# 5.3 Unit review

## Remembering

1 **List** four ways you can save energy.

2 **List** the types of appliances that must carry an energy rating label in Australia.

3 **Recall** the direction of heat flow by selecting the correct words to complete the following statement.

*Heat flows from regions of lower/higher temperature to regions of lower/higher temperature.*

4 **State** the aviation record that the Wright brothers achieved in 1903.

## Understanding

5 **Explain** why incandescent light globes have now almost completely been replaced by compact florescent globes.

6 **Explain** what the star rating in Figure 5.3.1 on page 191 tells a consumer about the energy efficiency of this appliance.

7 **Describe** three ways in which the house shown in Figure 5.3.4 on page 193 reduces household energy consumption.

8 **Explain** how adding insulation to a house and sealing up gaps can reduce the energy costs of heating and cooling the house.

9 **Explain** how regenerative braking makes a car more energy efficient.

10 It is important for developers to improve the efficiency of organic photovoltaics to ensure their use in the future. **Explain** why.

11 **Explain** how a dry washing machine could save energy compared to a regular washing machine.

## Applying

12 You touch a cool glass of soft drink on a warm day. **Identify** whether heat flows from your hand into the glass or from the glass into your hand.

## Analysing

13 **Analyse** why the bodies of aircraft needed to become enclosed in order to improve their efficiency in the air.

## Evaluating

14 The energy rating label system was revised for use in Australia in the year 2000. At that time, the most energy-efficient appliances on the market only had a rating of 3 or 4 out of a possible 6 stars. **Propose** why the designers of the system set it up in this way.

15 **Predict** what a car would be like if it was 100% efficient.

## Creating

16 **Construct** a scale timeline outlining the important years of aviation history as described on pages 195 and 196.

17 **Design** an advertisement for a new energy-efficient appliance. **Outline** how your appliance will save energy and why people should buy it.

## Inquiring

1 Investigate how the shape of the wing of a paper plane affects how far the plane will travel. Using sheets of A4 paper, test the effect of three different designs. Summarise your findings and include diagrams of the three designs you tested.



2 The typical energy consumption of new refrigerators and freezers decreased by 40% in the years 1993 to 2006.

- a Find information about the energy labelling system currently used in Australia.
- b Using a suitable Australian website, compare the energy use of three different brands of washing machines, toasters and clothes dryers. Rank the appliances from most to least energy efficient.

3 Research the work of Sir George Cayley or Otto Lilienthal and outline the contribution they made to aviation.

4 In the World Solar Challenge, teams build and race solar-powered vehicles some 3000 km from Darwin to Adelaide. Research and write a newspaper report or interview about the winning team from the most recent World Solar Challenge.

# 5.3 Practical activities

## 1 Building a kettle

### Purpose

To build a model kettle and study its energy transformations.

### Materials

- 40 cm nichrome wire
- pencil
- 150 mL beaker
- connecting wires
- power supply
- thermometer (or data-logging temperature probe)
- bench mat



**SAFETY**

Do not touch the nichrome wire while it is hot as it can give a nasty burn. Let it cool completely on a bench mat before packing it away.

### Procedure

1 Make a heating element as shown in Figure 5.3.12 by winding the middle section of the nichrome wire around a pencil. Leave 10 cm of straight wire at each end as connecting leads. Remove the pencil.

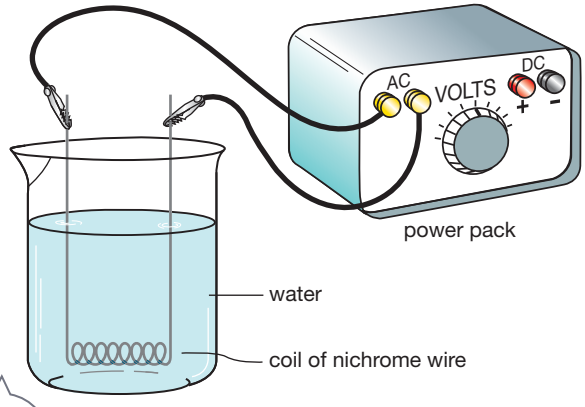



Figure 5.3.12

2 Add about 70 mL of water to the beaker.

3 Place the heating element in the beaker, making sure it is completely covered by water.

4 Connect the element to the power supply using the connecting wires.

5 Set the power pack to 4 volts and switch the power supply on.

6 Record the temperature of the water every minute for 10 minutes in a table like the one below.

### Results

1 Copy the results table into your workbook and record the temperatures.

| Time (min) | Temperature (°C) |
|---|---|
| 0 | |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |

2 Construct a line graph showing the temperature of the water in the beaker over the 10 minutes.

### Discussion

1 **Use** your graph to **predict** how long it would take for the water to boil.

2 **State** the energy source for your kettle.

3 **Name** the form of energy it was converted into.

4 **Identify** three household appliances that rely on the same energy transformation as this kettle.

5 If this kettle was graded for an energy rating label, it would probably have a rating of zero or 1 star.

a **Explain** why the kettle would not have a high star rating.

b **Propose** two ways of changing its design to make it more energy efficient.

## 2 Effect of double-glazing on heat loss

### Purpose

To investigate the effect of double-glazing in preventing heat loss.

### Materials

- 2 × 100 mL beakers
- cling wrap
- 4 cardboard discs of the same size, slightly larger in diameter than a 250 mL beaker
- stopwatch
- 2 thermometers (or data-logging temperature probes)
- hot water



**SAFETY!**

Be careful when handling hot liquids.

### Procedure

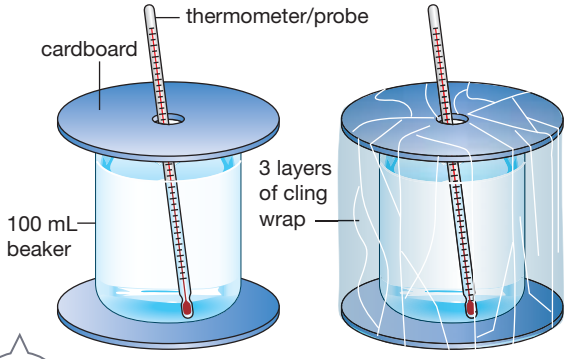



Figure 5.3.13

1. Copy the results table into your workbook.
2. Wrap one beaker with three layers of cling wrap.
3. Position each beaker on a cardboard disc. Punch identical holes in the centre of the two remaining discs to fit a thermometer or probe as shown in Figure 5.3.13.
4. Carefully add 80 mL of hot water to each beaker. (Ensure water is the same temperature in each.)
5. Place cardboard discs on top of each beaker and insert the thermometers or temperature probes.
6. Record the temperature in each beaker every minute for 10 minutes.

### Results

Copy the results table into your workbook and record the temperatures.

| Time (min) | Water temperature in beaker without cling wrap (°C) | Water temperature in beaker with cling wrap (°C) |
|---|---|---|
| 0 | | |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

### Discussion

1. **State** whether the layers of cling wrap had an effect on the heat loss from the beaker.
2. **Explain** how double-glazing windows can reduce energy losses from a house.
3. **Propose** how the design of this experiment could be improved.

# 5 Chapter review

## Remembering

1 **State** another name for *stored energy*.

2 **List** four types of stored energy.

3 **Name** the process in which green plants use light from the Sun to produce chemical energy.

4 **Name** a device that can directly convert the Sun's light into another form of energy.

## Understanding

5 **Describe** three examples of an object with kinetic energy.

6 Your body still needs energy while you are asleep. **Explain** why this is the case.

7 **Explain** how energy rating labels help consumers who are purchasing new electrical appliances.

## Applying

8 **Identify** an example to match each form of energy.

| Form of energy | Example of something it can make happen |
|---|---|
| Sound | Makes windows vibrate |
| Kinetic | |
| Light | |
| Heat | |
| Electrical | |

9 A particular electric hot water system is 60% efficient. This means for every 100 J of energy supplied, 60 J of heat energy is produced. If the system needs 60 000 J of heat energy to heat a body of water, **calculate** how many joules of electrical energy must be supplied.

## Analysing

10 Appliances are independently tested under Australian standards to produce the energy rating label of each device. **Discuss** what could happen if there were not strict rules about testing these products.

## Evaluating

11 A Washwell washing machine has 3 stars and a SudZ washing machine has 4½ stars.

- a **Assess** which washing machine is more energy efficient.
- b **Specify** which machine will require fewer joules of electrical energy to complete a load of washing.
- c **Evaluate** whether this would make a difference over the lifetime of the washing machine.

## Creating

12 A ball of steel wool was added to a solution of copper sulfate as shown in Figure 5.4.1. The temperature of the copper sulfate solution was initially 15°C. One minute after the steel wool was added, the temperature was 29°C.

- a **Construct** an energy flow diagram to show the energy changes that happened in this experiment.
- b **Predict** whether the solution will remain at 29°C all day.
- c **Propose** what will happen to the temperature of the solution and explain why.

13 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

kinetic energy
sound energy
energy transfer
heat energy
energy transformation
gravitational potential energy
chemical energy
energy efficiency
light energy
elastic potential energy

5.9

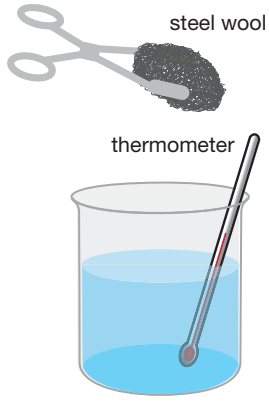



Figure 5.4.1

# Thinking scientifically

**Q1** Lucy accidentally drops a chocolate cake on the floor. Select the most likely sequence of energy transformations that occur:

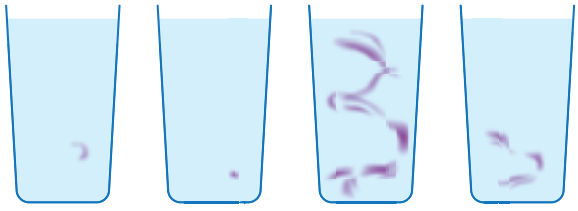
**A** heat energy → gravitational potential energy → kinetic energy → sound energy

**B** gravitational potential energy → kinetic energy → sound energy → heat energy

**C** kinetic energy → gravitational potential energy → heat energy → sound energy

**D** sound energy → kinetic energy → heat energy → gravitational potential energy

**Q2** The temperature of particles is a measure of their average kinetic energy. Particles at a higher temperature have more kinetic energy than particles at a lower temperature. Sarah adds one drop of food colouring to each of four samples of water. Study the spread of the dye through the samples.

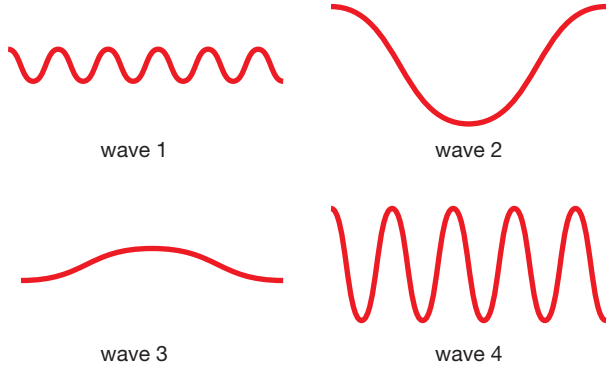



Which of the following correctly ranks the water in the glasses in order of increasing temperature?

**A** glasses 3, 4, 1, 2 **B** glasses 2, 1, 4, 3

**C** glasses 4, 3, 1, 2 **D** glasses 1, 2, 4, 3

**Q3** The sound energy you hear can be represented as a wave on a device called a cathode ray oscilloscope. As the pitch of a sound increases, it gets squeakier and the waves bunch up. As the sound gets louder, the waves get taller.

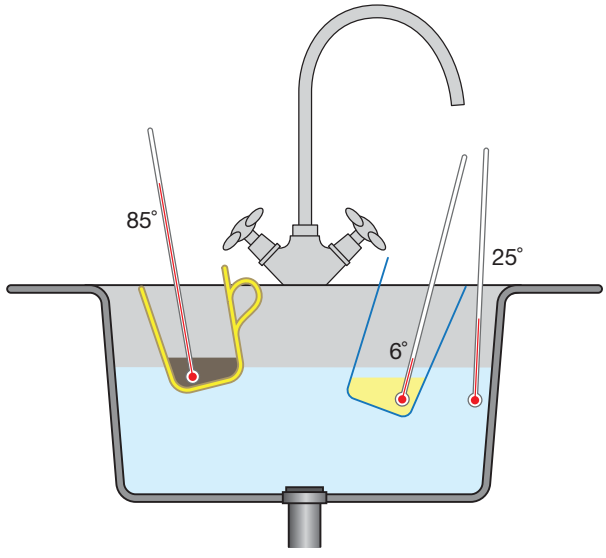



Which of the following lists, in the correct order, the sample waves that represent a quiet, low-pitched sound and a loud, high-pitched sound?

**A** waves 1, 2 **B** waves 2, 1

**C** waves 3, 4 **D** waves 4, 3

**Q4** Angelo is about to start washing the dishes when he is called to answer the front door. He leaves half a mug of coffee and half a glass of lemonade floating in the sink. At the moment he leaves, these have the temperatures shown in the diagram below.




Angelo is gone for 15 minutes. When he returns, the coffee in the mug, the lemonade in the glass and the washing-up water in the sink are most likely to be which temperature?

**A** 90°, 11°, 20° **B** 80°, 5°, 19°

**C** 20°, 25°, 25° **D** 75°, 10° 18°.

# Glossary

## Unit 5.1

**Chemical energy:** energy stored within a substance such as fuel or food that may be released when the substance is burnt or digested

**Elastic potential energy:** energy stored within a stretched or compressed object, like a spring or elastic material

**Electrical energy:** energy that causes charged particles to move

**Energy:** the ability to make a change happen; different forms include heat energy, light energy and sound energy

**Gravitational potential energy:** stored energy of an object that is held above the Earth's surface

**Heat energy:** a measure of the total kinetic energy possessed by particles in a substance

**Joule (J):** unit of measurement for energy

**Kinetic energy:** energy possessed by a moving object



Kinetic energy

**Light energy:** form of energy that is visible, such as that produced by the Sun

**Nuclear energy:** energy stored inside an atom

**Photosynthesis:** process in which green plants convert light energy into chemical energy



Light energy

**Potential energy:** stored energy possessed by an object, such as elastic potential energy of a squashed spring

**Sound energy:** energy that travels as vibrating waves and can be heard by our ears as sound



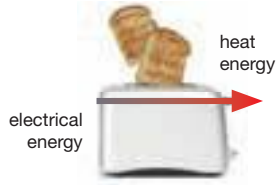
Potential energy

**Work:** this is done whenever an object is moved or is forced to change shape

## Unit 5.2

**Energy efficiency:** the proportion of useful energy output from a device compared to the amount of energy that is input. This is usually expressed as a percentage.

**Energy flow diagram:** diagram using arrows that shows the way energy is passed on or changed into other forms in a particular situation




Energy flow diagram

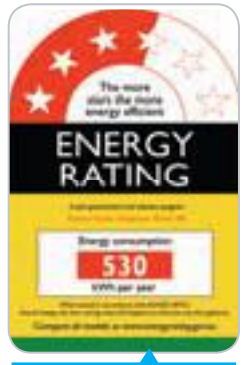
**Energy transfer:** the flow of energy from one object into another object; for example, the flow of heat from a metal spoon to your hand, or the flow of kinetic energy from a bat to a ball that it hits

**Energy transformation:** the conversion of one type of energy into another type of energy; for example, the conversion of electrical energy used in an MP3 player into sound, light and heat energy

**Law of conservation of energy:** Energy cannot be created or destroyed. It can only be transferred from one object to another or transformed into another form of energy.

## Unit 5.3

**Energy rating label:** a label showing a number of stars (usually from 1 to 6), which can be used to compare the energy efficiency of different appliances




Energy rating label

**Insulation:** material added into ceilings and between the walls of a house to reduce heat transfer

**National House Energy Rating Scheme:** a scheme that uses computer simulations to provide a star rating (to a maximum of 10 stars) to houses based on the effectiveness of the external walls against heat loss

**Organic photovoltaics:** a new generation of flexible and cheap solar cells made from carbon-based materials

**Regenerative braking:** vehicle braking system that stores some of the kinetic energy of a car as it slows down and uses this energy to power the car

# Physical and chemical change

# 6

## HAVE YOU EVER WONDERED…

- where sugar goes when it dissolves?
- why you feel hot after exercise?
- how they put the bubbles in soft drink?
- why iron rusts but aluminium doesn't?

## After completing this chapter students should be able to:

- use particles to explain the properties of different states of matter
- describe the arrangement of particles in solids, liquids and gases
- outline the link between the energy of particles and temperature changes
- investigate systems for collecting and recycling household waste
- identify the differences between chemical and physical changes
- identify evidence that a chemical change has taken place
- explain how chemical change involves substances reacting to form new substances
- investigate simple reactions
- explain how the chemical properties of a substance will affect its use
- investigate how our understanding of the nature of matter has changed over time.

# 6.1 When substances change



The world around you is constantly changing. Whether it is the passing of the seasons, a cool breeze or ice blocks melting in a drink, changes are occurring. Most of these changes can be classified as physical or chemical changes depending on whether any new substances are produced.

## Identifying physical change

The key feature of a **physical change** is that no new substance is produced during the change. Physical changes include a change in shape or form, expansion and contraction, a change of state (solid, liquid or gas) or mixing substances together. The physical properties of the substance may change but no new substance is formed. For this reason, physical changes are often reversible. Figure 6.1.1 shows four types of physical change.




During these physical changes, no new substances are produced.

**Figure 6.1.1**

## Changing shape or form

The simplest example of a physical change is one that changes the shape or form of a substance. In this case, a force is applied to break, bend, stretch, crush, twist or compress the object. These changes do not produce new substances. For example, when you crush an aluminium can, its shape changes but it is still made of the same aluminium as before. Similarly, if you crush an aspirin tablet into a powder, it is still aspirin but in a different form.

## Expansion and contraction

Physical changes also occur when the temperature of a substance increases or decreases. When solids, liquids and gases are heated, they expand and take up more space. When **expansion** occurs, the volume of the object increases and its density decreases but no new substances are formed. When a solid, liquid or gas is cooled, it contracts (takes up less space). When **contraction** occurs, the volume of an object decreases and its density increases.

Thermometers use expansion and contraction of liquids such as ethanol and mercury to measure temperature. When the temperature increases, the liquid in the thermometer expands and moves up the thermometer. When the temperature decreases, the liquid contracts and moves down.

Hot-air balloons use the expansion of heated air to lift off the ground. Figure 6.1.2 shows how hot-air balloons use a burner to heat the air inside. As the air heats, it expands to fill the balloon. The hot air inside is much less dense than the cooler air outside so the balloon floats and lifts off the ground.



Figure 6.1.2 Heating the air inside the balloon causes it to expand and become less dense than the air outside. As a result, the balloon floats.

## Changes of state

If enough heat is applied to a substance, then it will not only expand but will also change state from a solid to a liquid (**melting**) or from a liquid to a gas (**evaporation**). Likewise, if a substance is cooled enough, it will not just contract but change state from a gas to a liquid (**condensation**) or from a liquid to a solid (**freezing** or **solidification**). A few substances change directly from a solid to a gas (**sublimation**) or a gas to a solid (**deposition**).

### Melting and freezing

When a solid is heated enough, it will melt and change into a liquid. For example, when you place an ice cube in your mouth, the heat from your mouth melts it into liquid water. Also, when butter is spread on hot toast, the butter melts and soaks into the bread. The physical properties of the solid and liquid may be very different. However, they are both made from the same substance and therefore melting is a physical change.

Freezing is the reverse of melting. When a liquid is cooled enough, it will form a solid. This is what happens when liquid water is put in the freezer to form ice cubes. Solidification can also be seen when drops of liquid candle wax cool and become solid again.

### Evaporation and condensation

Evaporation occurs when a liquid is warmed and becomes a gas. Evaporation occurs at the surface of a liquid at all temperatures but becomes faster as the temperature of the liquid increases. This is the reason that puddles of water dry faster in hot weather. It is also why tumble-driers heat clothes to dry them more quickly. If the liquid is heated above a certain temperature, known as the **boiling** point, then bubbles of gas will form within the liquid and the liquid is said to boil.

## High and dry

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Australia has recently experienced one of the worst droughts in recorded history. This has had devastating effects, forcing many farmers to leave their homes. It has also cost the Federal Government billions of dollars in the form of drought assistance. Unfortunately, drought may be a fact of life for many Australians in the future and we may need to access alternative supplies of fresh water such as desalination and water recycling.



## Mixing

Mixing two substances represents another type of physical change. Figure 6.1.4 shows a bucket of different coloured balls. It is an example of a mixture that can be seen by eye. The different coloured balls mix but no new balls are formed.



Figure 6.1.4 Although the different coloured balls may spread evenly through this mixture, the balls do not change or form new colours.

The opposite of evaporation is condensation. Condensation is when a gas cools and becomes a liquid. When you leave a cold can of soft drink out of the fridge, it develops moisture on the outside, as shown in Figure 6.1.3. This is because water vapour in the air condenses on the cold outside of the can to form liquid water. Similarly, when you breathe out on a cold day, 'fog' may come out of your mouth. This 'fog' is water vapour in your breath condensing to form a mist of tiny liquid water droplets.



Figure 6.1.3 When a cold can is left out of the refrigerator, water vapour from the air will condense as liquid water on the outside.

### Sublimation

In some cases, a substance can change from a solid directly into a gas. This change of state is called sublimation. Dry ice is an example of a substance that sublimes. Dry ice is solid carbon dioxide. At temperatures above –78.5°C, dry ice sublimes to form carbon dioxide gas. This makes dry ice perfect for use in smoke machines in theatres and concerts as it produces a thick, white fog without leaving behind any liquid. Other substances that sublime are iodine, graphite and naphthalene (mothballs).

### Dissolving

When a solid (solute) is dissolved in a liquid (solvent), they form a **solution**. A solution is a mixture. The smallest particles of the solute mix and spread evenly throughout the smallest particles of the solvent—just like a mixture of balls but invisible to the naked eye.

In a solution, the solute seems to disappear. In reality, the solute is broken down into such small particles that they are invisible. If the solvent is removed by boiling or evaporation, then the solute particles join together again to form crystals.

For example, when sugar is dissolved in water, the sugar particles spread evenly throughout the water to form a sugar solution. However, the sugar particles remain sugar particles and the water particles remain water particles—a physical change has occurred. If the water is boiled off or left to evaporate, then sugar crystals are left behind. Liquids and gases can also be dissolved. Figure 6.1.5 shows liquid food colouring dissolving in water.

1 p212



Figure 6.1.5

When two substances mix, one substance is spread evenly through the other but no new substances are formed.

# Identifying chemical change

To distinguish between a **chemical change** and a physical change, you need to determine if a new substance has formed. If a new substance has been produced, then a chemical change has occurred.

The new substance formed in a chemical change could be a solid, liquid or gas. You can detect its presence by:

- seeing a change in colour
- smelling a gas or seeing bubbles
- seeing a new solid (known as a **precipitate**) forming in a clear solution
- observing that energy is produced or absorbed in the form of heat or light.

2 p212

These indications of chemical changes are shown in Figure 6.1.6. However, these are just guidelines. Identifying chemical change also requires a good understanding of physical changes to know when there may be exceptions to these rules.

## Permanent colour change

When you observe something changing colour, it is very likely that a chemical change has occurred. This happens because the new substance produced by the chemical reaction has a different colour to what you started with. Burning a match, paper or a piece of toast produces a black powder, which is carbon. If iron is left in the rain, then it turns orange-brown because iron oxide (rust) is produced.

Other examples include green apples ripening to turn red, the changing colour of leaves in autumn, bleaching or dyeing clothes or hair (as shown in Figure 6.1.7) and a bruised leg turning purple.



Figure 6.1.7

Dyeing hair is an example of a permanent colour change caused by a chemical reaction.




Figure 6.1.6

Some indications of a chemical change

INQUIRY science 4 fun

## Invisible ink

Yes

Can you use a chemical change to write a secret message?

### Collect this…

- lemon juice
- paper
- fine paint brush
- warm light globe or hairdryer

### Do this…

1. Use the paint brush to write a secret message on the paper in lemon juice.
2. Let the paper dry and then give the secret message to a friend.
3. To read the message, tell your friend to hold the message up to a warm light globe or use a hairdryer to heat the paper.

### Record this…

**Describe** what happened.

**Explain** why you think this happened.

Sometimes a physical change can also cause a colour change. For example, when snow melts to form liquid water it turns from white to colourless. This is not a chemical change because snow and liquid water are both made of water.

Mixing paint is also an example of a physical change that causes a colour change. Figure 6.1.8 shows yellow and blue paint being mixed together. They produce green paint. However, no new substances are formed. The yellow and blue particles are mixed so closely together that they give the illusion of green paint.



Figure 6.1.8

Although mixing paint causes a colour change, it is still a physical change because no new substance has been formed.

## A gas is given off

The production of a gas also indicates a chemical change. A gas produced during a chemical change may be observed as bubbles, a new smell or perhaps smoke. When vinegar is added to bicarbonate of soda, many bubbles of carbon dioxide (chemical formula $CO_2$) are formed. Carbon dioxide is also formed by chemical changes in soft drink to create fizz or when Alka-Seltzer tablets are dissolved in water.

SciFile

### Life-saving gases

A chemical reaction that has already saved many lives is the one used to inflate car airbags. In a car accident, an electrical current ignites a small pellet of sodium azide. The sodium azide burns very rapidly, producing enough nitrogen gas to fill the airbag in just 0.03 second.



Rotten eggs are well known for their pungent smell. This smell is the gas hydrogen sulfide (chemical formula $H_2S$), which is produced when eggs rot. Therefore, rotting is another example of a chemical change. Often when something is burning, the first thing you notice is the smell. This is because burning causes a chemical change that also produces smelly gases.

An exception to this rule is in the case of boiling or sublimation. In these cases, a solid or a liquid becomes a gas but no new substance is produced.

## A precipitate forms

Occasionally, when two solutions are mixed a new solid is produced, indicating that a chemical change has occurred. The solid precipitates (falls) out of the solution and sinks to the bottom. The new solid is known as the precipitate. Precipitation occurs in pipes and drains when scale or lime deposits inside, as shown in Figure 6.1.9. Crystals can also precipitate inside the body. Some collect in the kidneys and can cause very painful kidney stones.

A precipitate can also form when a gas is bubbled through a liquid. This type of precipitation is the basis of a simple test for carbon dioxide gas. When carbon dioxide gas is bubbled through a solution of calcium hydroxide (limewater), it precipitates solid calcium carbonate that turns the clear solution milky white.



**Figure 6.1.9** Scale or lime can precipitate from water, causing blockages in pipes.

## Energy is produced or absorbed

A chemical change is often associated with the production or absorption of energy in the form of heat, light or sound. A chemical change that produces energy is described as **exothermic**, while a chemical change that absorbs energy is described as **endothermic**.

### Exothermic chemical change

Exothermic chemical changes give off energy in the form of heat, light and sound. Some exothermic chemical changes include fireworks, sparklers, firing a bullet or burning magnesium ribbon. The explosion in Figure 6.1.10 is a spectacular example. Exothermic change is happening when a match is burnt or natural gas is burnt in a stove or a Bunsen burner. You have an exothermic chemical change going on in your body right now. An exothermic chemical change occurs when your body converts food into energy through the process of respiration. When you exercise, you speed up the process of respiration and may start to feel overheated.



**Figure 6.1.10** Fires and explosions are examples of extreme exothermic reactions—they release large amounts of heat and light energy.

### Endothermic chemical change

Endothermic reactions absorb energy from the surroundings. If an endothermic reaction occurs in a test-tube, then the test-tube will feel cold because the reaction absorbs the heat energy from your skin. This is how the chemical ice pack shown in Figure 6.1.11 works. When the ammonium nitrate and water inside the ice pack are allowed to mix, an extremely endothermic reaction takes place. This absorbs heat from your skin, making it feel icy cold.

Physical changes can also be exothermic and endothermic. Evaporation is an endothermic physical change. You feel cooler when you sweat, because the sweat evaporates and absorbs the heat from your skin. Condensation is exothermic. This is why steam is particularly dangerous. It can produce terrible burns as it condenses on the skin and releases heat energy.



**Figure 6.1.11** The reaction in a chemical ice pack causes a dramatic drop in temperature as it absorbs heat from the surroundings. It is an example of an extremely endothermic change.

# SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

## Recycling



Figure 6.1.12 Aluminium is recycled because it is cheaper than making it from new material.

**Today, there is a large range of recyclable materials including paper, glass, plastics and aluminium.**

By recycling these materials, society is able to conserve these resources and reduce the cost of producing new materials. In most cases when a material is recycled, the form of the material may change but the material itself stays the same. Therefore, the recycling process is simply a series of physical changes.

6.2

### Physical changes when recycling aluminium cans



**Crushing**: When you finish a can of soft drink you might crush the can before throwing it away.



**Mixing**: When you throw the can in the rubbish bin it is mixed with all the other materials, creating a mixture of garbage.



**Separation**: Before the aluminium cans can be recycled, they must be separated out of the garbage and cleaned.



**Shredding**: Once cleaned, the aluminium cans are shredded into tiny pieces.



**Melting**: The aluminium pieces are then melted into liquid aluminium, which is then poured into moulds.



**Solidification**: The liquid aluminium is allowed to cool and solidify, forming blocks of pure aluminium, known as ingots.



**Processing**: The ingots can then be processed into any aluminium product, including more aluminium cans to start the process all over again.

3 p213

# 6.1 Unit review

## Remembering

1 **List** four examples of physical changes.

2 **List** four indications of a chemical change.

3 **State** an example of a physical change that causes a gas to be produced.

4 **Name** the reverse process for the following changes of state.
   - a condensation
   - b solidification
   - c sublimation

5 **State** the two components of a solution.

6 **List** the physical changes that take place during the recycling of aluminium cans.

## Understanding

7 **Explain** why heating the air inside a hot-air balloon allows it to float.

8 **Explain** why mixing paints should be considered a physical change even though there is a colour change.

9 **Define** the term *precipitate*.

10 **Explain** how sweating helps to keep you cool on a hot day.

## Applying

11 **Identify** three examples of both physical and chemical changes you might see in the home.

12 **Identify** the missing labels and complete the flow diagram shown in Figure 6.1.13.

## Analysing

13 **Contrast** the terms *endothermic* and *exothermic* and give examples of each.

14 Write out the steps for your favourite recipe and **classify** them as physical or chemical changes.

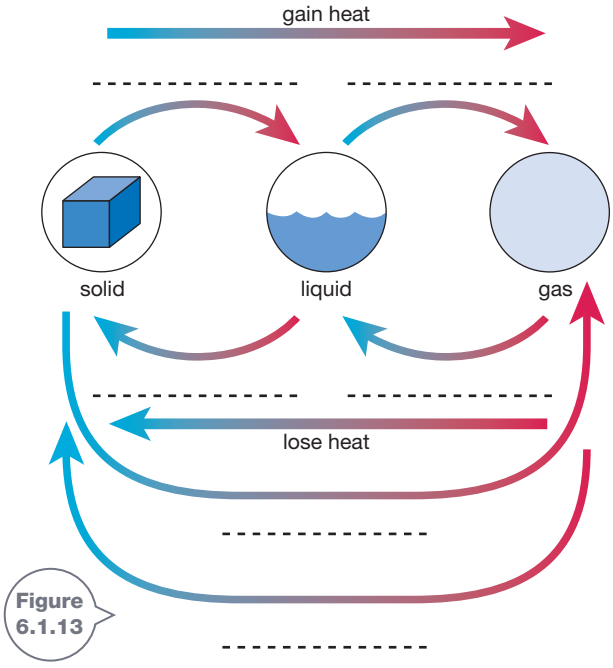



Figure 6.1.13

## Evaluating

15 You are performing a chemical reaction and notice condensation on the outside of the test-tube.
   - a **Deduce** if the reaction is exothermic or endothermic.
   - b **Justify** your answer.

## Creating

16 **Construct** a flow diagram of the physical changes that paper goes through when it is recycled.

17 Using pictures from magazines or the internet, **construct** a poster split into two halves. On one half show examples of physical changes and on the other half examples of chemical changes.

## Inquiring

1 Research water recycling or desalination. List the purification processes as either physical or chemical processes.

2 Investigate a method for extracting iron, aluminium or gold from its ore. Classify the steps as either physical or chemical changes.

# 6.1 Practical activities

## 1 A model thermometer

### Purpose

To construct a model thermometer that uses the expansion of gases to measure temperature.

### Materials

- conical flask
- rubber stopper with single hole
- glass tubing
- water
- food dye
- retort stand
- bosshead and clamp
- clear plastic tubing
- ice cube

**SAFETY**

Food dye can stain your clothing or skin.

### Procedure

1. Build the model thermometer shown in Figure 6.1.14.
2. When you have built your thermometer, wrap your hands gently around the flask to warm it. Observe what happens to the water in the plastic tubing.
3. Place an ice cube on top of the flask to cool it. Again, observe what happens.

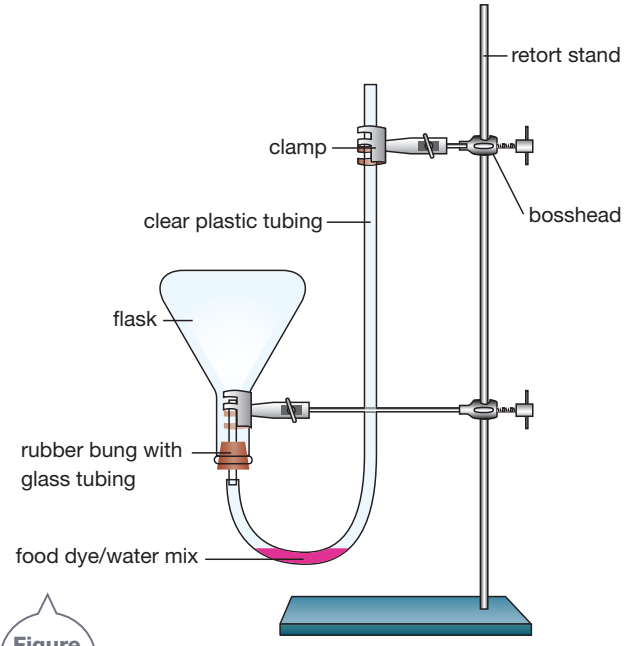



Figure 6.1.14

### Discussion

1. **Explain** why gases expand when heated and contract when cooled.
2. **Explain** how this model thermometer could be used to measure temperature.

## 2 Observing chemical reactions

### Purpose

To observe different examples of chemical change.

### Materials

- 4 large test-tubes and rack
- 3 droppers
- thermometer
- dilute hydrochloric acid
- blue litmus paper
- piece of magnesium metal
- silver nitrate
- sodium hydroxide solution

**SAFETY**

Silver nitrate stains the skin.

Hydrochloric acid and sodium hydroxide are corrosive and burn.

### Procedure

1. Place blue litmus paper in the first test-tube.
2. Use a dropper to place 2 drops of dilute hydrochloric acid on the blue litmus paper. Record your results in the table.
3. Use the dropper to put to 2 cm of dilute hydrochloric acid in each of the next three test-tubes, as shown in Figure 6.1.15.
4. In the second test-tube, add the magnesium metal. Record your results.
5. In the third test-tube, use a separate dropper to add 10 drops of silver nitrate.
6. Use the thermometer to measure the temperature of the hydrochloric acid in the fourth test-tube. Record your results. Rinse the thermometer.

7 Use a separate dropper to add 2 cm of sodium hydroxide solution to the fourth test-tube then remeasure the temperature. Record your results. Rinse the thermometer.

### Results

1 Copy and complete this table.

| Reaction number | Reaction | Observation |
|---|---|---|
| 1 | Blue litmus and dilute hydrochloric acid | |
| 2 | Magnesium metal and hydrochloric acid | |
| 3 | Silver nitrate and hydrochloric acid | |
| 4 | Sodium hydroxide solution and hydrochloric acid | |

### Discussion

In each case, **identify** the clue(s) that suggests that a chemical change has taken place.

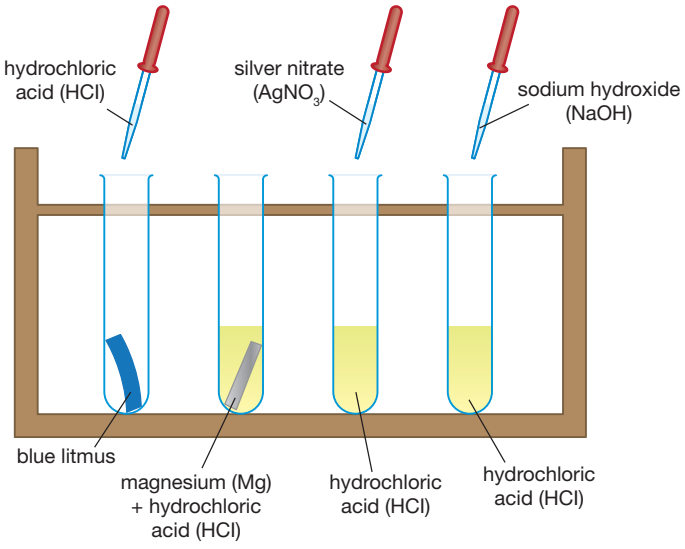



Figure 6.1.15

## 3 Making recycled paper

### Purpose

To see how physical changes can be used to process materials into different shapes and different purposes.

### Materials

- 4 sheets of newspaper
- warm water
- large bowl or bucket
- absorbent paper towels
- frame with fine mesh stretch across it and stapled in place
- deep tray larger than the frame, blender (optional)

### Procedure

1 Cut or shred the newspaper into small pieces.

2 Create a paper pulp either by placing the shredded paper and warm water in a blender and blending until finely chopped or by allowing the paper to soak in the large bowl overnight and mashing it by hand.

3 Place the frame and mesh in the tray with the mesh at the bottom.

4 Pour the paper pulp into the tray

5 Gently lift out the frame and allow the water to drain. Ensure that the mesh is covered evenly by the paper pulp.

6 Place the frame on some paper towel to absorb excess water.

7 Leave in a warm sunny place to dry.

8 Remove the paper from the frame.

### Discussion

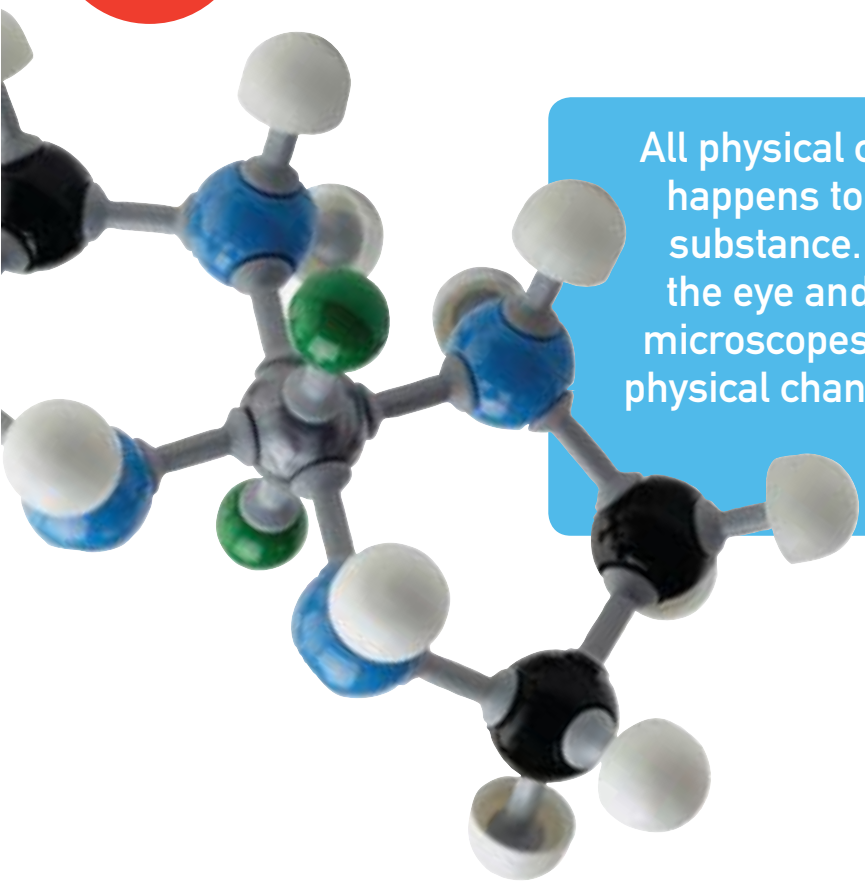
1 **List** all of the physical changes that occurred during the recycling process.

2 **Describe** how the paper you made was different from the paper you started with.

3 a **Assess** whether this is an efficient method for recycling paper

b **Justify** your answer.

# 6.2 Understanding physical change



All physical changes occur because of what happens to the particles making up a substance. These particles are invisible to the eye and even the most powerful optical microscopes. Therefore, to understand physical change, scientists use models to help explain and understand their observations.

## Understanding physical change

Most physical changes can be understood by using the **particle model**, as shown in Figure 6.2.1. The particle model is a simplified representation of solids, liquids and gases. It can explain some but not all of their properties.

The particle model assumes that all forms of matter (solids, liquids and gases) are made up of invisible, ball-like particles that are:

- hard, incompressible (not able to be squashed) and indivisible (unable to be split)
- attracted to each other
- constantly moving.

In solids, the attraction between particles binds them tightly and rigidly together. For this reason, solids are incompressible and hold their own shape. Although the particles in solids are fixed in position, they vibrate on the spot. These vibrations increase with temperature.

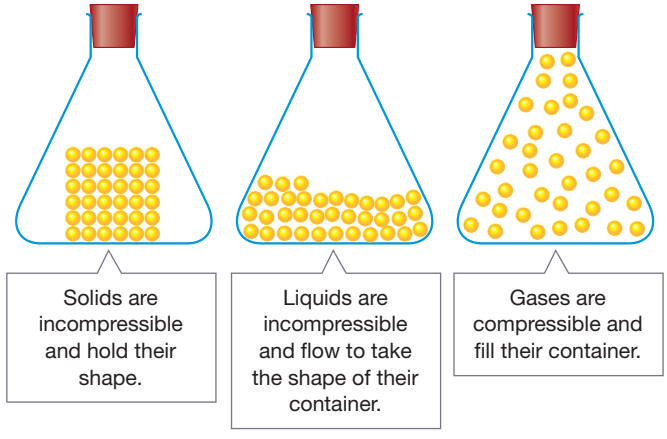



**Figure 6.2.1** The physical properties of solids, liquids and gases can be explained by the particle model.

In liquids, the particles are packed tightly together, which makes liquids incompressible. However, the particles in a liquid are not stuck rigidly to each other so liquids flow to take on the shape of their container. Particles in a liquid vibrate but can also move freely throughout the liquid. The particles move faster as the temperature increases.

In gases, the particles are not stuck to each other at all and there are large spaces between gas particles. For this reason, gases are highly compressible. The particles are free to move anywhere within their container and move in straight lines until they collide with another gas particle or the side of the container. This is why gases will always fill their container.

## Expansion, contraction and pressure

The physical changes of expansion and contraction can be understood by looking at how the motion of particles changes with temperature. In solids, the particles vibrate in fixed positions. As the temperature increases, so too do the vibrations—pushing the particles further apart and causing the solid to expand (get larger) as shown in Figure 6.2.2. When the solid is cooled, the reverse happens. The particles vibrate less, allowing them to be packed more tightly and the solid contracts (shrinks).

The particles in liquids also vibrate more when they are heated. This causes liquids to expand when heated and contract when cooled. However, in liquids the particles are free to move, so liquids tend to expand and contract more than solids.

Gases will always expand or contract to fill their container. However, as the temperature of a gas is increased, the particles travel faster. This means they hit the sides of their container more frequently and with more force. If the container is flexible (such as the balloon in Figure 6.2.3) then increasing the temperature of the gas will cause the balloon to expand. If the container is rigid, such as a glass bottle, then heating the gas will cause the pressure inside the container to increase.

The reverse is also true. If a gas is cooled, then the particles travel slower and hit the sides of their container less frequently and with less force. This results in lower pressure. If the gas is cooled in a flexible container, then the container will contract. A rigid container will not contract but the pressure inside the container will be reduced.

1 p219

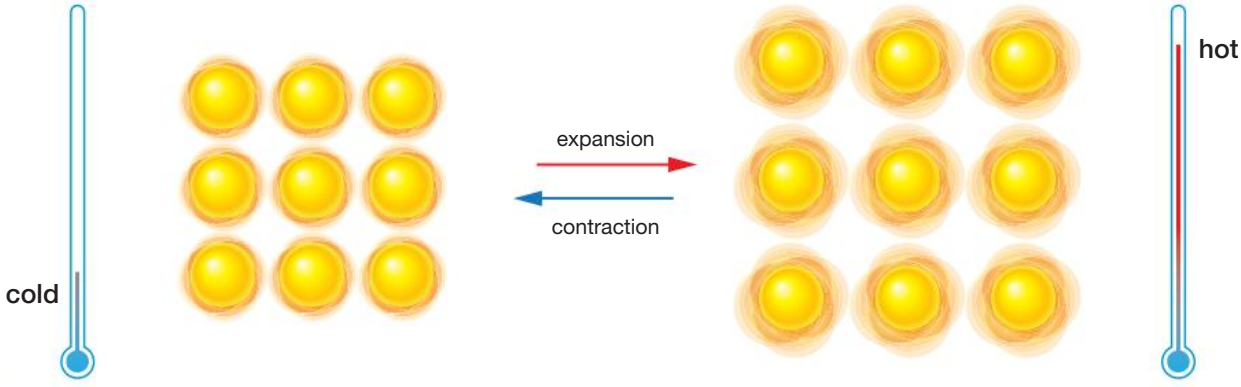



**Figure 6.2.2** Increasing temperature causes the particles in solids and liquids to vibrate more. As are result, solids and liquids expand with increasing temperature.

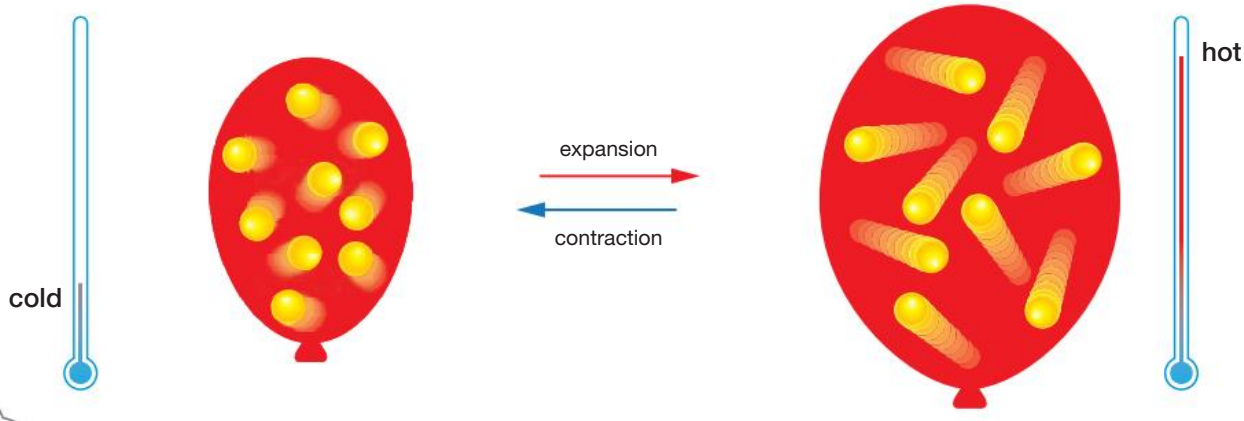



**Figure 6.2.3** When the temperature of a gas is increased, the particles travel faster, hitting the sides of their container more frequently and with more force. If the container is flexible, such as a balloon, it will expand.

## Changes of state and the particle model

The particle model explains changes of state by looking at the relationship between how the particles move and the attraction between them (Figure 6.2.4).

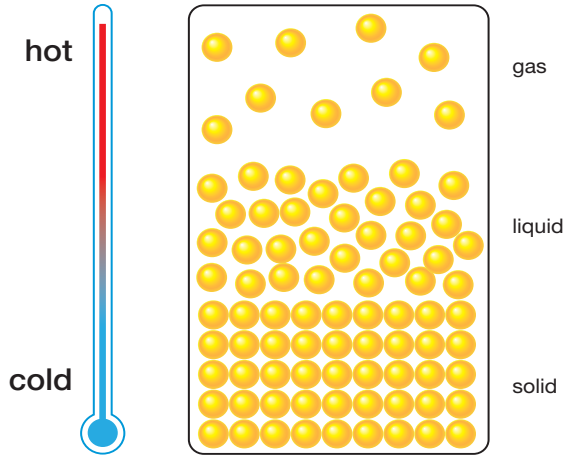



Figure 6.2.4 Increasing the temperature of a solid gives its particles enough energy to overcome the attraction between them and they form a liquid. Increasing the temperature of a liquid gives the particles enough energy to overcome the forces of attraction holding them together and they form a gas.

### Melting and freezing

In a solid, the particles vibrate but are held in position by the forces of attraction between them. As the temperature increases, the vibrations increase and the solid expands. As the temperature is increased further, the solid melts. This is because the vibrations become so energetic that the attraction between the particles can no longer hold them in fixed positions. At this point, the particles become unstuck and start moving freely. However, there is still a small amount of attraction between the particles that holds them together as a liquid.

Freezing is the exact opposite of melting. As the free-moving particles in the liquid are cooled, the particles become slow and less energetic until the attraction between the particles is able to fix them in position, forming a solid.

### Evaporation and condensation

Evaporation occurs when particles in a liquid escape from the surface of the liquid to form a gas. The particles in a liquid are stuck together by only weak forces of attraction. As the liquid particles are heated, they move faster until they are able to escape from the surface of the liquid to form a gas. In other words, the particles evaporate. At the boiling point, the particles within the liquid are moving so fast that they fly apart and form bubbles within the liquid.

Condensation occurs in reverse. As a gas is cooled, the particles move slower until a point where the forces of attraction between the particles can hold and stick them together to form liquid droplets.

2 p219

## Mixing

Mixtures are formed when two or more pure substances are mixed together. A mixture of sand and iron filings is an example of a large-scale mixture that you can see. However, substances can also mix on the particle level to form solutions and alloys. This process of mixing can also be understood through the particle model.

### Solutions and the particle model

Solutions are an example of a mixture. When a solute dissolves, the solvent particles surround the solute particles and carry them away as in Figure 6.2.5. As a result, the solute seems to disappear. However, the solute particles are not destroyed. They are simply spread so thinly throughout the solvent that they appear invisible. The individual solute particles are so small that they cannot be seen with even the most powerful optical microscope.

3 p219

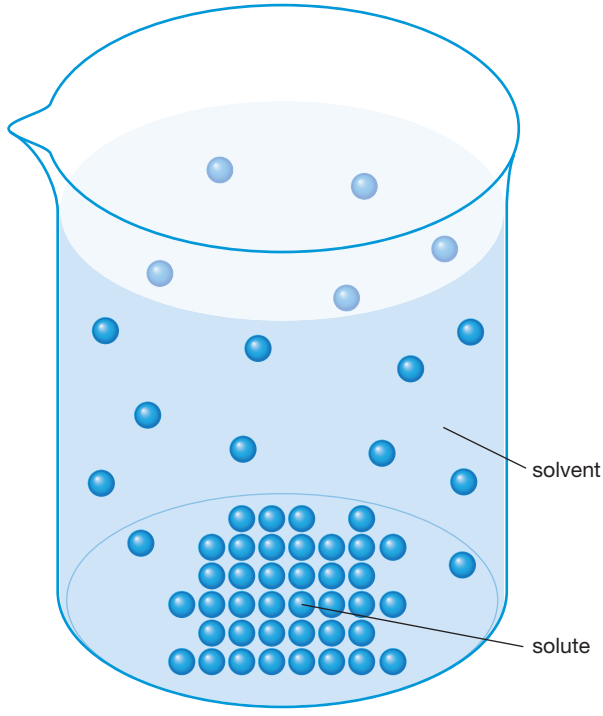



Figure 6.2.5 When a solute dissolves, its particles are spread evenly through the solvent. The particles are so small that they are invisible—even with the most powerful optical microscope.

### Diffusion and the particle model

The particles of two gases or two liquids will mix evenly (or diffuse) without stirring. This process is known as **diffusion**. For example, when a bottle of perfume is opened on one side of a room, the perfume particles will diffuse through the air particles. That is why you will smell the perfume on the other side of the room after a short while.

During diffusion, gas particles travel in a zig-zag fashion. This is shown in Figure 6.2.6. The particles move in straight lines until they collide with another particle and then change direction. However, eventually the particles will be distributed evenly throughout the container. Increasing the temperature speeds up diffusion because the particles will travel faster.

Diffusion in liquids occurs less rapidly because the liquid particles are packed closer together. However, the liquids will ultimately spread evenly through one another.

4 p220

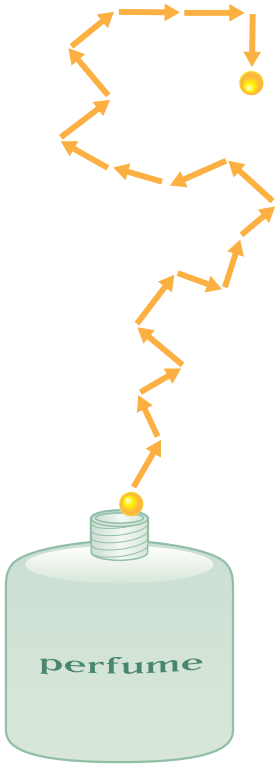



**Figure 6.2.6** The perfume particle makes its way across the room in a zig-zag fashion, travelling in straight lines but changing direction whenever it collides with a particle in air.

6.3 6.4 6.5

INQUIRY science 4 fun

## What smells?

Yes

How does a smell spread throughout a room?

#### Collect this ...

- air freshener, perfume or aftershave in a spray bottle

#### Do this ...

1. Everyone is to spread out around the room.
2. One person should spray a 'squirt' of the air freshener, perfume or aftershave into one corner of the room.
3. Raise your hand when you are able to smell the fragrance.

#### Record this ...

**Describe** what happened.

**Explain** why you think this happened.

SciFile

### Deadly diffusion

The process of liquid diffusion helps sharks track their prey. The blood from an injured animal diffuses through the water and can be detected by sharks several kilometres away due to their extreme sense of smell.



# 6.2 Unit review

## Remembering

1 **List** the assumptions made by the particle model.

2 **Outline** the changes that occur when a gas is heated in a container that does not have flexible walls.

3 **Name** the opposite process for the following physical processes.
- **a** expansion
- **b** melting
- **c** evaporation
- **d** dissolving

## Understanding

4 **Describe** the arrangements of particles in solids, liquids and gases.

5 **Outline** how the particle model explains expansion and contraction.

6 **Describe** how gas particles exert a pressure on their container.

7 **Explain** why you can smell something that is burning on the other side of the room.

8 **Describe** what happens to the particles in a solid as it is heated up to its melting point.

9 **Explain** why a solid seems to disappear when dissolved into a liquid.

## Applying

10 **Use** the particle model to **explain** why your bike tyres may seem deflated on a cold day.

11 **Use** the particle model to **explain** why powerlines may sag more on a hot day.

## Analysing

12 **Compare** dissolving and diffusion.

13 **Compare** the properties of solids, liquids and gases by copying and completing the following table.

| | Solid | Liquid | Gas |
|---|---|---|---|
| Shape | Fixed | | |
| Compressibility | Very low | | |
| Strength of attraction between particles | | Weak | |
| Movement of particles | | Medium | |
| Space between particles | | | A large amount |

## Evaluating

14 **Propose** reasons why a scented candle spreads its smell quickly through a room while it is burning but not when it's unlit.

15 **Propose** a reason why gas barbecue bottles should not be left in the sun.

## Creating

16 **Construct** diagrams showing what happens to gas particles in a solid container at low and high temperatures. Indicate on the diagrams which has high pressure and which has low pressure.

17 **Create** a short story from the perspective of a particle in a solid that is being heated. **Describe** what happens to you as the solid changes to a liquid and then to a gas.

## Inquiring

1 Investigate Brownian motion, who it is named after and how it helped in the development of the particle model.

2 Investigate the life of Robert Boyle and his contribution to the particle theory.

# 6.2 Practical activities

## 1 Expansion and heat

### Purpose
To observe how heating a gas causes it to expand.

### Materials
- glass bottle
- hot tap water
- balloon

### Procedure
1. Fill the glass bottle with hot tap water.
2. Pour out the hot water and quickly stretch a balloon over the mouth of the bottle.
3. Let the bottle cool or place it in a tub of cool water and observe what happens.

### Results
Construct a series of diagrams that shows what happened.

### Discussion
1 a **State** whether this is a chemical or physical change.
   b **Justify** your answer.
2 **Use** the terms *expansion* and *contraction* to **describe** your observations.
3 **Describe** what is happening inside the balloon using the particle model.

## 2 Observing sublimation

### Purpose
To observe the change of state from a solid to a gas.

### Materials
- small pieces of dry ice
- 1 L beaker
- hot and cold water
- drops of detergent
- tray
- gloves
- tweezers
- stopwatch




### Procedure
1. Using gloves and tweezers, place a piece of dry ice on your bench top and observe it as it sublimes.
2. Use the tweezers to slide the dry ice across your bench top and observe its motion.
3. Fill the bottom of the 1 L beaker with cold water and add a small amount of detergent.
4. Place some dry ice in the beaker and record how much time it takes to fill the beaker with bubbles.
5. Repeat steps 3 and 4, using hot water instead of cold.

### Results
Record the time required to create 1 L of carbon dioxide bubbles with hot and cold water.

### Discussion
1 a **Describe** how the dry ice moves across your bench top when you push it.
   b **Explain** why it moves in this manner.
2 a **State** whether increasing the temperature increases or decreases the rate of sublimation.
   b Use your results to **justify** your answer.
3 In this experiment, a change occurred in which bubbles were produced, normally a sign of a chemical change. **Explain** how you know that this activity shows a physical change and not a chemical change.

## 3 Dissolving and temperature

### Purpose
To determine how the temperature of a solution affects the amount of solute that can be dissolved.

### Materials
- 250 mL beaker
- thermometer
- stirring rod
- spatula
- 500 g sugar
- hot plate
- electronic balance
- watch-glass

Dissolving and temperature continued

Dissolving and temperature continued

## Procedure

1. Fill the beaker with 100 mL of water.
2. Use the thermometer to measure the temperature and record the temperature in the table below.
3. Use the spatula to place approximately 20 g of sugar on to the watch-glass.
4. Use an electronic balance to measure the exact mass and record this value in the table below.
5. Add the sugar to the beaker of water and stir until it is dissolved.
6. Repeat steps 3–5 until the sugar will no longer dissolve.
7. Use the hotplate to increase the temperature to approximately 40°C, using the thermometer to measure the exact temperature.
8. Continue to add sugar approximately 20 g at a time until no more will dissolve.
9. Repeat steps 7 and 8 for temperatures of 60°C and 80°C.

## Results

Record all your results in a table like that shown below.

| Temp. (°C) | Mass of sugar added each time (g) | | | | | | | Total mass (g) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## Discussion

1. **State** the name of the solute and the solvent in this experiment.
2. **Describe** how increasing the temperature changes the amount of solute that is dissolved.
3. **Use** the particle model to **propose** why the solubility changes in this way.
4. **Propose** a way the experiment could be changed to make it more accurate.

# 4 Rate of diffusion

## Purpose

To observe the rate of diffusion with temperature.

## Materials

- shallow tray
- overhead transparency with a grid of 2 cm × 2 cm squares printed on it
- hot and cold water
- food colouring
- dropper
- stopwatch

## Procedure

This prac should be performed in pairs or small groups.

1. Place the gridded transparency on the bottom of the shallow tray.
2. Fill the tray with cold water.
3. With one person measuring time on the stopwatch, place a drop of food colouring and estimate how many squares are coloured after 5, 10 and 20 seconds.
4. Repeat the experiment with hot water.

## Results

Copy and compete the following table.

| | Number of squares | | |
|---|---|---|---|
| | After 5 s | After 10 s | After 20 s |
| Cold water | | | |
| Hot water | | | |

## Discussion

1. **State** the name of the process that allows the food colouring to move through the water and whether this is a physical or chemical change.
2. **Compare** and **contrast** your observations for cold and hot water.
3. **Explain** your results in terms of the particle model.

# 6.3 Density

Some materials like lead, gold, granite and steel are very heavy for their size. Other materials like foam rubber, cork, balsa wood and feathers are so light that huge piles don't weigh much at all. Density measures how much matter is packed into a space. Density determines how heavy a handful of a substance will be and whether it floats or sinks in water.



INQUIRY science 4 fun

## Salty lava lamp

Yes

Can you make your own lava lamp?

**Collect this…**

- tall glass or 250 mL beaker
- cooking oil
- salt shaker
- food dye
- water

**Do this…**

1. Pour water into the glass or beaker until it is one-third full.
2. Add a few drops of food dye.
3. Pour in an equal quantity of cooking oil and observe which layer is on top.
4. Sprinkle salt into the glass and carefully observe what happens to the grains of salt.

**Record this…**

**Describe** what happened.

**Explain** why you think this happened.

## Density: a physical property

The physical properties of a substance describe things such as:

- its appearance
- the temperatures at which it melts, freezes and boils
- its hardness (how easily it is to scratch the material).

**Density** is one of the physical properties of a substance. Density depends on how heavy a substance is, but it is not the same as its weight or mass. For example, 1 kilogram of lead always weighs exactly the same as 1 kilogram of polystyrene, which weighs as much as 1 kilogram of feathers. Density instead measures how much matter is packed into a space (Figure 6.3.1).



Figure 6.3.1 Stones are much more dense than feathers. This makes a small pile of stones weigh a lot more than a big pile of feathers.

# Comparing densities

Density is normally measured in grams per cubic centimetre (symbol g/cm$^3$). Different substances pack different masses into the same size cubes, as shown in Figure 6.3.2. The densities of different solids, liquids and gases can be seen in Tables 6.3.1, 6.3.2 and 6.3.3.

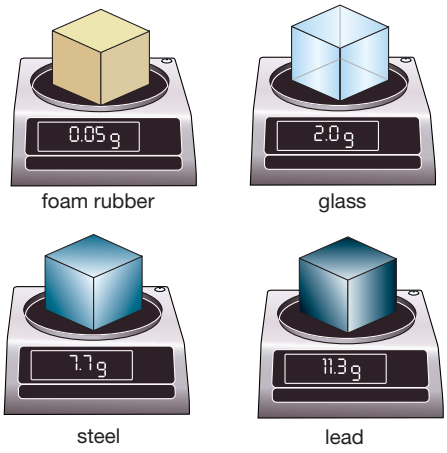



**Figure 6.3.2** Density measures how many grams of matter are in a cubic centimetre of material. Density is measured in g/cm$^3$.

**Table 6.3.1 Densities of gases**

| Gas | Density (g/cm$^3$) |
|---|---|
| Hydrogen (at 0°C) | 0.000 09 |
| Helium (at 0°C) | 0.000 18 |
| Air (at 40°C) | 0.001 1 |
| Air (at 0°C) | 0.001 3 |
| Oxygen (at 0°C) | 0.001 4 |

**Table 6.3.2 Densities of liquids at 25°C**

| Liquid | Density (g/cm$^3$) |
|---|---|
| Petrol | 0.80 |
| Vegetable oil | 0.91 |
| Water | 1.00 |
| Honey | 1.36 |
| Mercury | 13.6 |

**Table 6.3.3 Densities of solids**

| Solid | Density (g/cm$^3$) |
|---|---|
| Polystyrene foam | 0.03 |
| Wood (oak) | 0.65 |
| Concrete | 2.40 |
| Copper | 8.90 |
| Gold | 18.9 |



**Figure 6.3.3** The overall density of a hot-air balloon is less than the air around it, allowing it to rise into the sky.

# Density and packing

The particles in a solid are usually packed a little more closely than they are in a liquid, making most solids a little denser than liquids of the same material.

The particles in a gas are very spread out, making gas the least dense of the three states. When a gas is heated, its particles spread out even further, lowering its density even more. For this reason, hot air is less dense than cold air and will rise above it (Figure 6.3.3). Likewise, bubbles of gas rise through liquid, as seen in Figure 6.3.4. This is why smoke rises—the air is hot and it carries soot and burnt material up with it.



**Figure 6.3.4** Gases are much less dense than liquids and will bubble upwards through them.

# Floating and sinking

Density determines how different substances will arrange themselves when mixed together. The densest substance will drop to the very bottom while the least dense will rise to the top.

Cooking oil, for example, floats on top of water because its density is less than that of water. A steel bolt will sink in water because its density is far greater than that of water.

The density of water is 1.0 g/cm$^3$. Anything more dense than this will sink when placed in water. Anything less dense will float on top of the water. Figure 6.3.5 shows two types of rock of very different densities.




**Figure 6.3.5** Density determines whether things float or sink.

1 p228

# Mass, volume and density

Density depends on the mass of the substance and the volume that mass takes up.

## Mass

**Mass** measures how much matter is in a substance. It is sometimes incorrectly referred to as weight. Scientists use grams (g) to measure small masses such as a twig, a mouse or a spatula load of chemicals, kilograms (kg) for heavier masses such as a dog or a human, and tonnes (t) for even bigger masses such as a car or an aircraft. Mass is measured using a beam balance or electronic balance.

## Volume

**Volume** is the amount of space a substance takes up. Several different methods can used to measure volume. The method used depends on what is being measured.

### Regular solids

The volume of solids that have a regular shape (such as a cube, a box-shaped block, a sphere or a cylinder) can be calculated by measuring their dimensions (length, width, height or diameter), and then using the appropriate mathematical formula.

Volume is measured in cubic millimetres (mm$^3$) for really small objects such as crystals of salt, cubic centimetres (cm$^3$) for larger objects such as sugar cubes, and cubic metres (m$^3$) for much larger objects such as the amount of concrete in a building.




### Calculating the volume of a rectangular prism

A rectangular prism is a box-shaped block, much like a shoe box. Its volume is calculated using the mathematical formula:

Volume = length × width × height

$V = lwh$

## WORKED EXAMPLE

### Calculating the volume of a rectangular prism

#### Problem

Calculate the volume of the shoe box shown in Figure 6.3.6.

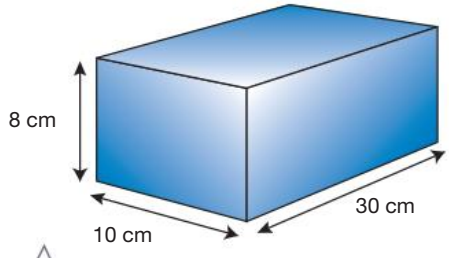



**Figure 6.3.6** A rectangular prism

#### Solution

$V = lwh$

$= 30 \times 10 \times 8$

$= 2400$ cm$^3$

### Liquids

The volume of a liquid can be measured accurately using a measuring cylinder. The volume of liquids is usually measured in litres (L). For example, large bottles of soft drink come in 1.25 L and 2 L sizes. Smaller volumes are usually measured in millilitres (mL). For example, cans of soft drink normally hold a volume of 375 mL.

It is easy to convert between mL and $cm^3$ since 1 mL is exactly the same as 1 $cm^3$.

$$1 \text{ mL} = 1 \text{ cm}^3$$



**Figure 6.3.7** Archimedes (about 287 to 212 BCE) was supposedly given the task of determining whether the wreath of his king was pure gold or not. To do this he needed to measure its volume and density without destroying it. He found the volume by submerging the wreath in water and measuring how much water was displaced.

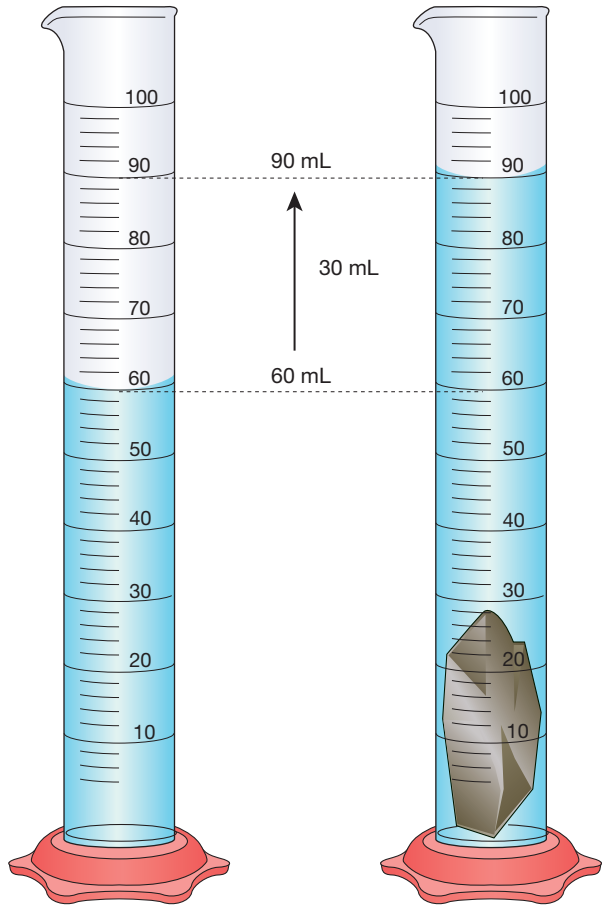



**Figure 6.3.8** The volume of an irregular solid can be determined by dropping it into a measuring cylinder. If the level goes up by 30 mL then the solid must take up 30 mL.

### Irregular solids

Many solids do not have predictable regular shapes. This means that you can't calculate their volume easily using a mathematical formula. Instead, their volume is measured by dropping them into water in a measuring cylinder. When you place a solid in water, it displaces (pushes upwards) a volume of water equivalent to its own volume. This is shown in Figure 6.3.8. That's why the level of water in the bath goes up when you get in.

**SciFile**

**Danny Deckchair**

Helium is a gas that is less dense than air. In 1982, US man Larry Walters tied 45 large helium-filled balloons to his aluminium garden chair and floated to a height of 4900 metres. After 45 minutes he punctured some of his balloons and crashed down among power lines. A similar flight was used in the plot of the 2003 Australian film *Danny Deckchair*.

## Calculating density

Density is the amount of matter (or mass) packed into a certain space (volume). This can be represented by the mathematical formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Using symbols, this formula can be written as:

$$d = \frac{m}{V}$$

For density calculations, mass is normally measured in grams (g) and volume in cubic centimetres ($cm^3$). Using these units, density is measured in grams per cubic centimetre ($g/cm^3$).

6.6
2 p229

## Using the density formula

The triangle in Figure 6.3.9 can be used to calculate the density, mass or volume of a substance.

Simply cover the quantity you want to calculate and do what the rest of the triangle indicates.

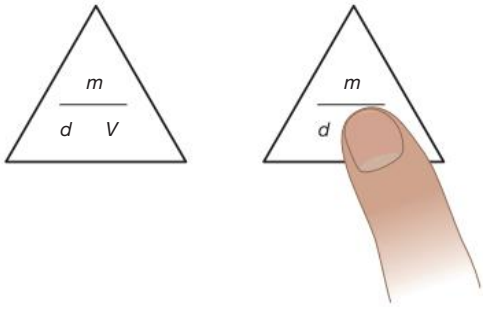



**Figure 6.3.9** This triangle makes the density formula much easier to use. For example, to calculate volume, cover *V* with your finger. The part of the triangle not covered shows that you must divide mass by density.

## Unit conversions

Scientists often need to convert one unit into another before they calculate the density of an object. In the SI or metric system, these conversions are carried out by multiplying or dividing by 10, 100, 1000 or some other factor of ten. Table 6.3.4 shows how to carry out some simple unit conversions.

**Table 6.3.4 Converting mass and volume**

| Measurement | From | Convert by | To |
|---|---|---|---|
| Mass | tonne (t) | x 1000 | kilogram (kg) |
| | kilogram (kg) | x 1000 | gram (g) |
| Volume | litre (L) | x 1000 | millilitre (mL) |
| | millilitre (mL) | x 1 | cubic centimetres ($cm^3$) |

## WORKED EXAMPLE

### Calculating density

#### Problem

The mass of the cube shown in Figure 6.3.10 is 72 g. Calculate its density and identify what the cube is most likely made from.

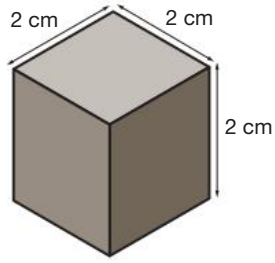
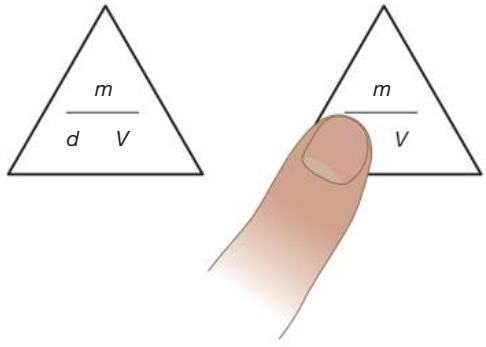



**Figure 6.3.10** A 72 g cube of an unknown metal, with each side 2 cm long.

#### Solution

$$V = l \times w \times h$$
$$= 2 \times 2 \times 2$$
$$= 8 \text{ cm}^3$$

You want to calculate density so cover *d* in the triangle.




$$d = \frac{m}{V}$$
$$= \frac{72}{8}$$
$$= 9 \text{ g/cm}^3$$

This is roughly the density of pure copper and so the block was most likely copper.

#### Problem

Ice has a density of 0.9 $g/cm^3$. An ice cube has a mass of 9 g. Calculate the volume of the ice cube.

#### Solution

You need to calculate the volume, so cover the *V* in the density triangle.

$$V = \frac{m}{d}$$
$$= \frac{9}{0.9}$$
$$= 10 \text{ cm}^3$$

# Icebergs

Water acts just like other liquids above 4°C and ice acts just like other solids below 0°C—it expands when heated and contracts when cooled. Between 0°C and 4°C, however, water does the exact opposite. Water at 4°C is denser than at any other temperature, and drops to the bottom of any pond, lake or swimming pool. Colder water floats on top of it, and any ice will float on the surface of that colder water. This is shown in Figure 6.3.11.

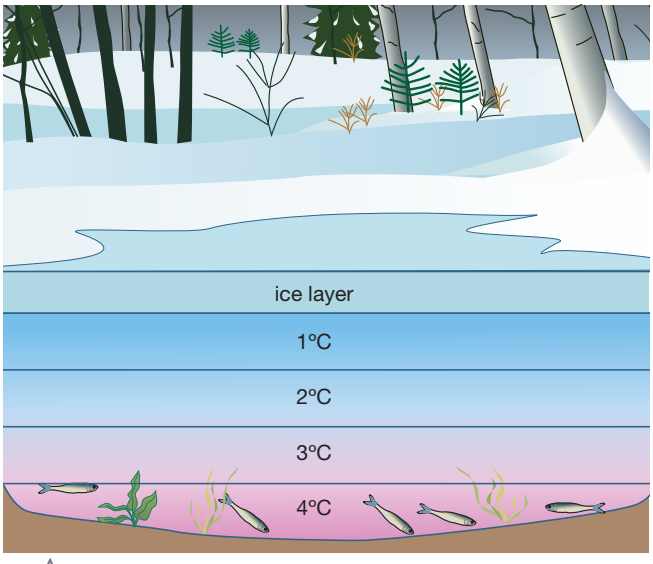



**Figure 6.3.11** The water at the bottom of a pond, lake or swimming pool is always the densest. Even in freezing conditions, this layer is unlikely to drop below 4°C, giving fish some chance of survival.

Thicker, heavier chunks of ice will be partly submerged with only their top exposed, forming an iceberg. Despite their huge size and mass, icebergs float because their density is less than that of seawater, as shown in Table 6.3.5.

**Table 6.3.5 Densities of water**

| Substance | Density (g/cm$^3$) |
|---|---|
| Ice | 0.92 g/cm$^3$ |
| Pure water | 1.00 g/cm$^3$ |
| Seawater | 1.03 g/cm$^3$ |

Icebergs are incredibly dangerous to shipping because:

3 p230

- they shift with ocean currents and winds, often into shipping lanes.
- 80–90% lies hidden below the water as shown in Figure 6.3.12. This hidden part doesn't melt as fast as the ice above the water, and so it usually extends wider than the ice visible above the water line. Any ship that comes near can collide with this bulge, making a hole and sinking the ship.



**Figure 6.3.12** A composite photo showing how much of an iceberg is hidden.

Although radar gives modern shipping some warning of a nearby iceberg, disaster can still happen. In 2007, the Canadian cruise ship MS *Explorer* (shown in Figure 6.3.13) hit submerged ice off Antarctica and sank.



**Figure 6.3.13** When MS *Explorer* sank, all 154 passengers and crew were saved by a nearby cruise ship.

There was no radar in 1912 when RMS *Titanic* hit an iceberg and sank on its maiden (first) voyage from England to the USA. Although the crew knew that icebergs lay in its path and were watching out for them, it was a moonless night and the iceberg was only seen at the last moment.

# 6.3 Unit review

## Remembering

1 **State** whether each of the following is true or false.
- a 1 kg of lead weighs more than 1 kg of polystyrene.
- b 1 kg of lead takes up less space than 1 kg of polystyrene.
- c 1 kg of lead has the same density as 1 kg of polystyrene.

2 **Recall** the densities of different states and forms of water by arranging the following in order from least dense to most dense:

ice, seawater, pure water at 1°C, pure water at 4°C, water vapour

## Understanding

3 **Describe** how mass is normally measured.

4 **Describe** how you could measure the volume of a:
- a cube of stone
- b rough pebble.

5 **Explain** why it is easier to float in the sea than in a freshwater lake.

## Applying

6 **Use** the densities in Tables 6.3.1, 6.3.2 and 6.3.3 on page 222 to **explain** why:
- a lifesaving rings are usually made of polystyrene
- b helium balloons rise
- c firefighters recommend you do not run out of a burning house but that you drop to the floor and crawl out to escape
- d spilt petrol forms a slick on top of water.

7 **Calculate** the density of a solid that has a:
- a volume of 2 $cm^3$ and a mass of 3 g
- b mass of 8.4 g and a volume of 4 $cm^3$.

8 **Calculate** the volume of a solid that has a:
- a mass of 6 g and a density of 3 $g/cm^3$
- b density of 3 $g/cm^3$ and a mass of 39 kg (be careful!).

9 For each of the objects shown in Figure 6.3.14, **calculate** the:
- i volume (in $cm^3$)
- ii density (in $g/cm^3$).

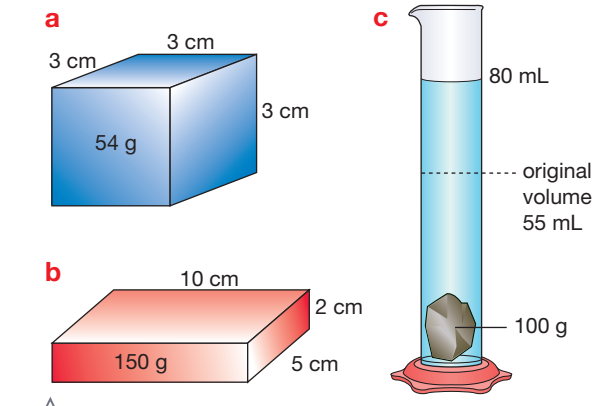



Figure 6.3.14

## Evaluating

10 a **Predict** whether you are more or less dense than water.
- b **Justify** your answer.

11 Newspaper usually floats on water but then sinks after a while. **Propose** reasons why.

## Creating

12 a **Construct** a diagram showing a measuring cylinder containing all the liquids shown in Table 6.3.2 on page 222.
- b Small lumps of wood, copper and gold were then dropped into the measuring cylinder. On your diagram, show where each would settle.

## Inquiring

1 Find evacuation procedures recommended by your state fire service. Construct a simple poster that displays one evacuation procedure.

2 Construct a timeline that shows the important events in the sinking of RMS *Titanic*.

3 Search the internet for videos of icebergs calving (breaking off).

# 6.3 Practical activities

## 1 Density tower

### Purpose

To construct a tower of different liquids, layered according to their densities.

### Materials



- large measuring cylinder
- corn syrup or honey
- food dyes
- water
- vegetable oil
- ethanol or methylated spirits
- dishwashing liquid (coloured)
- a variety of small solids (such as a cornflake, single penne pasta, cork, sultana, bolt, small rubber stoppers, grape, Lego® block)
- digital camera or mobile phone with camera function (optional)

### Procedure

1. Carefully squeeze the honey into the measuring cylinder so that it forms a layer at least 1 cm thick on the bottom.
2. Carefully squeeze or pour a similar quantity of dishwashing liquid into the measuring cylinder. Do this by tilting the cylinder and slowly pouring the dishwashing liquid down its side.
3. Choose a food dye that is a different colour from the dishwashing liquid and add a few drops of it to a small beaker of water. Tilt the cylinder again, and carefully pour the coloured water in to form a layer of about the same thickness as the others.
4. Use the same method to carefully pour a layer of vegetable oil on top of the coloured water.
5. Add a few drops of food dye to a small beaker of ethanol or methylated spirits. As before, make another layer by gently pouring the ethanol or methylated spirits down the side of the measuring cylinder.
7. Stand the measuring cylinder upright and allow the contents to settle.
8. Construct a labelled sketch showing the layering of liquids in the tower. Alternatively, photograph the tower with a digital camera or the camera function of your mobile phone.
9. Gently lower the small solids, one by one, into the measuring cylinder. Record on your diagram the level at which each one settles.

### Discussion

1. **Explain** why:
   - a the liquids formed layers
   - b some objects floated and others sank.
2. **Identify** the least dense:
   - a liquid
   - b object.
3. **Explain** how you came to this conclusion.
4. **List** in order from most to least dense all the:
   - a liquids you tested
   - b solids you tested
   - c liquids and solids you tested.

## 2 Density of an irregular shape

### Materials

- 100 mL measuring cylinder
- a selection of irregularly shaped objects (such as a rubber stopper, bolt, pebble, pencil sharpener, piece of bark)
- short length of thin wire
- access to an electronic balance

### Procedure

1. Make sure that every object that you are about to test fits inside the 100 mL measuring cylinder.
2. Use the electronic balance to measure the mass of each object. Record each mass in a table like that shown below.
3. Approximately half-fill the measuring cylinder with water as shown in Figure 6.3.15.
4. Record the start volume (in mL) in the measuring cylinder in your table. Make sure you read the water level from the bottom of the meniscus.
5. Carefully slide an object into the measuring cylinder. If it floats, use the piece of thin wire to push the object completely under the water.
6. Record the final volume (in mL) in the measuring cylinder.

### Results

1. Copy the table below into your workbook. Use it to record your measurements and calculations.
2. Calculate the volume of the object (in mL) by subtracting the starting volume of water from the final volume of water. Convert your answer into $cm^3$ (remember 1 mL = 1 $cm^3$).
3. Use the formula $d = \frac{m}{V}$ to calculate the density (in $g/cm^3$) of each object you tested.

### Discussion

**List** the objects from least dense to most dense.

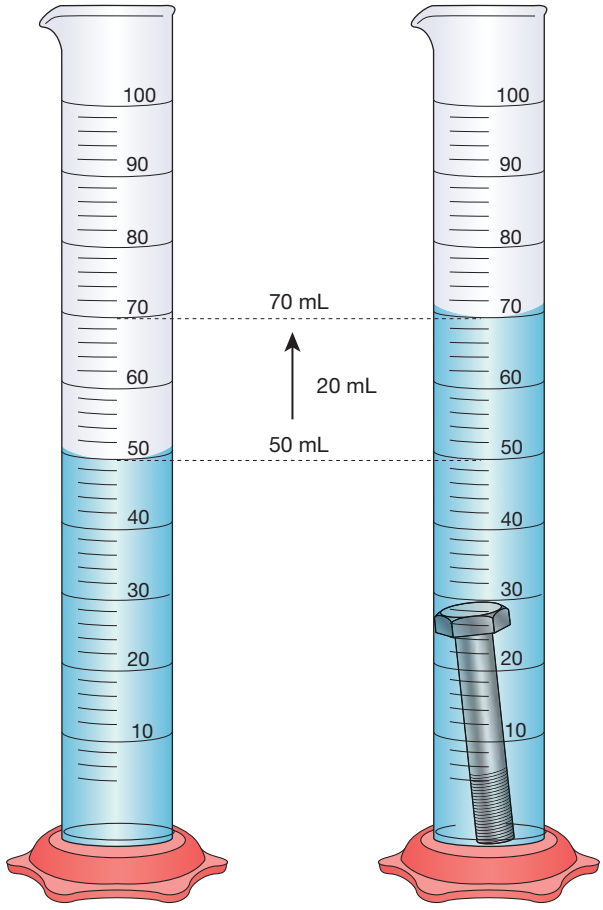



Figure 6.3.15

| Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 | Column 7 |
|---|---|---|---|---|---|---|
| **Object** | **Mass (g)** | **Initial volume (mL)** | **Final volume (mL)** | **Volume = column 4 – column 3 (mL)** | **Volume = column 5 ($cm^3$)** | **Density = column 2 ÷ column 6** |
| | | | | | | |
| | | | | | | |

## 3 Icebergs and eggbergs

### Purpose

To demonstrate how the different densities of fresh and salt water change how something floats.

### Materials

**For both parts**

- water
- salt
- spoon

**For Part A: Icebergs**

- glass or 250 mL beaker
- 2 ice cubes
- plastic 30 cm ruler

**For Part B: Eggbergs**

- 2 tall glasses, tall beakers or large measuring cylinders, wide enough to take an egg
- fresh uncooked egg
- large spoon
- salt
- water

### Method

**Part A: Icebergs**

1. Three-quarters fill the glass or beaker with water.
2. Slide in a cube of ice.
3. Use the ruler to measure how much of the ice cube is above water and how much is below water.
4. Use a calculator to calculate the percentage of the ice cube that lies below the water.

$$\% = \frac{\text{how much ice cube is below water}}{\text{total height of ice cube}} \times 100$$

5. Use the spoon to fish out the ice cube. Add salt to the water and stir. Keep stirring and adding salt until no more will dissolve.
6. Slide in another cube of ice and repeat your measurements.

**Part B: Eggbergs**

7. Fill two tall glasses, tall beakers or large measuring cylinders with approximately the same amount of water.
8. Add spoonfuls of salt to one glass until no more will dissolve.
9. Use the spoon to lower the fresh egg gently into the glass of fresh (non-salty) water. Observe what happens.
10. Lower the egg into the glass of salt water. Observe what happens.
11. Remove the egg and pour half the salt water out.
12. Very slowly add half the fresh water, making sure that it does not mix with the salt water. The best way of doing this is by slowly pouring the fresh water down the inside of the glass.
13. Use the spoon to lower the egg gently into the water. Watch where the egg settles.

### Discussion

1. **List** the evidence that suggests that salt water is more dense than fresh water.
2. **List** the following substances in order from most dense to least dense:
   egg, fresh water, ice cube, salt water
3. **Use** the evidence found in this experiment to **explain** why icebergs are so dangerous to shipping.
4. Although many attempts were made to find the wreck of RMS *Titanic*, it was only discovered in 1985, 21 km away from its last recorded position. Some scientists think that the wreck may not have hit the bottom immediately but settled somewhere in the water above it. **Use** observations made in this activity to **explain** how this might have happened.

# 6.4 Chemical reactions



Chemical reactions play a vital role in your everyday life. When you take a deep breath, you start a series of chemical reactions that keep you alive. When you place a log on a fire, the chemical reactions keep you warm. Chemical reactions in a car's engine keep it running. Chemical reactions are also used to create new and useful materials such as fuels, plastics, foods and medicines.

## Understanding chemical change

Matter is made up of particles. The very simplest of these particles are called **atoms**. Atoms are the building blocks from which all substances are made. Atoms can be thought of as hard spheres. Atoms rarely exist by themselves but usually group together to form clusters called **molecules**. A typical atom and molecule are shown in Figure 6.4.1.

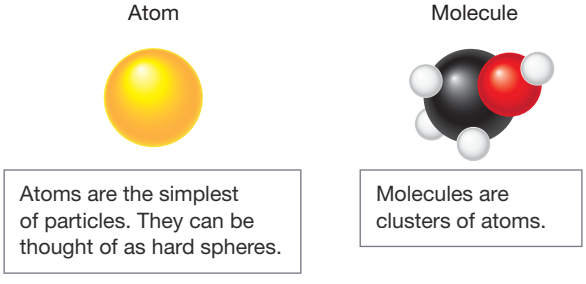



**Figure 6.4.1** Chemical changes can be understood by assuming that the particles making up a substance are molecules made up of atoms.

This is known as the atomic theory of matter and was first written down by English chemist John Dalton in 1803. The five principles of Dalton's atomic theory of matter are as follows:

1 All matter is made up of hard, tiny, invisible particles called atoms.
2 Substances made of one type of atom are called elements. For example, the element carbon is made of carbon atoms.
3 The atoms of different elements can be distinguished by their different masses.
4 Atoms can combine to form new substances called molecules.
5 Atoms are not created or destroyed during chemical change.

From these basic principles, scientists know that the molecules in a pure substance all have the same number of atoms and are identical in size and shape. When a chemical change occurs, the atoms in the molecules rearrange to form a different combination of atoms. This is how new substances are produced during a chemical change.

For example, when carbon (C) is burnt in oxygen gas ($O_2$), an atom of carbon will combine with a molecule of oxygen and rearrange to form carbon dioxide gas ($CO_2$). This is shown in Figure 6.4.2.

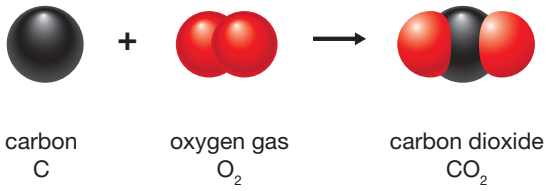



**Figure 6.4.2** When carbon is burnt in oxygen gas, the atoms rearrange to form carbon dioxide.

If the atoms rearrange to form a new substance with a different colour, then a permanent colour change will be observed. If the atoms rearrange to form a new substance that is a gas, then you will see bubbles or smoke, or smell an odour. If the atoms rearrange to form a new substance that is a solid, then a precipitate might be observed.

During a chemical change, atoms are never created or destroyed—they simply rearrange. When hydrogen gas ($H_2$) burns in oxygen gas ($O_2$), the atoms in the hydrogen and oxygen molecules rearrange to form water ($H_2O$). However, if just one hydrogen molecule reacted with just one oxygen molecule, there would be an oxygen atom left over. Therefore, two molecules of hydrogen must combine with each oxygen molecule. Their atoms then rearrange to form two molecules of water as shown in Figure 6.4.3.

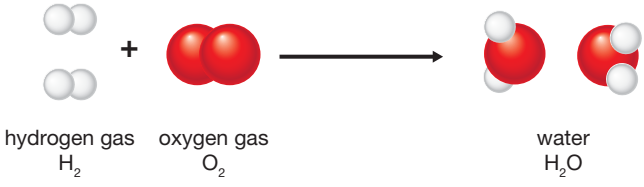



**Figure 6.4.3** When hydrogen burns in oxygen, two hydrogen molecules react with one oxygen molecule to form two water molecules.

## Chemical change and reactions

When a chemical change is observed, scientists say that a chemical reaction has occurred. A **chemical reaction** is when atoms rearrange to form new substances. The starting substances of a chemical reaction are known as the **reactants**. The substances that are formed are known as the **products**.

### Atoms in chemical reactions

During a chemical reaction, the atoms in the reactants rearrange to form the products. The atoms can only rearrange—they cannot appear, disappear or change type. For example, when nitric oxide (NO) reacts with ozone gas ($O_3$), the atoms rearrange to produce nitrogen dioxide ($NO_2$) and oxygen gas ($O_2$). This chemical reaction is shown in Figure 6.4.4.

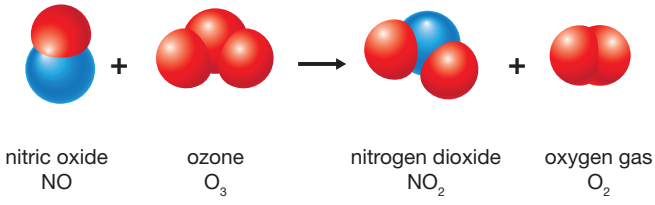



**Figure 6.4.4** When nitric oxide is heated with ozone, atoms rearrange and combine to form nitrogen dioxide and oxygen gas.

In this chemical reaction, two reactants (nitric oxide and ozone gas) form two products (nitrogen dioxide and oxygen gas). In the reactants, there is one nitrogen atom and four oxygen atoms. The product molecules contain one nitrogen atom and four oxygen atoms. No new atoms were created and no atoms were destroyed. The chemical reaction simply rearranged the nitrogen and oxygen atoms.

Figure 6.4.5 shows what happens when sodium hydroxide (NaOH) reacts with hydrochloric acid (HCl). They rearrange to form sodium chloride (NaCl) and water ($H_2O$).

1 p241

Figure 6.4.6 shows that if magnesium metal (Mg) reacts with sulfuric acid ($H_2SO_4$), then their atoms rearrange to from two products—hydrogen gas ($H_2$) and magnesium sulfate ($MgSO_4$).

6.7

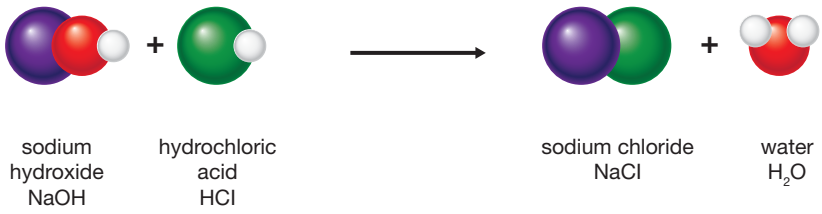



Figure 6.4.5

When sodium hydroxide is mixed with hydrochloric acid, the atoms rearrange to form sodium chloride and water.

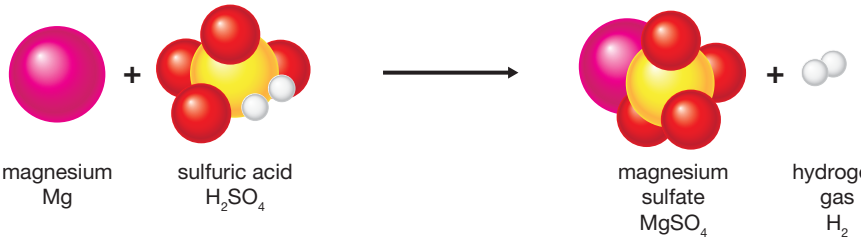



Figure 6.4.6

Reacting magnesium with sulfuric acid just rearranges atoms.

# Energy in chemical reactions

Energy plays an important part in chemical reactions. The atoms in molecules and lattices are held together by chemical bonds that store energy. It is the energy in these bonds that is released when you use a battery, burn fossil fuels like petrol or convert food into energy for your body.

## Spontaneous and non-spontaneous reactions

Some chemical reactions need a constant supply of energy while others will start and continue naturally. Reactions that proceed by themselves are known as spontaneous reactions. There are two types of spontaneous reactions. The first type can obtain enough energy from the surroundings to start and continue. Rusting is an example of this type of spontaneous reaction. Other spontaneous reactions need a kick-start from an external energy source but then produce enough energy to continue the reaction. Although you need an initial flame to start wood burning, the chemical reaction produces enough heat to continue the reaction spontaneously. The burning sparkler in Figure 6.4.7 is another example of a spontaneous reaction. It only stops when the fuel itself runs out.

Other chemical reactions require energy to be added constantly—otherwise the reaction will stop. These reactions are known as non-spontaneous reactions. A hydrogen fuel cell (like the one in Figure 6.4.8) converts water ($H_2O$) into hydrogen ($H_2$) and oxygen ($O_2$). Although this is a clean source of energy, it requires an electrical current to be applied constantly for the reaction to proceed.



Figure 6.4.7

A sparkler is an example of a spontaneous reaction. Once ignited, it continues spontaneously.



Figure 6.4.8

Water can be broken down into oxygen and hydrogen. This requires energy to be constantly put into the reaction. Therefore this reaction is non-spontaneous.

# Representing chemical reactions

Describing chemical reactions in pictures or sentences is a very clumsy way of describing what is happening in a chemical reaction. For this reason, scientists have developed a shorthand way of showing what is happening. This shorthand version is called a chemical equation. Chemical equations make describing chemical reactions clearer, faster and easier. The simplest and most general chemical equation is:

reactants ⟶ products

The arrow (⟶) means that the reactants become the products. Chemical equations can be used to specify the reactants and products of any chemical reaction.

## Word equations

The simplest way to write a chemical equation is to use the chemical names of the reactants and products.

For example, when hydrochloric acid (HCl) is mixed with sodium hydroxide (NaOH), they combine to form a solution of sodium chloride (NaCl) and water ($H_2O$). To describe this chemical reaction with a **word equation**, chemists write:

hydrochloric acid + sodium hydroxide ⟶ sodium chloride + water

**WORKED EXAMPLE**

### Constructing word equations

#### Problem

When natural gas, methane ($CH_4$), is burnt in oxygen gas ($O_2$), it produces carbon dioxide ($CO_2$) and water ($H_2O$). Write a word equation for this reaction.

#### Solution

The reactants are methane and oxygen and the products are carbon dioxide and water. The general form for a chemical reaction is:

reactants ⟶ products

Replacing the reactants and products with their chemical names gives the word equation:

methane + oxygen gas ⟶ carbon dioxide + water

## Formula equations

Even word equations are quite clumsy to write. For this reason chemists write **formula equations** instead. In a formula equation, the chemical name for a reactant or product is replaced with its chemical formula. In the case of hydrochloric acid (HCl) reacting with sodium hydroxide (NaOH) to form sodium chloride (NaCl) and water ($H_2O$), the formula equation is simply:




$HCl + NaOH \longrightarrow NaCl + H_2O$

**WORKED EXAMPLE**

### Constructing formula equations

#### Problem 1

When a sodium chloride (NaCl) solution is mixed with a silver nitrate ($AgNO_3$) solution, white silver chloride (AgCl) is produced, leaving behind a sodium nitrate ($NaNO_3$) solution. Write the word and formula equations for this chemical reaction.

#### Solution

Reactants: sodium chloride (NaCl), silver nitrate ($AgNO_3$)

Products: silver chloride (AgCl), sodium nitrate ($NaNO_3$)

The general equation for a chemical reaction is:

reactants ⟶ products

This makes the word equation:

sodium chloride + silver nitrate ⟶ silver chloride + sodium nitrate

Replace the chemical names with the chemical formulas to get the formula equation:

$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

#### Problem 2

When sulfuric acid ($H_2SO_4$) is added to sodium carbonate ($Na_2CO_3$), it produces sodium sulfate ($Na_2SO_4$), carbon dioxide ($CO_2$) and water ($H_2O$). Write the word and formula equations for this chemical reaction.

#### Solution

Reactants: sulfuric acid ($H_2SO_4$), sodium carbonate ($Na_2CO_3$)

Products: sodium sulfate ($Na_2SO_4$), carbon dioxide ($CO_2$), water ($H_2O$)

The general equation for a chemical reaction is:

reactants ⟶ products

This makes the word equation:

sulfuric acid + sodium carbonate ⟶ sodium sulfate + carbon dioxide + water

Replace the chemical names with the chemical formulas to get the formula equation:

$H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + CO_2 + H_2O$

# Chemistry in context: corrosion

Corrosion is a chemical reaction that costs the world billions of dollars every year. The term *corrosion* refers to chemical reactions where a metal reacts with oxygen. The most common and most costly form of corrosion is rusting.

The properties of metals determine how they are used. For example, iron is strong, making it ideal for ships and bridges. In contrast, aluminium is light and so is used in aircraft and drink cans.

The chemical properties of some metals make them more likely to corrode.

## Rusting

Rusting is the name given to the corrosion of iron. In this reaction, iron metal reacts with oxygen in the air or water to produce the orange-brown compound iron(III) oxide ($Fe_2O_3$), which is more commonly known as rust. The word equation for this reaction is therefore:

iron + oxygen ⟶ iron(III) oxide

This chemical reaction can destroy anything made from iron such as cars, ships and bridges.

### The true cost of iron

SciFile

Rusting is an example of an unwanted and very destructive chemical reaction. Although iron is cheap to make, the CSIRO estimates that corrosion costs Australia $13 billion each year.



## Rust prevention

The impact of rusting on the world's iron structures is so extensive and costly that scientists have put a lot of effort into understanding how rusting occurs and how it can be prevented. The rusting of iron is usually minimised in three ways:

2 p241

- coating
- galvanising
- alloying.

### Coating

The simplest and cheapest way to protect iron from rusting is to coat the iron with a material such as paint, plastic or another metal such as chromium. The coating forms a barrier between the iron metal and the oxygen in the atmosphere. As a result, rusting cannot occur. This is a cheap method of protection that is useful for large structures such as the Golden Gate Bridge (Figure 6.4.9) or large mass-produced items such as cars. However, if the coating is scratched or cracked, then the barrier is removed and rusting will occur once more.



**Figure 6.4.9** Despite its name, the Golden Gate Bridge in San Francisco is actually painted red. It takes a team of 38 painters to maintain the paint coating and prevent corrosion.

### Galvanising

If the iron is coated with zinc metal, then the zinc coating will continue to protect the iron even if the coating is scratched or cracked. This form of protection is known as galvanisation. Galvanisation works because oxygen reacts more easily with zinc than with iron. Therefore, even when the zinc is scratched and the iron is exposed to oxygen, the oxygen will not react with the iron but will react with the zinc instead. This form of protection is useful for some building materials such as nails, pipes or corrugated iron sheets as shown in Figure 6.4.10.



**Figure 6.4.10** Galvanised iron is useful for producing building materials such as sheets of corrugated iron.

### Alloying

If iron is mixed with other metals or carbon, then its chemical and physical properties can change dramatically. These mixtures of metals are known as alloys. Iron is almost never used in its pure form because pure iron is too soft and undergoes corrosion rapidly. For this reason it is usually mixed with carbon and other metals to produce steel, which is harder and more resistant to corrosion. Stainless steel is an alloy of iron that is particularly rust-resistant. It is a mixture of about 90% iron and 10% chromium. Stainless steel is more expensive than other alloys of iron so is mostly used for small items such as cutlery, watches and pots like those in Figure 6.4.11. However, it has been used in the construction of statues and bridges and to add decoration to buildings.



**Figure 6.4.11** Stainless steel is an alloy of iron and chromium. It is much more expensive than other alloys of steel so is mainly used for small household items.

## Corrosion of other metals

Aluminium (Al) also reacts easily with oxygen but does not corrode in the same way as iron. When aluminium reacts with oxygen, it forms a thin layer of aluminium oxide ($Al_2O_3$) on the surface. Unlike rust, the aluminium oxide coating forms a protective layer that prevents oxygen from reacting with the aluminium metal underneath as shown in Figure 6.4.12. As a result, aluminium can be used as a building material, without the need to apply any extra protection against corrosion.

Most metals will react with oxygen and therefore undergo corrosion. Some metals such as sodium (Na) and potassium (K) react with oxygen very rapidly and explosively to form sodium oxide ($Na_2O$) and potassium oxide ($K_2O$). Other metals such as zinc (Zn), copper (Cu) and silver (Ag) corrode more slowly with oxygen to produce zinc oxide (ZnO), copper(II) oxide (CuO) and silver oxide ($Ag_2O$). Metals such as gold (Au), platinum (Pt) and mercury (Hg) don't react with oxygen at all and are therefore referred to as noble metals.

INQUIRY science 4 fun

## A cheap silver oxide remover

No

Can you remove the silver oxide from a necklace with simple household ingredients?

### Collect this …

- tarnished silver necklace
- tray
- aluminium foil
- bicarbonate of soda
- water
- electric kettle
- tongs

### Do this …

1. Place the aluminium foil in the tray.
2. Place the tarnished necklace on the aluminium foil and cover it with bicarbonate of soda.
3. Boil water in the electric kettle.
4. Pour the boiling water over the necklace.
5. Remove the necklace with tongs and observe.

### Record this …

**Describe** what happened.

**Explain** why you think this happened.

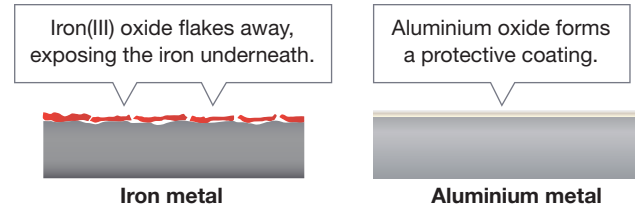



**Figure 6.4.12** When iron corrodes, the oxide breaks away from the metal, allowing more oxygen in to attack the metal beneath. When aluminium corrodes, the oxide forms a perfect coating that protects the metal underneath from further corrosion.

# SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

## The alchemists



Figure 6.4.13 The alchemists studied chemical and physical change but did not use scientific methods. This distinguishes them from modern-day chemists.

Today, the study of physical and chemical changes is called **chemistry** and the people who study them are known as chemists. Before chemistry, the study of physical and chemical changes was surrounded by myth and magic. These studies were performed by a group of people called alchemists. Today, scientists know that most of the things alchemists tried to achieve are technically impossible. However, many of the techniques they developed became the foundations of modern chemistry.

### Who were the alchemists?

The study of alchemy can be traced back to ancient Greece and the Roman Empire. However, alchemy began to flourish in the Islamic world during the Middle Ages, and then in Europe from the 13th to the 18th centuries. Figure 6.4.13 shows what an alchemist's workshop might have looked like. Although alchemy was shrouded in mysticism, it attracted the attention of some of the brightest scientists of the time including Sir Isaac Newton (Figure 6.4.14) and Robert Boyle.

6,9



Figure 6.4.14 The famous scientist Sir Isaac Newton discovered important laws of forces, gravity and optics. He was also interested in alchemy.

In addition to the study of physical and chemical changes, alchemists aimed to achieve ultimate wisdom (knowing everything there is to know) and eternal life (the ability to live forever). It is this spiritual side of alchemy that distinguishes it from chemistry today. Another difference is that alchemists studied physical and chemical change by trial and error rather than using scientific method.

The word *alchemy* comes from the Arabic word *alkimia*, which means 'the art of transformation'. This is because alchemists tried to transform base metals such as lead into precious metals such as gold and silver. Alchemists also tried to discover a universal solvent (a liquid that could dissolve anything), the elixir of life for immortality and the panacea (a single medicine that could cure all disease).

### Pee is for phosphorus

SciFile

In 1669, German alchemist Hennig Brand accidently discovered a new element while attempting to extract gold from urine. He collected 1100 litres of urine and let it rot until it produced a terrible smell. He then boiled it down into a paste and passed the vapours through water. Instead of gold, he obtained just 60 grams of a white substance that glowed in the dark. He'd discovered phosphorus, symbol P.



**Figure 6.4.15** Phosphorus was discovered by an alchemist by accident in 1669.

## The philosopher's stone

The philosopher's stone is one of the most well-known myths of the alchemists. It was a stone or tool that was believed to have the ability to change lead into gold. Others also believed that the philosopher's stone could give ultimate wisdom and eternal life. As a result, it was one of the most sought-after objects by alchemists in Europe. Today, it is regarded as myth but is often referred to in popular culture including the book and movie *Harry Potter and the Philosopher's Stone.*

## Alchemy and modern chemistry

Through their studies, the alchemists developed many tools and techniques for studying and processing substances that are still in use today. An example is shown in Figure 6.4.16. Although the alchemists did not contribute a lot to our knowledge of chemistry, they did begin the first studies of matter and therefore can be considered the forefathers of modern chemistry.

Then in the 18th and 19th centuries, scientists began to realise that everything was in fact made of invisible particles called atoms and could explain all physical and chemical changes without the need for magic and mysticism. This marked the beginning of chemistry and the end for alchemy. As people's understanding of matter grew, it became increasingly apparent that the idea of transforming base metals was only a myth. So was eternal life.



**Figure 6.4.16** Some laboratory processes and techniques developed by alchemists are still used today.

# 6.4 Unit review

## Remembering

1 **State** where the chemical potential energy released from a reaction is stored.

2 **State** what the symbol (⟶) refers to in a chemical reaction.

3 **List** the five principles of the atomic theory of matter suggested by John Dalton.

4 **Recall** the word equation for the corrosion of iron.

5 **State** whether or not atoms can be created and destroyed during a chemical reaction.

## Understanding

6 **Explain** what happens to the atoms during a chemical change.

7 **Explain** the difference between reactants and products.

8 **Explain** why iron structures need protection from corrosion while aluminium structures do not.

9 **Explain** why lighting a sparkler is considered a spontaneous reaction even though it doesn't start spontaneously.

10 **Explain** why scientists use chemical equations to describe chemical reactions.

11 **Explain** the difference betweem alchemy and chemistry.

12 **Describe** what is happening in Figure 6.4.17.

## Applying

13 During the process of photosynthesis, plants use sunlight to convert carbon dioxide from the atmosphere and water into the oxygen we breathe and glucose in the foods we eat. **Use** a word equation to **summarise** this chemical reaction.

14 When iron oxide is heated in the presence of carbon monoxide, they combine to produce carbon dioxide and pure iron metal. **Use** a word equation to **summarise** this chemical reaction.

15 When magnesium sulfate solution ($MgSO_4$) is mixed with a solution of barium hydroxide ($Ba(OH)_2$), white barium sulfate ($BaSO_4$) is produced, leaving behind a solution of magnesium hydroxide ($Mg(OH)_2$). **Use** word and formula equations to **summarise** this chemical reaction.

16 **Identify** the word equations (a–e) with its formula equations (i–v) and match the equivalent reactions.

- **a** sodium hydroxide + hydrochloric acid ⟶ sodium chloride + water
- **b** copper sulfate + barium chloride ⟶ copper chloride + barium sulfate
- **c** hydrogen + sulfur ⟶ hydrogen sulfide
- **d** nitric acid + lithium hydroxide ⟶ lithium nitrate + water
- **e** sulfuric acid + copper carbonate ⟶ copper sulfate + carbon dioxide + water
  - **i** $H_2 + S \longrightarrow H_2S$
  - **ii** $CuSO_4 + BaCl_2 \longrightarrow CuCl_2 + BaSO_4$
  - **iii** $H_2SO_4 + CuCO_3 \longrightarrow CuSO_4 + CO_2 + H_2O$
  - **iv** $NaOH + HCl \longrightarrow NaCl + H_2O$
  - **v** $HNO_3 + LiOH \longrightarrow LiNO_3 + H_2O$

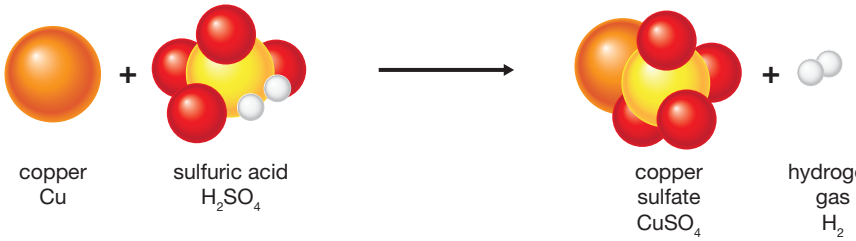



Figure 6.4.17

# 6.4 Unit review

## Analysing

**17** For each formula equation in Question 16:

- **a** **calculate** the number of each type of atom in the reactants
- **b** **calculate** the number of each type of atom in the products
- **c** **state** what you notice about the number of each type of atom on each side of the formula equation.

**18** **Compare** spontaneous and non-spontaneous reactions by listing their similarities and differences.

## Evaluating

**19** **Propose** why alchemists are not considered chemists even though they worked with chemicals and used similar techniques.

**12** You are an engineer asked to build a second bridge across Sydney Harbour.

- **a** **Propose** whether you should use painted iron, galvanised iron, stainless steel or aluminium.
- **b** **Justify** your answer.

## Inquiring

**1** Construct a labelled diagram of a blast furnace used to extract iron from its ore.

**2** Research the process of respiration.

- **a** What is respiration?
- **b** Why is respiration important?
- **c** What are the reactants?
- **d** What are the products?
- **e** Where do you get the reactants?
- **f** What happens to the products?



**Figure 6.4.18** Respiration in your body would not happen without the oxygen your lungs breathe in.

# 6.4 Practical activities

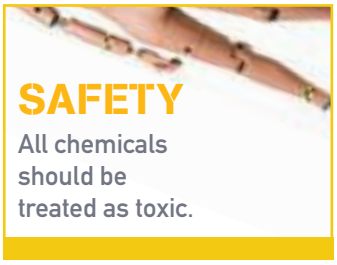
## 1 A precipitation reaction

### Purpose

To observe the precipitation of barium sulfate.

### Materials

- large test-tube
- barium hydroxide ($Ba(OH)_2$) solution
- magnesium sulfate ($MgSO_4$) solution
- 2 droppers




### Procedure

1. Using a dropper, add about 2 cm of barium hydroxide to the test-tube.
2. Using the second dropper, add about 2 cm of magnesium sulfate solution.



### Results

Record your observations.

### Discussion

1. **State** what indications there are that a chemical reaction is taking place.
2. Given that the precipitate is barium sulfate ($BaSO_4$), **predict** what other chemical may be produced during this reaction.
3. With this knowledge, **construct** the word and formula equations for this reaction.

## 2 Rust prevention

### Purpose

To study the conditions under which rusting occurs.

### Materials

- 3 large test-tubes and test-tube rack
- 3 small pieces of steel wool
- distilled water
- sodium chloride solution (salt water)

### Procedure

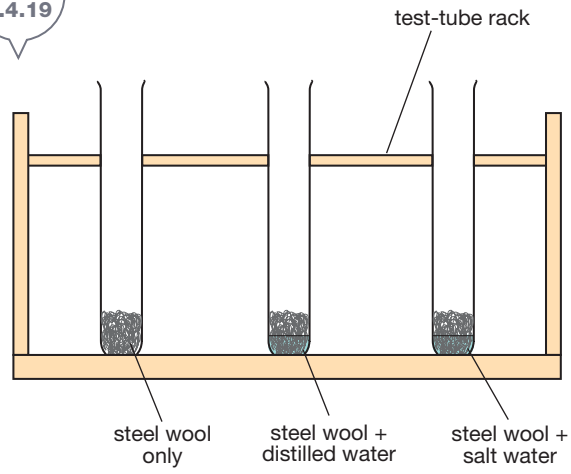
1. Place one piece of steel wool in each of the three test-tubes.
2. Do not add anything else to the first test-tube.
3. To the second test-tube, add distilled water so that the wool is half submerged.
4. To the third test-tube, add salt water solution so that the wool is half submerged (Figure 6.4.19).
5. Observe the reaction over the next 5 days.

### Results

Copy and complete the following table.

| Day | Observations | | |
|---|---|---|---|
| | No water | Water | Water + salt |
| | | | |
| | | | |

Figure 6.4.19




### Discussion

1. **State** what evidence there is that a chemical reaction has taken place.
2. **Recall** the word and formula equations for rusting.
3. **List** what is necessary for rusting to occur.
4. **State** what else helps rusting to occur.
5. **Explain** why iron structures such as car bodies rust faster in coastal areas rather than inland.

# 6 Chapter review

## Remembering

1 **List** four examples of physical changes and four of chemical changes.

2 **List** four things that indicate a chemical change has occurred.

3 **List** the changes of state that occur as you heat a solid to a gas and cool a gas to a solid.

4 **List** three ways that iron can be protected from corrosion.

## Understanding

5 **Explain** why iron structures corrode while aluminium structures do not even though both metals react easily with oxygen.

6 **Outline** the physical changes that aluminium undergoes when it is recycled.

7 **Discuss** whether a kilogram of feathers has the same mass as a kilogram of rocks.

8 **Describe** how you would measure the volume of an irregular solid like a blob of clay.

## Applying

9 **Use** the particle model to **describe** what happens to the particles of a solid as it is heated to form a liquid and then heated further to form a gas.

10 When methane gas is burnt in oxygen they produce carbon dioxide and water. **Use** a word equation to **describe** this reaction.

11 When magnesium metal (Mg) is combined with sulfuric acid ($H_2SO_4$) they react to form hydrogen gas ($H_2$) and magnesium sulfate ($MgSO_4$). **Use** word and formula equations to **describe** this reaction.

12 **Identify** which of the following formula equations match the word equations.

- a $KOH + HCl \longrightarrow KCl + H_2O$
- b $H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + CO_2 + H_2O$
- c $C + O_2 \longrightarrow CO_2$
- d $HCl + AgNO_3 \longrightarrow AgCl + HNO_3$
- e $CuCl_2 + Pb(NO_3)_2 \longrightarrow Cu(NO_3)_2 + PbCl_2$
  - i carbon + oxygen ⟶ carbon dioxide
  - ii potassium hydroxide + hydrochloric acid ⟶ potassium chloride + water
  - iii sulfuric acid + calcium carbonate ⟶ calcium sulfate + carbon dioxide + water
  - iv copper chloride + lead nitrate ⟶ copper nitrate + lead chloride
  - v hydrochloric acid + silver nitrate ⟶ silver chloride + nitric acid

13 A mobile phone has a mass of 80 g and a volume of 40 $cm^3$. **Calculate** the density of the mobile phone.

## Analysing

14 **Classify** the following as physical or chemical changes: rotting apples, breaking a plate, dissolving copper sulfate, baking bread, making popcorn, melting butter, boiling oil, bending a paperclip, mixing paint, fermenting wine.

## Evaluating

15 **Propose** why steel bridges are painted and not galvanised to protect them from corrosion.

## Creating

16 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

| | |
|---|---|
| matter | mixing |
| physical change | chemical reaction |
| chemical change | atoms |
| change of form | molecules |
| change of state | chemical equation |



# Thinking scientifically

**Q1** During a physical change, no new substances are produced. Which of these processes is *not* an example of a physical change?

**A**



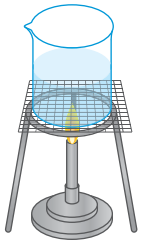
**B**



**C**



**D**



**Q2** When a chemical change occurs new substances are produced. This may result in:

- a permanent colour change
- a gas being produced
- a solid precipitate being produced
- energy being produced or absorbed in the form of heat or light.

Identify which of these processes is *not* an example of a chemical change.

**A**



**B**



**C**



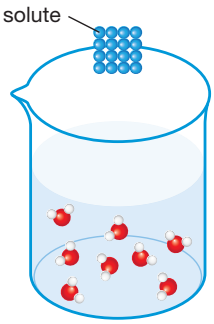
**D**



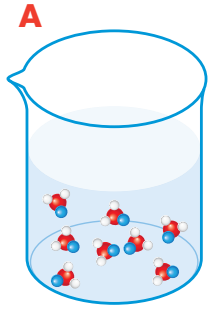
**Q3** When Sanjay mixes sodium bicarbonate with vinegar, a chemical reaction occurs that releases a large amount of carbon dioxide gas. What would be the most obvious indication that a chemical change has occurred?

**A** a permanent colour change
**B** bubbles produced
**C** precipitate formed
**D** heat produced

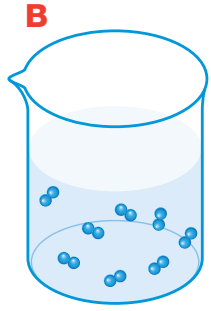
**Q4** When a solute is dissolved in a solvent, the solute particles are distributed evenly through the solvent. Which of the following diagrams best represents what happens when the particles of the blue solute are dissolved in a beaker of water?



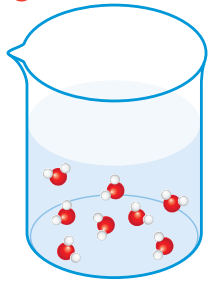

**A**



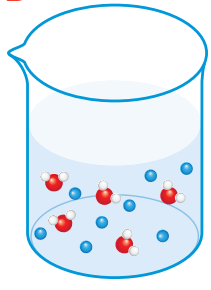
**B**



**C**



**D**



# Glossary

## Unit 6.1

**Boiling:** a change of state where a liquid is heated and changes to a gas within the liquid

**Chemical change:** a change that results in a new substance being formed

**Condensation:** a change of state where a gas is cooled and forms a liquid

**Contraction:** a decrease in size

**Deposition:** a change of state from gas to solid

**Endothermic:** describes a process that absorbs energy from the surroundings

**Evaporation:** the change of state where a liquid changes to a gas at the surface of the liquid

**Exothermic:** describes a process that gives off energy in the form of heat, light or sound

**Expansion:** an increase in size

**Freezing:** the change of state from liquid to solid

**Melting:** the change of state when a solid is heated and forms a liquid

**Physical change:** a change that does not result in a new substance being produced

**Precipitate:** a solid formed during a chemical change

**Solidification (freezing):** the change of state from liquid to solid

**Solution:** a mixture where the substances are mixed on the atomic level

**Sublimation:** a change of state from solid to gas



Boiling



Condensation



Exothermic

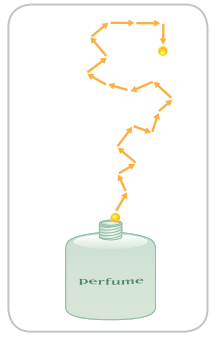


Precipitate

## Unit 6.2

**Diffusion:** a process where two liquids or two gases mix due to the motion of their particles

**Particle model:** a simplified representation of solids, liquids and gases




Diffusion

## Unit 6.3

**Density:** a measure of the mass per unit volume of a substance, $d = \frac{m}{V}$ (unit: g/cm$^3$)

**Displaces:** pushes upwards, as in pushes water upwards

**Mass:** measures how much matter is in a substance (unit: g)

**Volume:** measures how much space is occupied by a substance (units: mL or cm$^3$)

## Unit 6.4

**Atom:** the smallest building block that makes up all substances

**Chemical reaction:** when atoms rearrange to form new substances

**Formula equation:** a type of chemical equation where the chemicals in the reaction are represented by their chemical formulas

**Molecule:** a cluster of atoms

**Products:** the substances formed in chemical reactions

**Reactants:** the starting substances in chemical reactions

**Word equation:** a type of chemical equation where the chemicals are represented by the chemical names



Molecule

# Elements, compounds and mixtures

7



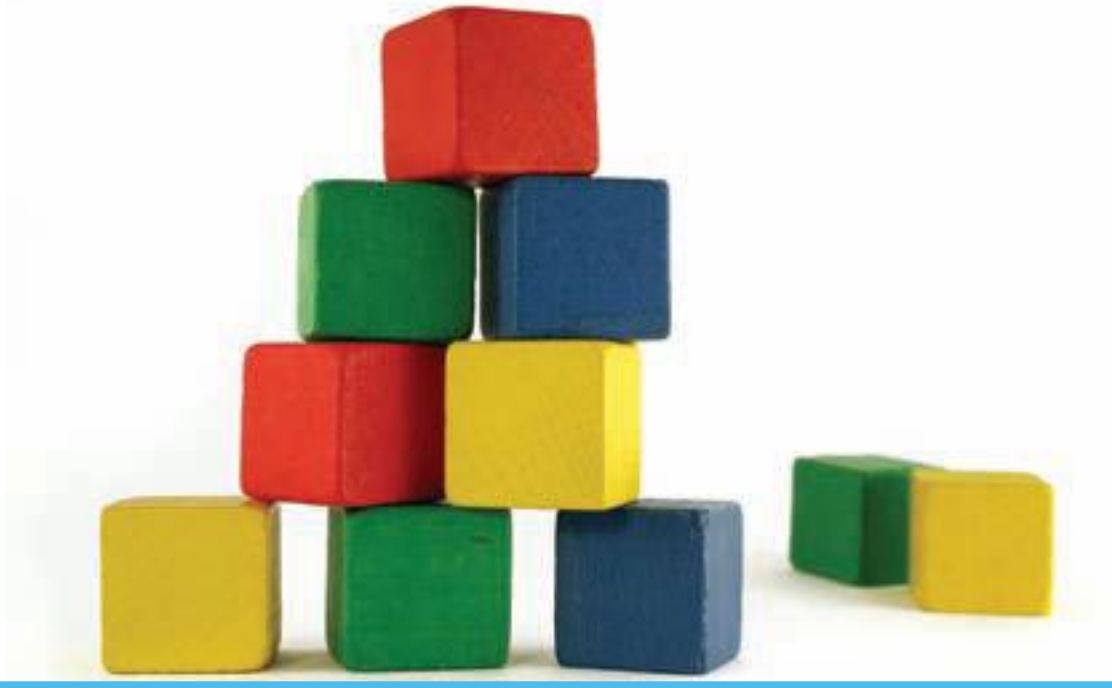
## HAVE YOU EVER WONDERED…

- why you can feel a breeze even though it's invisible?
- why diamond is the hardest natural substance on Earth?
- why water can be written as $H_2O$?

**After completing this chapter students should be able to:**

- describe differences between elements, compounds and mixtures in terms of the particle model
- describe the arrangement of particles in elements and compounds
- use symbols and formulas for elements and simple compounds
- identify and locate elements on the periodic table
- investigate how the idea of elements has developed over time
- investigate how scientists have created new materials.

# 7.1 Elements



Elements are the most basic materials for building the world around you—chairs, desks, windows, your skin, the trees, the ocean, the Sun and the stars. By understanding elements, scientists can use them to create new materials for building bridges, powering cars, making clothes and curing disease.

## Atomic Lego®

Every substance in the universe is made up of building blocks known as **atoms**. There are only about 100 types of atoms but they can be arranged in different combinations to create countless types of different substances. In this way, atoms are like tiny pieces of Lego. Imagine you just have red, blue and green blocks of Lego. It would still be possible to create many different Lego combinations with just these three types. Figure 7.1.1 shows just a few. In a similar way, the 100 or so different types of atoms can be used to create the millions of substances you see in the world around you.

Unlike blocks of Lego, atoms are round like tiny balls. They are so small that they cannot be seen with even the most powerful optical microscope. Instead, scientists must use a **scanning tunnelling microscope (STM)** to obtain images of atoms such as the copper atoms shown in Figure 7.1.2.

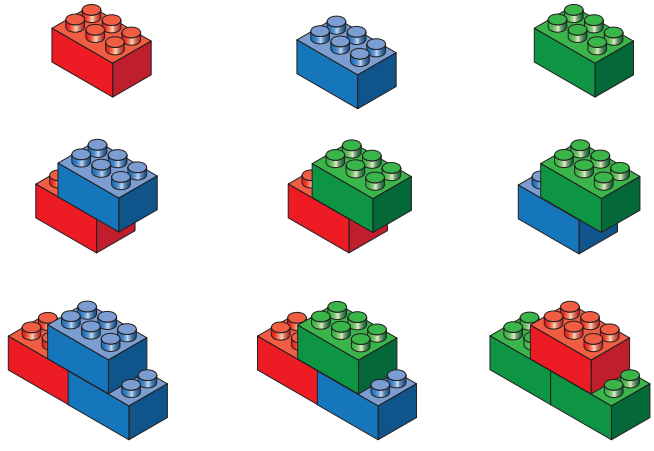


**Figure 7.1.1** With just a few types of Lego, you can create many different combinations. Similarly, it takes just 100 or so different types of atoms to make up every substance in the universe.

# Elements

**Elements** are substances that are made up of just one type of atom. Figure 7.1.2 shows an STM image of copper atoms. The air you breathe is mostly made up of two elements—the gases oxygen and nitrogen. Billions of invisible oxygen and nitrogen atoms surround you and they are what you feel hitting your skin when a breeze blows. Apart from these two elements, there are many other elements useful in everyday life. Each element has a unique set of characteristics that scientists refer to as its **properties**.

7.1

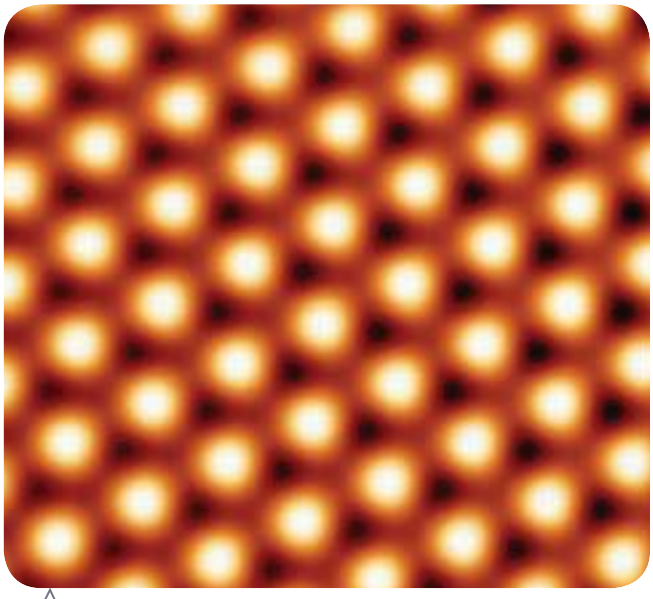


**Figure 7.1.2** An STM is the only type of microscope powerful enough to get an image of these copper atoms.

## Metallic and non-metallic elements

Elements can be broadly classified into metallic and non-metallic elements. Aluminium, iron, mercury, gold and silver are all examples of metallic elements that are used every day in construction, electronics and jewellery. Metallic elements (such as the ones shown in Figure 7.1.3) all share some properties. **Metals**:

- tend to be shiny (or can be polished to make them shiny)
- are solid at room temperature (except mercury which is a liquid)
- are good conductors of heat and electricity, allowing heat and electricity to flow easily through them
- can be bent and hammered into sheets (when metals act this way, they are referred to as being **malleable**)
- can be stretched into wires (metals are referred to as being **ductile**).

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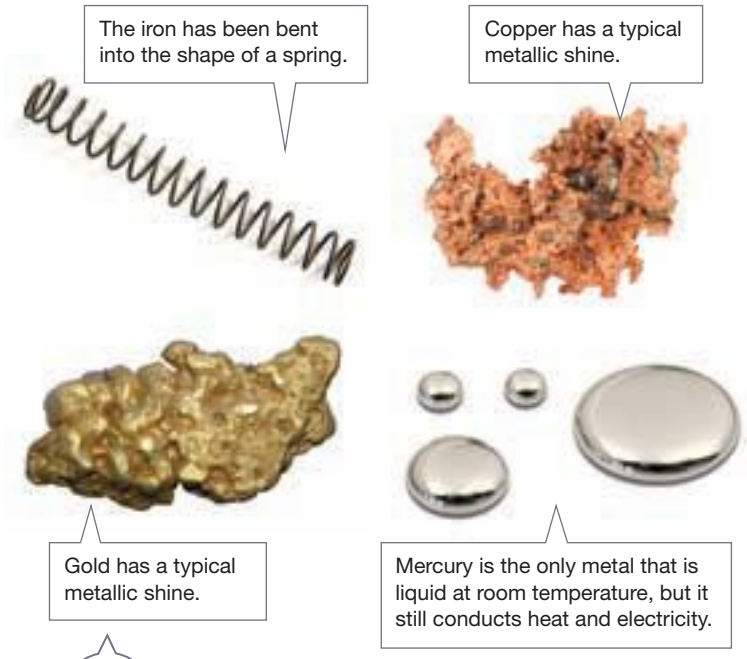



**Figure 7.1.3** Common metallic elements

INQUIRY science 4 fun

## Metals for breakfast

Yes

Is the element iron in your breakfast cereal?

### Collect this…

- iron-rich cereal such as Special K®
- mixing bowl
- magnet
- sticky tape
- potato masher
- long pencil
- water

### Do this…

1. Place 2–3 cups of iron-rich cereal in the mixing bowl.
2. Crush the cereal to pinhead-sized pieces using the potato masher.
3. Add enough water to just cover the cereal and continue to mix with the potato masher for 10 minutes until it looks like soup.
4. Use the sticky tape to attach the magnet to the end of the pencil and use it to stir the cereal soup for 5 minutes.
5. Check the end of the magnet for iron particles.

### Record this…

**Describe** what you saw.

**Explain** why you think this happened.

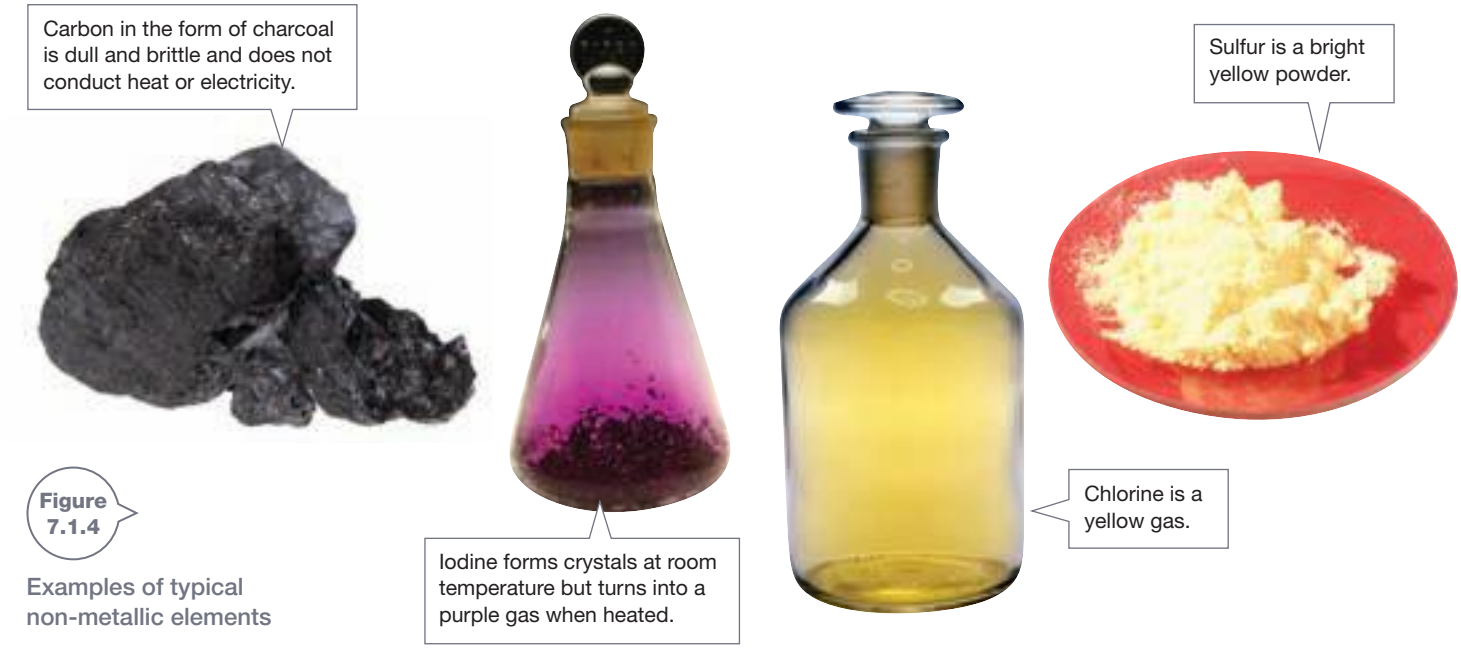



**Figure 7.1.4**
Examples of typical non-metallic elements

Non-metallic elements tend to be solids or gases at room temperature. Bromine is the only non-metal that is liquid at room temperature. Some non-metallic elements are shown in Figure 7.1.4. **Non-metals**:

- tend to be dull (not shiny)
- do not conduct heat or electricity
- break or crumble when you bend them (non-metals are referred to as being **brittle**).

The black ash or charcoal formed when you burn a piece of paper or wood is made of the element carbon, and is typical of non-metallic solids. The element helium is a non-metallic gas that is light and non-toxic and can be used safely in party balloons.

## Naming elements

There are 117 known elements but only 92 of these occur naturally—the rest are synthetic and must be made in a laboratory. Each element has a name and a chemical symbol.

Scientists display all the known elements and their symbols in a table called the **periodic table**, shown in Figure 7.1.6. The periodic table lists the elements from lightest to heaviest and helps scientists to understand some of their physical properties.

### The elements of war

SciFile

As Figure 7.1.5 shows, the non-metallic element chlorine was used in World War I as one of the first 'weapons of mass destruction'. Chlorine is extremely toxic when breathed in, causing a burning feeling in the chest and painful suffocation. It is much heavier than air so it filled the trenches where the soldiers fought. The first use of chlorine received worldwide criticism but started a trend in chemical warfare. For this reason, World War I is sometimes referred to as 'the chemists' war'.

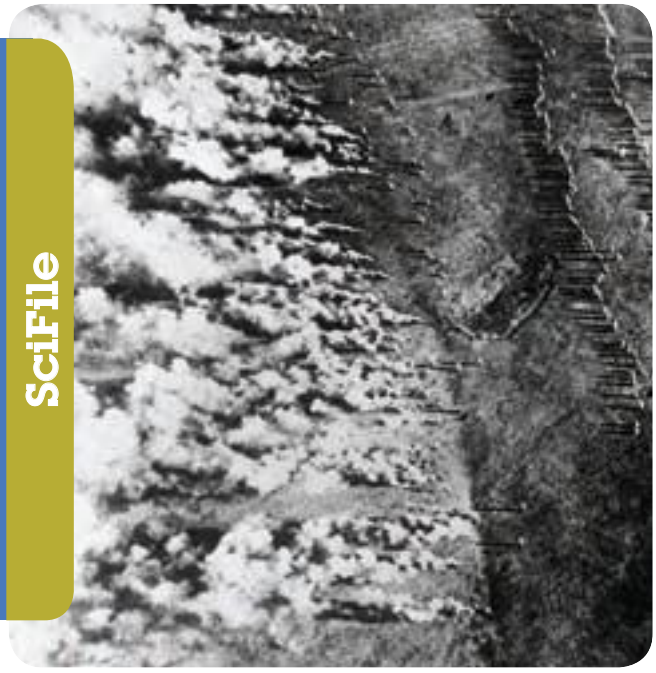


**Figure 7.1.5**
Chlorine gas floating over the trenches during World War I.

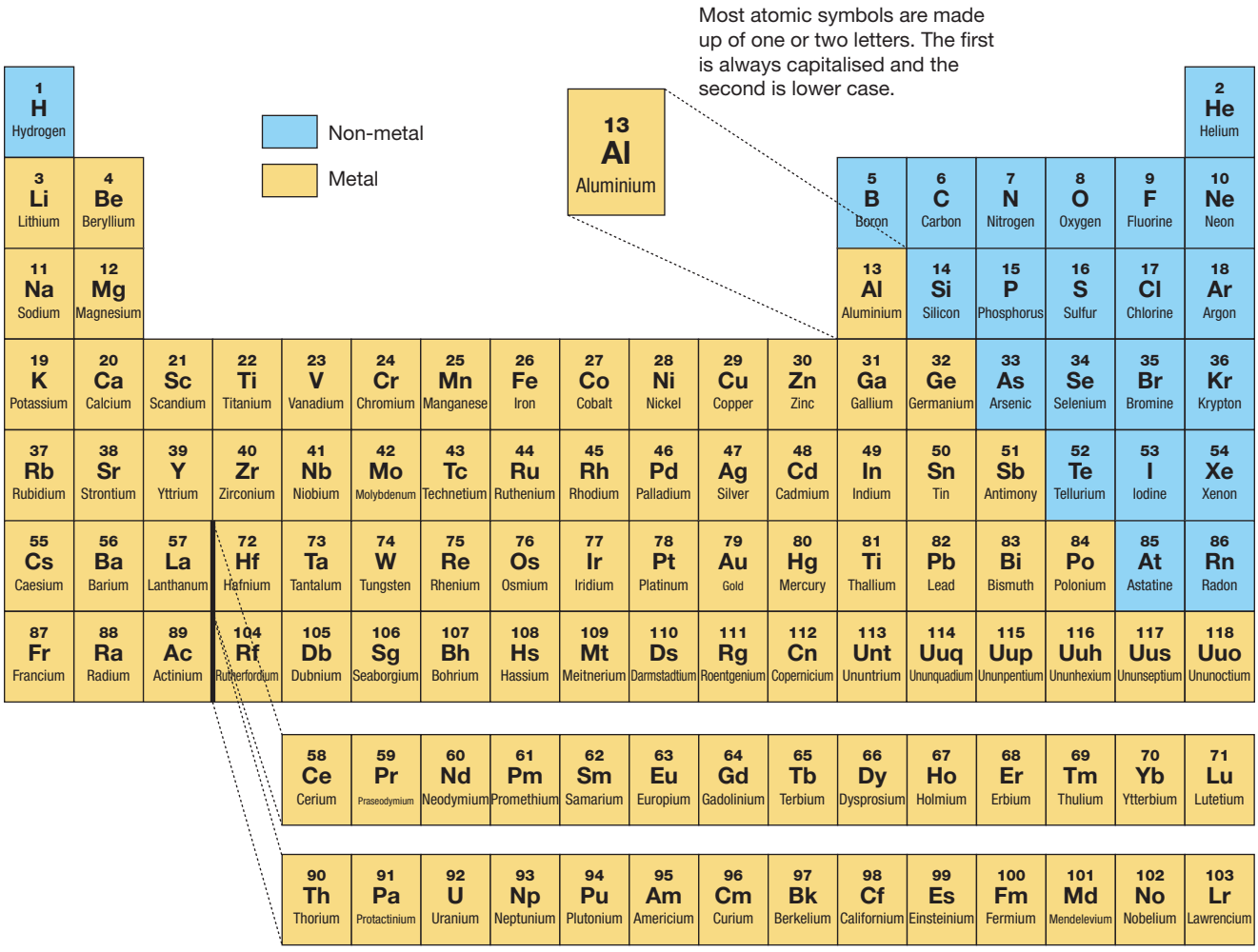



**Figure 7.1.6** The periodic table is a list of the known elements from the lightest to the heaviest.

Often the chemical symbol of an element comes directly from its name. For example, the element calcium is given the symbol Ca, carbon has the symbol C and magnesium has the symbol Mg. However, sometimes the symbol of an element does not appear to relate to the name at all. For example, potassium has the symbol K and sodium has the symbol Na. This is because their symbols come from the Latin names for the elements, names which may be different from those used in English. In Latin, the name for potassium is *kalium*, while sodium is *natrium*—knowing this, their symbols K and Na actually make sense.

From the periodic table you can see that the chemical symbol is always made up of one, two or three letters. The first letter is always in upper case and the others are always lower case. So the chemical symbol for chlorine is always written as Cl and never CL or cl.

7.2

7.3

## Atoms in elements

Elements are made up of just one type of atom. However, the atoms in elements can be arranged in different ways. The atoms can exist:

- as single atoms (this is referred to as being monatomic)
- in clusters of atoms called molecules
- in large grid-like structures called lattices (like the one in Figure 7.1.7 on page 250).

The way the atoms are arranged in an element determines many of the physical properties of the element. Physical properties include whether the element is solid, liquid or gas, its melting and boiling points, how well it conducts heat or electricity and if it can bend or whether it breaks when a force is applied.

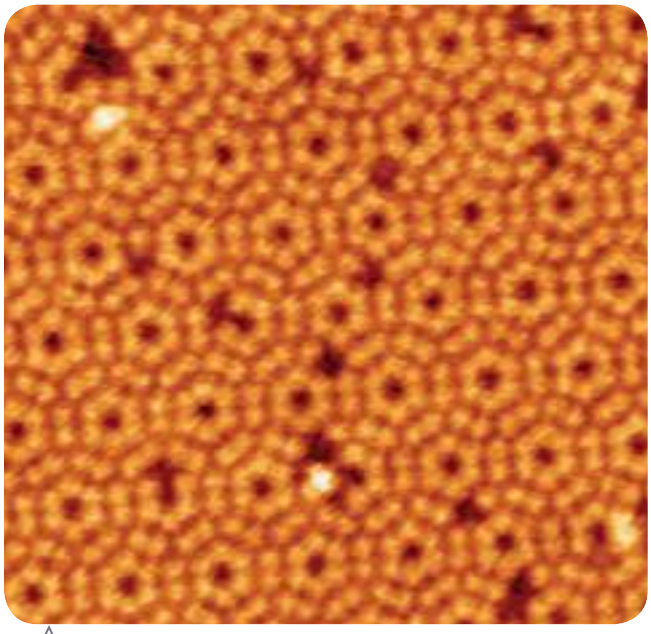


Figure 7.1.7 An image of a lattice of silicone atoms taken with a powerful microscope known as a scanning tunnelling microscope (STM).

## Monatomic elements

An element that consists of just single atoms is known as monatomic. **Monatomic** elements are rare, with only six of the 92 naturally occurring elements being monatomic. These are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). These elements are all non-metallic gases. Three of them are shown in Figure 7.1.8.

The monatomic element helium (He) is used in party balloons because it is lighter than air and so the balloons float. Neon (Ne) is used in neon lights for creating signs of different colours. Old-fashioned light globes contained the monatomic element argon (Ar) to stop the filament from burning.

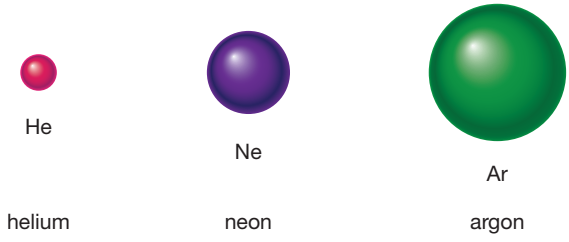



Figure 7.1.8 Helium, neon and argon are monatomic and do not combine with other elements.

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### An element by a different name

The symbols for elements sometimes make more sense in other languages. For example, the symbol for silver, Ag (which comes from the Latin *argentum*), makes perfect sense in French (*argent*) and Italian (*argento*). Similarly, the word for sodium in German, Swedish and Norwegian is *natrium*. In these languages, the symbol for sodium, Na, is logical.

## Molecular elements

Most non-metallic elements are made up of molecules. **Molecules** are clusters of two or more atoms bonded (joined) together. In a molecular element, all the molecules are identical with the same size, shape, number and type of atoms. Molecules of some common elements are shown in Figure 7.1.9.

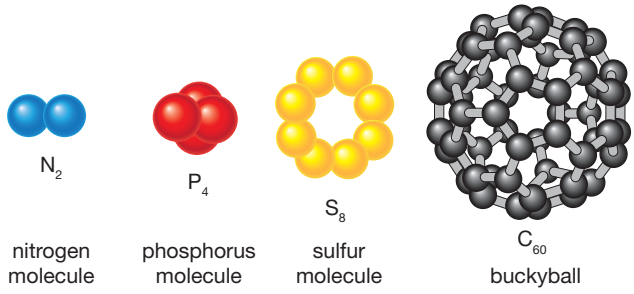



Figure 7.1.9 Non-metallic elements tend to form molecules like these where every molecule contains just one type of atom.

The oxygen you're breathing in right now is made up of billions of oxygen molecules. Each oxygen molecule contains two oxygen atoms. For this reason scientists represent oxygen gas by the molecular formula $O_2$. Each type of molecule has its own different molecular formula. The molecular formulas show what atoms are in a molecule and how many there are of each. The molecular formula $O_2$ shows that each oxygen molecule has two oxygen atoms. Other non-metallic elements that are made up of molecules with just two atoms are nitrogen ($N_2$), hydrogen ($H_2$) and chlorine ($Cl_2$).

Some non-metallic elements are made up of molecules with more than two atoms. For example, phosphorus commonly has four atoms, giving it the molecular formula $P_4$. Sulfur forms ring-shaped molecules of different sizes. One ring has just six sulfur atoms (with a molecular formula $S_6$) while other rings contain eight sulfur atoms ($S_8$) and 20 sulfur atoms ($S_{20}$).

Carbon is unique among the non-metallic elements in that it can form very large molecules of almost any size. The most famous is called the buckyball. This is a molecule that has 60 carbon atoms arranged in the shape of a soccer ball and has the molecular formula $C_{60}$.

2 p256

## Elements in lattices

### Metallic lattices

Eighty per cent of the known elements are metals. The atoms in metals do not form molecules but instead form large grid-like structures known as crystal **lattices**. An example is shown in Figure 7.1.10. This structure makes metals strong and solid at room temperature (with the exception of mercury, which is a liquid). Unlike non-metallic solids, the atoms in metallic lattices can slide and move over each other without breaking the lattice. This is why metals can be bent, hammered into thin sheets or drawn out into thin wires.

### Non-metallic lattices

Only a few non-metallic elements form lattices. A notable example is carbon, which forms crystal lattices to make graphite and diamond (Figure 7.1.10). In these lattices, the atoms are bound tightly to each other and are fixed in position. In graphite, the atoms bond together in sheets that can slide over one another. This makes graphite a good lubricant. In diamond, the carbon atoms are bonded strongly to each other in four directions. This is the reason why diamond is the hardest natural substance on Earth.

7.4

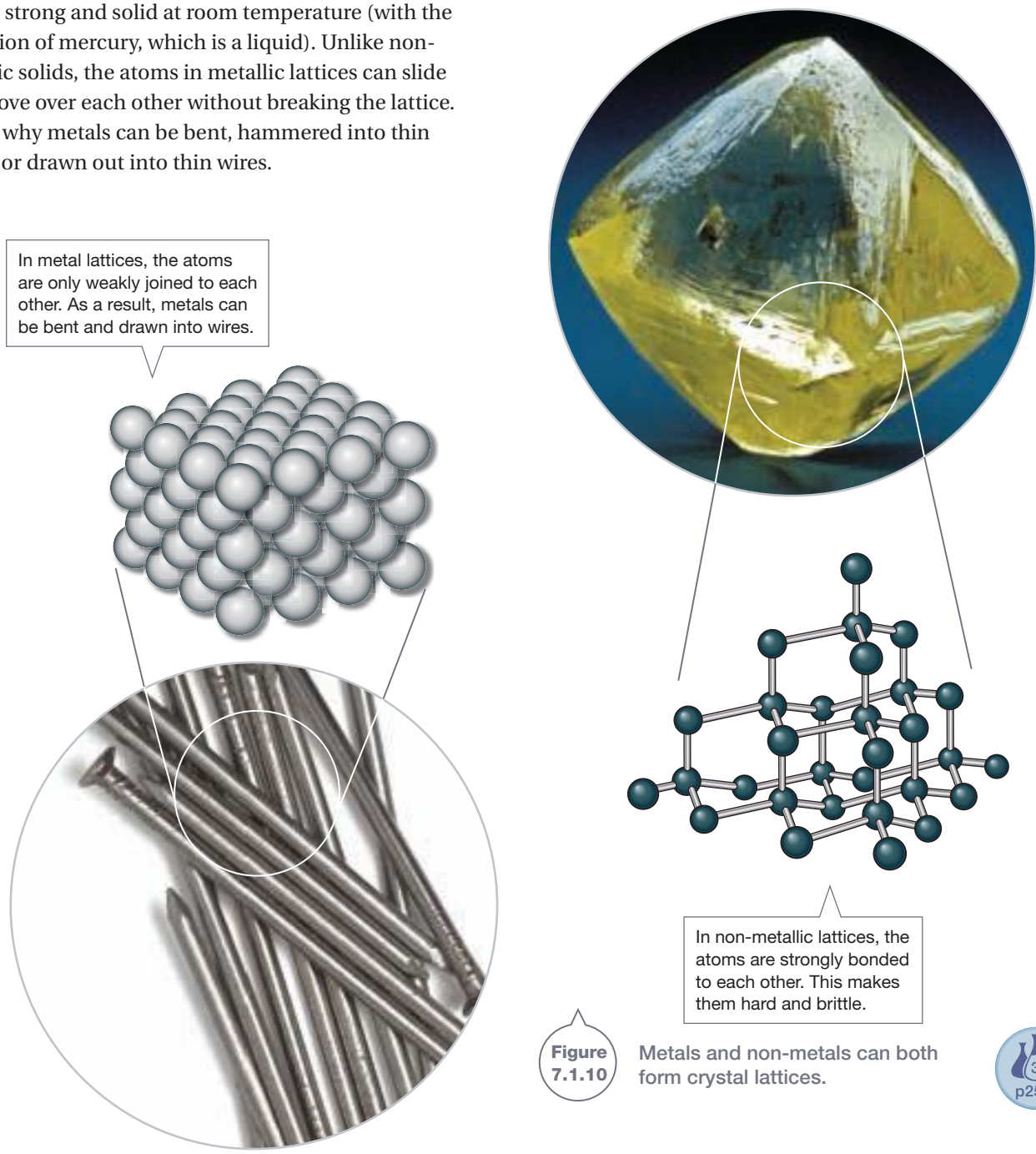



**Figure 7.1.10** Metals and non-metals can both form crystal lattices.

3 p256

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

## The many faces of carbon



Figure 7.1.11 Diamonds don't look like burnt toast but are made from the same substance.

ENDEAVOUR

Carbon is an incredibly versatile element and can be found in many different forms. Different forms of the same element are called **allotropes** and almost every allotrope of carbon is useful to humans.

### Charcoal

7.5

When most people think of carbon, they think of the black powdery ash or charcoal left over after paper or wood have been burnt. Charcoal is used by artists for sketching (Figure 7.1.12) but it is also used in industry for processes such as the smelting of iron. Charcoal can also adsorb certain gases so is used as tablets to help with digestive problems, as odour-eaters in shoes and as poisonous gas filters in gas masks.



Figure 7.1.12 Carbon in the form of charcoal is used for drawing because it is black and soft and crumbles easily.

### Graphite

In graphite, the carbon atoms form sheets that are stacked on top of each other as shown in Figure 7.1.13. The sheets do not break easily but can slide across each other. This makes graphite a good lubricant for industrial machinery. The lead in grey-lead pencils is also made of graphite mixed with clay. As you write, the thin layers of graphite are slowly rubbed off onto the page. Graphite can also withstand very high temperatures and conducts electricity so can be used to replace electrical wiring in very hot situations such as industrial kilns for firing clay tiles.

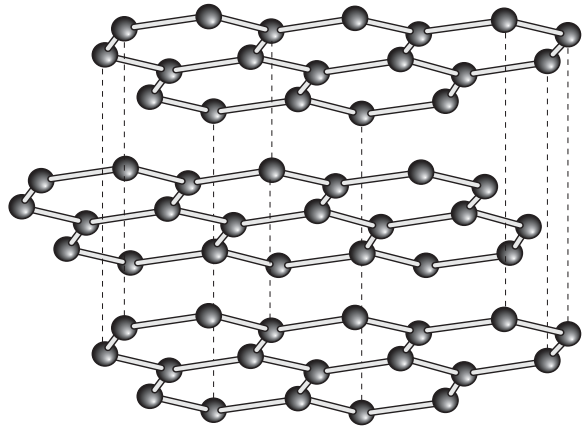


Figure 7.1.13 The carbon atoms in graphite form layers. The layers are difficult to break but can slide over each other easily. This makes graphite an excellent lubricant.

## Diamond

Diamond is another form of carbon. Unlike graphite, all of the carbon atoms in diamond are tightly bonded to each other in a rigid crystal lattice. As a result, diamond is extremely hard and does not conduct electricity. Most people will know diamonds as the sparkling and very expensive jewels such as the one shown in Figure 7.1.14. However, only 20% of diamonds mined are used in jewellery. The rest are used by industry to make long-lasting tools for cutting and drilling.



Figure 7.1.14

Carbon in the form of diamond is the hardest natural substance on Earth because the bonds between the carbon atoms are extremely strong.

### Wear the ones you love

SciFile

It is now possible to keep your loved ones wrapped around your little finger—quite literally. A company called Life Gem in the USA creates synthetic diamonds from the carbon ashes of your dead loved ones. The diamonds can then be made into jewellery such as rings, bracelets and necklaces.

## Carbon fibre

Carbon fibres are very thin strands of compressed crystals of carbon. These fibres can be woven together to form new types of material that are very strong but also very lightweight. As a result, carbon fibre materials are ideal for things such as tennis racquets, bike frames (like the one in Figure 7.1.15) and aircraft, which require maximum strength yet minimum weight.



Figure 7.1.15

Carbon fibre is very light, very strong and flexible and so is often used in sporting equipment such as this mountain bike.

## Buckyballs and nanotubes

In 1985, Americans Robert Curl and Richard Smalley and Briton Harold Kroto discovered yet another allotrope of carbon that they called buckyballs. These are balls of 60 carbon atoms that have the same geometric shape as a soccer ball. This discovery led to a whole new area of chemistry and the development of another allotrope of carbon called nanotubes. Nanotubes are sheets of carbon rolled into hollow tubes like the one shown in Figure 7.1.16.

Like graphite, carbon nanotubes conduct electricity. This means they can be used to construct nanowires for miniature electrical circuits. Nanotubes are also very strong. For this reason, the CSIRO is currently studying ways to mass–produce carbon nanotubes. This would allow creation of a new generation of materials which are strong, lightweight and heat–resistant.



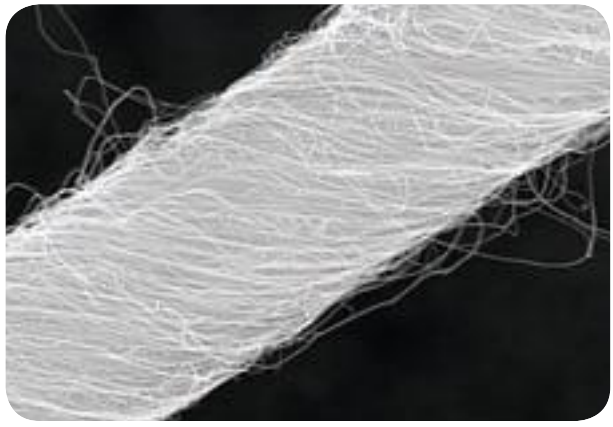


Figure 7.1.16

A carbon nanotube can be thought of as a sheet of carbon rolled into a tube. These tubes are very tough so scientists at CSIRO are researching how to spin them into yarn to create new-age materials.

# 7.1 Unit review

## Remembering

1 **Name** the invisible particles that make up all matter.

2 **List** four properties of metallic elements.

3 **Name** three monatomic elements and give their element symbols.

4 **Recall** the atomic symbols of the following elements: hydrogen, helium, carbon, oxygen, nitrogen.

5 **List** three allotropes of carbon and give examples of where they are used.

## Understanding

6 **Define** what is meant by the *properties of an element*.

7 **Explain** why metallic elements bend while solid and non-metallic elements break or crumble.

8 **Define** the following terms.
- a ductile
- b malleable
- c brittle

## Applying

9 **Use** the periodic table to **identify** an example of an element and a non-element.

10 **Use** the periodic table to **identify** an element named after:
- a a famous scientist
- b a continent
- c an American state.

11 **Identify** the number and type of atoms in the following molecules.
- a nitrogen ( $N_2$)
- b oxygen ($O_2$)
- c ozone ($O_3$)
- d phosphorus ($P_4$)
- e sulfur ($S_{20}$)

## Analysing

12 a **Compare** the way carbon atoms are arranged in diamond and graphite.
- b **Use** these arrangements to help **contrast** the properties of diamond and graphite.

13 **Classify** the following elements as either metallic or non-metallic: carbon, iron, copper, chlorine, helium, gold, oxygen, sulfur, nickel.

14 **Classify** the following elements as monatomic, molecular or lattice: helium, oxygen, copper, chlorine, silicon, neon, iron, nitrogen, germanium, argon, gold.

## Evaluating

15 The atoms in both diamond and gold form lattices. **Propose** a reason why diamond is much harder than gold.

16 **Propose** reasons why graphite might be used instead of gold or copper wires to conduct electricity in very hot situations such as an industrial kiln.

## Creating

17 Use coloured modelling clay to **construct** models of molecular and lattice elements presented in this unit.

18 Use the periodic table to **construct** a table of elements with chemical symbols that do not match their name in English.

## Inquiring

1 Oxygen has two allotropes, oxygen gas, $O_2$ and ozone $O_3$. Research the properties of these two allotropes and compare the two.

2 Investigate when the first 10 elements in the periodic table were discovered and construct a timeline showing these dates.

3 Investigate how the idea of elements has developed from 'air, earth, fire and water' to our current list of over 100 elements.

4 Investigate how natural and synthetic diamonds are formed.

# 7.1 Practical activities

## 1 Measuring density, a physical property

### Purpose

To measure the density of metals.

### Materials

- cubes of metallic elements such as iron, copper and aluminium
- electronic balance
- ruler
- calculator

### Procedure

1. Use the electronic balance to measure the mass of each metallic cube and record your measurements in a table like the one below.
2. Use the ruler to measure the length, width and height of the cubes. Once again, record your measurements.

### Results

1. In your workbook, construct a table like that below.
2. Enter all the masses and sizes you measured in the table.
3. Calculate the volume of each cube by multiplying length × width × height and enter these values into the table.
4. Calculate the density of each cube by dividing the mass by the volume. Enter these into the table.

### Discussion

1. From your table, **identify** which element is most dense and which is least dense.
2. The official densities for these metals are:
   - iron 7.88 g/cm$^3$
   - aluminium 2.70 g/cm$^3$
   - copper 8.93 g/cm$^3$.

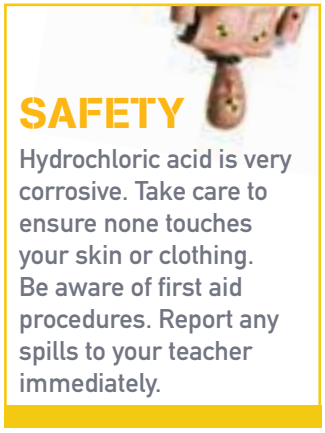
   **Compare** these values with the ones you measured.
3. **Propose** reasons why your values might be a little different from the ones you calculated.
4. **Propose** ways that your experiment could be done more accurately.

| Metal | Mass (g) | Length (cm) | Width (cm) | Height (cm) | Volume ($l \times w \times h$) (cm$^3$) | Density (mass/volume) (g/cm$^3$) |
|---|---|---|---|---|---|---|
| Iron | | | | | | |
| Aluminium | | | | | | |
| Copper | | | | | | |

## 2 Obtaining hydrogen, a non-metallic element

### Purpose
To form the element hydrogen

### Materials
- magnesium metal strip
- test-tube
- 2 M hydrochloric acid
- scissors
- eyedropper




### Procedure
1. Use scissors to cut the magnesium ribbon into small pieces (2 cm) and place them into the test-tube.
2. Using the eyedropper, add enough hydrochloric acid to cover the pieces of magnesium metal.
3. Watch what happens.

### Results
Record your observations.

### Discussion
1. The bubbles you see in this experiment are hydrogen. **Discuss** what evidence there is that a new substance is being produced.
2. **State**:
   a. whether hydrogen is a solid, liquid or gas at room temperature
   b. the colour of hydrogen.
3. **Use** the periodic table to find the following information for hydrogen.
   a. Chemical symbol
   b. Atomic number
   c. Whether it is a metal or non-metal
4. a. **State** whether hydrogen would exist in a monatomic form, as a lattice or as molecules.
   b. **Justify** your answer.

## 3 Obtaining copper, a metallic element

### Purpose
To form crystals of metallic copper.

### Materials
- beaker
- zinc metal strip
- 0.1 M copper sulfate solution
- filter paper
- magnifying glass or microscope




### Procedure
1. Half-fill the beaker with copper sulfate solution.
2. Place the zinc metal strip so that it is partly immersed in the copper sulfate solution.
3. Observe the copper crystals as they deposit on the zinc strip.
4. Once you have seen a noticeable change, remove the zinc strip and place it on the filter paper.

### Results
1. Record your observations as the copper crystals form.
2. Record what happens to the colour of the copper sulfate solution as the experiment proceeds.
3. Once you have removed the zinc strip, observe the copper crystals more closely and record what you see. Use a magnifying glass or microscope if possible.

### Discussion
1. **Use** the periodic table to find the following information for copper:
   a. chemical symbol
   b. atomic number
   c. whether it is a metal or non-metal.
2. a. **State** whether copper would exist in a monatomic form, as a lattice or as molecules.
   b. **Justify** your answer.

# 7.2 Compounds



The billions of substances in the universe are all made up of just 100 or so elements. By understanding how the elements combine to form new substances, scientists can develop useful materials such as plastics, perfumes and medicines. Scientists can also synthesise natural materials such as vitamins, flavours and even blood in the laboratory.

## Compounds

Most substances you encounter every day are made up of more than one type of atom. These forms of matter are known as **compounds**. Like elements, every compound has a unique set of characteristics that scientists call its *properties*. However, the properties of compounds are usually very different from the properties of the elements that make them up. Some compounds found around your home are shown in Figure 7.2.1.

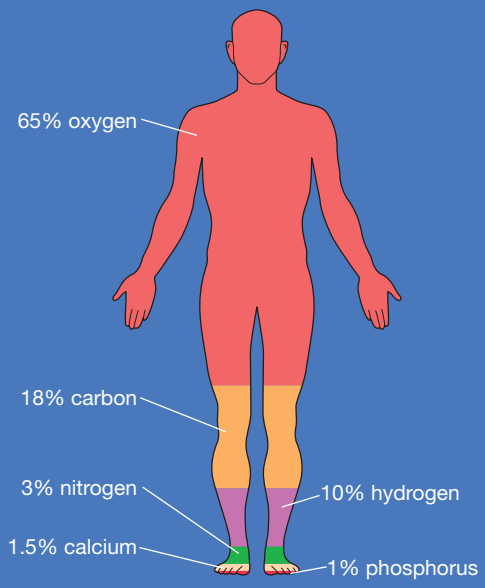
Some compounds are made up of molecules—such as water, wax and vegetable oil. The molecules in these compounds each contain two or more types of atoms. Other compounds form crystal lattices. For example, table salt is made of a lattice of sodium and chlorine atoms while beach sand is a lattice of silicon and oxygen.




**Figure 7.2.1** Common compounds seen around the home. Water is a clear liquid, table salt is a white, crystalline solid, candle wax is a soft solid that melts easily and vegetable oil is a thick, yellow liquid.

## What are you made of?

The human body is made up of just 16 elements. However, 98.5% of the body is made up of just six! These are oxygen (65%), carbon (18%), hydrogen (10%), nitrogen (3%), calcium (1.5%) and phosphorus (1%).




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## Molecular compounds

The molecules in many compounds are small and contain just a few atoms. Carbon monoxide (formula CO), for example, has just one carbon (C) atom and one oxygen (O) atom. The molecules in other compounds, such as some plastics, contain thousands of atoms. However, all the molecules in any compound are all identical in size, shape and number of atoms. Figure 7.2.2 shows molecules of three common compounds—carbon monoxide, water and glucose (a type of sugar). Despite all having very different properties, each molecule is made by combining different numbers of the same elements, oxygen, hydrogen and carbon.

1 p264

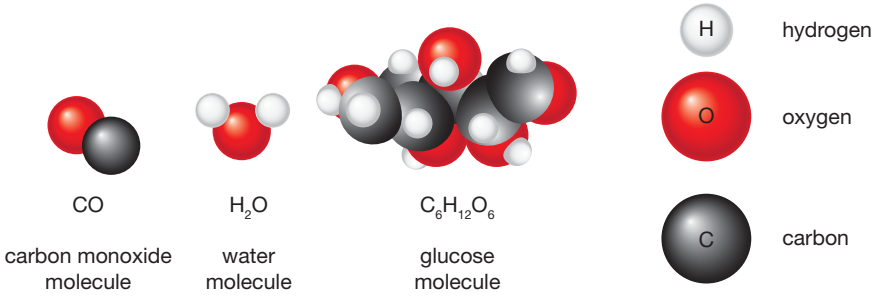



Figure 7.2.2 Molecules of three common compounds. All of these compounds are made of just three elements—oxygen, hydrogen and carbon.

Scientists represent the molecules of compounds in a similar way to the molecules of elements. Water is a molecular compound with the molecular formula $H_2O$. The chemical formula indicates that there are two hydrogen (H) atoms and one oxygen (O) atom in each water molecule. Carbon dioxide has the molecular formula $CO_2$ (representing one carbon and two oxygen atoms) and glucose is $C_6H_{12}O_6$ (six carbon atoms, twelve hydrogens and six oxygen atoms).

### WORKED EXAMPLE

### Constructing molecular formulas

#### Problem

Determine the chemical formula for the sulfuric acid molecule shown in Figure 7.2.3.

#### Solution

1. Identify the atomic symbol of each type of element contained in the molecule: hydrogen, H; sulfur, S; oxygen, O.
2. Identify the number of each type of element: 2 hydrogens; 1 sulfur; 4 oxygens.
3. Write the atomic symbols for each element with the numbers below (as subscripts) to construct the formula: $H_2SO_4$.

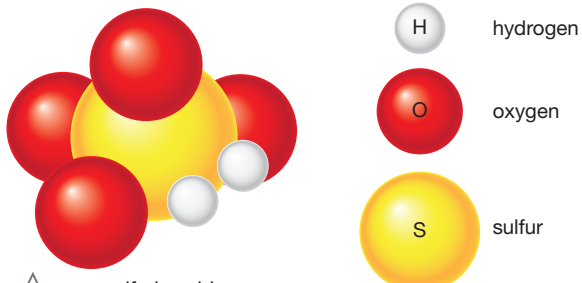



Figure 7.2.3

SciFile

## DNA

The DNA in each of your body cells is an extremely long molecule. The fine threads of DNA shown below would be 2–3 metres long if stretched to their full length.



## Compound lattices

Compounds can also form crystal lattices. In these lattices, the atoms are bonded very strongly to each other so they tend to be very hard solids at room temperature. Two common examples of compound lattices are table salt and beach sand.

The lattice for table salt is shown in Figure 7.2.4. The scientific name for table salt is sodium chloride and its chemical formula is NaCl. From the chemical formula, you can see that table salt is made from sodium (Na) and chlorine (Cl). However, NaCl is not a molecular formula because it does not contain molecules. Instead the formula tells you that in the crystal lattice there is one sodium for every chlorine.

2 p264

Beach sand has the scientific name silica or silicon dioxide. Its chemical formula is $SiO_2$. This formula indicates that in a grain of beach sand, there is one silicon atom for every two oxygen atoms.

3 p265

7.6

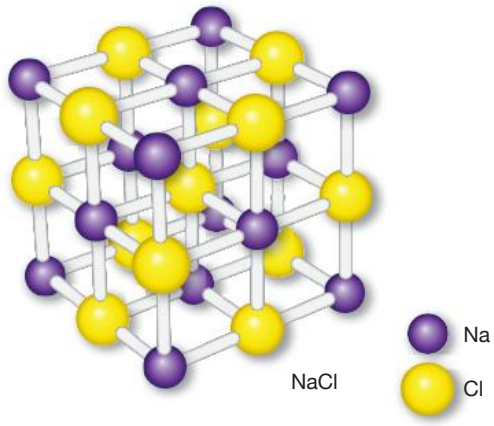



**Figure 7.2.4** In a lattice of sodium chloride, sodium and chlorine atoms form a grid-like structure with one sodium atom for every chlorine atom.

## Mixtures

Many of the substances used every day are not simply elements or compounds but are **mixtures** of elements and compounds. Air, for example, is a mixture of the elements oxygen ($O_2$) and nitrogen ($N_2$) with compounds such as water vapour ($H_2O$), carbon dioxide ($CO_2$) and

INQUIRY science 4 fun

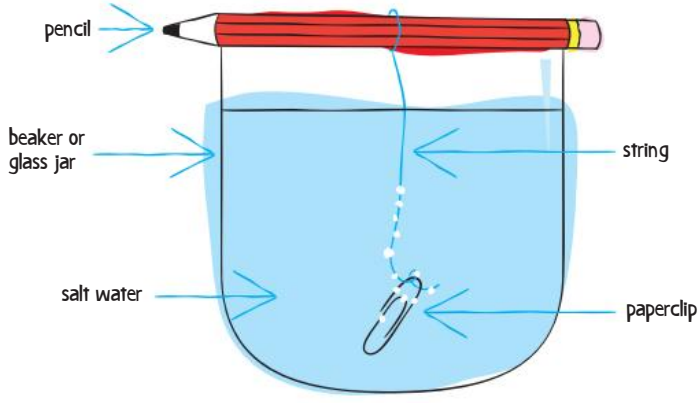
## Stringy crystals

Can you grow crystals on a string?

### Collect this…

Yes

- beaker or glass jar
- water
- string (15–20 cm)
- paperclip
- pencil
- table salt
- teaspoon
- kettle




### Do this…

1. Boil water in the kettle and leave it to stand for a minute.
2. Pour the hot water into the beaker or jar. Take care not to spill the water or touch the sides.
3. Dissolve salt in the water one teaspoon at a time until no more salt will dissolve. Stirring will help to dissolve the salt.
4. Tie one end of the string to the paper clip and one end to the middle of the pencil.
5. Drop the paperclip into the salt water and suspend the string by sitting the pencil across the top of the beaker.
6. Crystals should begin to form within 24 hours and continue to grow for a week.

### Record this…

**Describe** what you saw.

**Explain** why you think this happened.

carbon monoxide (CO). The water from the tap is also not pure $H_2O$ but a mixture including chlorine, fluorine and many other trace elements. Anything that has a list of ingredients, such as shampoo or soft drink, is a mixture. Figure 7.2.5 shows the ingredients of a typical mixture

The main difference between a mixture and elements or compounds is that the molecules in a mixture are not identical. As a result, no chemical formula can be written for a mixture.




**Figure 7.2.5** Any substance made up of two or more ingredients is a mixture.

## Gaseous mixtures

Any two gases can be easily mixed together because the particles of a gas are separated by large distances. The air you are breathing right now is a mixture of nitrogen (78%), oxygen (21%) and carbon dioxide (less than 1%). The air you breathe out is about 78% nitrogen, 17% oxygen and 4% carbon dioxide.

Solids and liquids can also be mixed into gases. When small solid particles are mixed with a gas, it is usually referred to as a smoke or dust. Examples include ash particles floating out from a chimney or fine sand particles in a dust storm.

When small liquid particles are mixed into a gas, it is referred to as a mist or fog. Clouds are a mixture of tiny liquid water droplets suspended in the air.

7.7

## Liquid mixtures

Not all liquids can be mixed together. Liquids that can be mixed, such as water and food colouring, are said to be **miscible**. Liquids that do not mix, such as oil and water, are said to be **immiscible**.

Gases and solids can also be mixed into liquids. When gases are mixed into liquids, they may dissolve to form a solution such as the carbon dioxide gas dissolved in soft drinks. Alternatively, the gases may remain within the liquid as bubbles, such as in shaving cream (Figure 7.2.6) or beaten egg whites. In these cases, the mixture is called a foam.

Solids may also dissolve in liquids to form solutions. If the solid does not dissolve but the particles are very small, then the solid–liquid mixture is called a colloid. Milk and blood are examples of colloids. If the solid particles are bigger, then mixture is known as a suspension, such as when you throw sand into water. The main difference between a colloid and a suspension is that the particles in a suspension will eventually fall to the bottom of the liquid. In contrast, colloids will never separate out of the liquid.



**Figure 7.2.6** Shaving foam is a mixture of gas bubbles in a liquid.

## Alloys

**Alloys** are a mixture of a metal with other metals or non-metals. Alloys are particularly important because they often have very different and useful properties compared to the pure metal. For example, iron is cheap to produce but is soft and rusts easily—making it less useful. Adding small amounts of carbon to iron produces steel, which is strong and useful for building skyscrapers, bridges, machinery and cars. Adding chromium and nickel produces stainless steel, which stops it rusting. Some other common alloys are shown in Figure 7.2.7.




**Figure 7.2.7** Common alloys

# SCIENCE AS A HUMAN ENDEAVOUR

Nature and influence of science

## Supramolecular chemistry

Figure 7.2.8 Are nanobots the future of medicine?

A supramolecule is a large molecule made up of smaller molecules designed to perform a specific task. In other words they are molecular machines.

## Supramolecular chemistry

Nanobots are miniaturised robots and are a common theme in sci-fi movies. Examples are shown in Figures 7.2.8 and 7.2.9. While nanobots currently exist only in fiction, scientists are creating nano-sized (smaller than micro) machines by using supramolecular chemistry. These 'machines' are 1000 times smaller than a grain of pollen.

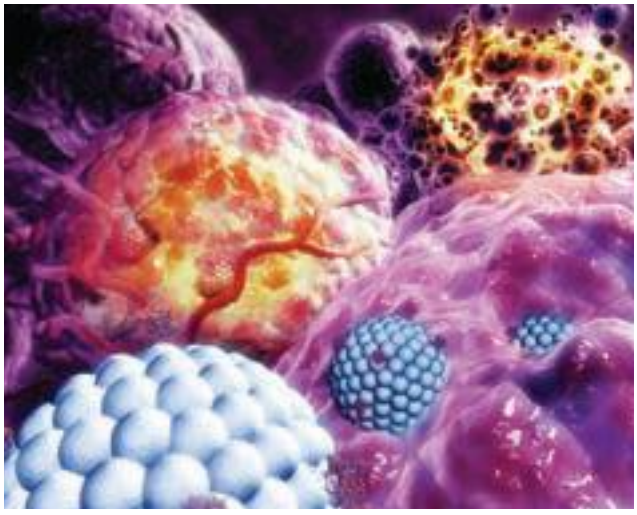


Figure 7.2.9 This artist's impression shows nanobots attacking cancer cells.

## Supramolecules in nature

The most complicated supramolecules are found in nature. Chlorophyll is the chemical found inside the chloroplasts in the cells of plants and is what makes leaves green. Chlorophyll is a supramolecule that plays a key role in photosynthesis, the process by which plants make their own food. Photosynthesis does this by converting sunlight into chemical energy.

Haemoglobin is another supramolecule. It makes your blood red and is responsible for transporting oxygen to your cells and removing carbon dioxide. There are many examples of supramolecules in your body but perhaps the most impressive is DNA (Figure 7.2.10). DNA acts like molecular computer software with the program for creating a person and all their physical characteristics.

7.8



A DNA molecule is made up of two very long molecules twisted together in a spiral called a double helix. Figure 7.2.10

## Imitating nature

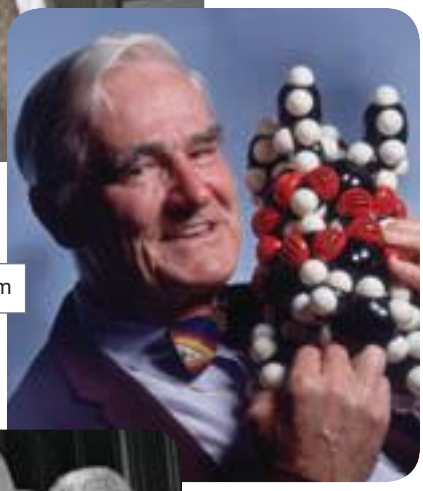
Scientists are still learning how to create the extremely complicated supramolecules found in nature. Americans Donald Cram and Charles Pedersen and Frenchman Jean-Marie Lehn (Figure 7.2.11) are considered the pioneers of supramolecular chemistry. In the 1960s, they studied crown ethers, which are large molecules shaped like doughnuts. In 1987, they were awarded the Nobel Prize in Chemistry.

Since then, there have been many other examples of supramolecules made in the laboratory. For example, genetic engineers use special molecules called enzymes to cut the DNA molecule up into pieces. The enzymes used to do this are known as *molecular scissors*. Other useful supramolecules include:

- molecular claws for catching and trapping atoms like the one shown in Figure 7.2.13
- molecular motors that rotate when an electrical current passes through them
- molecular tweezers for clasping other molecules.



Jean-Marie Lehn



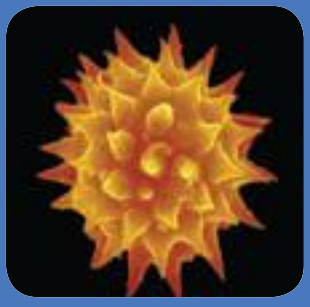
Donald Cram



Charles Pedersen

Donald Cram, Jean-Marie Lehn and Charles Pedersen were jointly awarded the Nobel Prize in Chemistry in 1987 for their work on supramolecules.

Figure 7.2.11



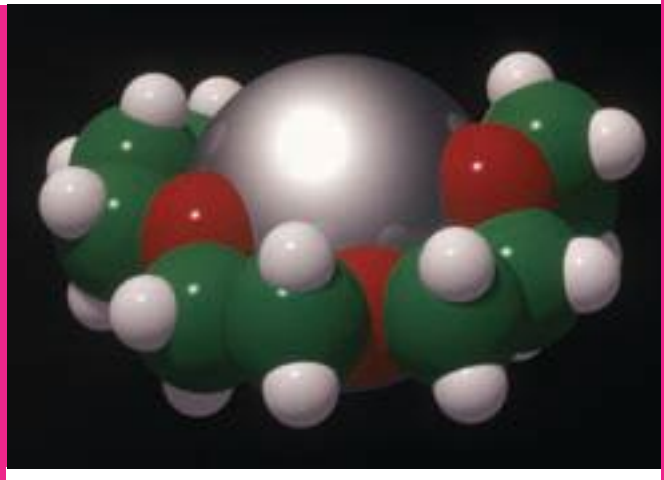
This grain of pollen is approximately 30 000 nm wide.

Figure 7.2.12

### SciFile

### Getting some perspective

People often use the word *nano* to describe anything that is very small. However, scientists use *nano* in a very specific way. A nanometre (nm) is a measure of length that is a billion times smaller than a metre. To put this in perspective, a human hair is about 50 000 nm wide, a grain of pollen (Figure 7.2.12) is around 30 000 nm wide, blood cells are 5000 nm wide and the holes in filter paper are about 100 nm wide.



The first supramolecules could be described as molecular cages or molecular claws. They are like hollow balls that can trap single atoms inside.

Figure 7.2.13

# 7.2 Unit review

## Remembering

1 **State** two examples of molecular compounds and two examples of lattice compounds.

2 a **List** three alloys.

b **State** a use for each of the three alloys.

3 **List** three examples of molecular machines made in the laboratory.

4 **State** the ratio of elements in these compound lattices.

a sodium chloride, NaCl
b magnesium chloride, $MgCl_2$
c aluminium chloride, $AlCl_3$
d sodium oxide, $Na_2O$
e aluminium oxide, $Al_2O_3$

## Understanding

5 a **Explain** what the chemical formula of a molecular compound tells you about the molecules that make up the compound.

b **Recall** an example of a molecular compound.

6 a **Explain** what the chemical formula for a crystal lattice compound tells you about the atoms in the crystal lattice.

b **Recall** an example of a crystal lattice.

7 **Explain** why a chemical formula cannot be written for a mixture.

8 **Explain** why iron is rarely used in its pure form.

9 **Define** the term *supramolecule*.

## Applying

10 **Identify** the number and type of atoms in each of the following molecules.

a carbon monoxide, CO
b carbon dioxide, $CO_2$
c nitrous oxide, $NO_2$
d glucose (sugar), $C_6H_{12}O_6$
e trinitrotolulene (TNT), $C_7H_5N_3O_6$
f acetic acid (vinegar), $CH_3COOH$
(Be careful with this one!)

## Analysing

11 **Contrast** elements and compounds.

12 **Contrast** mixtures and compounds.

13 **Determine** a chemical formula for the molecule in Figure 7.2.14.

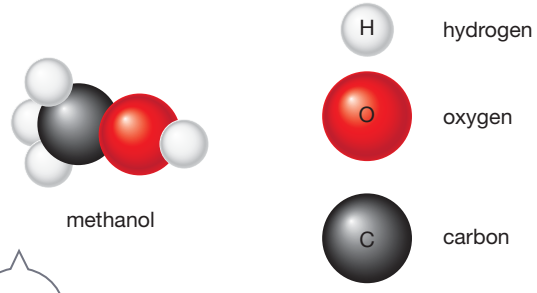



Figure 7.2.14

14 **Classify** the following compounds as either molecular or lattice: water, table salt, carbon monoxide, silicon dioxide, carbon dioxide.

15 **Classify** the following as element, compound or mixture: pool water, helium, air, nitrogen, gold, sugar, salt, cordial, carbon dioxide.

## Creating

16 **Construct** diagrams of beakers containing an element, a compound and a mixture. Use labels to show the differences.

## Inquiring

1 Research the properties of an alloy and compare and contrast the alloy with the elements that make it up.

2 Water has the chemical formula $H_2O$ while bleach has the chemical formula $H_2O_2$.

a Describe what these formulas tell you about the two molecules.

b Research, compare and contrast the properties of these two compounds.

3 a Research how table salt is harvested at the Dampier salt mines in Western Australia.

b Construct a diagram to summarise your findings.

# 7.2 Practical activities

## 1 Forming carbon dioxide, a molecular compound

### Purpose

To form the molecular compound carbon dioxide, $CO_2$.

### Materials

- 0.1 M hydrochloric acid
- sodium carbonate
- test-tube
- spatula
- dropper
- wooden splint
- matches



**SAFETY**

Hydrochloric acid is corrosive.

### Procedure

1. Use the spatula to deposit a small amount of sodium carbonate in the test-tube.
2. Use the dropper to add hydrochloric acid to the sodium carbonate.
3. Light the end of the wooden splint with a match, and then blow out the splint so that the end is glowing red.
4. Place the glowing splint in the test-tube.

### Discussion

1. **State** what evidence there is that a new substance is being formed.
2. **State** whether carbon dioxide is a solid, liquid or gas at room temperature.
3. **State** the colour of carbon dioxide.
4. **Explain** why you think the splint glows in air but not in carbon dioxide.

## 2 Forming alum, a lattice compound

### Purpose

To grow crystals of potassium aluminium sulfate, also known as alum.

### Materials

- 250 mL beaker
- water
- glass rod
- measuring cylinder
- string
- alum
- filter paper
- spatula
- electronic scales
- hotplate or Bunsen burner, bench mat, tripod and gauze mat
- thermometer
- digital camera (optional)



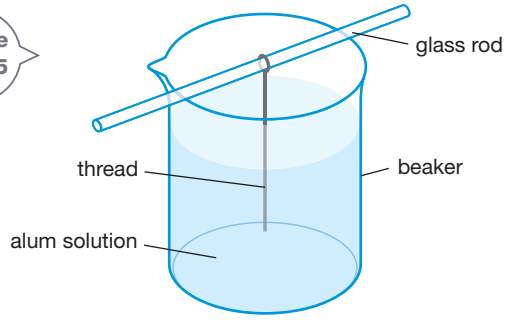
**SAFETY**

Take care when using Bunsen burners and boiling liquids. Tie long hair back when using a Bunsen burner.

### Procedure

1. Use the electronic balance to measure out 10 g of alum onto the filter paper.
2. Pour the alum into the 250 mL beaker.
3. Add approximately 70 mL of water.
4. Heat the mixture to 60°C and stir with the glass rod until all the alum is dissolved. Then carefully remove it from the heat.
5. Wash the glass rod and tie a string around the middle as shown in Figure 7.2.15.

Figure 7.2.15



6 Lie the glass rod across the top of the beaker so that approximately 3 cm of string is immersed in the solution.

7 Place the beaker in a sunny spot and observe each day for 7 days.

### Results

Use diagrams or digital photos to record your observations every day.

### Discussion

1 **List** three physical properties of the alum crystals.

2 **Describe** where the crystals initially began to grow and **explain** why you think they grew there first.

3 **Describe** where the biggest crystals were.

4 **Predict** what might happen if you prepared a new solution of potassium aluminium sulfate and deposited these crystals in it.

## 3 Making models

### Purpose

To construct models of different compounds.

### Materials

- different-coloured sticks of modelling clay

### Procedure

1 Use modelling clay to construct models of the following compounds:
   - **a** carbon monoxide molecule (CO)
   - **b** sulfuric acid ($H_2SO_4$)
   - **c** water molecule ($H_2O$)
   - **d** glucose ($C_6H_{12}O_6$)
   - **e** sodium chloride lattice (NaCl).

### Results

Copy the table below into your workbook.

| Compound name | Chemical formula | Molecule or lattice | Number and type of atoms in each molecule |
|---|---|---|---|
| Carbon monoxide | | | |
| Sulfuric acid | | | |
| Water | | | |
| Glucose | | | |
| Sodium chloride | | | |

### Discussion

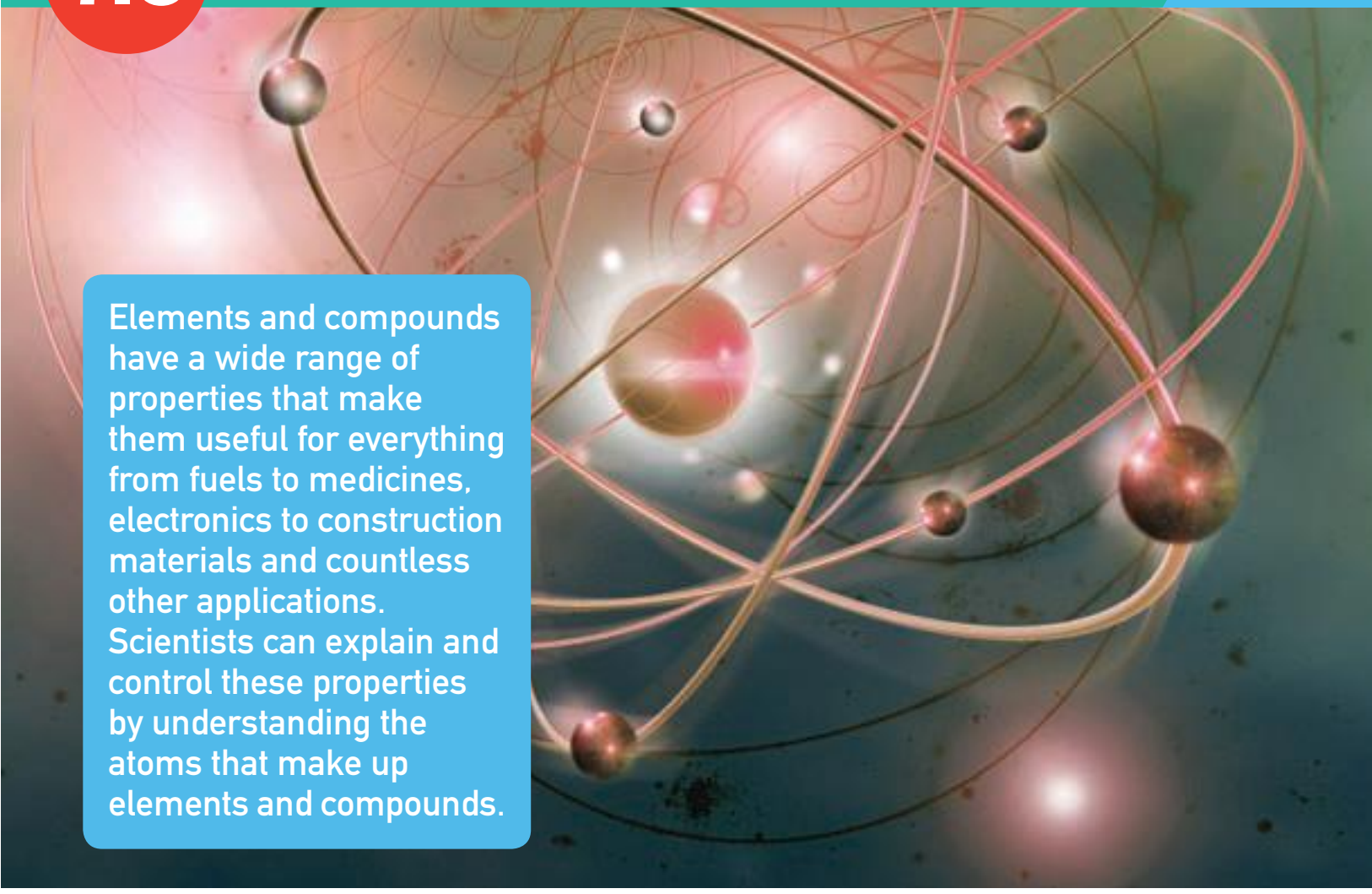
1 **Explain** why you cannot give a number of atoms per molecule for sodium chloride.

2 **Describe** what the chemical formula for a lattice compound tells you about the number and type of atoms in the compound.

3 **Explain** what a molecular formula tells you about the atoms in the molecules of a compound.

4 **Explain** how chemical formulas help scientists to communicate scientifically.

# 7.3 A closer look at atoms



Elements and compounds have a wide range of properties that make them useful for everything from fuels to medicines, electronics to construction materials and countless other applications. Scientists can explain and control these properties by understanding the atoms that make up elements and compounds.

## Atoms in matter

Atoms make up everything around you but are so small that they cannot be seen with even the most powerful optical microscope. Instead, scientists 'see' atoms using a scanning tunnelling microscope or STM. An STM scans a very sharp tip across the surface of crystals. This is similar to the way that a visually impaired person scans their finger across the bumps in a page to read Braille, as shown in Figure 7.3.1. The STM tip senses the atoms as bumps on the surface line by line. It then constructs an image of the atoms like the one shown in Figure 7.3.2.

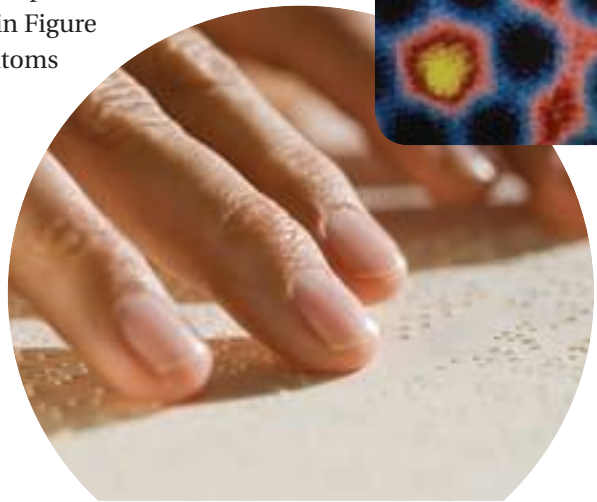


Figure 7.3.1 An STM 'reads' the surface of a crystal like fingers 'read' Braille.

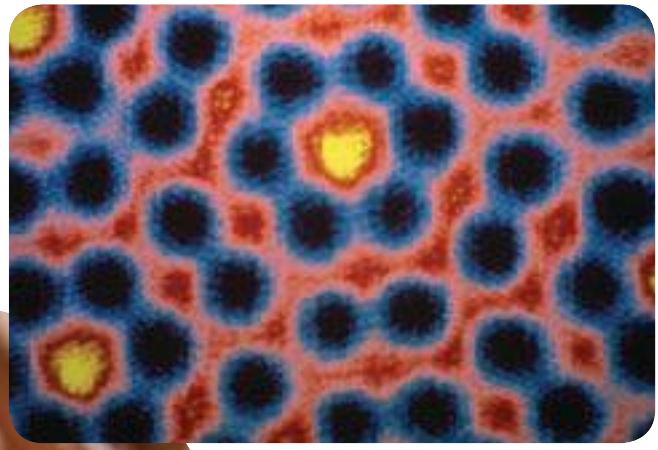
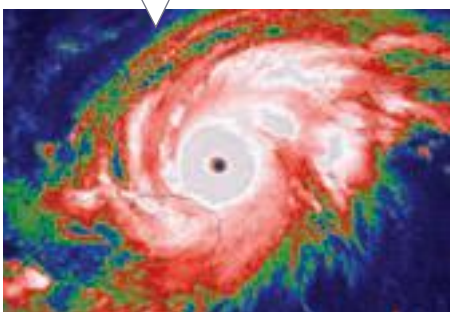


Figure 7.3.2 STM image of a silicon surface made up of silicon atoms arranged in a crystal lattice.

Computer models are used to predict the weather.



Scale models can be used to study how the shape of a plane affects how it will move through air.



Detailed plans are used to understand how a house will look before it is built.



1 p271

**Figure 7.3.3** Models are used in all areas of everyday life.

## The atomic theory of matter

Scientists proposed that matter was composed of atoms long before STMs were invented. The word *atom* comes from *atomos*, a word used by the ancient Greek philosopher Democritus to describe the smallest particles of matter that could not be divided. Since then, scientists have developed a full understanding of atoms through indirect experimental evidence rather than direct observation. From this evidence, they have constructed a scientific **model** that explains what is in an atom and what its structure looks like. This understanding is known as the atomic theory of matter.

A scientific model is a simplified idea that can be used to help make predictions or test assumptions. Some are shown in Figure 7.3.3. For example, a model aeroplane does not have all the complicated moving parts of a real plane but could be used to predict how well the plane will move through the air or explain how a plane flies.

In 1803, British scientist John Dalton (his portrait is shown in Figure 7.3.4) developed a model of matter that used atoms as its building blocks. His model forms the basis of the modern atomic theory of matter. Dalton predicted that:

- all matter is composed of indivisible particles called atoms
- some forms of matter, known as elements, are made up of only one type of atom
- some forms of matter, known as compounds, are made up of more than one type of atom
- atoms cannot be created or destroyed but can be rearranged to form different substances.

Since Dalton developed his atomic theory of matter, there have been many experiments that have confirmed his predictions and provided much more information about the different types of atoms.



**Figure 7.3.4** John Dalton is considered to be the first person to propose the fundamental ideas behind the modern atomic theory of matter.

INQUIRY science 4 fun

## Magic finger

Yes

Can you observe detergent molecules by indirect observation?

### Collect this…

- dinner plate
- washing detergent
- ground pepper
- water

### Do this…

1. Fill the dinner plate with water.
2. Cover the surface of the water evenly with ground pepper.
3. Place a small amount of detergent on the end of your finger and dip your finger in the plate of water.

### Record this…

**Describe** what happened to the pepper.

**Explain** what you think is happening to the detergent particles on your finger.

# Types of atoms

Although there are countless types of matter, there are only 117 known types of atoms. Each atom has a unique set of characteristics that scientists know as its properties. These properties can be:

- physical properties such as its size and mass
- chemical properties, which determine how the atom interacts with other atoms.

# Inside atoms

All atoms are different. When you put many gold atoms together, you get a nugget of gold that is heavy, metallic and solid. However, if you put many oxygen atoms together, you get oxygen—a light and invisible non-metallic gas. To understand why, you need to look inside the atoms.

Atoms are not simply solid balls but have a very complicated internal structure. It is this internal structure that gives each element its properties.

Atoms are made up of even smaller particles known as **subatomic particles**. These subatomic particles are called **protons**, **neutrons** and **electrons**. Figure 7.3.6 shows how these particles make up an atom. The protons and neutrons sit at the centre of the atom in a cluster called the **nucleus**. The electrons, which are 1800 times lighter than the protons and neutrons, form a cloud around the nucleus.

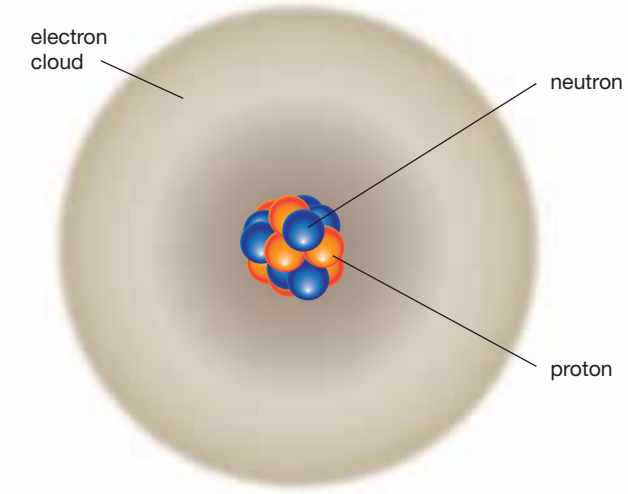



Figure 7.3.6

Atoms are made up of a positive nucleus that contains protons and neutrons. The nucleus is surrounded by a cloud of negatively charged electrons.

SciFile

## Now that's strong!

The positive charge on protons means that they would normally repel each other and fly apart. However, protons and neutrons are held together by the strongest force in the Universe, known appropriately as the *strong force*. The strong force is 100 000 000 000 000 000 000 000 000 000 000 000 000 times stronger than gravity. However, the strong force does not reach very far. So the protons or neutrons must be very close before the strong force can stick them together.

The electrons are bound tightly to the nucleus because electrons have a negative charge, –1, and protons have a positive charge, +1. These opposite charges attract each other like the opposite poles of a magnet. However, the total charge of an atom is zero because there are equal numbers of electrons and protons. Neutrons are charge neutral, which means they have no charge. These properties are summarised in Table 7.3.1.

SciFile

## Atom smashing

Scientists learn about what's inside atoms by literally smashing them together to see what comes out. This requires huge machines called particle colliders that accelerate the atoms to extremely high speeds before smashing them together. The world's largest particle collider is called the Large Hadron Collider (shown in Figure 7.3.5). It consists of a circular tunnel 27 km long passing under the border between Switzerland and France. The particles travel so fast that they go around the tunnel more than 11 000 times per second at speeds close to the speed of light!



Figure 7.3.5

The Large Hadron Collider. The scientist riding a bike alongside it gives an idea of its size.

## Atomic number and mass number

The number of protons in the nucleus determines what type of atom it is and what element it belongs to. For example, all gold atoms contain 79 protons while all oxygen atoms contain eight protons. The number of protons in an atom is called the **atomic number**. In the periodic table, the atoms are ordered by atomic number.

Table 7.3.1 Properties of subatomic particles

| Subatomic particle | Location | Mass compared to an electron | Charge |
|---|---|---|---|
| Proton | In the nucleus | ×1800 | +1 |
| Neutron | In the nucleus | ×1800 | 0 |
| Electron | In the electron cloud surrounding the nucleus | ×1 | –1 |

The number of protons and neutrons in an atom is called the **mass number**. These numbers are often written alongside the chemical symbol. For example, an atom of sodium, Na, can be shown as:

Mass number → 23
Atomic number → 11
Na

From this one symbol, you can calculate the number of protons, neutrons and electrons in the sodium atom:

- The number of protons is the atomic number, 11. So there are 11 protons in the nucleus.
- The number of neutrons is the mass number minus the atomic number, 23 – 11 = 12. So there are 12 neutrons in the nucleus.
- The number of electrons is equal to the number of protons so there are 11 electrons spinning in a cloud around the nucleus.

7.9

**WORKED EXAMPLE**

### Calculating numbers of subatomic particles

#### Problem

An iron atom has the atomic symbol $^{56}_{26}\text{Fe}$.

Identify the mass number and atomic number, and then calculate the number of protons, neutrons and electrons.

#### Solution

Mass number = 56

Atomic number = 26

Number of protons = atomic number = 26

Number of neutrons = mass number – atomic number
= 56 – 26 = 30

Number of electrons = atomic number = 26

## Electron shells

Even the electron cloud that surrounds the nucleus has structure. The electron cloud can be broken down into **electron shells** that surround the nucleus like the layers of an onion, as shown in Figure 7.3.7. Each shell can only hold a certain number of electrons. The innermost shell is small and can only hold two electrons, the second shell holds eight electrons, the third shell holds up to 18 electrons while the fourth electron shell can hold a maximum of 32 electrons. The nucleus is tiny in comparison, being around 100 to 1000 times smaller than the electron shells. This means that the electron shells take up most of the space in an atom.

2 p271

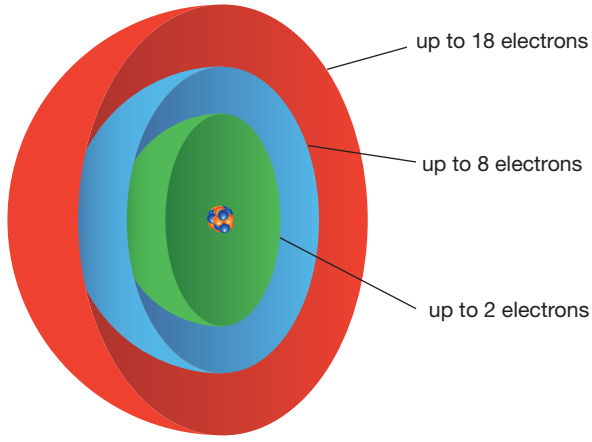



Figure 7.3.7 The electron clouds form shells around the nucleus. The innermost shell is small and can only hold two electrons, the second shell can hold up to eight and the third shell can hold up to 18 electrons.

**SciFile**

### Empty atoms

If the nucleus of an atom was the size of a golf ball, then the electron cloud would be the size of football stadium and the electrons would be the size of a single grain of sand. This means most of an atom is empty space!

# 7.3 Unit review

## Remembering

1 **State** the names and charges of the three subatomic particles in an atom.

2 **List** Dalton's four predictions that make up the basis of the modern atomic theory of matter.

3 **Specify** the feature of an atom that determines which type of atom it is.

4 **Recall** how many electrons can be contained in the first, second and third electron shells.

## Understanding

5 **Define** these terms:
- a atomic number
- b mass number.

6 **Describe** the structure of an atom in terms of protons, neutrons and electrons.

7 **Explain** what a scientific model is and how scientists use them.

8 **Explain** why the electrons in an atom don't fly off.

9 **Outline** how the number of neutrons can be calculated from the atomic and mass numbers.

## Applying

10 i **State** the name of the following atoms.
ii **Calculate** the number of protons, neutrons and electrons in each.

a $^{4}_{2}\mathrm{He}$ b $^{14}_{7}\mathrm{N}$

c $^{39}_{19}\mathrm{K}$ d $^{63}_{29}\mathrm{Cu}$

11 **Determine** the atomic symbol that completely describes the following atoms.
- a An oxygen atom with 8 protons, 8 neutrons and 8 electrons
- b A calcium atom with 20 protons, 20 neutrons and 20 electrons
- c A gold atom with 79 protons, 114 neutrons and 79 electrons
- d A uranium atom with 92 protons, 146 neutrons and 92 electrons

## Analysing

12 **Compare** the five lightest atoms by copying and completing Table 7.3.2 below.

## Evaluating

13 Early alchemists tried to change lead into gold.
- a **Assess** what would need to happen to change a lead atom into a gold atom.
- b **Propose** why the alchemists weren't successful.

14 a **Assess** whether you think it would be easier to remove an electron from the first electron shell or the second electron shell.
- b **Justify** your answer.

## Creating

15 **Construct** a diagram of the carbon atom $^{12}_{6}\mathrm{C}$ showing the correct number of protons and neutrons in the nucleus and the correct number of electrons in each of its shells.

## Inquiring

Investigate the life of a scientist who has had an important impact on the development of the atomic model. Outline their life and other scientific achievements. Some names to start with are: Dalton, Bohr, Rutherford, Thomson and Democritus.

Table 7.3.2

| Atom | Atomic number | Mass number | Number of protons | Number of neutrons | Number of electrons | Atomic symbol |
|---|---|---|---|---|---|---|
| Hydrogen | 1 | | | 0 | 1 | $^{1}_{1}\mathrm{H}$ |
| Helium | | 4 | | 2 | | |
| Lithium | 3 | | | 4 | | |
| Beryllium | 4 | 9 | | | | |
| Boron | | | | | | $^{11}_{5}\mathrm{B}$ |

# 7.3 Practical activities

## 1 Indirect observation

### Purpose
To determine the nature of objects through indirect observation.

### Materials
- objects of various shapes and sizes such as ball bearings, pebbles, paperclips, erasers etc.
- opaque drawstring bag or similar

### Procedure
1. Work in pairs. One person should fill the drawstring bag with 1–5 objects and give it to their partner.
2. The second person should use indirect observation to write down as much detail as possible about the marbles in the bag.
3. Open the bag to see how accurate the description was and what could not be observed.
4. Once this is complete, reverse roles and repeat.
5. Record your observations in the table like the one in the Results section.

### Results
Copy and complete the following table.

| Trial number | Properties observed by indirect observations | Properties observed by direct observation |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

### Discussion
1. **List** the properties of the objects that could be determined by indirect observation.
2. **List** the properties of the objects that could not be determined by indirect observation.
3. **Explain** how this problem is similar to when scientists try to determine the structure of an atom.

## 2 Coloured flames

### Purpose
To observe the coloured light produced when electrons hop between shells.

### Materials
- wooden icy-pole sticks soaked in distilled water and solutions of barium chloride, copper chloride, potassium chloride, sodium chloride and strontium chloride
- Bunsen burner, bench mat and matches
- tongs



**SAFETY**
Wooden icy-pole sticks should be dried, not burnt, in the flame. Remove the icy-pole stick from the flame at the first signs of charring.

### Procedure
1. Use the tongs to hold each soaked icy-pole stick in a blue Bunsen burner flame as shown in Figure 7.3.8.
2. Record your observations in the table like the one in the Results section.

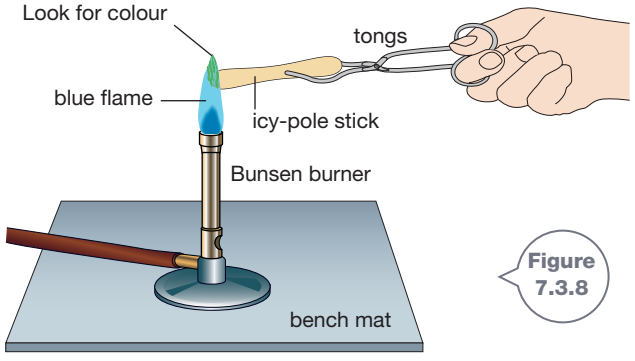



Figure 7.3.8

Coloured flames continued on next page

Coloured flames continued

## Results

Copy and complete the following table.

| Solution | Chemical formula | Elements present | Ratio | Observations |
|---|---|---|---|---|
| Distilled water | $H_2O$ | | | |
| Barium chloride | $BaCl_2$ | | | |
| Copper chloride | $CuCl_2$ | | | |
| Potassium chloride | KCl | | | |
| Sodium chloride | NaCl | | | |
| Strontium chloride | $SrCl_2$ | | | |

## Discussion

1 a **Identify** what elements are present in each compound and add them to your table.

b **Identify** if the ratio of the elements in each compound is 1:1 or 1:2. Add your answer to the table.

2 Coloured light is produced whenever electrons hop between electron shells.

a **State** whether you think the structure of the electron shells is the same or different for each element.

b **Justify** your answer.

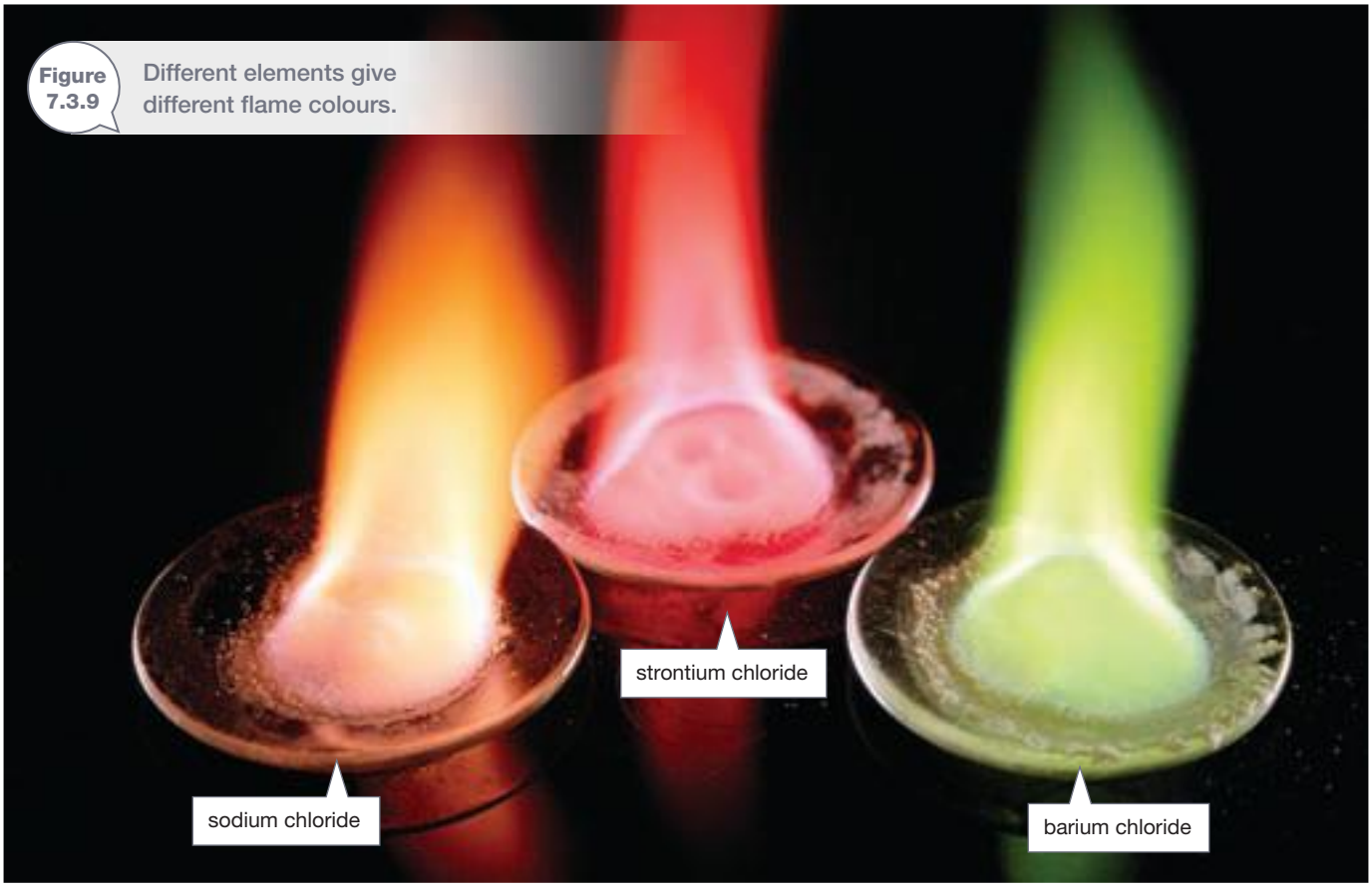



Figure 7.3.9 Different elements give different flame colours.

# 7 Chapter review

## Remembering

1 **Name** the tiny particles that make up all matter.

2 **State** the two broad categories that elements can be divided into.

3 **List** the names of two elements and three compounds found in air.

4 **List** the names of the three subatomic particles that make up atoms.

5 **State** the number of electrons that can be held in the first, second, and third electron shells of an atom.

## Understanding

6 **Explain** why it is impossible to have a monatomic compound.

7 **Describe** the structure of an atom in terms of the three subatomic particles.

8 **Explain** what an alloy is and why they are useful.

9 **Explain** why electrons stay around the nucleus of an atom.

## Applying

10 **Identify** the name and number of each type of atom in the following molecules.

- a Ozone, $O_3$
- b Hydrofluoric acid, HF
- c Water, $H_2O$
- d Natural gas, $CH_4$
- e Petrol, $C_8H_{18}$
- f Deadly nightshade poison, $C_{45}H_{73}NO_{15}$

11 **Identify** the name of each of the following atoms and calculate the number of protons, neutrons and electrons each.

- a $^{12}_{6}C$
- b $^{16}_{8}O$
- c $^{35}_{17}Cl$
- d $^{65}_{30}Zn$

## Analysing

12 **Compare** elements, compounds and mixtures by listing their similarities and differences.

13 **Classify** the following as elements, compounds or mixtures: lemonade, carbon (C), zinc (Zn), bronze, air, tap water, pure water ($H_2O$), carbon dioxide ($CO_2$), chlorine gas ($Cl_2$), sodium chloride (NaCl), shampoo, iron (Fe).

14 **Classify** the following as monatomic, molecular or crystal lattice: gold, helium, pure water, sodium chloride, carbon dioxide, copper, neon, nitrogen.

## Evaluating

15 **Propose** a reason why neutrons might be needed to stabilise the protons in the nucleus.

## Creating

16 **Construct** a three-part diagram showing how:

- two hydrogen atoms and one oxygen atom form a molecule of water
- molecules of water form a glass of water.

17 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

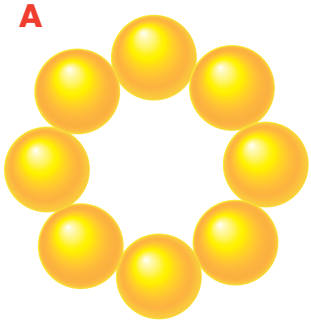
matter
atom
molecule
crystal lattice
element
compound
mixture
electron
proton
neutron



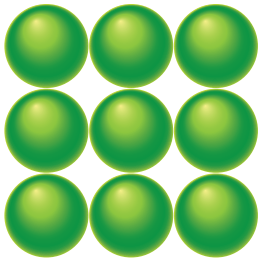
# Thinking scientifically

**Q1** Elements are substances made up of only one type of atom. Which one of the following does *not* represent an element?

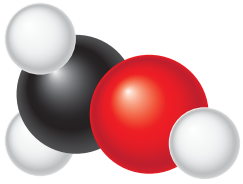
**A**



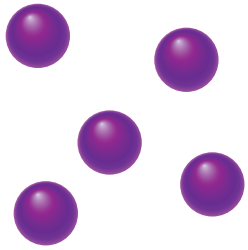
**B**



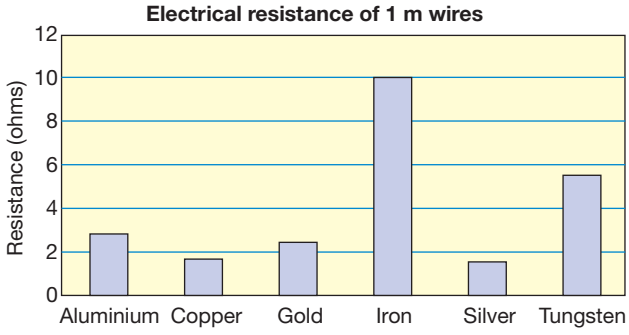
**C**



**D**



**Q2** Alberto measures the electrical resistance of 1-metre wires made from different metals and plots the resistances in the graph below.




The three wires with the highest resistance in order from highest to lowest resistance are:

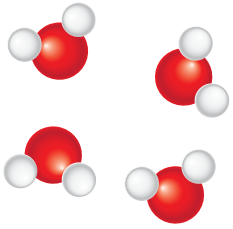
**A** silver, copper, gold
**B** iron, tungsten, aluminium
**C** iron, tungsten, gold
**D** aluminium, tungsten, iron.

**Q3** Compounds are substances that are made up of more than one type of atom. Which one of the following diagrams does *not* represent a compound?

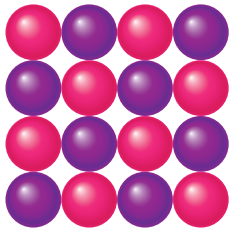
**A**



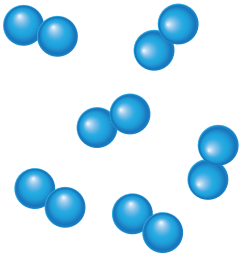
**B**



**C**

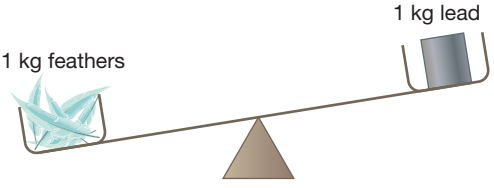


**D**

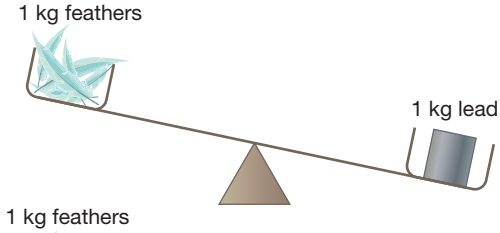


**Q4** 1 kilogram of feathers and 1 kilogram of lead were placed on a balance. Which of the following diagrams shows what would happen?

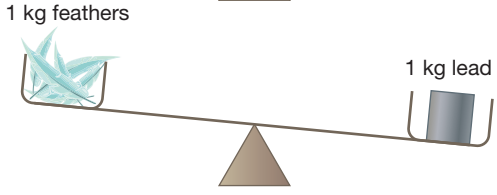
**A**



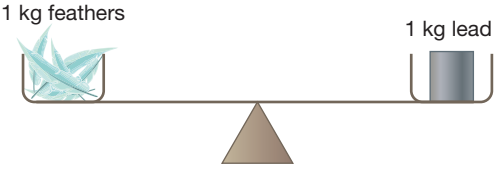

**B**




**C**




**D**



# Glossary

## Unit 7.1

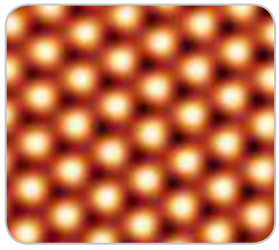
**Allotropes:** different forms of the same element

**Atoms:** the smallest building blocks of matter

**Brittle:** easily crumbled or shattered

**Ductile:** able to be stretched to form a wire

**Elements:** substances made up of only one type of atom

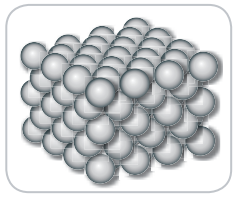


Atoms

**Lattices:** grid-like structures of atoms

**Malleable:** able to be hammered or bent into new shapes

**Metals:** substances that have a metallic shine, conduct heat and electricity, and can be hammered into sheets and drawn into wires



Metal

**Molecules:** clusters of atoms

**Monatomic:** elements that consist of single atoms

**Non-metals:** substances that are usually dull (not shiny), do not conduct heat and electricity and break or crumble



Non-metal

**Periodic table:** a table that shows all the known elements

**Properties:** the characteristics of a substance

**Scanning tunnelling microscope (STM):** a microscope that can see atoms by scanning a tip across the surface of crystals and sensing the atoms as bumps on the surface

## Unit 7.2

**Alloys:** mixtures of a metal with other metals or non-metals



Alloy

**Compounds:** substances made of lattices or identical molecules with two or more types of atoms

**Immiscible:** liquids that do not mix

**Miscible:** liquids that can be mixed

**Mixtures:** any combination of two or more elements and compounds



Mixture

## Unit 7.3

**Atomic number:** the number of protons in an atom

**Electrons:** the negatively charged subatomic particles that form a cloud around the nucleus of an atom

**Electron shells:** areas around the atom in which electrons spin

**Mass number:** the number of protons and neutrons in an atom

**Matter:** anything that has mass and takes up space

**Model:** a simplified representation



Model

**Neutrons:** the neutral subatomic particles that sit in the nucleus of an atom with the protons

**Nucleus:** the cluster of protons and neutrons at the centre of an atom



Nucleus

**Protons:** the positive subatomic particles that sit in the nucleus of an atom with the neutrons

**Subatomic particles:** the particles that make up atoms—protons, neutrons and electrons

# SCIENCE TAKES YOU PLACES

## Look who is using science

### FOOD TECHNOLOGIST



**My name is Robert Reeves. I'm a food technologist and I work in food science. Like many food technologists, I started my career as a chef. I moved into food science when I joined a food manufacturing company.**

Food technologists ensure safe and tasty foods are available in supermarkets. Part of my job is product development. Here I combine my skills and tastebuds from my career as a chef with food science to create new foods. Studying food science allows you to understand what happens to foods when you blend them together and cook them in different ways.

Food technologists also look at ways of preserving food using methods such as freezing, canning and drying. I ensure that food is safe to eat not just on the day it is prepared, but for several days, weeks, months or, in the case of some canned food, years.

### GEOLOGIST



**My name is Courtney Brennan and I am a geologist. Geologists study rocks to understand how they form. I work for an energy company.**

A day's work could see me using high-tech software on a computer to imagine what ancient landscapes looked like millions of years ago, or studying rock fragments under a microscope. All this work is used to predict where oil and gas may be found underground. I also plan how to best get these materials out of the ground while taking care of the environment at the same time. It's very exciting and often quite challenging work.

I studied geology and physics at university. So far my job has taken me across Australia and to Asia, Africa and the Americas, giving me a first-hand look at geology in the field. Geology has been really great for me because I learn something new every day and can be creative at the same time. If you like nature and understanding how things work, you might enjoy being a geologist too!

### CHEMICAL ENGINEER



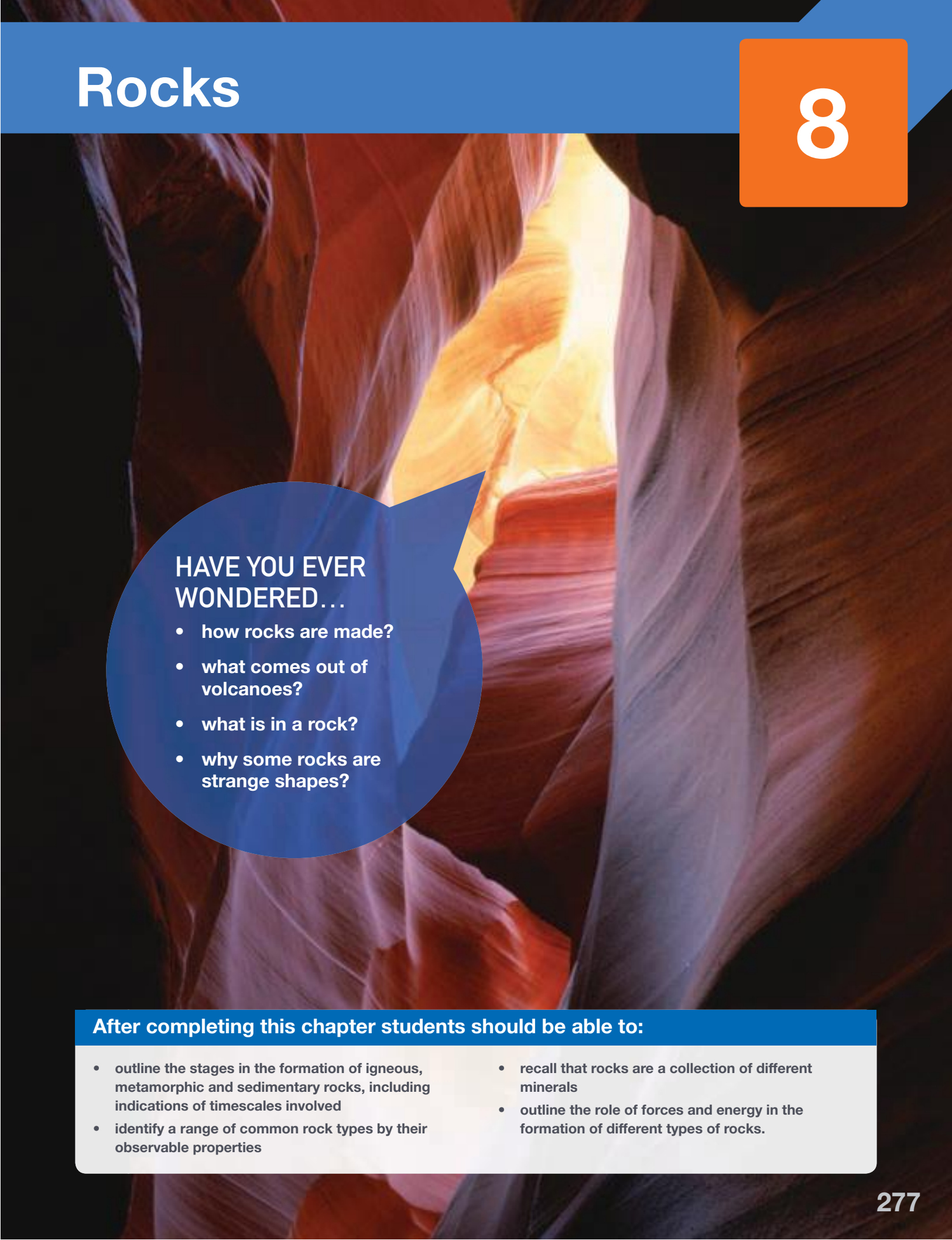
**My name is Francisco Trujillo and I'm a chemical engineer.**

Chemical engineering studies changes at a large (industrial) scale. Chemical engineering combines the sciences of physics, chemistry and biology with mathematics to change raw materials into other useful substances. Most of the objects that you see around you have been produced by chemical engineering processes. For example, paper and cardboard are produced from wood. The gasoline that runs your car is processed and transformed from petroleum.

Chemical engineering also deals with foods that are produced at an industrial scale, such as chocolate bars and potato chips. Chemical engineers are involved in improving the environment by designing processes to purify wastewater and transform waste material into a useful form again. Chemical engineering is a very exciting profession, one where you can apply science and creativity to transform the world around you.

# Rocks

8



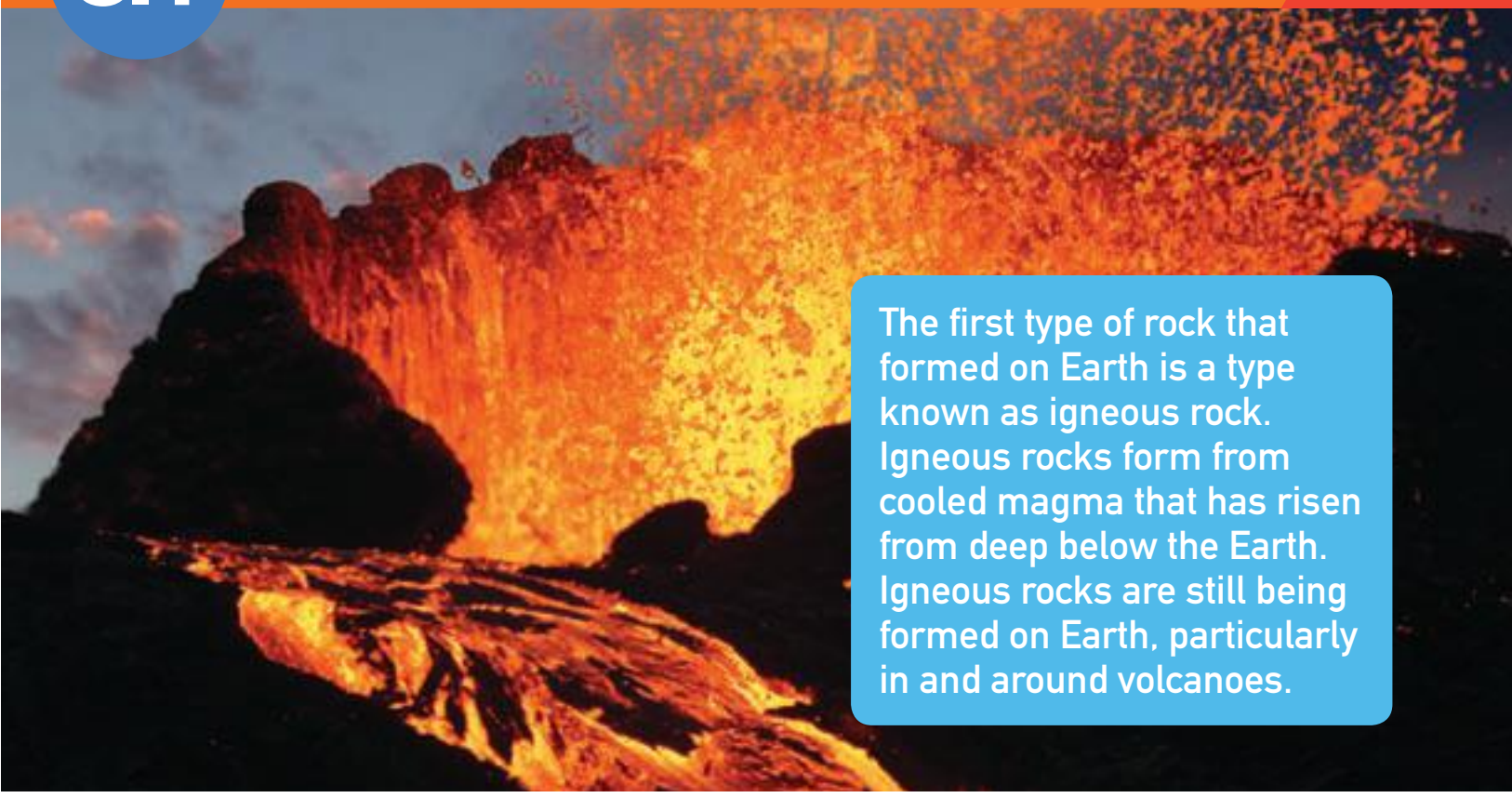
HAVE YOU EVER WONDERED…

- how rocks are made?
- what comes out of volcanoes?
- what is in a rock?
- why some rocks are strange shapes?

**After completing this chapter students should be able to:**

- outline the stages in the formation of igneous, metamorphic and sedimentary rocks, including indications of timescales involved
- identify a range of common rock types by their observable properties
- recall that rocks are a collection of different minerals
- outline the role of forces and energy in the formation of different types of rocks.

# 8.1 Igneous rocks



The first type of rock that formed on Earth is a type known as igneous rock. Igneous rocks form from cooled magma that has risen from deep below the Earth. Igneous rocks are still being formed on Earth, particularly in and around volcanoes.

## Structure of the Earth

**Geology** is the study of rocks. Although geologists cannot actually see what is inside the Earth, their research shows that it consists of layers. This structure is shown in Figure 8.1.1.

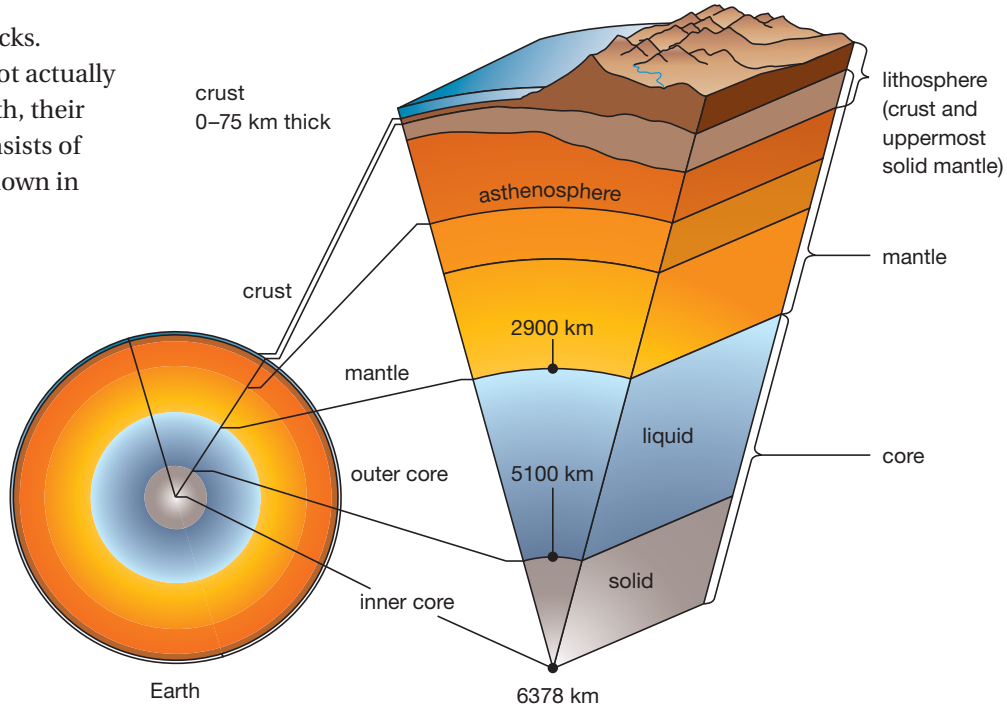



**Figure 8.1.1** Every earthquake and earth tremor and every volcano provides geologists with a little more information about the structure of the Earth. They have concluded that the Earth is composed of layers.

# The first rocks

The first rocks of the crust and upper **mantle** formed long ago when material called magma cooled and solidified. **Magma** is very hot molten (melted) rock.

Scientists think that magma forms within the lower mantle. Dissolved gases make magma less dense than the surrounding rock and pushes it upwards through any fault or crack in the crust above. On the way, magma melts more rock from the upper mantle and crust. If the magma reaches the surface, it is known as **lava**. Lava has a temperature of about 1200°C when it erupts at the surface of the earth. These eruptions form volcanoes, one type of which is shown in Figure 8.1.2. Below the surface, the magma is even hotter.

# Igneous rocks

Magma rising into the crust begins to cool because it loses heat to the cooler rocks around it. If magma reaches the surface to become lava, then it cools very rapidly, especially if the eruption happens under the ocean. Magma that does not reach the surface cools much more slowly. Rock is formed when the magma or lava cools so much that it solidifies. Some rocks form at the surface or under the ocean, and some form below ground.

Rocks formed from cooling magma are known as **igneous rocks**. Igneous rocks were the first types of rocks to form and were the start of the Earth's crust. Rocks formed by magma reaching the surface are classified as **extrusive igneous rocks** as shown in Figure 8.1.3. Those rocks formed from magma cooling below the ground surface are classified as **intrusive igneous rocks**.



**Figure 8.1.3** Lava cools to form extrusive igneous rocks.

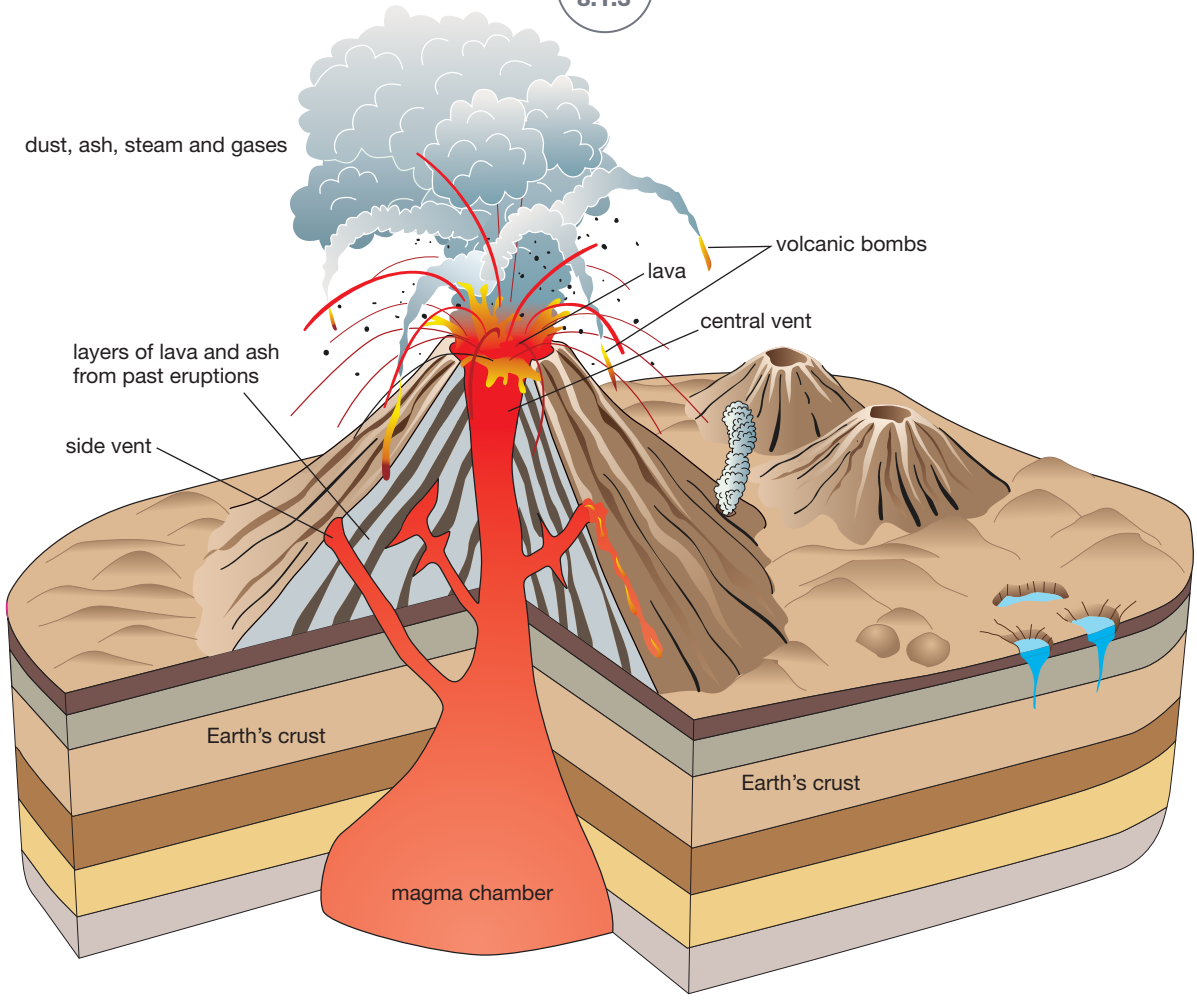



**Figure 8.1.2** Structure of a volcano

## Crystals

When magma is solidifying, particles in the liquid may clump together to form structures called crystals. **Crystals** are solids that have a variety of special shapes. You can see some in Figure 8.1.4.

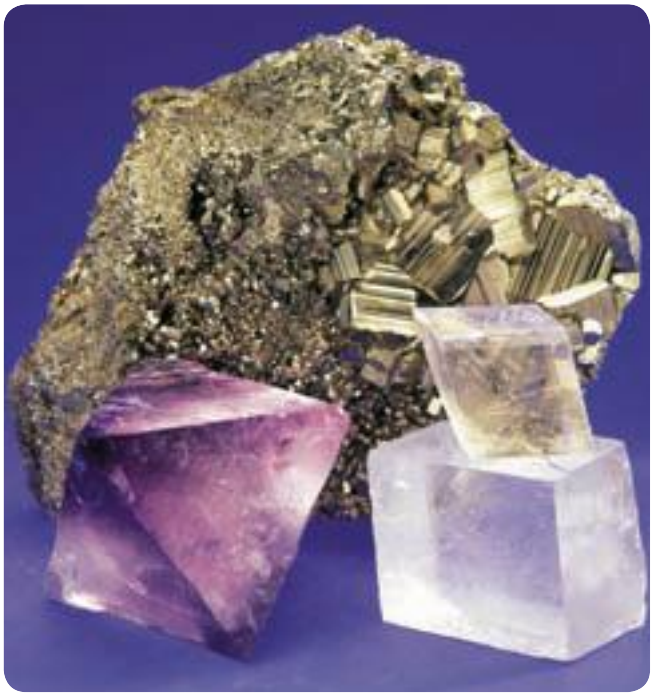


Figure 8.1.4 Crystals form in igneous rock. The slower the cooling on formation, the larger the crystals formed.

When magma cools quickly, it forms rock with very small crystals or no crystals at all. This is because rapid cooling does not give crystals enough time to grow.

Slow-cooling magma produces larger crystals because the crystals keep growing for longer. While the magma remains liquid, the particles can move around and keep adding to a nearby growing crystal. Rock formed by slow cooling usually has crystals large enough to see without using a magnifying glass.

## Minerals

Rocks are made up of chemical substances called **minerals**. Minerals are particular combinations and arrangements of atoms that can be identified by their physical properties. Two physical properties of minerals are the size and shape of the crystals that form them.

# Characteristics of igneous rocks

Not all rocks are igneous. The other rock types are sedimentary and metamorphic. The following general characteristics will help you identify which rocks are igneous. Igneous rocks are:

- hard, because the minerals they contain are hard
- strong, because the mineral crystals that make them up are strong
- made of interlocking crystals that have grown into each other and lock together.

INQUIRY science 4 fun

## Comparing crystals

No

Are all crystals the same?

### Collect this…

- super-saturated solutions of magnesium sulfate, sodium chloride, aluminium potassium sulfate and copper sulfate
- 4 test-tubes in a test-tube rack
- 4 eye-droppers or Pasteur pipettes
- petri dish
- stereomicroscope or monocular microscope (40×)
- 4 glass slides
- methylated spirits from your teacher
- access to marking pen

### Do this…

1. Label each test-tube and glass slide with the name of one of the solutions using the marking pen.
2. Put a drop of each solution on its labelled slide and observe it under the microscope. Look first at the edge of the drop of solution.
3. If the crystals are slow to form, ask your teacher to add a drop of methylated spirits. Try it both with and without methylated spirits.

### Record this…

**Describe** what happened.

**Explain** why you think this happened.

1 p287

**Interlocking crystals** are crystals that have grown into each other. Sometimes this is very difficult to see unless you use a microscope. You can see what interlocking crystals look like in Figure 8.1.5.

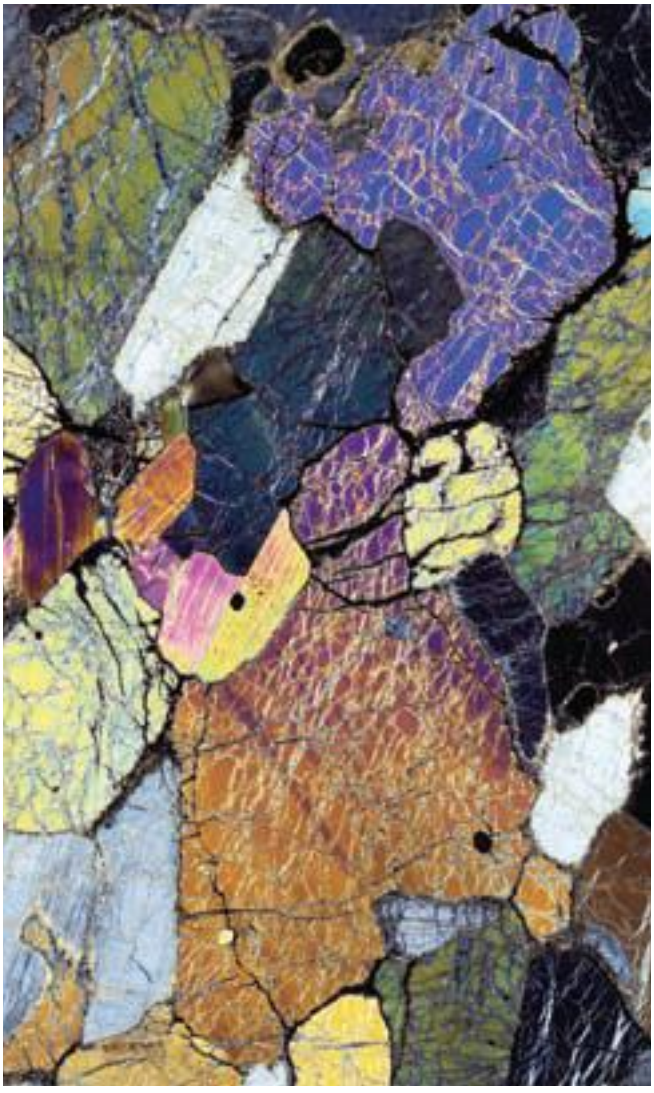


Figure 8.1.5

A jigsaw-like pattern of interlocking crystals indicates that the rock is an igneous rock. These are interlocking crystals of the igneous rock peridotite.

## A sea of lava

SciFile

The Deccan Traps in India is an area about half the size of India, consisting of layers of basalt more than 2 km thick. It was formed by massive volcanic eruptions about 66 million years ago that lasted about 30 000 years.

# Classifying igneous rocks

Many igneous rocks were formed millions of years ago. Since they formed, many underground intrusive rocks have been exposed at the surface, and many above-ground extrusive rocks have been buried. Therefore the current position of an igneous rock is not enough to classify it as intrusive or extrusive. To do this, geologists need to look at the texture and colour of the rock.

Texture describes whether the rock is smooth or has obvious grains, lumps, air bubbles or interlocking crystals in it.

Colour is linked to the minerals the rock contains. Dark-coloured rocks usually have a high content of heavy minerals such as olivine, a green mineral. Olivine contains heavier elements such as iron. Light-coloured rocks contain high levels of silica-like minerals. These have lighter elements, such as silicon, oxygen and aluminium. Typical minerals are quartz and the feldspars. Figure 8.1.6 shows examples of igneous rocks.




Figure 8.1.6

Colour is a characteristic that can be used to classify igneous rocks.

## Extrusive igneous rocks

Extrusive igneous rocks have very small crystals in them. The rapid cooling of these rocks makes the minerals solidify very fast, so large crystals don't have a chance to grow. The crystals may be hard to see with eyes alone, but usually can be seen very clearly with a microscope. The rock may have to be sliced into thin sections to be able to see the crystals. Figure 8.1.7 shows a view through a microscope of the crystals in an extrusive igneous rock.



**Figure 8.1.7** A microscopic view of an extrusive igneous rock

Basalt is an example of an extrusive rock with small, visible crystals, while obsidian is an example of an extrusive rock with no crystals. Obsidian is like glass, and is often called volcanic glass. It cools too fast for any crystals to form. You can see the glassy texture of obsidian in Figure 8.1.8.



**Figure 8.1.8** Obsidian is an extrusive igneous rock that is characterised by its lack of crystals.

Many extrusive rocks contain a large number of spaces in them. These are caused by gas bubbles, trapped when the magma cooled very quickly. This gives them a rough bubbly texture. An example is pumice, a light grey igneous rock. It is so light that it floats in water. It has obvious holes and is not very hard.

Scoria is another type of rock that explodes out of volcanoes, and it also has many holes. Scoria has no obvious crystals, is a dark colour, and is much more dense than pumice. It sinks if placed in water. You can see samples of pumice and scoria in Figure 8.1.9.




**Figure 8.1.9** Pumice and scoria are extrusive igneous rocks exploded out as volcanic bombs. These rocks are full of holes caused by gas bubbles.

## Intrusive igneous rocks

Intrusive igneous rocks contain large crystals, which can usually be seen without a microscope. These crystals are the result of slowly cooling magma. The crystals also interlock with each other. Two examples of intrusive igneous rocks are granite and dolerite. It is easy to see the crystals in the granite shown in Figure 8.1.6 on page 281. It is composed of three main minerals: quartz, feldspar and biotite. Figure 8.1.10 shows these three minerals as clumps of pure crystals.




**Figure 8.1.10** The three main minerals in granite are quartz, feldspar and biotite.

### The sparking rock

When quartz is squeezed, it gives out a burst of electricity, which can form a spark to light your gas barbecue. This property of quartz is called piezo electricity, and the igniters are called piezo igniters.

SciFile

2 p288

8.1

# Uses of igneous rocks

Most igneous rocks are very hard and strong. They are very good for buildings and other stone structures that need to be strong and last a long time. Some common uses for igneous rocks are listed in Table 8.1.1. Two uses are shown in Figure 8.1.11.

**Table 8.1.1 Uses of igneous rocks**

| Igneous rock | Use |
|---|---|
| Basalt | Buildings (for example Melbourne bluestone), concrete (as crushed rock), floor tiles |
| Dolerite | Road surfaces (where it is called 'blue metal'), concrete (as crushed rock) |
| Granite | Buildings, monuments, road surfaces, kitchen benchtops |
| Scoria | Landscaping, filters and concrete (all as crushed rock), barbecue rocks |
| Pumice | Cleaning dead skin off feet, emery boards for shaping nails, some soaps that feel rough on your skin |
| Obsidian | Scalpel blade for surgery in hospitals, ornaments and jewellery. Ancient people used it for cutting, spear and arrow points, and pots and vases |

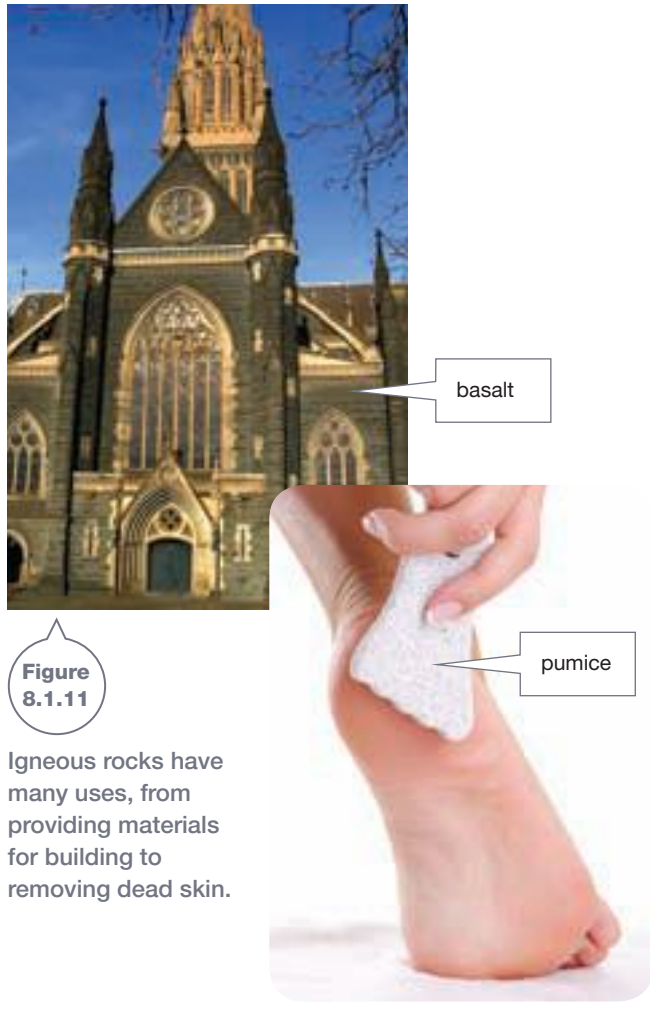



**Figure 8.1.11** Igneous rocks have many uses, from providing materials for building to removing dead skin.

# SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

## All four engines have failed!

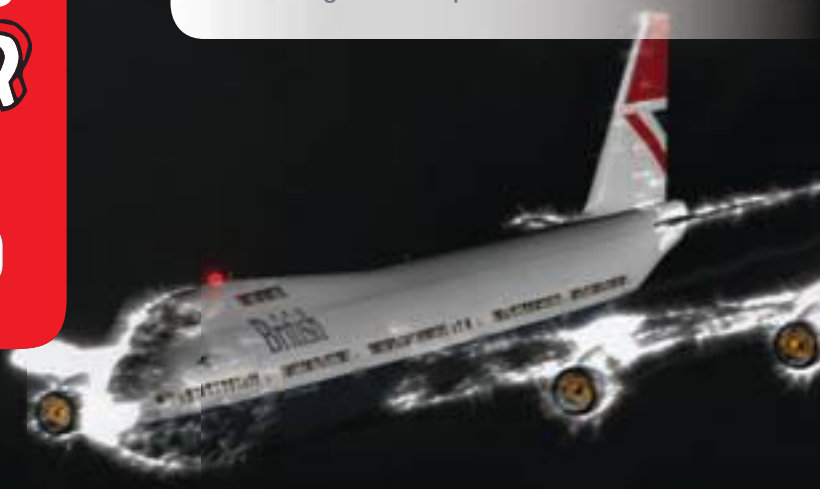


Figure 8.1.12 Volcanic dust first caused BA009 to glow in an effect called St Elmo's fire. It then caused all four engines to stop.

'Ladies and gentlemen, this is your captain speaking. We have a small problem. All four engines have stopped. We are doing our best to get them going again. I trust you are not in too much distress.' These are the words of Captain Eric Moody, British Airways Flight 009, 24 June 1982.

This announcement marked one of the first encounters with volcanic ash by a commercial airliner. On the night of 24 June 1982, a British Airways Boeing 747 was flying from Kuala Lumpur (Malaysia) to Perth. It flew through an ash cloud from Indonesia's Mount Galunggung volcano.

All four engines failed and the plane began a slow steady fall from the sky. For the next 14 minutes the crew tried to re-start the engines. They succeeded at last, but only after the plane had fallen 7000 metres to only 4000 metres above the Indian Ocean. The aircraft then made an emergency landing at Jakarta, Indonesia.

Later examination showed that the aircraft engines had stalled because of the volcanic ash. The engines only re-started once the aircraft had descended out of the volcanic ash cloud and into clear air.

Volcanic ash clouds consist of fine particles of rock, mainly silica. These rock particles are like tiny glass beads. There are also corrosive gases in the ash clouds that react to form droplets of sulfuric acid and other substances. When this ash melted in the hot section of the engine, it formed a glassy coating. This caused loss of thrust and engine failure. The ash particles also wore away engine parts, the body and the windscreen, and clogged fuel and cooling systems.

All countries responded to the incident. Their solution was to gather meteorological observations from various sources on the ground and the air in many countries along the flight routes. They then identify the ash clouds and forecast their height, movement and dispersion (spread). The information is then sent to guide aircraft clear of any threat.

8.2

SciFile

### Chaos in the air!

In April 2010, Mt Eyjafjallajökull in Iceland began a series of eruptions that threw huge clouds of volcanic ash into the air. Winds then pushed the ash across Great Britain and Europe. As the winds shifted direction, so did the ash cloud, covering different countries as it did so. As a safety precaution, all aircraft in those countries were grounded (not allowed to fly). The disruption lasted a month.

# 8.1 Unit review

## Remembering

1 **Name** the outer layer of the Earth.

2 **Name** the hot molten rock that:
   a pours out of volcanoes
   b has not reached the surface.

3 **Name** two igneous rocks that are:
   a extrusive
   b intrusive.

4 **List** the three minerals in granite.

5 **List** the main characteristics of igneous rocks.

## Understanding

6 **Define** the following terms.
   a geology
   b igneous rock
   c extrusive igneous rock
   d lithosphere

7 **Explain** how and why crystal size is affected by how fast rocks cool.

8 Pumice can be formed by lava cooling in water. **Explain** why igneous rocks such as this do not have any visible crystals.

9 **Explain** why dark-coloured igneous rocks tend to be heavier than light-coloured ones.

## Applying

10 A geologist removed some rock from the edge of an old lava flow. No crystals could be seen when the rock was studied under a microscope. The rock was a dark colour and it was hard, but very brittle. It was easily broken into pieces by hitting it, and broke into very sharp, thin strips, which were very lustrous (shiny). **Apply** your knowledge of rock types and formation to:
   a **identify** the type of igneous rock it is
   b **explain** why no crystals could be found even though the rock was obviously igneous.

## Analysing

11 **Compare** interlocking crystals with the pieces of a jigsaw puzzle.

12 **Contrast** the mineral composition of dark- and light-coloured igneous rocks.

13 a **Contrast** the uses of granite and scoria.
   b **Explain** why each rock suits that use.

14 **Compare** the ways in which intrusive and extrusive igneous rocks form by listing their similarities and differences.

15 **Contrast** the appearance of igneous rocks that are extrusive and those that are intrusive.

16 Copy the following table into your workbook.

| | Small crystals | Large crystals | Holes | 'Glassy' |
|---|---|---|---|---|
| Light colour | | | | |
| Dark colour | | | | |

   a **Identify** where each of the following rocks should be placed in the table: basalt, granite, pumice, obsidian, scoria.
   b Rhyolite is an extrusive igneous rock that is chemically very like granite but has very small crystals. **Analyse** the data and decide where you would place rhyolite in the table.
   c Gabbro is an intrusive igneous rock that is chemically like basalt. **Analyse** this information and decide where you would place gabbro in the table.

## Evaluating

17 **Evaluate** the following two statements. Are they correct, incorrect or a bit of both? **Justify** your answers.
   a All magma is lava.
   b All lava was once magma.

18 Dolerite is an igneous rock formed below the Earth's surface. It is similar to basalt in its chemical composition, containing relatively little silica.
   a **Assess** whether dolerite is likely to have smaller or larger crystals than basalt.
   b **Justify** your decision.

# 8.1 Unit review

19 Porphyry is an igneous rock that has a mixture of crystal sizes. It has large crystals set in a rock consisting of mainly fine grains, often too small to see. You can see an example in Figure 8.1.13. It has been suggested by geologists that porphyry forms in two stages. **Use** your knowledge of crystallisation and cooling rates to **propose** an explanation for how this type of rock most likely forms.

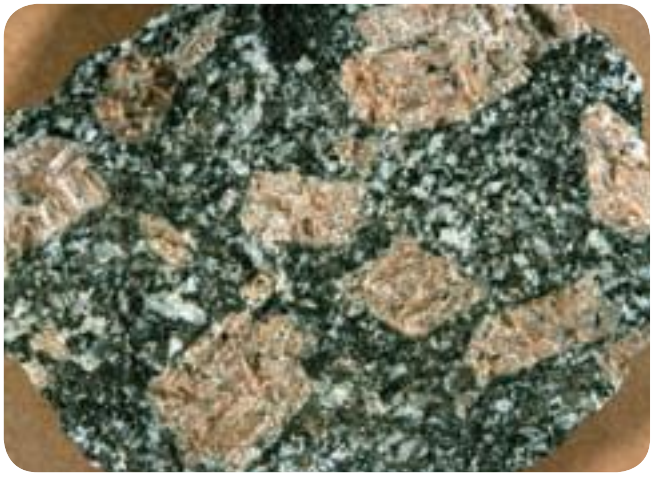


Figure 8.1.13 Porphyry

20 In the Science4Fun activity on page 280, it was suggested that you look at the edge of the solution for crystals and not in its centre. **Propose** a reason why.

21 Refer to page 284 and **propose** reasons why the following happened.

a i Before the engines failed, the pilots of BA009 observed a glow known as St Elmo's fire around their aircraft.

ii The windscreen of BA009 was so badly scratched that the pilots needed to look out of their side windows to land the aircraft.

b i All aircraft were grounded in parts of Europe after the eruption of Mt Eyjafjallajökull.

ii Although the disruption lasted a month, different countries were affected at different times.

iii All aircraft in Iceland were still flying while Mt Eyjafjallajökull was erupting.

## Creating

22 a **Construct** a diagram of an erupting volcano on the edge of the sea, showing at least three different places where extrusive and intrusive igneous rocks may form.

b In your diagram, **construct** magnified views showing what the different rocks may look like. Add short notes next to each magnified view explaining what these views show.

## Inquiring

1 Search around your home and find two rocks or objects made from rocks you suspect are igneous. Write a brief description of each rock and list the features that you used to decide it was igneous. After checking with your parents, bring the rock to school if possible and ask if you can observe it with a hand lens or stereomicroscope. Classify the rock as best you can into the categories shown in the table in Question 16, and identify an igneous rock that is most like yours.

2 Research the importance and uses of quartz. Explain how the use of the mineral is due to its properties.

3 The Earth has a magnetic field around it, which can be detected by a compass. Research how ancient people could use the iron mineral called magnetite to navigate at sea.

4 Research the use of obsidian in scalpel blades and explain why it is used rather than steel.

# 8.1 Practical activities

## 1 Cooling and crystal size

### Purpose

To investigate how cooling rate affects the size of crystals.

### Materials

- rubber gloves
- oven mitt or towel
- 3 × 50 mL test-tubes and test-tube rack
- 4 × 250 mL beakers
- ice
- cotton wool
- hotplate or Bunsen burner, tripod, bench mat, gauze mat
- stirring rod
- filter funnel
- a sample of about 25 g of potash alum



**SAFETY**

Wash your skin with soap and water immediately if you come into contact with potassium aluminium sulfate solution.

Call your teacher immediately if it contacts your face or eyes.

Be careful at all times with boiling water.

### Procedure

1. Put about 100 mL of water into a 250 mL beaker and heat it until it is boiling. Turn the hotplate or Bunsen burner off once the water boils.
2. While waiting for your water to boil, make an ice bath by half-filling another of the beakers with ice water.
3. Insulate another beaker with enough cotton wool to allow a test-tube to sit upright in the middle.
4. Wearing rubber gloves, carefully lift the beaker of hot water off the gauze mat and tripod and place it on the benchtop. Dissolve all the potash alum in the hot water. It all should dissolve if you stir it well with the stirring rod.
5. Place the three test-tubes in a test-tube rack. Put a filter funnel in one of the test-tubes. Hold the beaker of hot solution with an oven mit or towel so it will not burn you. Carefully pour about 25 mL of the saturated solution into the filter funnel. The test-tube should be about half full. Repeat this process for the other two test-tubes. Place a plug of cotton wool in the mouth of each test-tube.
6. Place one test-tube in the cotton wool, one in the ice water, and one in an empty beaker as shown in Figure 8.1.14.

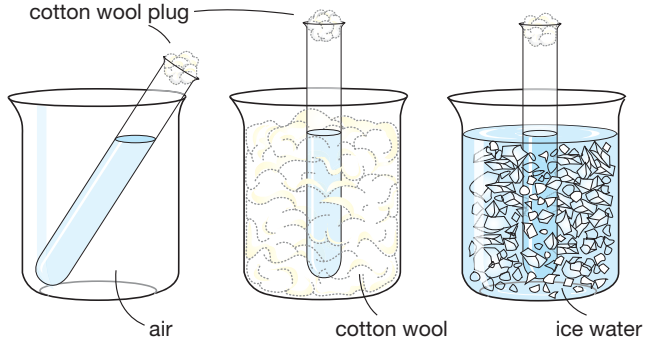



Figure 8.1.14

7. Leave the beakers in a safe place such as a cupboard for at least a day.

### Results

Observe the contents of the test-tubes in the next lesson. Record your observations.

### Discussion

1. **State** which test-tube had the biggest crystals and which had the smallest crystals.
2. **State** which test-tube cooled the fastest and which cooled the slowest.
3. **Use** the results of this experiment to **explain** the difference between crystal sizes in extrusive and intrusive igneous rocks.

## 2 Comparing igneous rocks

### Purpose

To compare the characteristics of different igneous rocks.

### Materials

- various igneous rock samples: pumice or scoria, basalt, obsidian, granite, dolerite, gabbro, porphyry
- access to stereomicroscope, hand lens or magnifying glass
- margarine lid or white tile
- blunt probe or mounted needle
- smashed up granite rock grains
- graph paper

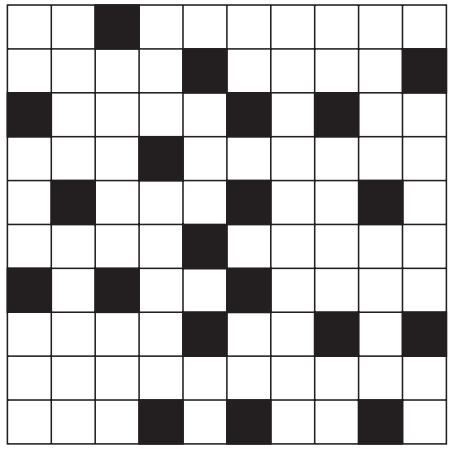


Figure 8.1.15

### Procedure

1 Use your microscope or hand lens to study the smashed-up granite rock sample. Describe the three main different minerals that are present. Use colour, crystal shape and hardness in your description.

2 Place each of the intact rock samples on a margarine lid or white tile, and record your observations in a table like the one below. Record the:
   - a main colour of the rock
   - b colour and size of its crystals (if visible). For size of crystals, try to estimate the length in millimetres. Do this for each of the different types of crystal that you can see.
   - c percentage of dark minerals. Do this by comparing your rock with a piece of graph paper on which you have coloured some squares black. Use a piece of graph paper 10 squares by 10 squares. If you colour in 20 of the squares, this will show you what 20% looks like, as in Figure 8.1.15. Create another piece for 30%, and so on. Compare these pieces of graph paper with the rock to estimate the percentage of the rock that is dark.

3 Use the crystal size as a guide to classify the rock as intrusive or extrusive. For other features, add anything else you notice about the rock, such as its weight, texture and lustre.

### Results

Copy the table below into your notes. Draw as many rows in as you have rock samples.

### Discussion

1 **Specify** which rocks were mainly dark coloured.

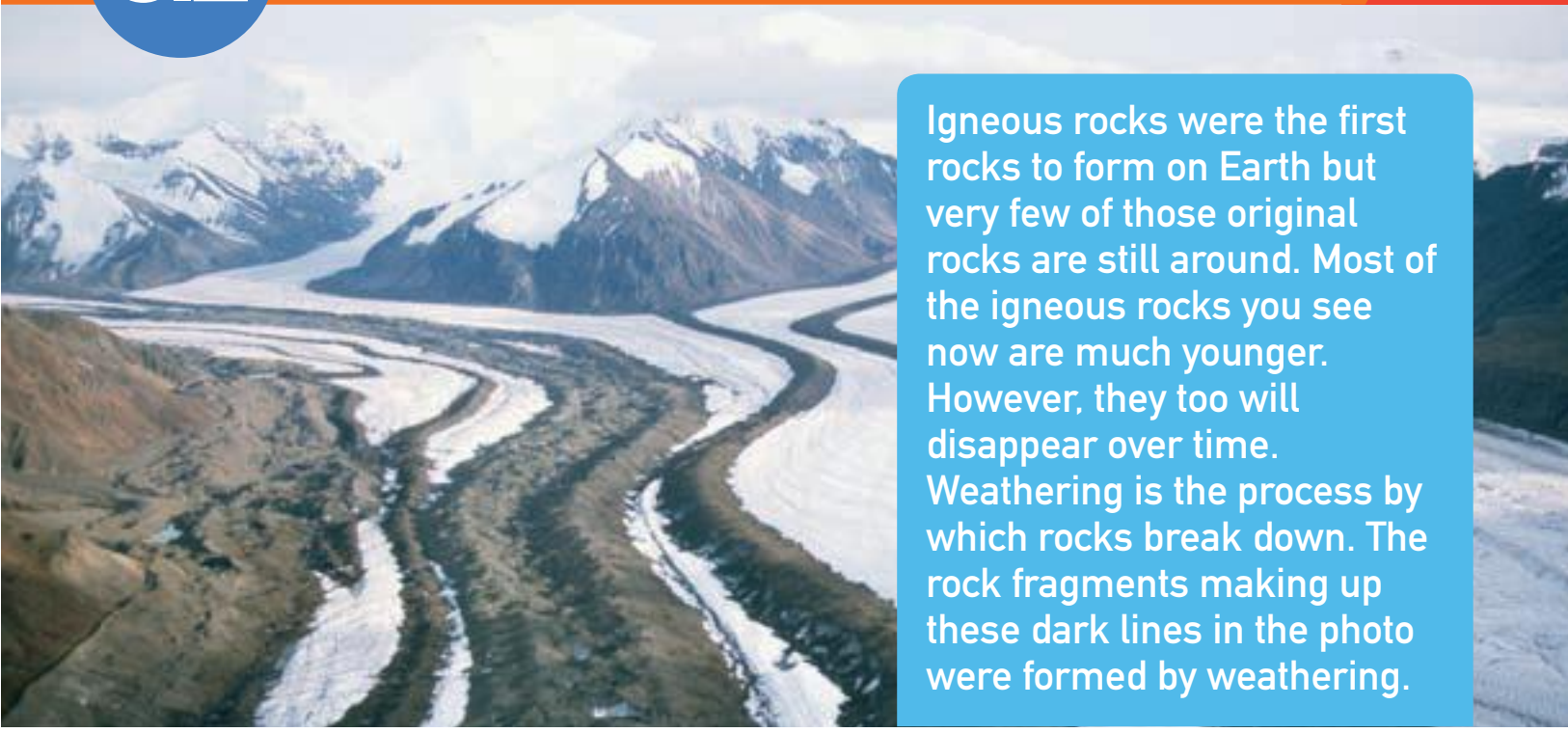
2 **Specify** which rocks had clearly visible crystals.

3 **Compare** the crystal size and the rock colours for your different samples. Was there any relationship between these? For example, did all dark rocks have large crystal sizes?

4 **Account** for the low density of any of these rocks.

| Rock name | Main colour of rock | Colour and size of crystals | Percentage of dark minerals | Extrusive or intrusive | Other features |
|---|---|---|---|---|---|
| Granite | | | | | |
| Basalt | | | | | |
| | | | | | |

# 8.2 Weathering



Igneous rocks were the first rocks to form on Earth but very few of those original rocks are still around. Most of the igneous rocks you see now are much younger. However, they too will disappear over time. Weathering is the process by which rocks break down. The rock fragments making up these dark lines in the photo were formed by weathering.

## Weathering

People often comment on the weather, complaining that it is too cold or too hot, too wet or too dry. In geology, a similar word is used but it has a very different meaning. **Weathering** in geology means the physical and chemical processes that break rocks down. Rocks do not last forever because weathering breaks them down into smaller pieces.



Figure 8.2.1 This large rock has been split by temperature changes.

## Physical weathering

Weathering can happen because of:

- temperature change
- the action of water and ice
- crystallisation of salts
- wind
- living plants.

Weathering due to these processes is called **physical weathering**.

### Temperature

Solids expand (get larger) when they are heated and contract (get smaller) when they are cooled. If the temperature change between day and night is very fast, this expansion and contraction can crack a rock. Once the rock splits, pieces can break off, especially if other physical processes are going on at the same time. Figure 8.2.1 shows where a piece of rock has broken away to expose a lighter grey, fresh rock surface. There are several cracks in the rock that show where pieces are likely to break away in the future.

### Ice and water

Ice can split rocks by cooling them rapidly. Ice also widens cracks in rocks. This is because any water that enters cracks will expand if it freezes. This is common in colder climates and on the cold tops of hills and mountains.

Glaciers are like frozen rivers of ice that move along their valleys very slowly. As they move, the ice scrapes pieces off the surrounding rocks, forming valleys that are U-shaped, rather than the V-shape carved by a river. The sides of the valley have been worn away by the ice. Where glaciers merge together, there are often dark lines that show the tracks of the dark rock particles being carried by the glacier. You can see some in the opening photo on page 289 at the start of this unit. Figure 8.2.2 shows how a U-shaped valley forms. Glaciers are only found in extremely cold places. Today this means places such as Greenland and on high mountains such as in New Zealand. They also occurred in Australia in the past, when the climate was much, much colder.

Water running or washing over rock can also gradually wear away some material. The rate of the weathering depends on the type of rock and the speed and power of the water. Rivers can cut deep through rock, forming gorges. Pounding waves at the beach also have this effect. For example, the rock cliffs near the Twelve Apostles in Victoria have been weathered faster in some places and weathered more slowly in others, leaving rock stacks behind. Some are shown in Figure 8.2.3.

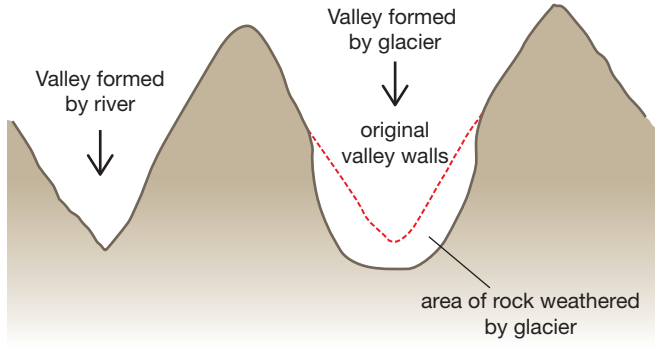



**Figure 8.2.2** The characteristic U-shaped valley is caused by rocks being scraped away by a glacier.



**Figure 8.2.3** The Twelve Apostles in Victoria show the effect of weathering by wave action. All will eventually fall into the sea. Weathering will also cause new ones to form.

### Salts

Water in the soil often contains dissolved chemicals called salts. One example is common table salt—sodium chloride. Salts such as sodium chloride and calcium sulfate form crystals as the water evaporates. If the crystals form inside a rock, then the expanding crystals can put a tremendous pressure on the rock and can break pieces off it. A similar effect can occur in brick and limestone walls.

INQUIRY science 4 fun

## Stretching water

What happens to water when it freezes?

#### Collect this …

- small narrow container like an egg cup or spice bottle (no cap)
- access to freezer
- water

#### Do this …

1. Fill the container right up to the top and place it in the freezer. Leave the top off.
2. Next day, check the container and observe the level of the ice at the top of the container.

#### Record this …

**Describe** what happened.
**Explain** why you think this happened.

### Wind

Fine particles of rock carried by wind can cause physical weathering. These fine rock particles blast the rock surface, wearing pieces away.

### Plants

As Figure 8.2.4 shows, plant roots can split rocks. They can grow through fine cracks, or even create their own cracks. As the root thickens, it splits the rock. Tree roots can be strong enough to seriously damage homes, paving and driveways.

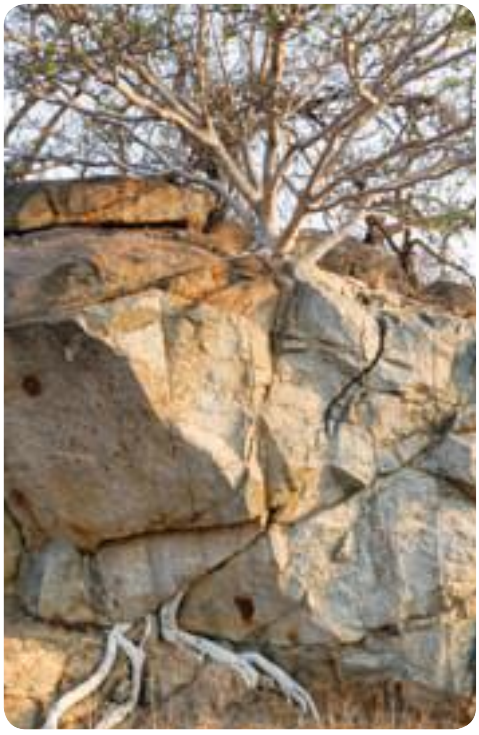


Figure 8.2.4

Tree roots can split rocks and walls.

## Chemical weathering

**Chemical weathering** involves water and chemicals in the water and air reacting with the rock and changing it.

### Gases

Air contains oxygen and carbon dioxide, and both can react with certain types of rocks. These gases make the rock change to form different chemicals that do not hold together as strongly. This causes the rock to crumble. The colour of the rock often changes too. For example, you often see red colours wherever dolerite rock weathers. This is because the iron in the dolerite forms iron oxide, a red substance similar to rust. Its colour is clearly seen in the soil of Figure 8.2.5.

### Acids

Rainwater contains dilute acids that attack the rock. The acids can naturally form in the air during lightning, but pollution also forms acids in the air. This is known as acid rain.



Figure 8.2.5

This red soil is the remains of dolerite after it has been chemically weathered.

### Water

Some rocks have soluble materials in them. This means that they can be dissolved by rain and running water, removing the 'cement' that holds the rock together. This can make the rock crumble.

p296

8.3

SciFile

### Red ochre

Australian Aborigines discovered that some rocks break down into a red-coloured clay, called ochre. The red colour comes from the chemical weathering of iron-rich rocks to a rust-like iron oxide. Ochre can be mixed with other materials to change the colour and paint bodies and caves, and to make bark paintings.



# Erosion

Small particles of rock broken off by weathering can be carried away by water, wind and ice. This removal of small rock particles is called **erosion**, and the water, wind and ice are said to be **agents of erosion**. Erosion is the carrying away of the particles, and is not the same as the weathering that breaks the particles off the rock in the first place.

The most common place that erosion occurs is on mountains or hills. This is because gravity makes water move more rapidly down a slope than on level ground.

# Sedimentation

The small rock particles that are carried away from the weathered rock are eventually dropped somewhere. The process of depositing eroded rock particles is called **sedimentation** or deposition.

Sedimentation occurs where the moving water, wind or ice that is carrying the particles slows down. In the case of rivers, this slowing down occurs in the bends of rivers, and also where rivers leave the mountains and enter plains. There the rivers slow down dramatically and larger rock particles are deposited. A river slows and stops once it has entered a lake or sea, so the smaller particles can no longer be carried. This is why lakes gradually fill up with sediment, and why new land often builds up at the mouth of a river. Rivers can also break their banks in a flood and deposit sediment on any plains that surround them. Figure 8.2.6 shows how sediments build up in a lake.

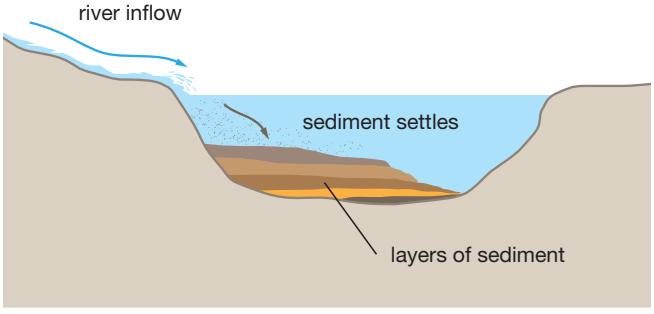



Figure 8.2.6 Sedimentation occurs where rivers slow down.

INQUIRY science 4 fun

## Sedimentation

What happens when sediments settle in water?

Yes

### Collect this ...

- 2 L soft-drink bottle with the top 5 cm cut off
- mixture of soil particles of different sizes, such as gravel, sand and clay

### Do this ...

1. Do this outside. Pour water into the bottle to about 5 cm from the top.
2. Drop a handful or two of your mixed soil into the container and let it settle without moving the container. Observe what is happening and then observe it again after a few hours.

### Record this ...

**Describe** what happened.
**Explain** why you think this happened.

# Soils

Sediments are the basic components of soil. The other components of soil are living organisms (such as bacteria and fungi), decaying wastes, dead leaves, twigs and insects, water, dissolved minerals and gases.

Soils affect plant growth and are therefore vital for the survival of many organisms, including humans. Soils affect humans in other ways as well, since they form the foundations of all our buildings, roads, bridges, sporting fields and other structures.

Plant growth depends on several characteristics of the soil, such as its texture, structure, water-holding capacity, permeability and consistency. Several of these characteristics also affect buildings.

## Texture

**Texture** is determined by the size of the particles that make up the soil. The main particles in soil are classified into clay, silt and sand (Figure 8.2.7). There are others as well, such as gravel. Clay and silt particles are tiny. There are hundreds to thousands more particles of clay and silt than sand in a spoonful of soil. Most soils have various combinations of these particles. For example, a soil

described as 'clay' may be 40% clay, 40% sand and 20% silt.

One way that texture can affect plant growth is in its effect on plant nutrients in the soil. Clay is better than sand at holding onto and releasing minerals needed for plant growth. So plants usually grow well in soils that have some clay in them. One that is not growing well is shown in Figure 8.2.8.

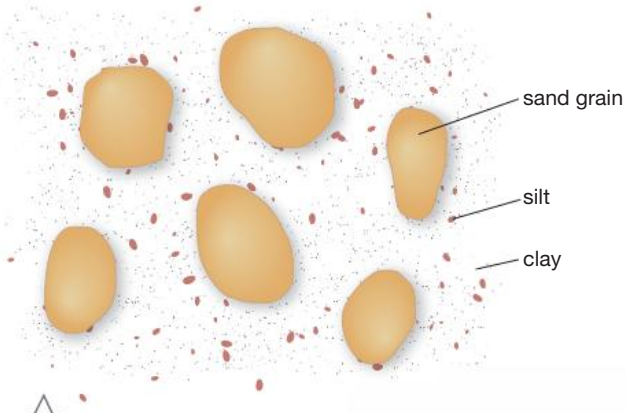



**Figure 8.2.7** Soils are composed of particles of different sizes, such as clay, silt and sand.

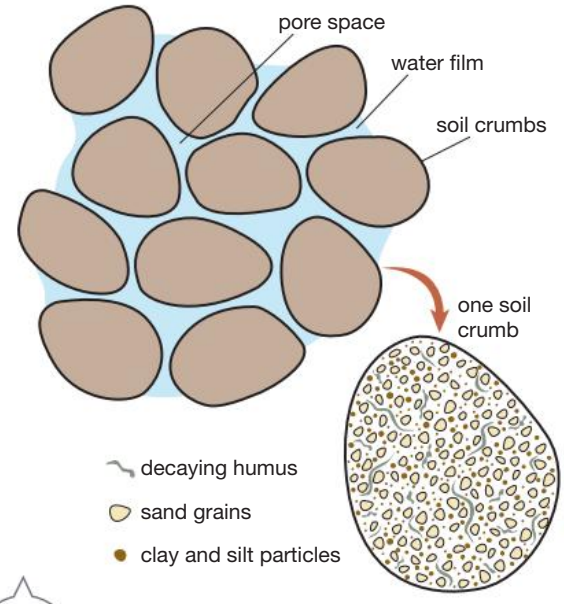



**Figure 8.2.9** Soil structure is about how particles clump together.



**Figure 8.2.8** Plants can wilt and die if soil cannot hold water or holds too much of it.

## Structure

**Structure** refers to how well the soil particles join up to form soil clods or crumbs. In most soils these crumbs are 3–5 millimetres wide. The size is important because it allows spaces called **pore spaces** to exist between the crumbs. As Figure 8.2.9 shows, pore spaces let water and air enter the soil to improve plant growth.



**SciFile**

### The Leaning Tower of Pisa

The Leaning Tower of Pisa in Italy was finished around 1272. Since then it has been sinking on one side because there was more clay in the soil on that side than the other. Changing water levels affected the clay, making the soil very unstable. Work done in the 1990s may have stopped the sinking.

## Water-holding capacity

**Water-holding capacity** is a measure of how much water a particular amount of soil can hold. Some soils hold onto water very strongly, so strongly that it is hard for plants to extract the water they need from them. Soils high in clay are like this.

Some clay soils can expand when they are wet and contract when they are dry. This can damage buildings, making them crack and potentially unsafe. Many wet clay soils are weak and cannot support buildings. For example, bridges may have to be built on piles that are hammered into rock beneath the soil, as shown in Figure 8.2.10.

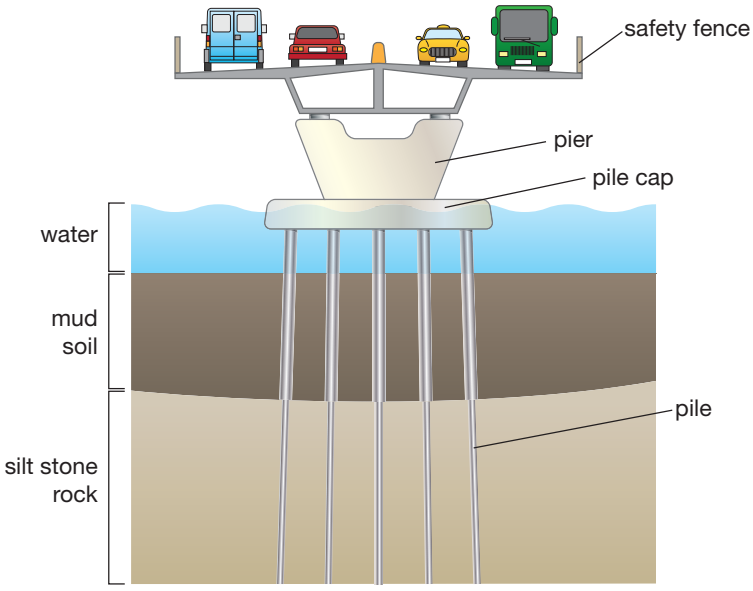



**Figure 8.2.10** Piles anchored into rock can be used to support bridges and other structures built on clay soils.

## Permeability

**Permeability** is a measure of how fast water enters the soil. If water enters the soil slowly and permeability is low, then the water is likely to run off and not enter the soil. This is a problem for farmers and gardeners because plants will dry out and die.

## Consistency

**Consistency** is the tendency of soil particles to stick together. Clay particles are attracted to each other and stick together very well, while sand particles do not. In farming, mine rehabilitation and market gardening, soils are commonly compacted by vehicle wheels. The soil forms a layer that sets like concrete, preventing water and air from entering.

Consistency is important for sporting surfaces such as cricket pitches. A good cricket pitch should have about 50% clay. Watering and compacting the soil with a heavy roller makes it set to a hard surface that gives good bounce for the ball. This is being inspected in Figure 8.2.11. The soil also holds together so that it will last for several days.




**Figure 8.2.11** Australian cricketer Ricky Ponting is inspecting a pitch that has just been rolled. You can see two different rollers next to the pitch.

# 8.2 Unit review

## Remembering

1 **List** the main agents of:
   a physical weathering
   b chemical weathering.

2 **List** five characteristics of soils important for plant growth.

3 **List** the agents of erosion.

## Understanding

4 **Define** the following terms.
   a weathering
   b sedimentation

5 **Explain** why igneous rocks exposed at the Earth's surface are not identical to how they were just after they were formed.

6 **Explain** how temperature change and water can split a rock.

7 **Explain** why sediments carried by a river will be deposited when the river flows into a lake or sea.

8 **Explain** what is meant by *soil structure*.

9 Plant growth is affected by soil texture, structure and consistency. **Explain** how.

## Applying

10 Figure 8.2.12 shows a satellite image of the coast of New South Wales.
   a **Identify** the process occurring in this photograph.
   b **Explain** what is happening.



Figure 8.2.12

11 Builders should know something about rocks and soils. **Apply** what you have learnt in this unit to **explain** why.

## Analysing

12 **Contrast** a crumb and a particle of rock in soil.

13 **Compare** erosion and weathering.

## Evaluating

14 **Propose** ways in which you could minimise soil erosion when camping, bushwalking or boating.

15 When a hilly area is excavated (dug out) to make a road, exposed banks are often left along the side. Workers sometimes cover these banks with various materials, such as a spray-on paper-like material that has plant seeds mixed with it. **Propose** reasons why they do this.

16 a **State** what caused the grey colouring in the rock in Figure 8.2.1 on page 289.
   b **Propose** what caused the red colouring.

## Creating

17 **Construct** a poster informing home gardeners of the differences in soils that may affect their garden plants.

## Inquiring

1 Design an investigation to demonstrate erosion caused by water as it runs across different soil types. You need to be able to test how the slope of the land affects this.

2 Design an investigation to compare the amount of pore space (air space) in sand and clay soils. Equipment that would be useful is two measuring cylinders, a beaker, some water and different soils. Show your procedure to your teacher and ask them if you can try your experiment.

3 Find a container of plant fertiliser and read the label to find out what plant nutrients are in the container. Pick three nutrients and research why they are needed by plants. Present your findings in a table or about ten lines of writing.

4 Research erosion of soil on farms and the methods farmers use to reduce the effects of erosion.

5 Research the preparation of a turf cricket pitch and explain the characteristics of soil that affect how a pitch performs.

# 8.2 Practical activities

## 1 Simulating weathering

### Purpose

To investigate how ice and chemicals can cause weathering.




### Materials

#### Part A: The effect of acid and water

- 6 test-tubes and a test-tube rack
- 2 small samples each of granite, limestone and sandstone (to fit test-tubes)
- vinegar

#### Part B: The effect of temperature

- 2 margarine containers or milk cartons
- small water balloon
- plaster of Paris
- spoon or spatula

### Procedure

#### Part A: The effect of acid and water

1. Label your test-tubes 1 to 6. Put small samples of granite into test-tubes 1 and 2, limestone in test-tubes 3 and 4, and sandstone in test-tubes 5 and 6 as shown in Figure 8.2.13.
2. Add water to test-tubes 1, 3 and 5.
3. Add the vinegar to test-tubes 2, 4 and 6.
4. Leave the test-tubes in the test-tube rack and record any observations. Leave them set up overnight or until your next science class.

#### Part B: The effect of temperature

5. Mix up enough plaster with water to half-fill two margarine containers or cut-down milk cartons.
6. Fill a small balloon with water and tie it. Push the balloon into the plaster in one container and keep it below the surface until the plaster sets.
7. At the end of class, put both the margarine containers or cut-down milk cartons in the freezer.

### Results

Record your observations next class for the test-tubes and the containers in the freezer.

### Discussion

1 a **Describe** what happened to different rocks when placed in the acid.

b **Use** this observation to **explain** weathering of rocks by chemicals.

2 a **Describe** what happened to the plaster and the jar left in the freezer.

b **Explain** what happened.

3 **Explain** why this experiment is relevant to the weathering of rocks.

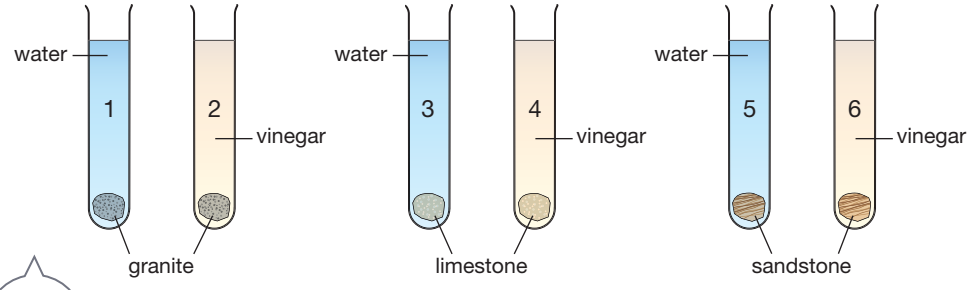
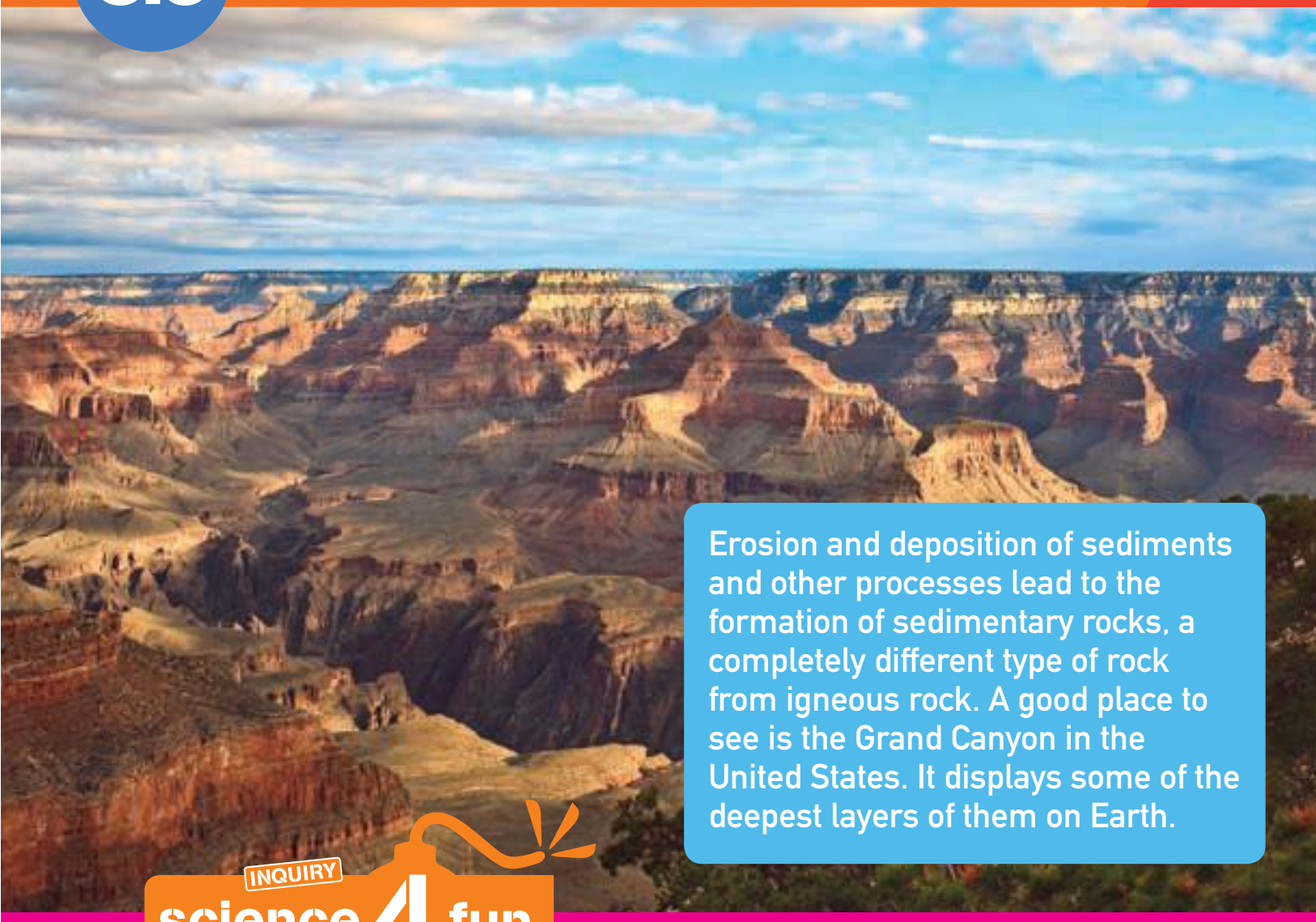



Figure 8.2.13

# 8.3 Sedimentary rocks



Erosion and deposition of sediments and other processes lead to the formation of sedimentary rocks, a completely different type of rock from igneous rock. A good place to see is the Grand Canyon in the United States. It displays some of the deepest layers of them on Earth.

INQUIRY science 4 fun

## Plaster rocks

What can plaster do to pieces of rock?

No

### Collect this…

- half a margarine container of small rock pieces of fingernail size
- spatula
- plaster of Paris



**SAFETY**
Do not mix plaster with your bare hands.

### Do this…

1. Place enough plaster in the container to fill all the gaps between the rocks. Pour in water a little at a time while mixing until the mixture is like cream. It must not be runny or it will take a long time to set. Leave the container to set.
2. When the contents look as though they have set hard, remove the mixture from the container by tipping it upside down and tapping the bottom hard.
3. Try to bend the solid mixture to see how strong it is.

### Record this…

**Describe** what happened to the mixture and how strong it was.
**Explain** why you think this happened.

# How sedimentary rocks form

As the name suggests, **sedimentary rocks** are rocks made from sediments. To form the rock, the sediments need to be cemented (stuck) together somehow. This occurs through pressure and because there are substances in rocks and soil that act as natural cements. One type of cementing material is plaster of Paris. This is used in making plaster casts for broken limbs, and for fixing internal walls in homes. Plaster of Paris comes from heating gypsum, the common name for the mineral calcium sulfate, which occurs naturally in the ocean, groundwater and many rocks. Gypsum can cement sediments to form rocks.

Sedimentary rocks are classified by their type of sediment. There are three basic types of sediment:

- from pieces of weathered rock
- from minerals crystallising from solution
- from dead animal or plant material.

## Weathered rock sediments

Weathered rock sediments are the sediments from weathering of rocks. The weathered rock can be from any type of rock. Sedimentary rocks formed from weathered rock sediments are known as **clastic sedimentary rocks**. Within the sediments you can sometimes find fossilised remains of long-dead organisms. **Fossils** are preserved remains of organisms that were once living. You can see a fossil in Figure 8.3.1.



**Figure 8.3.1** This fossilised lizard was found in a limestone quarry in Germany.

**Natural cements** are chemicals that can flow around the sediments and then set like cement. Natural cements include calcium carbonate (calcite), silica, quartz, iron oxide and clay minerals. Portland cement (used in bricklaying and to make concrete) is made from natural cements that contain silica. The cements set because the rock layer is squashed under pressure from the weight of all of the sediment above. This squeezes out the water in the sediment layer and lets the cementing agent solidify (Figure 8.3.2).

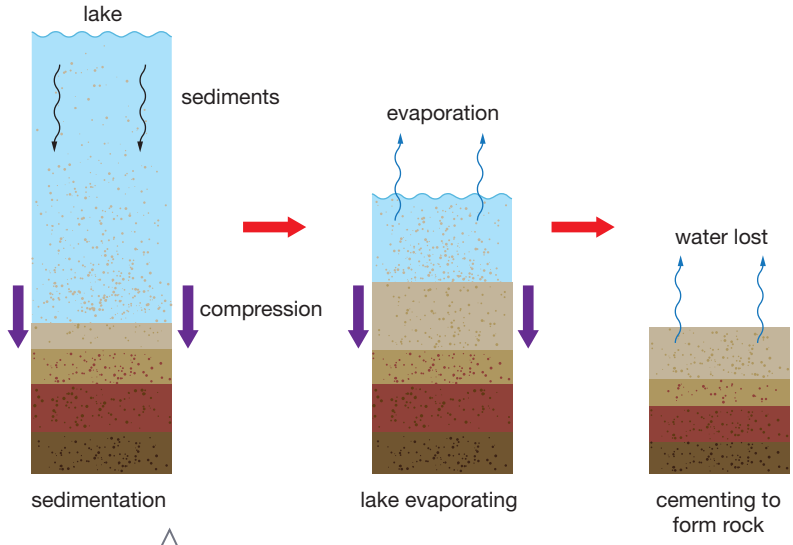



**Figure 8.3.2** Formation of clastic sedimentary rock involves sediments, cement and pressure.

## Chemical sediments

**Chemical sedimentary rocks** form when materials dissolved in water come out of solution, form a solid and sink to the bottom. This process is crystallisation, in which the dissolved minerals turn into solid crystals as the water evaporates. This process is shown in Figure 8.3.3.

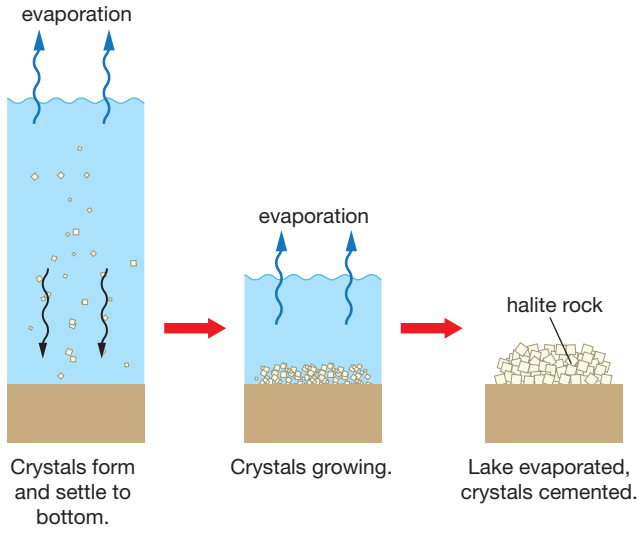



**Figure 8.3.3** Chemical sedimentary rocks form by evaporation and crystallisation.

**SciFile**

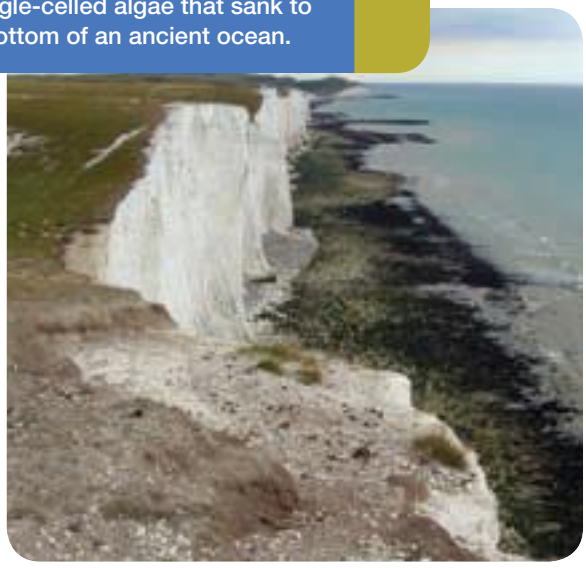
### Fibre optic rock

A chemical sedimentary rock called ulexite has amazing properties. Ulexite transmits light and images just like a fibre optic cable. Fibre optics have many uses including communication and decorations. A call from your mobile phone is coded into light signals that are passed along a fibre optic cable between the mobile phone towers.

## The White Cliffs of Dover

SciFile

The English town of Dover is famous for its white cliffs. The cliffs are about 100 metres high. They are composed mainly of soft sedimentary limestone and are commonly called chalk. The limestone came from the skeletons of single-celled algae that sank to the bottom of an ancient ocean.



## Organic sediments

**Organic sedimentary rocks** form when dead plant matter or animal debris accumulates and is then cemented together. The sediments are mostly from organisms, but there may be small amounts of clastic sediment. The formation of organic sedimentary rock is shown in Figure 8.3.4.

1 p303

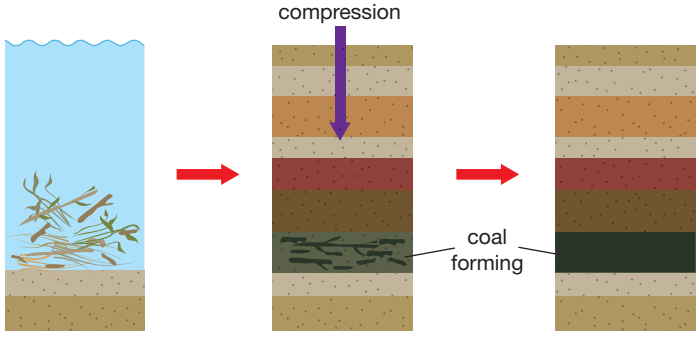



**Figure 8.3.4** Coal is an organic sedimentary rock.

# Characteristics of sedimentary rocks

There are three different types of sedimentary rocks:

- clastic
- chemical
- organic.

All have different characteristics because they were formed in slightly different ways.

## Clastic sedimentary rocks

Clastic sedimentary rocks have the following characteristics.

- They have layers like a stack of pages or books because the sediments build up one on top of the other as they are deposited. You may not see layers in a small piece of rock, but they are obvious when you are looking at several metres of a rock face.
- The grains do not interlock because they did not crystallise and grow together in the rock. They were cemented together.
- The rock may contain fossils, such as shells. Dead organisms sometimes sink into sediments, especially in water, become covered by them, and are preserved in the rock.

These characteristics are summarised in Figure 8.3.5.

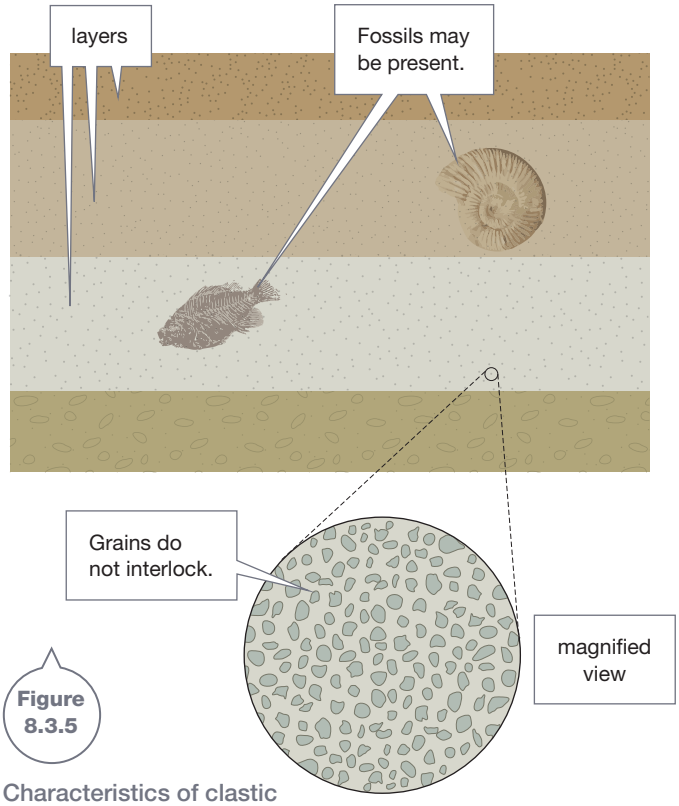



**Figure 8.3.5** Characteristics of clastic sedimentary rocks

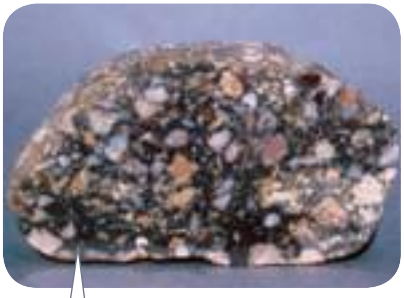
Clastic sedimentary rocks are classified mainly according to the size and nature of the rock grains and the chemical composition of the cement. You can see some in the photos in Figure 8.3.6.



**Conglomerate**
Large rounded rocks cemented between grains that are often microscopic



**Mudstone**
Particles often microscopic, very soft rock

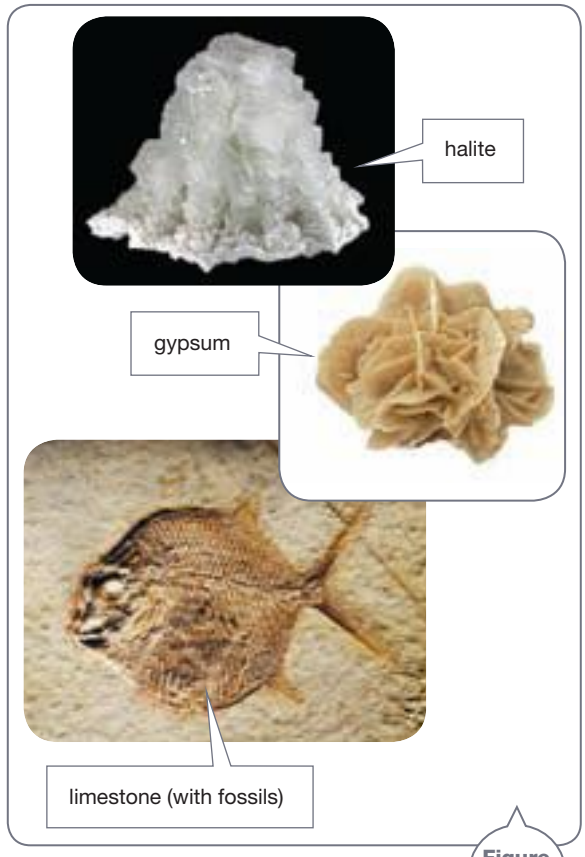


**Breccia**
Similar to conglomerate but lumps are sharp–edged



**Sandstone**
Particles of sand, usually harder than mudstone

**Figure 8.3.6** Four different clastic sedimentary rocks




Chemical sedimentary rocks **Figure 8.3.7**

## Organic sedimentary rocks

Organic sedimentary rocks can be layered, depending on the way in which the fossils and sediments are deposited. They are usually soft, although a few such as chert (also called flint) can be fairly hard. Some examples are shown in Figure 8.3.8.

2 p304 8.5

## Chemical sedimentary rocks

Most chemical sedimentary rocks have crystals in them. Chemical sedimentary rocks are quite soft, and this helps to distinguish them from the much harder igneous rocks. It is rare to see any layering in chemical sedimentary rocks. Occasionally some contain fossils, but only as a small proportion of the rock. Figure 8.3.7 shows some types of these rocks.




**Figure 8.3.8** Organic sedimentary rocks

# Uses of sedimentary rocks

Sedimentary rocks have many uses because there are so many types with lots of different properties. The rock used in your area will depend on what stone occurs naturally near you. For example, sandstone is common in New South Wales, while limestone is widely available in Western Australia.

Limestone is often used in garden walls and paving such as that in Figure 8.3.9. It once was widely used in buildings (Figure 8.3.10), but is not used as much now because it weathers very quickly. It can also be used as a base for roads.



**Figure 8.3.9** Limestone paving is often used around pools.

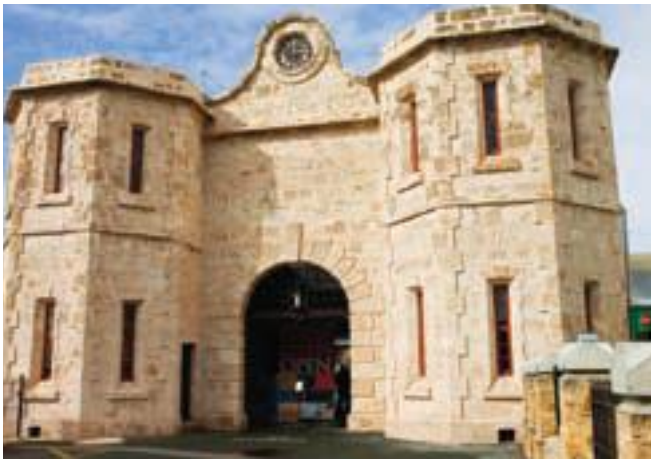


**Figure 8.3.10** Limestone was once often used in buildings such as the Fremantle Prison in Western Australia.

Sandstone was often used in buildings in the early years of European settlement of Australia, particularly in Sydney. One is shown in Figure 8.3.11. Sandstone is more resistant to weathering than limestone but is still soft enough to cut easily and to carve. This means it is suitable for decorative ornaments. Sandstone is still used in external and internal walls, foundations and paving.



**Figure 8.3.11** This government building in Sydney was built from sandstone in 1880.

In industry, sedimentary rock is used in many ways.

- Limestone is used in making cement, glass and steel.
- Sandstone is also used in making glass.
- Gypsum is used to make plaster.
- Rock phosphate (formed from ancient bird droppings) is used to make phosphate fertilisers.
- Coal (an organic sedimentary rock) is used for energy supply.

Some sedimentary rocks are used as a source of minerals, rather than the rock itself being used. Haematite is a mineral found in rocks and is a source of iron. Bauxite in rocks is a source of aluminium.

# 8.3 Unit review

## Remembering

1 **Name** the three main types of sedimentary rock.

2 **List** natural cements found in clastic sedimentary rocks.

3 **State** the general characteristics of clastic sedimentary rocks.

4 **List** five sedimentary rocks and their uses.

## Understanding

5 **Explain** how pressure from overlying sediments contributes to the formation of clastic sedimentary rocks.

6 **Explain** the reasons for the general characteristics of clastic sedimentary rocks.

## Applying

7 **Use** your knowledge of chemical sedimentary rocks to **explain** how they may form in a salt lake.

## Analysing

8 **Contrast** a breccia and a conglomerate.

9 Igneous rocks and chemical sedimentary rocks often have crystals in them. **Distinguish** between them.

10 **Classify** each of the following sedimentary rocks as clastic, chemical or organic.

- a mudstone
- b coal
- c chalk
- d gypsum
- e sandstone

11 Consider the following two facts about sedimentary rocks.

- Oil, gas and coal are only found in sedimentary rocks.
- Rock sediments contain fossil pollen grains from ancient plants now long extinct but that were common in the time that oil began forming.

**Analyse** these statements and **explain** how they may be used by geologists searching for oil, gas or coal.

## Evaluating

12 Early colonial settlers in Australia built most of their houses from wood rather than stone. The stone buildings they did construct were often made from sedimentary rocks such as sandstone or limestone. The stone buildings lasted longer than the wooden ones, but some of these early stone buildings are badly in need of repair. **Propose** reasons for these observations.

## Creating

13 **Construct** a table summarising the formation and characteristics of the three different types of sedimentary rocks.

## Inquiring

1 Research how plaster of Paris and Portland cement are made, and how they relate to sedimentary rocks.

2 Early colonial settlers in Australia burnt oyster shells to make building mortar. Research why this was done, what a mortar is, and how the shell mortar worked.

3 Chemical sedimentary rocks often form in caves. Stalactites and stalagmites can be found in limestone caves. Research on the internet and explain how stalactites and stalagmites form.

4 Design an experiment to test out the strength of different proportions of Portland cement and bricklayers' sand mix as recommended on a bag of cement for various tasks. Ask your teacher if you can try the experiment, and then determine the strongest mix and compare it with the information on the bag.



# 8.3 Practical activities

## 1 Making sedimentary rocks

### Purpose

To investigate what factors affect the strength of an artificial sedimentary rock.

### Materials

- gravel (about 5 mm diameter) and bricklayers' sand mix
- blue metal (similar size to gravel) and bricklayers' sand mix
- bricklayers' sand
- plaster of Paris
- Portland cement
- ice-cream container
- 4 margarine containers
- spoon or spatula
- setting box (see Figure 8.3.12)
- water
- 250 mL plastic beaker with volume scale
- G-clamp
- 6×500 g mass sets
- wire 15cm long by 1.5mm thick
- old towels or foam rubber
- slops bucket at front of class



**SAFETY**

Do not mix cement or plaster of Paris with your hands. They can damage your skin.

Wear rubber gloves and safety glasses at all times.



### Procedure

1. Each team in the class will be given one cement type (either Portland cement or plaster of Paris). Collect about 150 mL of your cement. Obtain about 100 mL of each of the three particle sizes in separate margarine containers.
2. For each margarine container, add 50 mL of your cement type. Mix with the spatula or spoon while dry. Slowly add water a little at a time while mixing until the particles are wet and stick together well. The mix should be like whipped cream rather than 'runny' like milk.
3. Transfer each cement–particle mix to a different section of the setting box. Label which is which. Leave the mixtures aside to dry for two days.

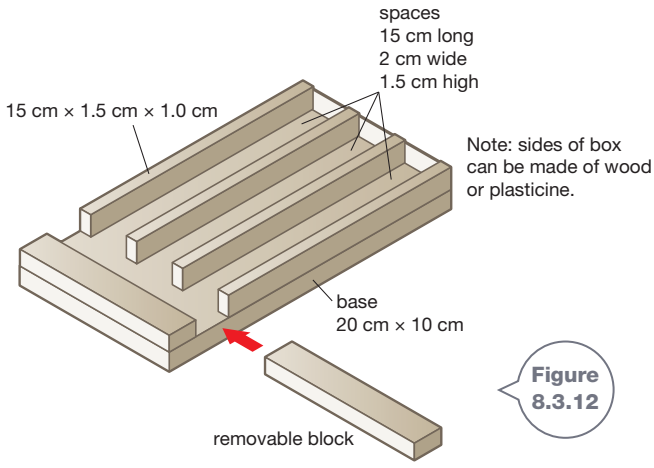



Figure 8.3.12

4. When your sedimentary 'rocks' are dry, remove them from the setting box.
5. Clamp one end of your rock to the edge of the bench, allowing about 8 cm to project over the edge. Loop the wire over the centre of the rock and attach the weight holder. Place the towels underneath to catch any weights that fall.
6. Add masses 100 g at a time until the 'rock' breaks. Make sure the rocks don't fall onto your feet. Copy the two tables shown below and enter your results in your Team results table.

### Results

1. Record your team's results onto the class results table on the board.
2. Copy the class results into your workbook when all teams have entered their results.

**Team results**

| Particle size | Mass added to 'rock' to just break it (g) |
|---|---|
| Gravel/sand | |
| Blue metal/sand | |
| Sand | |

**Class results: Average mass held before breaking (g)**

| Cement type | Particle size | | |
|---|---|---|---|
| | Gravel/ sand | Blue metal/ sand | Sand |
| Plaster of Paris | | | |
| Portland cement | | | |

Making sedimentary rocks continued on next page

Making sedimentary rocks continued

### Discussion

1 a Considering only your team results, **assess** which rock was strongest and which was weakest.

b **Justify** your decision.

2 a Considering the class results, **assess** which rock was strongest and which the weakest.

b **Justify** your decision.

3 Portland cement and plaster of Paris both come from natural cements found in sedimentary rocks. Portland cement is used in making concrete and mortar for brick walls in buildings. Plaster is used to cover walls, fix decorative edges on ceilings, and make lightweight panels for inside walls on houses. **Explain** how this experiment relates to these building uses.

## 2 Observing sedimentary rocks

### Purpose

To observe and describe different sedimentary rocks.

### Materials

- stereo microscope and/or hand lens
- numbered set of sedimentary rocks such as breccia, conglomerate, sandstone, limestone, coal, shale, mudstone, rock salt and gypsum

### Procedure

1 Choose a rock and write down its number. In a table like that shown on the right, write a brief description of what it looks like. (This is called a macroscopic view.) Note features such as colour, texture, layering and fossils.

2 Now take a microscopic view of the rock by viewing it with the microscope or hand lens. Try to determine if any grains are present. Note any grain colours, size and shape. Draw some grains.

3 Try to classify your rock into one of the three types of sedimentary rocks. Then give your rock a name.

4 Repeat with the next rock until you have examined them all.

### Results

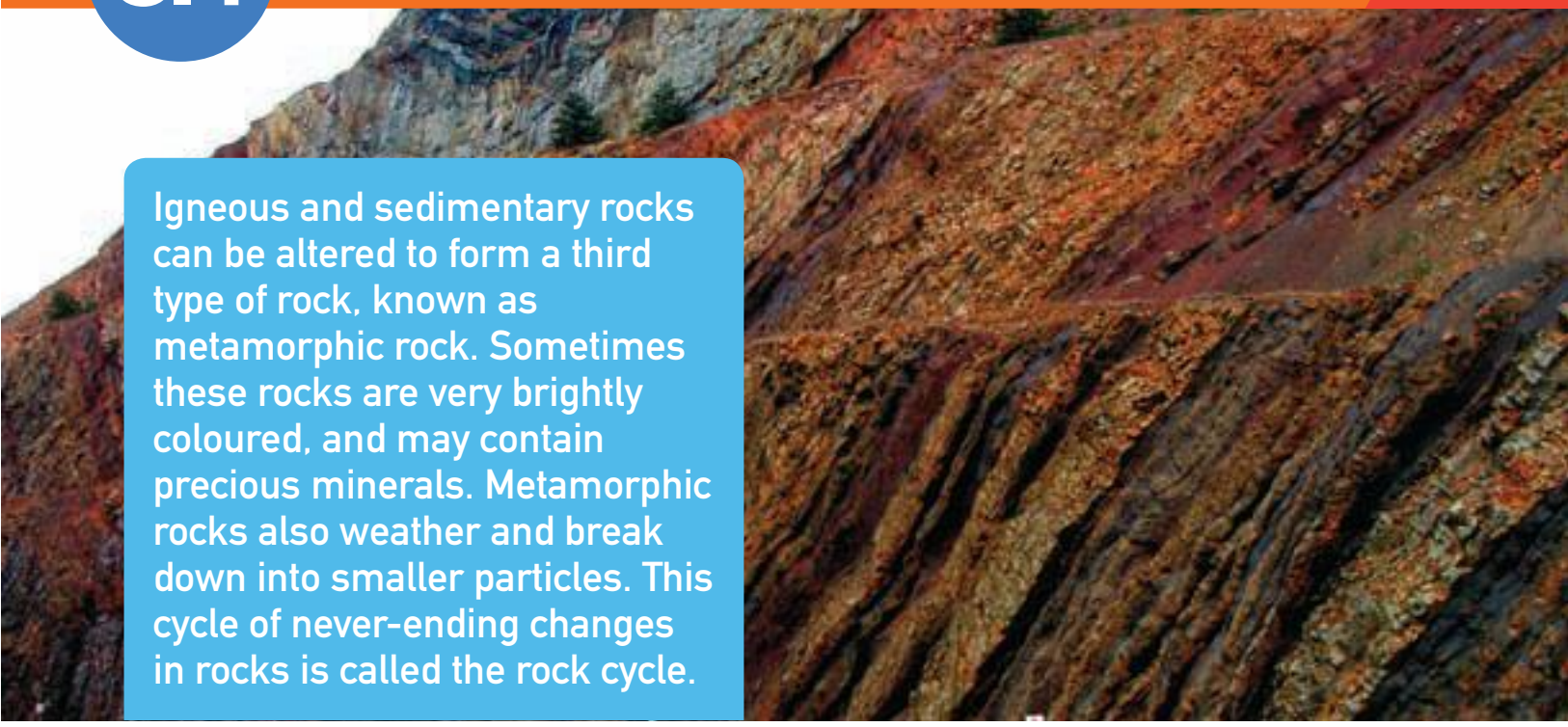
In your workbook, construct a table like the one shown below.

| Rock number | Macroscopic view | Microscopic view | Classification |
|---|---|---|---|
| | | | |
| | | | |

### Discussion

**Justify** your classification of each rock.

# 8.4 Metamorphic rocks



Igneous and sedimentary rocks can be altered to form a third type of rock, known as metamorphic rock. Sometimes these rocks are very brightly coloured, and may contain precious minerals. Metamorphic rocks also weather and break down into smaller particles. This cycle of never-ending changes in rocks is called the rock cycle.

INQUIRY science 4 fun

## Fire a rock

What happens to clay if you heat it?

**Collect this …**

- modelling clay
- ice-cream container
- spatula




**Do this …**

1. Make two identical models with your clay. Put one in a sunny place and take the other to the Art department to be fired in a kiln.
2. When the fired clay model is ready, compare it with the one that you left in the sunshine by trying to break a piece off each. See how strong the two pieces of clay are.

**Record this …**

**Describe** what happened.
**Explain** why you think this happened.

## Formation of metamorphic rock

Metamorphic means that the rock has changed form. **Metamorphic rocks** form when high temperature and pressure alter existing igneous and sedimentary rocks. Metamorphic rocks can also be formed from other metamorphic rocks.

Rock changes into metamorphic form when it experiences intense heat and extreme pressure. These changes can be physical or chemical, and include the formation of new minerals not seen in igneous or sedimentary rocks. For example, garnets (Figure 8.4.1) and the precious gems sapphire and ruby occur in metamorphic rocks.

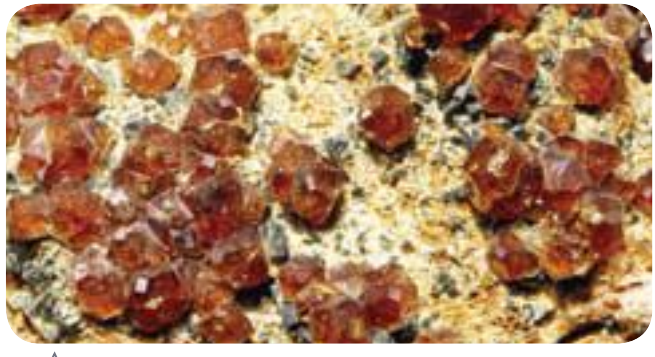


Figure 8.4.1 Garnets are semiprecious stones that can form in metamorphic rocks.

## Types of metamorphism

Metamorphic rocks can be formed deep beneath the Earth's surface, where the pressure is very high. The great weight of the rock above means the pressure can be thousands of times greater than the pressure of the atmosphere at the Earth's surface. Pressure alone may be enough to alter some rocks.

It also gets much hotter as you go deeper and deeper into the Earth's crust and mantle. The temperatures may be hundreds to thousands of degrees. Heat alone can alter rocks. This suggests that most of the lower part of the Earth's crust is probably made of metamorphic rock.

Extreme heat and pressure can also be caused by movements within the Earth's crust. The crust is broken into massive plates larger than continents, called **tectonic plates**. These move around on the mantle, and can collide and scrape past each other, and are heated up and compressed in the process. Some parts of the crust may sink down under other parts.

Metamorphism over a wide area as described above is called **regional metamorphism**.

A second type of metamorphism occurs in rocks that come in contact with hot magma as it pushes through the mantle and crust. This type is called **contact metamorphism** and it occurs in particular local places on a much smaller scale than regional metamorphism. It means that metamorphic rocks can also form in the crust near the surface. The sites for metamorphism are shown in Figure 8.4.2.

## Metamorphic changes

Heat and pressure can melt rock, causing a process called recrystallisation when new crystals grow as the rock cools down. When the rock is molten the particles can move around, and new minerals form in this process. That is why metamorphic rocks have many different minerals compared with igneous rocks.

**SciFile**

### Lapis lazuli

Lapis lazuli is beautiful blue rock formed by contact metamorphism. In ancient Egypt it was used in jewellery and ornaments such as the necklace in Figure 8.4.3.

**Figure 8.4.3**

This ancient Egyptian necklace is made of lapis lazuli, gold and another metamorphic rock called turquoise.

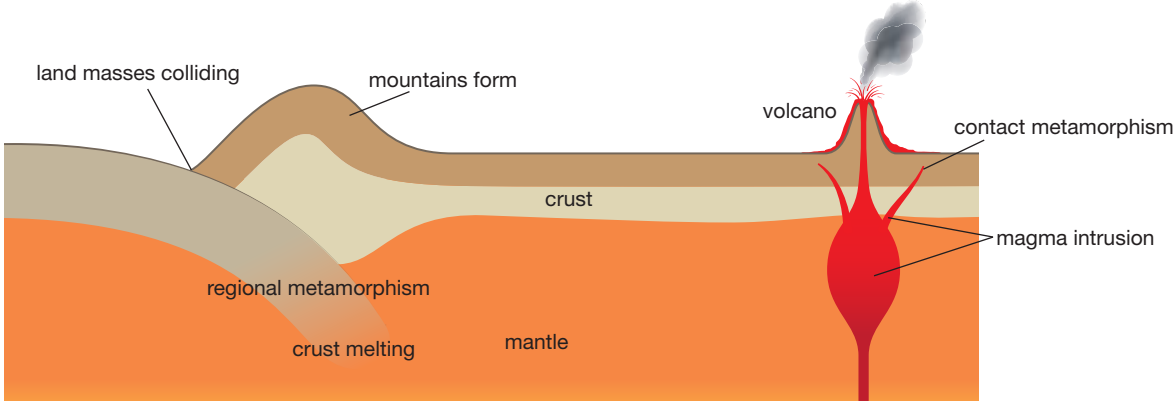


Diamonds can be formed in metamorphic rock when parts of the crust become pushed into the mantle. The crust sinks to depths of over 150 kilometres, where the high temperature and pressure change the rock. At temperatures of about a thousand degrees, the carbon in the rocks can crystallise to form diamonds. The diamonds are carried back up to the surface millions of years later by rising magma. This magma then solidifies, meaning that diamonds are found in igneous rocks, even though they were not formed there.

Another metamorphic change is in the texture of the rock. Minerals in these rocks can become squashed into layers. Minerals forming under pressure may become squashed flat or into long needle shapes. The rock may then develop layers or bands in a process called **foliation**. The amount of banding depends on the amount of heat and pressure.

**Figure 8.4.2**

Metamorphic rocks form in two main ways.



The bands in a rock are not always straight. Pressure can squash and crumple them, causing the bands to be wavy. You can see this in Figure 8.4.4.




**Figure 8.4.4** Some metamorphic rocks

Not all metamorphic rocks show bands. Metamorphic rocks without bands are known as non-foliated or unbanded. You can see some of the more common unbanded metamorphic rocks in Figure 8.4.6.

1 p310




**Figure 8.4.6** Unbanded (non-foliated) metamorphic rocks

## Big diamond

SciFile

The Cullinan diamond is the largest gem-quality diamond ever found. It was found in South Africa and with a mass of over 600 grams, the Cullinan diamond was cut into nine gems, the biggest of which are the Great Star of Africa (Figure 8.4.5) and the Cullinan II.

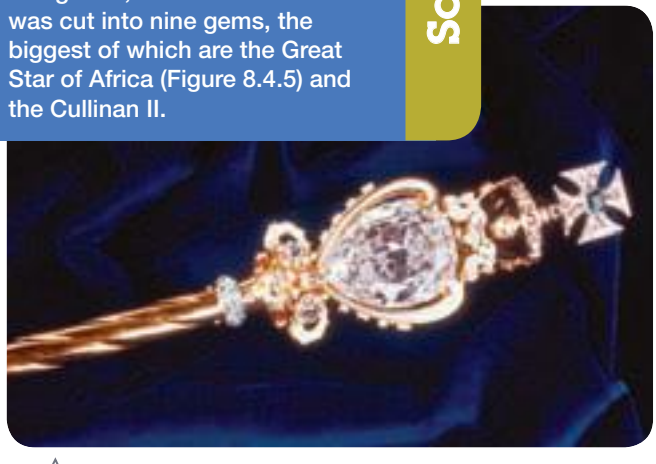


**Figure 8.4.5** The Great Star of Africa (or Cullinan I) is part of the British Crown Jewels

# Uses of metamorphic rocks

Metamorphic rocks are used for a variety of purposes. Some are shown in Figure 8.4.7 on page 308. Many metamorphic rocks are very hard and suited for building work. Gneiss and quartzite are good examples. Slate splits into flat sheets and is used for floors and roofing.

Many gemstones are found in metamorphic rocks, such as ruby, sapphire, turquoise, lapis lazuli, jade and garnet. These are all used in jewellery. Garnets are also used in abrasives. Diamonds are used as gemstones in jewellery and also on blades for power saws because they are the hardest natural substance. Diamond drill bits are used to cut through rock in oil exploration.

One widely used metamorphic rock is marble, which is used in sculptures because it is easily cut and carved. Marble is also used in building for walls and floors.

Quartzite is used in making glass because it has a high content of silica.

8.6



Slate is used for roofing.



Marble is used for building and sculpture.

Quartzite is used for stone tools.



**Figure 8.4.7** Metamorphic rocks are hard and beautiful, making them useful in buildings, sculptures and industry.

# The rock cycle

The **rock cycle** is a model geologists use to explain the endless cycle of change that rocks undergo. Figure 8.4.8 shows how it works. Rocks do not always stay the same after they are formed. Weathering breaks them continually down into smaller pieces. These pieces are then carried away by agents of erosion (water, wind and ice). The pieces can be deposited as sediments and re-form into sedimentary rocks. Any rock can also be melted by magma and turned into a metamorphic rock. All these changes are part of the process called the rock cycle.

2 p310

8.7

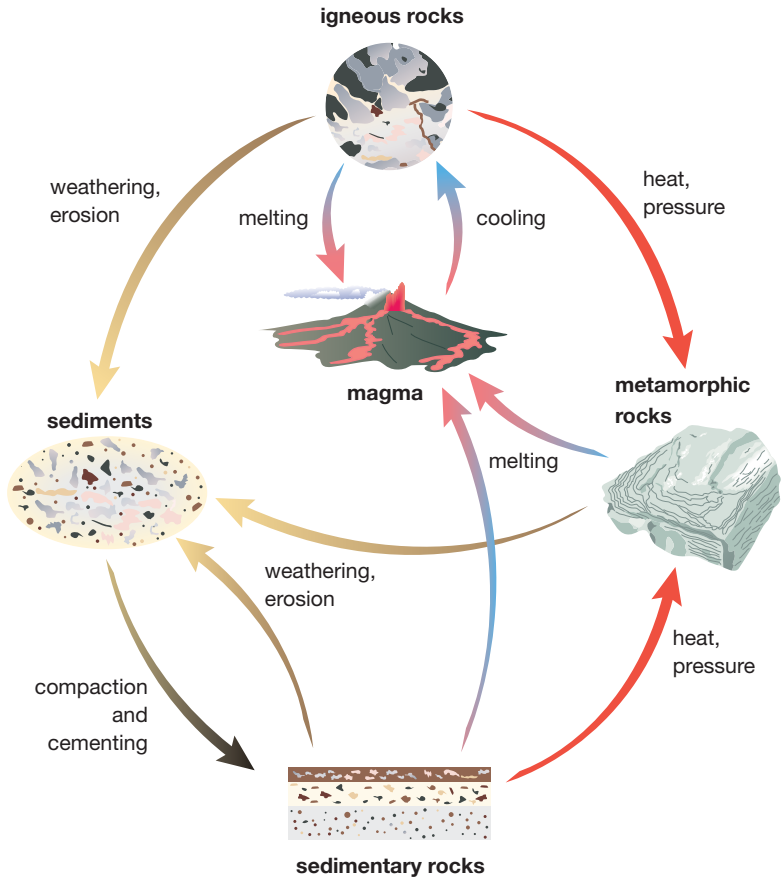



**Figure 8.4.8** All the rocks of the Earth are part of the rock cycle.

# 8.4 Unit review

## Remembering

1 **State** where metamorphic rocks form.

2 **List** the two main factors involved in forming metamorphic rock.

3 **State** the types of change that occur in rocks as they become metamorphic rock.

4 **Name** the model geologists use to explain the changes in rocks from one type to another.

## Understanding

5 **Outline** the factors that affect the pressure acting on a metamorphic rock as it forms.

6 A cycle is something that returns to its starting point. **Explain** why the rock cycle is called a cycle.

7 **Explain** what occurs to turn a rock into a foliate (banded) rock.

8 **Explain** how heat energy and force are important in the formation of metamorphic rock.

- a **Name** the type of metamorphic process that forms lapis lazuli.
- b **Outline** how this happens.

## Applying

9 It would be possible for metamorphic rocks to form at the Earth's surface. **Propose** how this might happen.

10 **Identify** what feature of a sedimentary rock would help you decide that it formed from weathering of a metamorphic rock.

## Analysing

11 Consider the following description of a rock.

*It is a light-coloured rock with white and grey crystals visible. The grains seem to be interlocking. It looks a bit like granite, but there are five wavy darker bands running right through the rock. The grains in the bands look like they are black or dark green. They seem to be very flat under the microscope, and fracture easily when they are squeezed by a needle. The flat dark crystals seem to be all lined up.*

- a **Classify** this rock as foliate (banded) or non-foliate.
- b This rock is called a granite gneiss. **Identify** the feature that gives you a clue that this is a metamorphic rock.
- c **Contrast** this rock with granite, from which it was formed.

## Evaluating

12 From the information in Question 11, **justify** your decisions by explaining how the rock probably formed.

13 Sometimes shale can turn into slate. Other times it may turn into schist. On other occasions again it can become another rock type called phyllite. **Propose** ways in which three different rocks could form from shale.

## Creating

14 **Design** a rock cycle poster. Include on it diagrams or photos of some actual rock types. Include brief outlines of the process that formed each rock.

## Inquiring

1 Lake Argyle Mine in Western Australia used to be the largest diamond mine in the world, but the diamonds are running out in this mine. Research how diamonds form and how diamond miners in Australia are searching for new sources of diamonds.

2 Research an Australian landform such as Uluru, the Olgas, the Warrumbungles or a different one if you prefer. Discuss the geological history of its formation. Include local Aboriginal views on the landform, and why it is an important area.

3 Research how Aboriginal Australians skilfully used rocks to make stone tools. Describe the types of rocks used and the process by which the tools were made by 'knapping' rocks together and by flaking with sticks.

4 Research and compare how long it takes for igneous, sedimentary and metamorphic rocks to form. Relate the time taken for formation of these rocks to processes such as weathering and erosion that are involved in their formation. A rock cycle diagram may assist you.

# 8.4 Practical activities

## 1 Metamorphic rocks

### Purpose
To observe metamorphic rocks and compare them with their parent igneous and sedimentary rocks.

### Materials
- labelled rock samples in containers: limestone and marble, shale and slate, shale and schist, granite and gneiss, sandstone and quartzite
- stereo microscope
- hand lens

### Procedure
1. Use the microscope and hand lens to examine the rock samples.
2. Use the information in this chapter and any other information available to you to match each metamorphic rock to its parent rock.
3. For each pair of rocks, write the name of the parent rock first and describe its characteristics. Then do the same for the metamorphic rock.

### Discussion
1. For each metamorphic rock, **describe** the characteristics that enable you to decide it is metamorphic.
2. **Explain** the changes that have occurred in each metamorphic rock as it altered from its parent rock.

## 2 Revising rocks

### Purpose
To identify unknown rock samples as igneous, sedimentary or metamorphic and revise the characteristics of each group of rocks.

### Materials
- numbered but unlabelled rock samples
- stereo microscope
- hand lens

### Procedure
1. Choose a numbered rock sample. Your first task is to describe the characteristics of the rock. Use your microscope and hand lens to take a clear look. Then decide if it is igneous, sedimentary or metamorphic, recording your reasons in a table like the one in the results section. You may need to check the earlier units in this chapter again to remind you. If you feel confident, try to name the rock.
2. Repeat step 1 for each rock.

### Results
In your workbook, construct a table like the one shown below.

| Rock number | Descri-ption | Classif-ication | Reasons | Rock name |
|---|---|---|---|---|
| | | | | |
| | | | | |

### Discussion
1. **State** the characteristic features of each of the main rock types: igneous, sedimentary and metamorphic.
2. **Explain** how the rock cycle is relevant to this practical activity.

# 8 Chapter review

## Remembering

1 **Recall** how each of the main types of rocks form by matching them with the best descriptions below.

| | |
|---|---|
| igneous | layers |
| sedimentary | change |
| metamorphic | volcanoes |

2 **Name** two igneous rocks that are:
- **a** intrusive
- **b** extrusive
- **c** dark-coloured.

3 **Name** two igneous rocks in which you cannot see crystals.

4 **Name** an igneous rock that is light enough to float in water and has holes in it.

5 **List** the general characteristics of igneous rocks.

6 **Name** two sedimentary rocks that are:
- **a** clastic
- **b** chemical
- **c** organic.

7 **Name** three metamorphic rocks that are:
- **a** foliated (banded)
- **b** non-foliated.

8 Choose three igneous, three metamorphic and three sedimentary rocks and **state** a use for each rock.

## Understanding

9 **Define** the term *geology*.

10 **Explain** the difference in crystal sizes of intrusive and extrusive igneous rocks.

11 **Outline** the weathering processes that act on rocks.

12 **Describe** the process of sedimentation.

13 **Outline** the formation of clastic sedimentary rocks.

## Applying

14 Choose three igneous rocks that have extreme differences in their appearance and **use** your knowledge of igneous rock formation to **explain** why they are like they are.

15 Choose three sedimentary rocks that have extreme differences in their appearance and **use** your knowledge of sedimentary rock formation to **explain** why they are like they are.

## Analysing

16 **Compare** the formation of igneous, sedimentary and metamorphic rocks.

17 **Contrast** foliated (banded) and non-foliated metamorphic rocks.

## Evaluating

18 Imagine you had to use rocks to build an important city office building that would last for generations into the future.
- **a** **Identify** suitable rocks for the walls, floor and roof.
- **b** **Justify** your choices.

19 **Propose** a reason why it is unwise to plant trees too close to a house.

## Creating

20 **a** **Construct** a diagram of the rock cycle

**b** **Explain** why it is a useful model in geology.

21 **Construct** a set of four cards. On each card, describe a type of rock without using its name. Write each rock on the back of the cards and swap with a partner. See if you can work out what rock each is without looking at the answer.

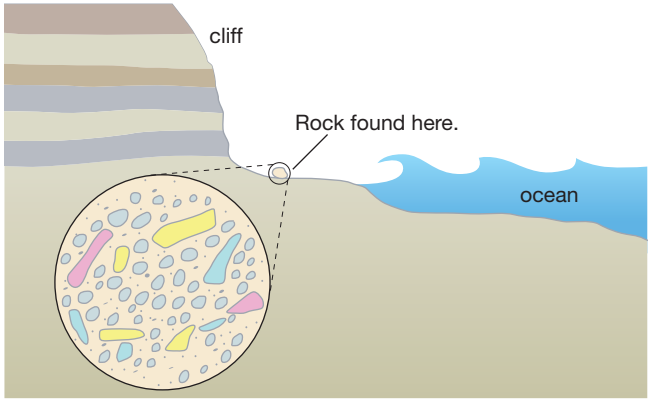
22 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

rock cycle
sedimentary
igneous
metamorphic
weathering
erosion
sedimentation
crystals
soil
magma



# Thinking scientifically

Questions 1 and 2 refer to the following information.




**Q1** Clastic sedimentary rocks have the following characteristics.

- They have layers.
- The grains do not interlock because they were cemented together.
- They may contain fossils.

Which of the following is a good reason to classify the rock in the diagram as a clastic sedimentary rock?

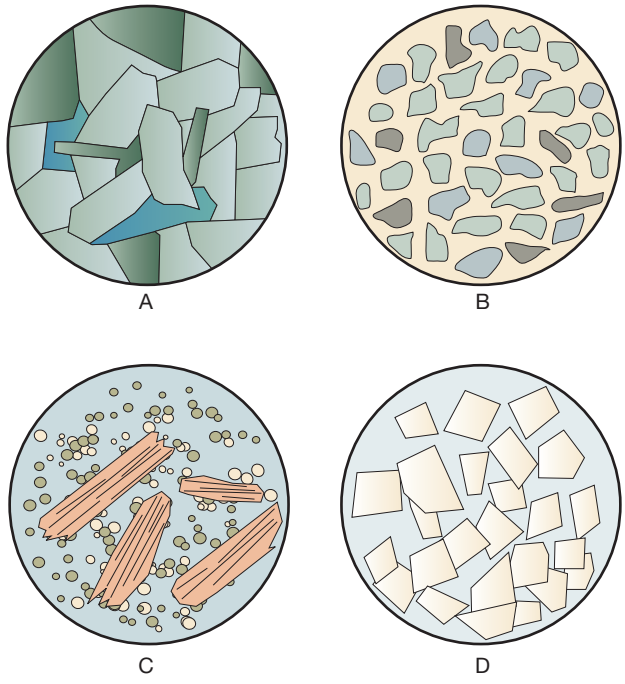
**A** The rock has layers in it.
**B** The grains are not interlocking.
**C** The crystals are large.
**D** There are no fossils in it.

**Q2** Grains in a sedimentary rock may have travelled a long way or a short way from the parent rock before they formed the sedimentary rock. Some rocks contain all rounded grains (like little balls) that are all about the same size. These grains have travelled the furthest before being cemented into the rock. Other rocks have grains with sharp edges and grains of many different sizes. These grains have not travelled very far before being cemented into the rock.

Which of the following would probably be true for the rock found in the diagram above, based on the following information? It was shown to be identical to the rocks in the top layer of the cliff.

**A** The rock formed from grains that have travelled a long way from their parent rock.
**B** The grains are similar in size and therefore they were carried a short distance.
**C** The grains indicate the rock formed from sediments in the rock cliff.
**D** The rock was formed from parent rocks that were fairly close to the rock cliff.

Questions 3 and 4 refer to the following diagrams of rocks.




**Q3** Choose the correct statement in the following.

**A** Rock A is igneous because the grains are interlocking.
**B** Rock B is igneous because the grains are angular.
**C** Rock C is an igneous porphyry because it is a mixture of large and small crystals.
**D** Rock D is metamorphic because the crystals are large and all the same size.

**Q4** In the diagram, the rocks most likely to be sedimentary are:

**A** A and B
**B** A and D
**C** C and D
**D** B and C.

# Glossary

## Unit 8.1

**Crystal:** solid that has a variety of special shapes

**Extrusive igneous rocks:** igneous rocks that form on the surface of the Earth

**Geology:** the study of rocks, their history and the processes that form and change them

**Igneous rocks:** rocks formed from cooling magma

**Interlocking crystals:** crystals that lock together and grow into each other in a rock

**Intrusive igneous rocks:** igneous rocks that form below the surface of the Earth

**Lava:** molten rock reaching the Earth's surface

**Magma:** molten rock that does not reach the Earth's surface



Interlocking crystals

**Mantle:** layer of the Earth below the crust

**Minerals:** chemical substances found in rocks

## Unit 8.2

**Acid rain:** rain water that includes acids from pollution in the air

**Agents of erosion:** factors that cause erosion—water, wind and ice

**Chemical weathering:** water or chemicals in the water and air reacting and breaking down rock

**Consistency:** the tendency of soil particles to stick together

**Erosion:** removal of weathered rock particles away from the site of the weathering

**Permeability:** a measure of how fast water enters the soil

**Physical weathering:** breakdown of rocks by physical processes

**Pore spaces:** the amount of space in the soil that could be filled with air or water



Physical weathering

**Sedimentation:** the process of water or wind depositing eroded rock particles

**Structure:** how well the soil particles join up to form lumps

**Texture:** the size of the particles that make up soil

**Water-holding capacity:** measure of how much water a particular amount of soil can hold

**Weathering:** the physical and chemical processes that break rocks down into smaller pieces

## Unit 8.3

**Chemical sedimentary rocks:** sedimentary rocks that form when dissolved materials precipitate from solution

**Clastic sedimentary rocks:** sedimentary rocks made from weathered sediments of other rocks

**Fossils:** preserved remains of living organisms

**Natural cements:** chemicals that can flow around sediments in water and then set like cement

**Organic sedimentary rocks:** rocks that form by the accumulation of plant or animal debris, which is then cemented together

**Sedimentary rocks:** rocks made by sediments being cemented together

## Unit 8.4

**Contact metamorphism:** metamorphism by contact with hot magma as it pushes through the mantle and crust

**Foliation:** process where minerals under pressure become squashed flat and the rock develops layers or bands

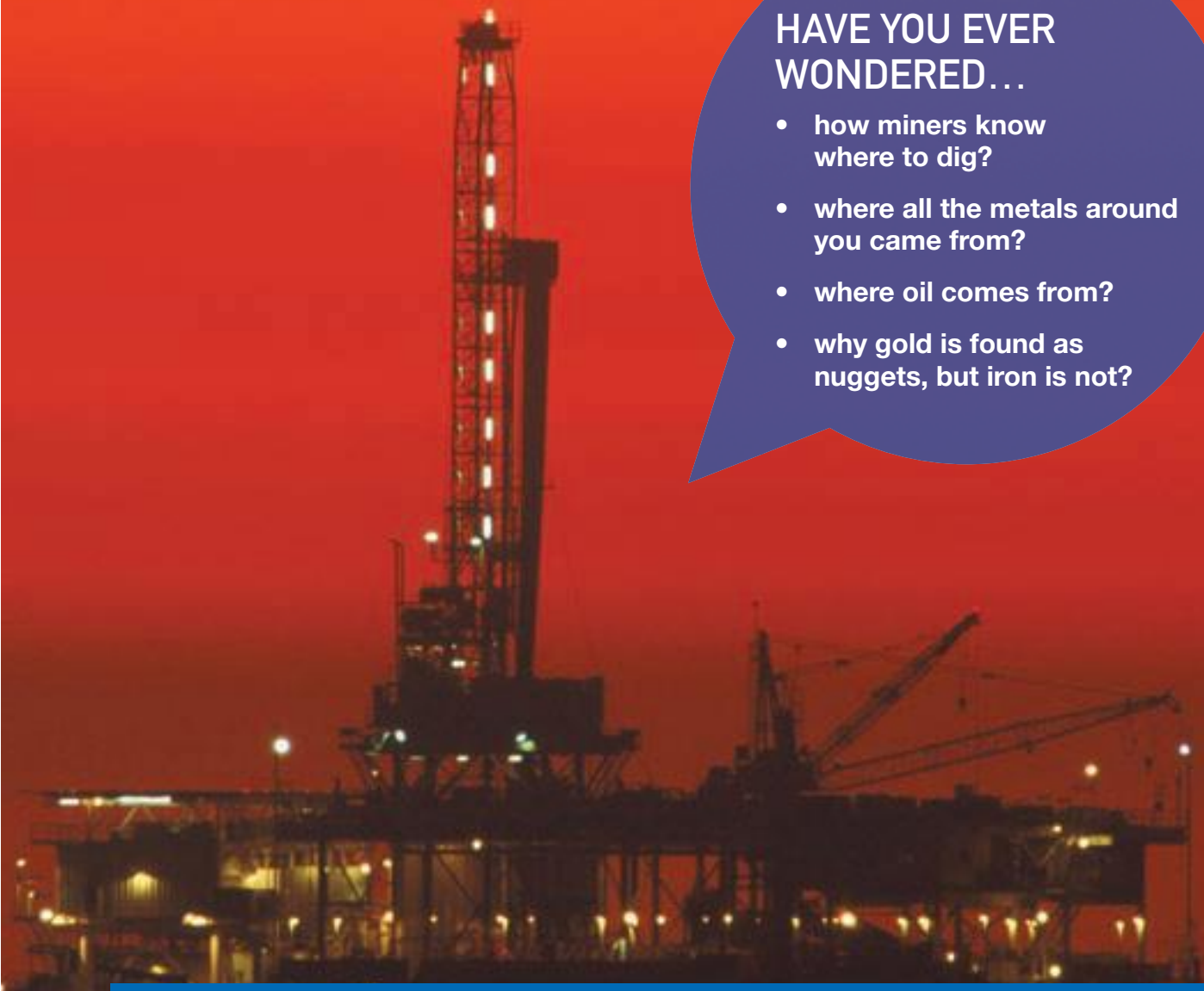
**Metamorphic rocks:** rocks formed when high temperature and pressure alter existing rocks

**Regional metamorphism:** metamorphism over a wide area below the crust caused by huge movements of the Earth's crust

**Rock cycle:** model geologists use to explain the endless cycle of change that rocks undergo as they change from one form to the other

**Tectonic plates:** massive plates that make up the Earth's crust

# 9 Exploration and mining



## HAVE YOU EVER WONDERED…

- how miners know where to dig?
- where all the metals around you came from?
- where oil comes from?
- why gold is found as nuggets, but iron is not?

**After completing this chapter students should be able to:**

- recall that rocks are a collection of different minerals
- recall that some rocks and minerals, such as ores, provide valuable resources
- describe how the location and extraction of mineral resources relies on expertise from across the disciplines of science
- outline the role of forces and energy in the formation of different types of rocks and minerals
- outline strategies implemented to maintain the environment
- describe how knowledge of the environment and ecosystems is important in a number of occupations.

# 9.1 Resources in the rocks

This gold nugget was found in Western Australia's goldfields in 1995 and has a mass of 25.5 kg! It is one of the largest nuggets ever found. There are many other valuable things that come from the Earth, such as oil. Without oil, there would be no petrol or plastics. Materials from the Earth are very important to Australia's economy.

## Resources and the economy

Humans have been digging up substances and using them for their own purposes for thousands of years. These substances are generally known as resources. Some, such as gold, only need a little cleaning before they can be used. Likewise, most coal can be used straight away with little or no processing. Other resources, such as iron and aluminium, are not found in their pure, element state but are found as compounds such as iron oxide and aluminium oxide. The pure metals then need to be extracted from these compounds. Oil is a mixture of chemical compounds and it too needs to be processed. The processing of oil separates it into its components of petrol, aviation fuel, diesel, kerosene and bitumen.

Resources can be classified as:

- minerals
- petroleum (oil and natural gas)
- coal.



Figure 9.1.1

These ships are loading up with iron ore from the Pilbara region of Western Australia.

The importance of resources to the Australian economy varies greatly as economic conditions in the world change. At present, mining and petroleum contribute about 5.6% of the value of goods and services made in Australia in a year. This is the highest amount for any developed country in the world. Minerals, coal and petroleum exports currently contribute around 35% of Australia's exports.

Australia is among the world's largest exporters of coal, iron ore (like that being loaded in Figure 9.1.1 on page 315), lead, diamonds, rutile, zinc, zirconium, gold, uranium and aluminium. Australia is a significant exporter of titanium, nickel, copper, tin and silver. Our natural gas production is also increasing greatly. Australia's position in the world as a supplier of various minerals, coal and petroleum varies as mines and wells open and close. This is affected by changing mineral prices and the 'life' of the mine or well. Mines and wells only continue while they are profitable or until the mineral or petroleum is used up.

# Minerals

Rocks are made up of chemical substances called minerals. A **mineral** is a naturally occurring liquid or solid in the Earth's crust, but oil, coal or natural gas are not minerals. While some minerals are pure elements such as gold and silver, most minerals are chemical compounds made up of different elements. Examples are iron oxide, copper sulfide and aluminium oxide. Other examples are shown in Table 9.1.1.

The rocks containing these minerals are known as **ores**. For example, copper is found in copper ore. Three types of copper ores are shown in Figure 9.1.2

**Figure 9.1.2** 'Native copper' is found as pure copper. More commonly, copper is found as an ore. Three copper ores are bornite, azurite and malachite.



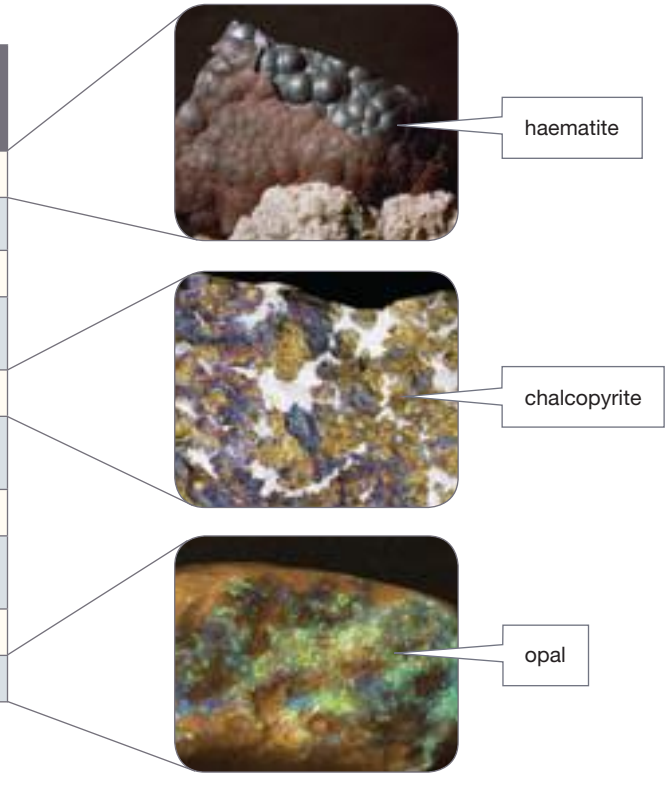

Sometimes the whole mineral is extracted from the ore and used. For example, the mineral titanium oxide can be:

- used to colour paints white
- separated into titanium metal and oxygen. The titanium can then be used in making steel alloys.

At other times, the metallic element needs to be extracted from its compound within the ore.

**Table 9.1.1 Common minerals**

| Mineral | Chemical compound in mineral | Element, compound or material used |
|---|---|---|
| Haematite | Iron oxide | Iron |
| Bauxite | Aluminium oxide | Aluminium |
| Galena | Lead sulfide | Lead |
| Azurite | Copper carbonate | Copper and gemstones |
| Chalcopyrite | Copper sulfide | Copper |
| Rutile | Titanium oxide | Titanium oxide, or titanium |
| Cassiterite | Tin oxide | Tin |
| Chromite | Iron oxide and chromium oxide | Chromium |
| Pentlandite | Nickel sulfide | Nickel |
| Opal | Silicon oxide | Gemstones |



## Beauty in the rocks

SciFile

Some people collect rocks and minerals because of their beautiful crystal shapes and colours. A good sample of some rare minerals can be worth tens of thousands of dollars and gem shows are held regularly around the world for enthusiasts. Some geologists chose their career because they were attracted by the beauty in the rocks.



Figure 9.1.3

This rhodochrosite (manganese carbonate) sample is called 'The Alma Queen'. It is one of the most famous mineral samples ever discovered.

# Properties of minerals

The main physical properties used to identify minerals are:

- hardness
- lustre
- colour
- streak colour.

## Hardness

**Hardness** is assessed by comparing minerals using Mohs scale. The scale is given in Table 9.1.2. A set of minerals is used to try to scratch the surface of an unknown mineral to determine its hardness.

Table 9.1.2 Mohs hardness scale

| Hardness | Mineral |
|---|---|
| 1 | Talc |
| 2 | Gypsum |
| 3 | Calcite |
| 4 | Fluorite |
| 5 | Apatite |
| 6 | Feldspar |
| 7 | Quartz |
| 8 | Topaz |
| 9 | Corundum |
| 10 | Diamond |

Another way of testing for hardness is shown in Table 9.1.3. It uses a range of commonly available materials to compare hardness. This is useful as a rough guide if a geologist is in the field and does not have a set of minerals to perform a Mohs test.

Table 9.1.3 An alternative test for hardness

| Test object | Will scratch materials of hardness less than |
|---|---|
| Fingernail | 2.5 |
| Copper washer | 4 |
| Cast iron | 4.5 |
| Window glass | 5.5 |
| Steel knife or nail | 6 |



### Using Mohs scale

To determine the hardness of an unknown mineral, you need to try to scratch it with the different minerals or objects listed in Tables 9.1.2 and 9.1.3. If the unknown mineral can be scratched, then it must be softer than whatever you scratched it with. If you can scratch something with the unknown mineral, then the unknown mineral is harder.

### WORKED EXAMPLE
### Using Mohs scale

#### Problem 1

On testing, topaz scratched an unknown mineral, but feldspar did not. State the hardness of the unknown mineral and identify what the mineral could be.

#### Solution

Topaz must be harder than the unknown mineral, so the hardness of the unknown mineral is less than 8 on Mohs scale. The unknown mineral scratched feldspar, so it is harder than feldspar (6 on the scale). The unknown mineral therefore has a hardness of between 6 and 8. It might be quartz, but could also be another mineral with similar hardness to quartz.

#### Problem 2

An unknown mineral was tested by a geologist in the field. Window glass scratched the unknown mineral but the mineral scratched a lump of cast iron. State the approximate hardness of the unknown mineral and identify what it could be.

#### Solution

The unknown mineral's hardness lies between cast iron (4.5) and window glass (5.5). The mineral could be apatite (5 on Mohs scale).

## Lustre, colour and streak tests

The appearance of a mineral can give a good idea of what it might be. The way a mineral looks can be analysed in three ways.

- Colour is very useful when prospecting (looking) for minerals. For example, gold shows up as a yellowish colour in rock and soil.
- **Lustre** is how shiny a mineral is. Lustre can be useful when you are out prospecting for minerals. For example, gold has a bright shiny surface when clean or wet.
- **Streak** is the colour left behind when you try to scratch an unglazed white tile with the mineral. The streak is often different from the colour of the mineral itself. For example, iron pyrites (commonly known as 'fool's gold') looks very similar to real gold. They both have a similar golden colour. However, fool's gold has a greenish black streak, while real gold has a gold streak. A streak test is shown in Figure 9.1.4.

p324




**Figure 9.1.4** Haematite is the mineral form of iron oxide, which is found in much of Australia's iron ore. The red form and the black form both show a rust-red streak. This helps to show that they are the same mineral.

## Flame tests

**Flame tests** are chemical tests that provide another way of identifying a mineral. In these tests, minerals are ground into powders and heated to a high temperature in a flame. If the mineral is soluble, then it can be dissolved and squirted into the flame as a liquid instead. The mineral glows and gives the flame a characteristic colour that may be used to identify the mineral. Though many minerals have similar colour flames, a flame test may help distinguish between two samples when used with the other tests. You can see a flame test in Figure 9.1.5.



**Figure 9.1.5** Minerals glow in a flame, giving out a distinctive colour such as the crimson red of strontium.

INQUIRY science 4 fun

### Flaming minerals

No

Do minerals burn with the same colour flame?

#### Collect this…

- atomiser bottle
- samples of different minerals in solution
- Bunsen burner and bench mat
- matches
- safety glasses

#### Do this…

1. Go to one of the different stations around the room.
2. Squirt the solution found at the station into the blue Bunsen flame and observe the colour of the flame.
3. Repeat steps 1 and 2 for the remaining mineral samples in the room.

#### Record this…

**Describe** what you observed.

**Explain** how your results could be used to identify a mineral in an ore.

# Formation of minerals

Minerals are found in particular locations because they formed there or they were moved there after being formed somewhere else. How minerals form is the subject of much research because this knowledge helps mining companies locate large ore deposits called **ore bodies**.

Some minerals form by crystallisation of magma and are therefore found in igneous rocks. Other minerals form by metamorphic processes, when heat from magma and pressure melts existing rocks to form new ones.

Other minerals are found in sedimentary rocks. These form when solutions of the compound flow through rock and the minerals slowly crystallise as the water evaporates. This may happen in a cave, forming crystals like those in Figure 9.1.6. Stalagmites (which rise from the floor of caves) and stalactites (which hang from the ceiling of caves) of calcium carbonate form this way too. Crystallisation may also happen at the ground surface, such as in a salt lake where halite, gypsum and other chemical sedimentary rocks form. It can also happen inside other rocks or cracks in the rocks.



**Figure 9.1.6** These 11-metre-long crystals of selenite (calcium sulfate), the largest crystals ever discovered, formed from hot volcanic fluids inside the Naica Cave in Mexico.

## Iron ore

Most iron ores around the world were formed by sediments deposited on the sea floor. The deposits became banded iron formations. These bands of iron oxide occur in a pattern of alternating layers with other minerals in between.

Banded iron deposits can be lifted to the surface by movements in the Earth's crust. Once exposed, the rock starts weathering to form iron-rich layered mountains such as Mt Tom Price and Mt Whaleback in the Hamersley Ranges, Western Australia. You can see these layers clearly in Figure 9.1.7.



**Figure 9.1.7** Iron ore deposits in the Pilbara region of Western Australia are sedimentary rocks. The red folded layers of iron oxide rock shown here contain iron oxide.

Some iron deposits in the Pilbara region of Western Australia were formed in a different way. Dissolved iron compounds precipitated from the water that carried them down from surface soils or rocks. The iron compounds solidified around small grains of sand and gradually built up into large gravel-like rocks. This formed the minerals limonite and goethite, found in the Hamersley Basin also in Western Australia.

**SciFile**

### Magnetic rock

Magnetite is magnetic iron ore. If a long, thin piece is suspended from a string, the magnetite spins around and once it stops spinning, one end will be pointing north. Ancient seafaring people used magnetite to form simple compasses.

## Copper ore

The world's major copper deposits were formed near magma that pushed into existing rocks. This is shown in Figure 9.1.8. The magma superheated (heated to above its boiling point) nearby water, which then dissolved some of the copper minerals in the surrounding rocks. These superheated liquids are called **hydrothermal fluids**. The hydrothermal fluid then flowed further away from the magma and into spaces in surrounding rocks. The fluids cooled and minerals solidified in these spaces, forming a rich copper mineral layer. The copper tends to be in a zone called an 'aura' that surrounds the old magma chambers. Other minerals tend to form in cracks in the rocks called 'veins'.

Some copper ores also formed in the ocean, where they became sedimentary rocks. Water flowing through copper-rich rocks on the land dissolved some copper. When the water reached the ocean, the copper precipitated and mixed with the other sediments. Copper carbonate ores can be formed in this way.

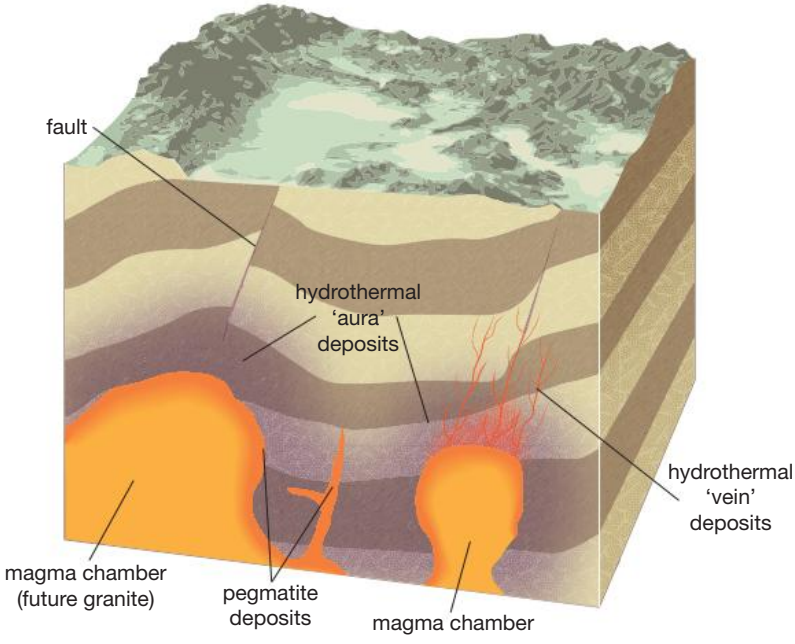



**Figure 9.1.8** Hydrothermal fluids can form mineral deposits around magma chambers (aura) and in cracks (veins) in rocks.

2 p325

## Gold

Gold is formed in a variety of ways. The main way involves hydrothermal fluids, the same as for copper. Some gold is deposited in igneous rocks, but is later dissolved by hydrothermal solutions. These fluids then move through other rocks and deposit the gold in cracks forming veins of gold like those in Figure 9.1.9.




**Figure 9.1.9** This gold deposited from hydrothermal fluids that flowed into cracks in granite rock.

Another process forming gold is deposition in gravel rocks containing iron oxide. Gold can be dissolved when it is weathered from a parent rock. Water carrying the dissolved gold flows away and deposits the gold around tiny sand grains elsewhere. The rocks gradually grow in size and may eventually look like gravel, but with fine grains of gold inside them.

Gold can also be found in soils or sedimentary rocks. However, gold is rarely formed there. It has simply been transported there by streams. The gold is deposited when the stream flow slows and there is not enough energy to carry the heavy gold particles. For this reason, gold prospectors like to know where old water courses are located.

9.1

# Formation of oil and gas

Oil and gas formed from microscopic animals and plants that lived in the oceans and lakes between 10 million and 160 million years ago. When these ancient plants and animals died, they sank to the bottom of the oceans and lakes and were covered by sediment. This sediment and lack of oxygen changed the way they decayed. Heat from the Earth slowly changed the chemicals making up the plants and animals, turning them into compounds high in carbon. The sediment slowly turned into sedimentary rock. As it did so, the carbon compounds became oil or gas.

Oil can flow through some types of rocks and can accumulate in spaces between the rock particles. Oil is less dense than water and so it often flows upwards from the rock where it was originally formed. It can enter rocks such as limestone and sandstone, which are porous and have large spaces that can hold a lot of oil. The oil can be trapped in these rocks if there are impervious rocks above that do not allow oil to flow through them and block the oil from rising any further. The rocks that block the oil are known as cap rocks. Figure 9.1.10 shows where oil is found.

# Formation of coal

Australia has large reserves of black coal mainly in the Bowen Basin in Queensland and the Hunter Valley in New South Wales. There are large reserves of brown coal in Victoria's Latrobe Valley. Coal is formed from plants that lived in swampy areas on land. Many of these were species of trees that are now extinct on Earth. They died and fell into the swamps, where they were covered by sediment. High pressure, heat and a lack of oxygen changed and compressed the plant remains to form coal.

Coal is solid and cannot flow into other rocks. A sample of coal is shown in Figure 9.1.11.



**Figure 9.1.11** Coal is partly decomposed plant matter, and fossils of ancient plants are often still visible in the rock.

# From Earth to final product

The process of obtaining minerals, oil or coal in the form required generally consists of several main steps.

1 *Exploration:* this is the search for the rocks containing the minerals, coal or oil.
2 *Mining:* this is the removal of the resource from the ground. For oil and gas, this involves drilling a deep hole.
3 *Enrichment:* this concentrates the resource, increasing how much there is of it in a particular volume of the mined material. This may involve removing other materials that aren't wanted. The rock may need to be crushed into smaller pieces and then ground down to fine particles like sand.
4 *Extraction:* some metals need to be extracted. This chemical process involves removing the wanted element from the compound in which the metal occurs. For example, iron needs to be extracted from iron ore. Iron ore is iron oxide, and the iron atoms and oxygen atoms need to be separated from one another.

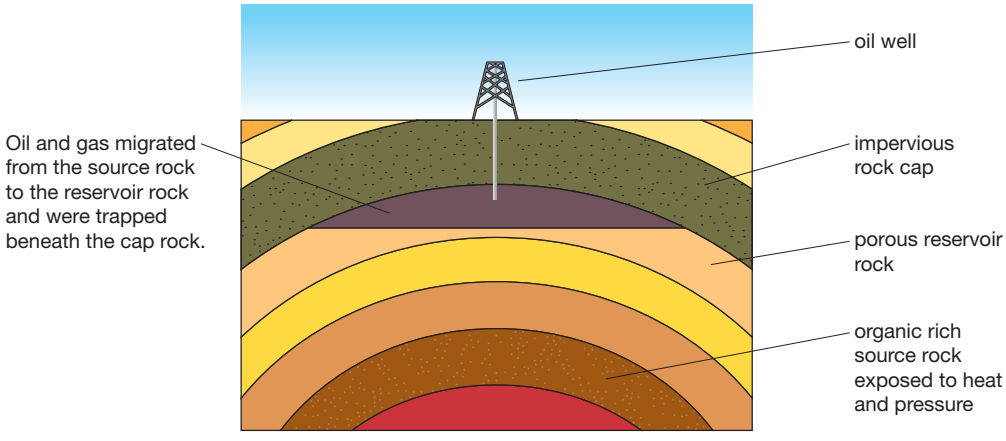



**Figure 9.1.10** Oil and gas accumulate in sedimentary rock layers beneath cap rocks. Cap rocks do not allow oil and gas to flow through, trapping them underground.

# SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

## Golden bacteria

Figure 9.1.12 Gold accumulated by the bacteria

Australian scientist Frank Reith, from the University of Adelaide, noticed that a bacterium called ***Cupriavidus metallidurans*** occurred on gold grains in southern New South Wales and northern Queensland. He wondered if the bacteria were involved in forming gold.

In 2006, Frank Reith organised an international team of scientists to carry out further research. The team was made up of scientists from the University of Adelaide, CSIRO (Commonwealth Scientific and Research Organisation), the United States, Canada, Germany, Belgium and France. Their experiments showed that the bacteria could accumulate gold compounds from a solution prepared in the laboratory. These gold compounds are toxic to the bacteria, so the bacteria defend themselves by turning the gold compounds into metallic gold. The tiny gold particles are produced inside the bacteria. You can see this in Figures 9.1.13 and 9.1.14.

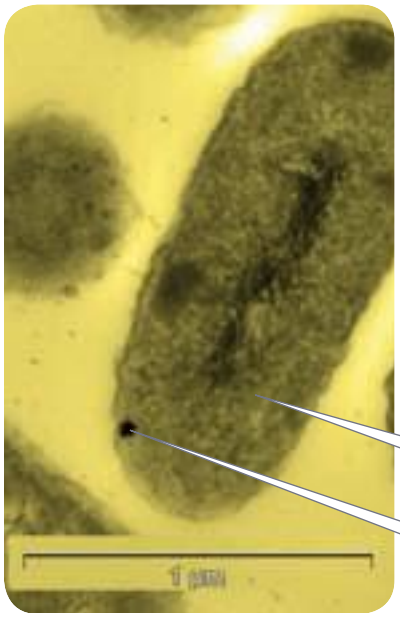



Figure 9.1.13 This is a single bacterial cell with a growing particle of gold inside it.

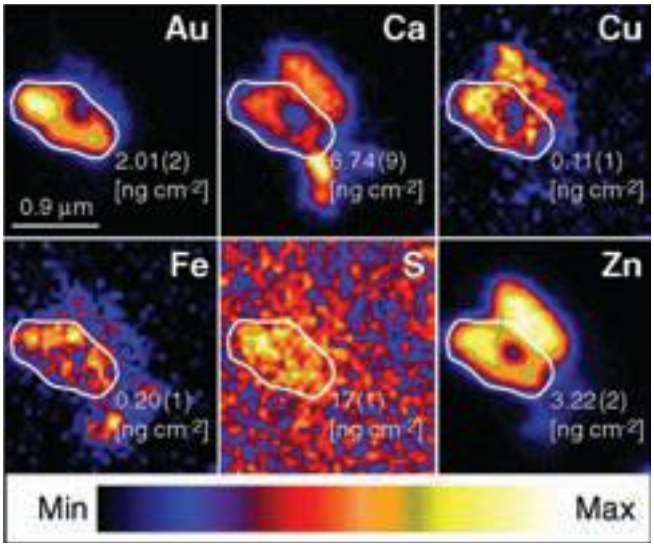



Figure 9.1.14 These X-ray fluorescence maps show the distribution of gold (Au), calcium (Ca), copper (Cu), iron (Fe), sulfur (S) and zinc (Zn) in an individual cell after one minute of exposure to the gold solution. This helps scientists determine how the bacteria react to the gold solution.

Reith has since been investigating whether the bacteria could be used as a 'biosensor'. If it works, they would become part of a biological system for detecting gold sources in rock. This will help companies exploring for gold. Further research is also planned to find the genes that control this unique cell chemistry of the bacteria.

9.2

# 9.1 Unit review

## Remembering

1 a **List** five minerals.
b **Name** the chemical compound in each of them.
c **Name** the element extracted from the compound.

2 **List** four physical properties used to identify minerals.

3 **List** the four main steps involved in obtaining a mineral from the Earth.

## Understanding

4 **Explain** how lustre and colour can help identify a mineral.

5 **Explain** how a streak test could be used to distinguish between two minerals.

6 **Explain** why minerals are so important to Australia.

7 **Explain** how a mineral may be formed as a result of chemical sedimentation.

8 **Describe** one way in which the following may form.
a iron ore
b copper minerals

9 **Describe** where oil and gas are usually found.

## Applying

10 **Use** Mohs scale to **identify** minerals that could:
a be scratched by a fingernail
b scratch a fingernail.

11 An unknown mineral was scratched by fluorite, but not calcite. **Use** Mohs scale to **state** the likely value for its hardness.

12 One of the minerals in Table 9.1.2 on page 317 was scratched by topaz but not by an iron nail. **Identify** what mineral it probably was.

## Analysing

13 **Compare** a rock, a mineral and an ore.

14 **Compare** the formation of coal and oil.

15 **Compare** the formation of gold and copper by hydrothermal fluids.

16 **Contrast** the involvement of water in the formation of iron ore and copper ore.

17 Imagine you are given two large white crystals labelled U1 and U2. Write a method to **compare** these two crystals to decide if they are different minerals or the same mineral.

## Evaluating

18 Two unknown white, lustrous minerals were tested for hardness and streak. Both had a hardness of 4, and had a white streak. **Draw** a conclusion from these tests.

19 Some gold nuggets that were rounded like sand grains were found by a prospector in dry soil nowhere near a stream. The prospector insisted that the gold was carried there by an ancient stream that disappeared long ago. The land was fairly flat but there were some hills about 1 km away. **Assess** the prospector's argument.

## Creating

20 **Construct** a table summarising the ways in which iron ore, copper ore, gold, coal, oil and gas form.

## Inquiring



1 Magnetite, cassiterite, tourmaline and haematite are black minerals. Research how you could perform laboratory tests using the physical properties of magnetism, density and streak to distinguish between them.
If your teacher has some of these minerals available, then ask if you can try your experiments.

2 Research where gold, copper, iron, uranium, diamond, coal and petroleum deposits are found in Australia. Construct a map of Australia showing the major mines and wells.

# 9.1 Practical activities

## 1 Comparing minerals

### Purpose

To compare the properties of different minerals.

### Materials

- minerals
- white unglazed tile
- stereomicroscope or hand lens
- steel nail
- copper washer or nail
- cast iron

### Procedure

1. In your workbook, copy the table shown in the results section. Draw enough rows for all the minerals.
2. Choose one mineral sample. Record its name from the label or identify it using Figure 9.1.15. Describe its colour and lustre.
3. Use the stereomicroscope or hand lens to observe the shape of any crystals. Describe or draw them in your table.
4. Do a streak test and record the colour in your table.
5. Test the hardness using Tables 9.1.2 and 9.1.3 on page 317 and enter the result in your table.
6. Repeat for all other mineral samples.

### Results

1. Copy and complete the following table for all the minerals you have.

| Mineral name | Colour and lustre | Crystal shape | Streak colour | Approximate hardness |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

### Discussion

1. **Describe** any difficulties you had in conducting these tests.
2. **Propose** some difficulties geologists may have if they rely only on these tests to identify a mineral.
3. **Propose** why minerals look different and have different properties.




Figure 9.1.15

## 2 Malachite

### Purpose

To investigate the composition of malachite, a green-coloured copper carbonate mineral found in rock.

### Materials

- malachite ore or powdered copper carbonate (about 2 g)
- 1 M sulfuric acid (about 10 mL)
- steel wool
- large test-tube with one-hole stopper and delivery tube
- test-tube and test-tube rack
- limewater
- video camera or mobile phone with video function (optional)



**SAFETY**

1 M sulfuric acid is highly corrosive.

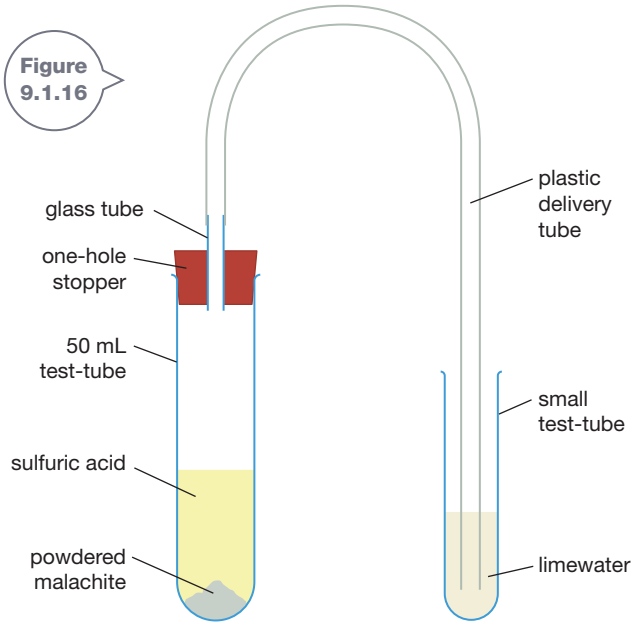
Wear safety glasses at all times.

Wear rubber gloves at all times.



### Procedure

1. Place about 2 cm (about 2 g) of the malachite or powdered copper carbonate in the test-tube with the stopper and delivery tube.
2. Pour about 3 cm of limewater into the other test-tube and place it in the rack.
3. Add about 5 cm of 1M sulfuric acid (approximately 10 mL) to the test-tube containing malachite. Replace the stopper and delivery tube, and bubble the gas through a limewater solution for no more than 30 seconds (Figure 9.1.16). Remove the end of the delivery tube from the limewater.
4. Let the test-tubes stand for a few minutes until a definite colour can be seen in the test-tube containing the malachite. Record your observations of both test-tubes.
5. Place some steel wool into the liquid in the test-tube with the malachite and leave it for 2 minutes.



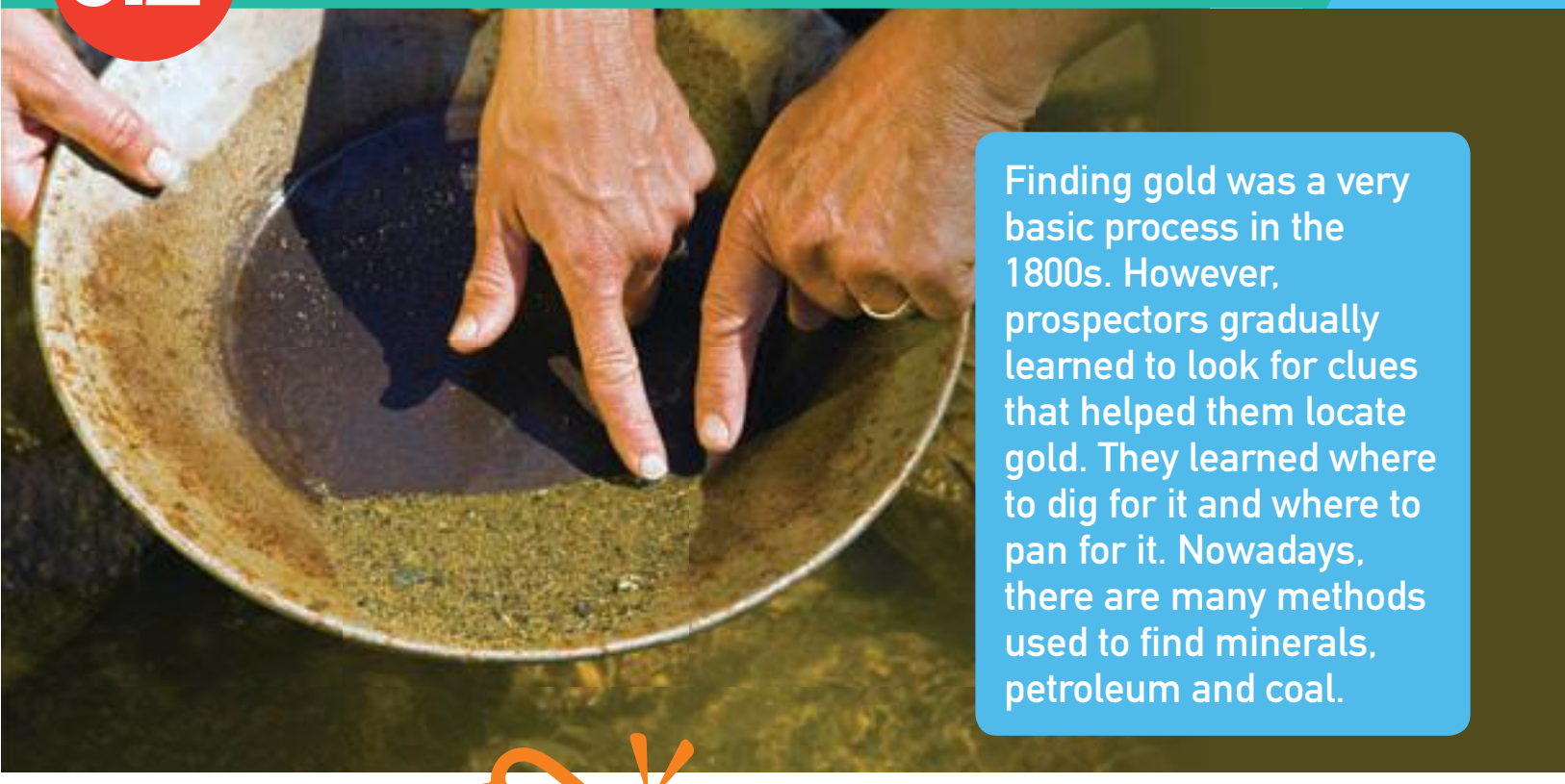

### Results

1. Record or video your observations.
2. Leave the test-tube until the end of the class and again record your observations.

### Discussion

1. **Describe** the changes in the test-tube containing the malachite as the acid was added.
2. Limewater turning milky white is a chemical test for carbon dioxide gas. **Propose** what the acid did to the malachite.
3. In the test-tube containing the malachite, there were two changes that were evidence of a chemical change. **Identify** these changes.
4. **Describe** the changes to the steel wool and the solution in the test-tube.
5. **Identify** the material on the steel wool based on your knowledge of the elements.

# 9.2 Exploration



Finding gold was a very basic process in the 1800s. However, prospectors gradually learned to look for clues that helped them locate gold. They learned where to dig for it and where to pan for it. Nowadays, there are many methods used to find minerals, petroleum and coal.

INQUIRY science 4 fun

## Magnetic field

Can you show a magnetic field?

**Collect this …**

- 1 sheet of thin cardboard
- magnet
- iron filings in a pepper shaker

**Do this …**

1. Place the magnet under the cardboard in the centre.
2. Sprinkle the iron filings over the cardboard until a clear series of lines appears.
3. Keep adding more near the centre of the cardboard so they stick upwards.

**Record this …**

**Describe** what happened.

**Explain** why you think this happened.

Many methods are used to explore for minerals. Some of the most common are:

- aerial methods—magnetic, gravity and electromagnetic surveys
- on-site methods—seismic and geochemical surveys
- satellite images.

## Aerial methods

Aerial methods of surveying are done from aircraft or helicopters. A great advantage of aerial surveying is that it can cover vast areas fairly quickly.

### Magnetic surveys

Earth has a magnetic field running between its north and south poles. Minerals containing iron, nickel or cobalt change the magnetic field around them. Sensitive instruments called **magnetometers** detect this change and show the effect as a disruption to the normal field or 'magnetic anomaly'. Figure 9.2.1 shows an aircraft equipped for magnetic surveys.



Figure 9.2.1 This aircraft is fitted with a magnetic system to detect magnetic anomalies in Earth's north–south field.

The magnetic data from the magnetometer is fed into a computer and a coloured map can then be constructed. Colours are used to indicate areas of interest. For example, a highly magnetic area may be coloured red, while an area of low magnetism may be coloured blue. This will show patterns that could indicate possible mine sites. Figure 9.2.2 shows an example of a magnetic anomaly in Mt Oscar in the Pilbara region of Western Australia. Drilling showed the mountain to be made of a magnetic iron ore called magnetite.

1 p332

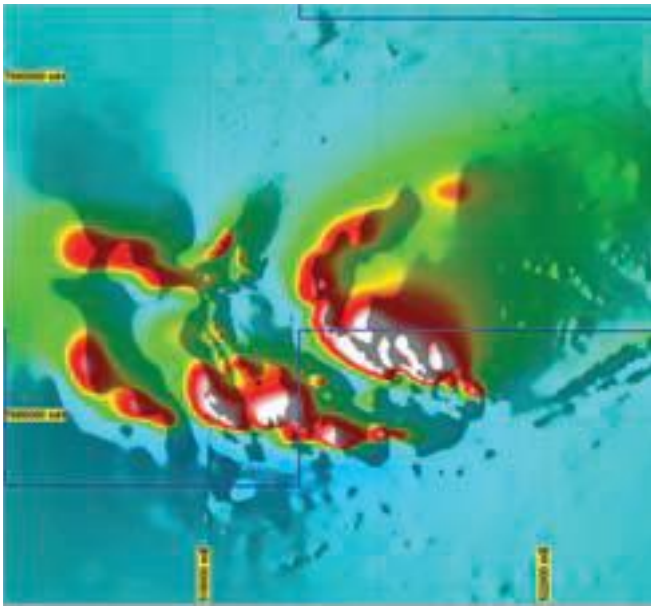


Figure 9.2.2 This map of magnetic anomalies near Mt Oscar in the Pilbara region of Western Australia helped in discovering a site of magnetite iron ore. White and red areas are more magnetic than the other colours.

**SciFile**

### North goes north-west

The magnetic field of the Earth is changing. The position of the magnetic north pole is moving north-west at a rate of about 40 km/year. Some scientists have predicted that the poles may reverse within a few hundred years. Then the current north-seeking end of a compass will point south.

## Gravity surveys

Small differences in the gravitational pull of the Earth can be detected by very sensitive instruments called **gravimeters**. These can be attached to an aircraft. Dense rocks and minerals affect the gravitational pull on the aircraft and gravimeters can detect this. Variations in gravitational pull are then shown on a map using colour to show differences. Such maps can give geologists clues about where particular minerals may be found. In Figure 9.2.3 you can see the image from a gravimetric survey in South Australia.

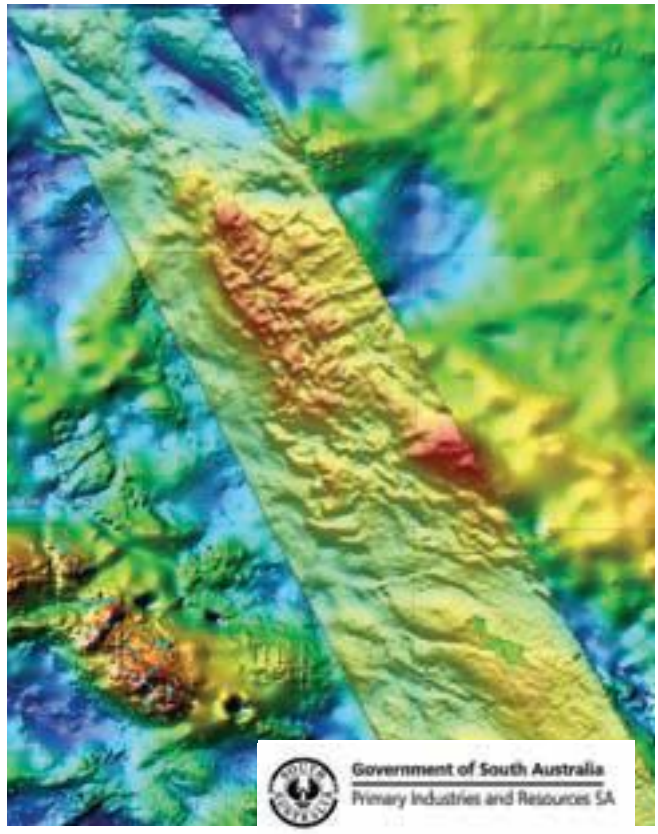



Figure 9.2.3 This is a gravity map of the land between Olympic Dam and Oodnadatta in South Australia. Red indicates the highest gravity (indicating the densest rocks) and blue indicates the lowest.

## Electromagnetic surveys

**Electromagnetic (EM) surveys** detect ore bodies that are good electrical conductors. A magnetic field is sent from a transmitter on an aircraft or helicopter like the one in Figure 9.2.4. The magnetic field creates tiny electrical currents (called eddy currents) in minerals in the Earth. These currents create their own magnetic field (called the secondary field), which is detected by a receiver. You can see this in Figure 9.2.5. This method is very good for detecting metal sulfides such as copper sulfide, lead sulfide and zinc sulfide, and also for detecting gold and silver.



Figure 9.2.4

This helicopter is towing an electromagnetic device that combines a transmitter and a receiver.

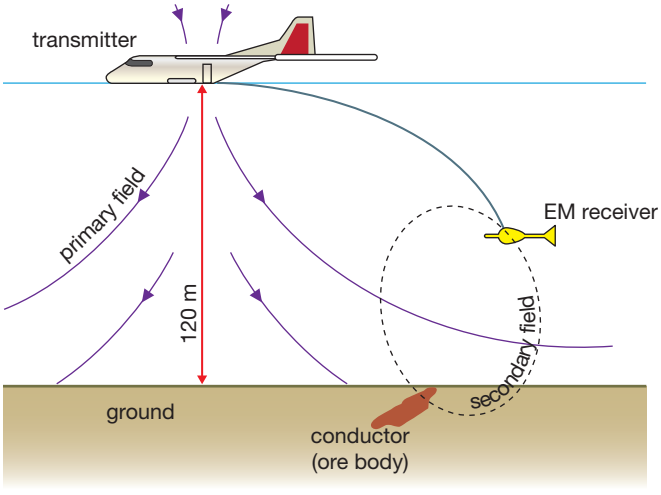



Figure 9.2.5

Airborne electromagnetic methods apply a magnetic field to the Earth and detect the secondary field created by the eddy currents in the ore body.

2 p333

# On-site methods

Aerial methods give a quick overview of large areas. More specific data can come from on-site methods.

## Seismic surveys

A **seismic survey** involves sending a shock wave into the ground surface, and recording the reflected sound waves. Different rocks layers reflect the sound waves in different ways and a 3D picture can be created from the reflections. Explosives can be used, but mechanical vibrators give a better picture and can go deeper. Detectors called geophones detect the reflected sound waves. The maps made from the sound waves help geologists predict likely areas where minerals can be found.

INQUIRY science 4 fun

## Echoes

Yes

Can you hear a reflected sound?

### Collect this…

2 flat pieces of wooden board about 30 cm long and 5 cm wide

### Do this…

1. Walk outside to a place where there is a large area of flat brick or concrete wall.
2. Stand about 10 metres (roughly 10 large paces) from the wall and hit the large flat surfaces of the boards together loudly. Listen for an echo. You should not hear one.
3. Step away from the wall a further 10 paces so that you are about 20 metres from the wall. Hit the boards together and listen for an echo. You may hear one but it may be very hard to be sure.
4. Step a further 10 paces away, use the boards and listen for an echo. You should definitely hear one here.

### Record this…

**Describe** what happened.

**Explain** how this is like a seismic survey.

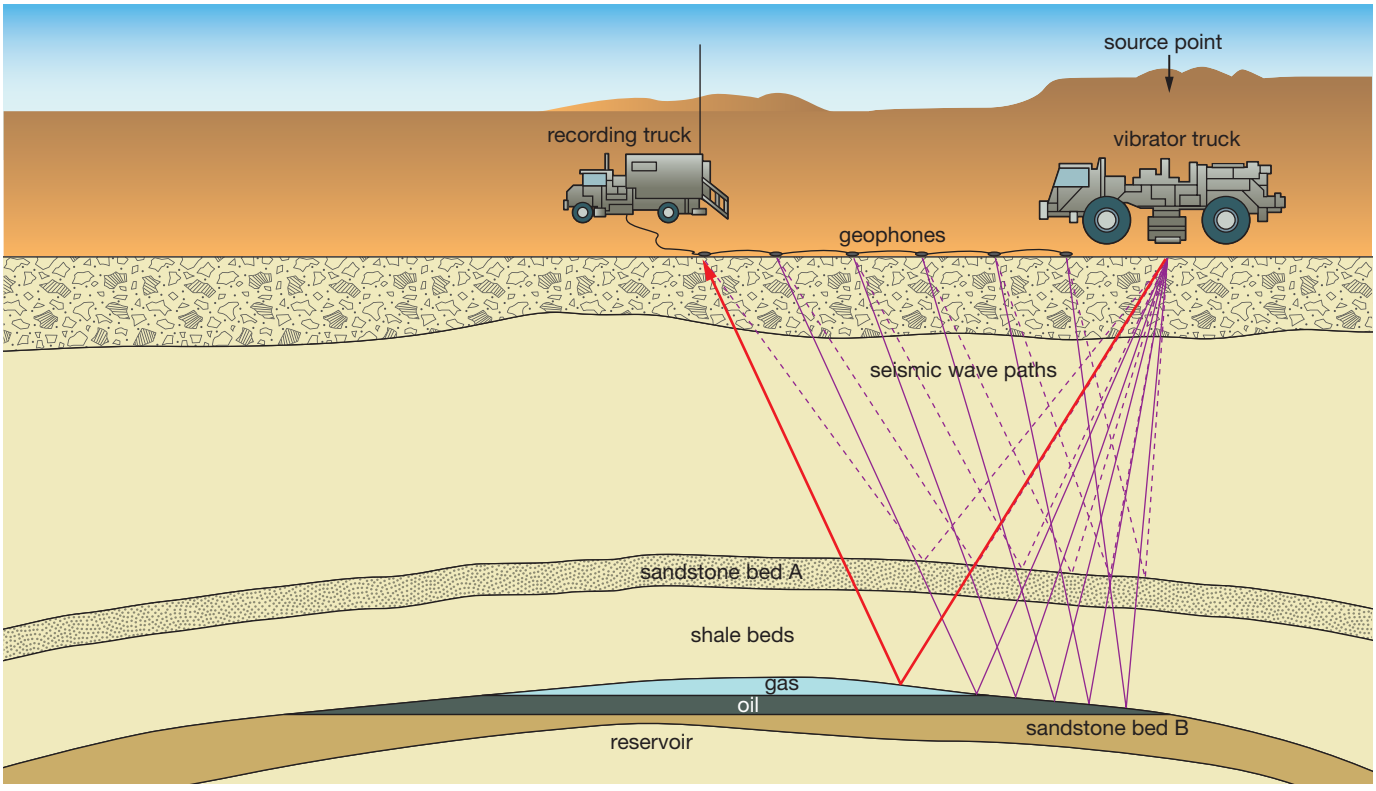



**Figure 9.2.6** A seismic survey sends sound waves through the Earth and detects reflected sound waves to create a picture of the rock layers.

Seismic surveys can also give information about the structure of the Earth's crust from 35 to 60 km deep. This helps geologists to better understand how minerals form. Figure 9.2.6 shows how a seismic survey is done.

## Geochemical surveys

**Geochemistry** uses chemistry to show what minerals are present in the area surveyed. Rock and soil samples from the surface may be used, but generally holes are drilled into the rocks to check the amount of mineral in them. The rock that is removed is called a **core sample**. Some core samples are shown in Figure 9.2.7. Sometimes the presence of one particular mineral gives geologists clues to what other minerals could also be in the rock. For example, uranium, arsenic and antimony are associated with gold deposits.

Water from the surface or below ground can also be used as an indicator of minerals in the rocks or soil. Groundwater dissolves minerals in buried rocks and is especially useful in detecting metals. Copper, gold, uranium, nickel, zinc and diamonds can be located in this way. Many sulfides of metals are detected by water sampling. However, surface water is not always a good indicator of what lies below ground, especially if the water has flowed there from somewhere else or has been there only a short while.



**Figure 9.2.7** Core samples of rock from holes drilled into a potential ore body are tested chemically for minerals of interest.

# Satellite images

Satellites have long been used to take photographs of the Earth below. However, satellites also enable geologists to create images using forms of light rays that the human eye cannot see. The sensors in satellites detect radiation called near-infrared, shortwave-infrared and thermal-infrared. The **satellite images** produced often help geologists see features in the landscape that they cannot see in normal satellite photos produced with visible light. These features often contain particular minerals. Typical satellite images can be seen in Figure 9.2.8.

9.3

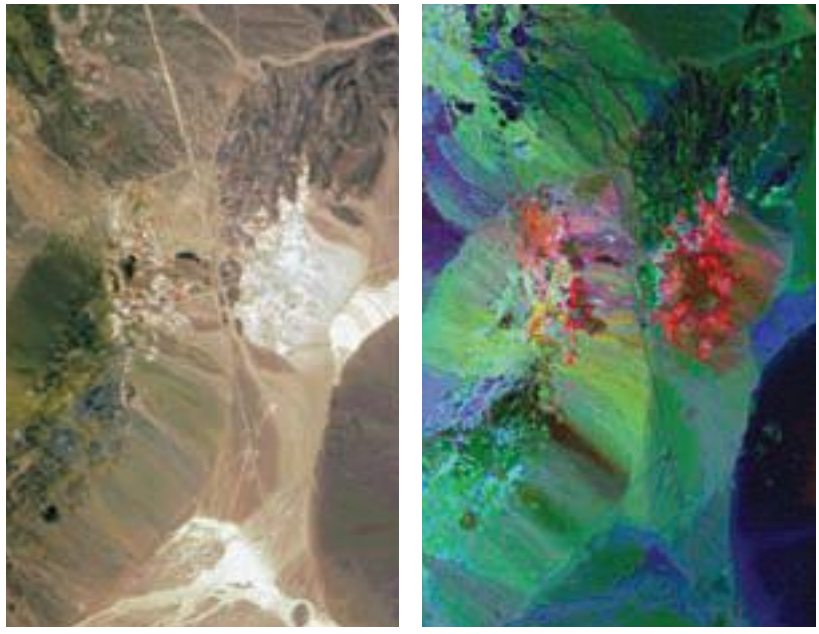


Figure 9.2.8

These two satellite images show the same area, in natural and infrared light. The red parts indicate deposits of azurite (an ore of copper).

# Geological maps

Geologists use aerial methods, on-site methods and satellite images to construct different kinds of maps (such as those in Figures 9.2.2 and 9.2.3 on page 327) to show likely mining areas. However, other maps may be needed to show the underground rock formations before geologists can work out the best way to mine the deposits.

It is useful to draw **geological maps** that show the appearance of the ore bodies from above and from the side. The side view is called a **cross-section**. Cross-sections are very useful because they help to give a 3D picture of how the ore bodies look. Then geologists can decide how best to mine the ore. You can see a geological map in Figure 9.2.9.

9.4

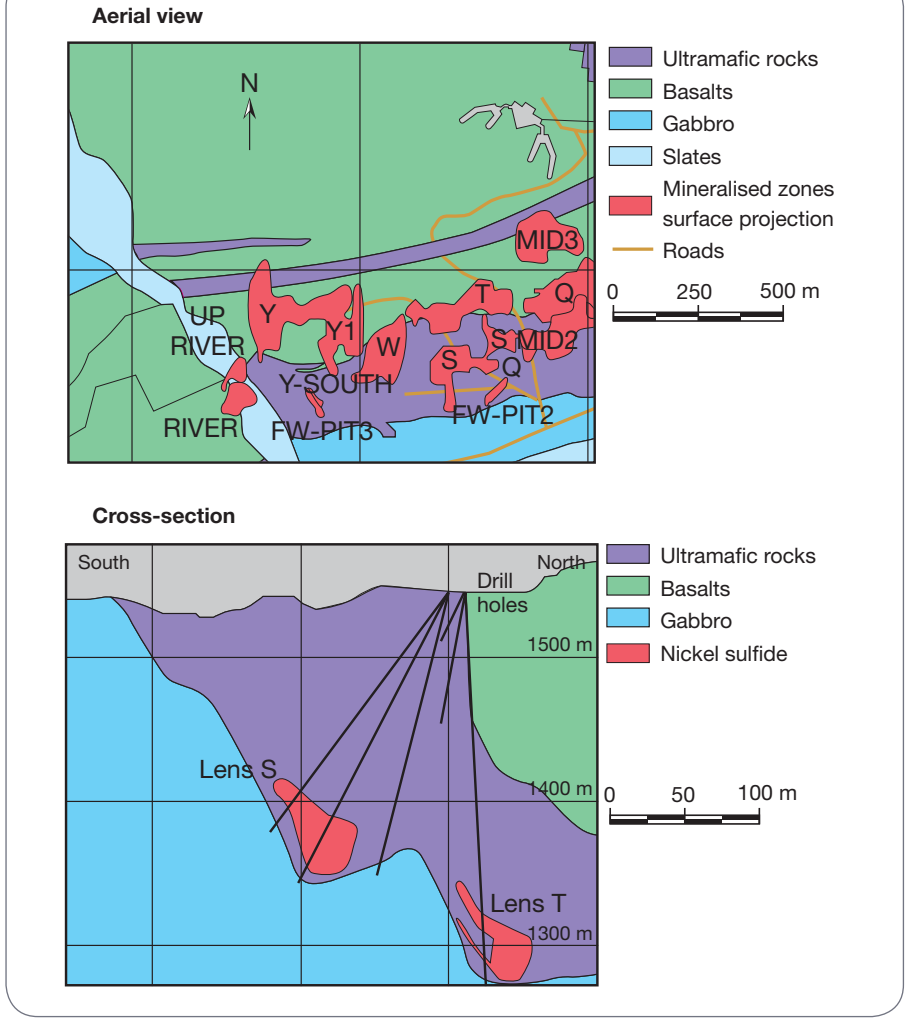



Figure 9.2.9

These geological maps show nickel sulfide ore bodies (red) from above and in cross-section. Each ore body has been given a different letter or name.

# 9.2 Unit review

## Remembering

1 **List** three aerial methods of exploration.

2 **List** two on-site methods of exploration.

3 **List** the type of invisible rays that are used by satellite sensors to construct images.

## Understanding

4 **Explain** what the following instruments do.
- a magnetometer
- b gravimeter

5 **Explain** the advantage of aerial methods of exploration.

6 **Explain** how aerial magnetic surveys can be used to create a map of the geology of an area.

7 **Outline** the uses of satellites in mineral exploration.

8 **Explain** how seismic surveying works.

9 **Explain** why geological maps are created.

## Applying

10 **Identify** the best places to mine in the area shown in Figure 9.2.2 on page 327.

11 a **Explain** what an eddy current is.
b **Identify** where the eddy current would occur in Figure 9.2.10.

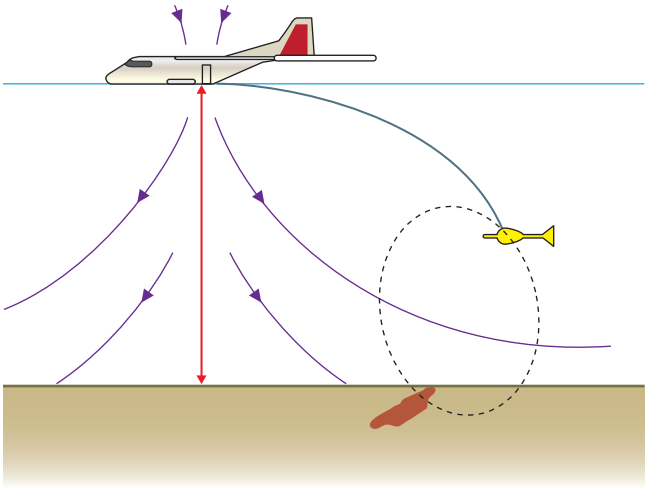


Figure 9.2.10

12 **Use** Figure 9.2.9 to **explain** how drill cores and geochemistry help create geological maps.

13 **Identify** approximately where the cross-section was done on the first diagram in Figure 9.2.9.

## Analysing

14 **Compare** geochemical surveys with satellite surveys.

15 **Compare** aerial magnetic surveys with aerial gravity surveys.

16 **Contrast** electromagnetic surveys with magnetic surveys.

## Evaluating

17 An aerial survey gave an extremely strong electromagnetic reading in an area. A gold mining company decided to do a ground survey of the area. They bored some holes in the soil and sampled the water. A laboratory test on the water they collected was negative for gold. However, a drill core of rock when analysed gave quite a high reading for gold. **Propose** why the water readings contradicted the drill core readings.

## Creating

18 **Construct** a table summarising the use of each of the methods of exploration mentioned in this unit.

## Inquiring

1 Research a company that uses one of the aerial survey methods for exploring. Research which method they are using, where they are exploring, what mineral they are searching for and what results they have had so far.

2 Research uranium exploration in Australia. Describe what uranium is used for, how much of the world's uranium deposits are thought to be in Australia and what exploration methods are used.

# 9.2 Practical activities

## 1 Detecting magnetic minerals

### Purpose

To model a magnetic survey to detect minerals.

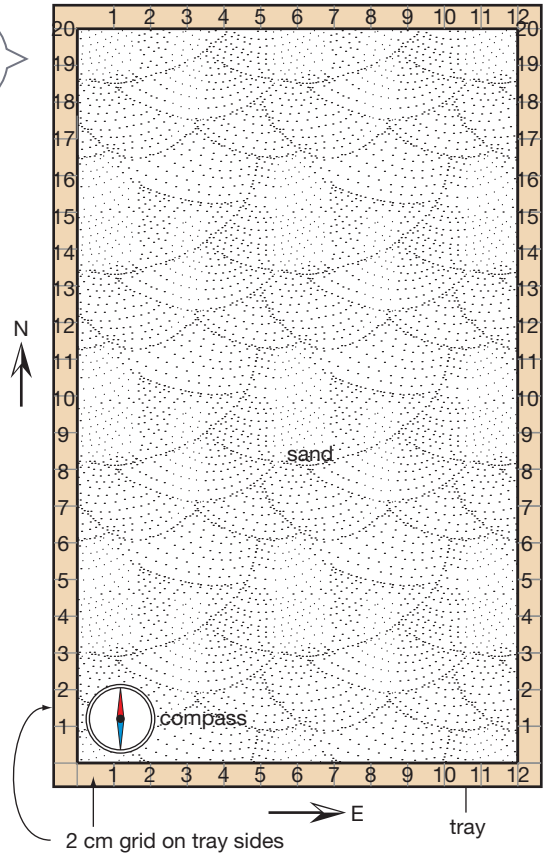
### Materials

- tray
- clean sand
- magnetic compass
- marking pen (non-permanent)
- 3 or 4 pieces of iron/steel (the 'mineral')

### Procedure

1 Fill your tray with sand and draw a 2 cm search grid along two sides. Call one side of the tray 'north' and the other 'east'. Use the compass to arrange the tray so that these sides point north and east. Number each square from 1 to as many as needed to cover the tray (see Figure 9.2.11).

Figure 9.2.11




2 One student (the experimenter) is to hide the pieces of iron or steel in the sand and the other (the surveyor) is to conduct the survey. The metal pieces are the 'mineral' the surveyor is trying to locate. The surveyor must not see where the experimenter hides the metal pieces or how many are hidden.

3 On a piece of A4 graph paper, the experimenter marks a grid representing the grid on the tray. This is your record sheet.

4 The surveyor now holds the magnetic compass a few centimetres above the sand in the first grid square: 1 North 1 East (1N1E). The experimenter must draw on the record sheet the direction in which the compass is pointing.

5 The surveyor must now decide what search pattern to use to find the 'minerals'.

6 Move the compass to the next square and show the direction of the compass needle on the record sheet. Continue until you think you have enough information.

7 The surveyor now uses the record sheet to try to determine where the ore body is located. When located, dig up the ore.

### Discussion

1 **Explain** why the compass needle detects the mineral.

2 In a real magnetic survey, **name** the devices that take the place of the compass.

3 **Describe** how you predicted the location of each ore body.

4 **Evaluate** your performance in detecting the ore bodies.

## 2 Electromagnetic surveys

### Purpose

To model an electromagnetic survey to detect minerals.

### Materials

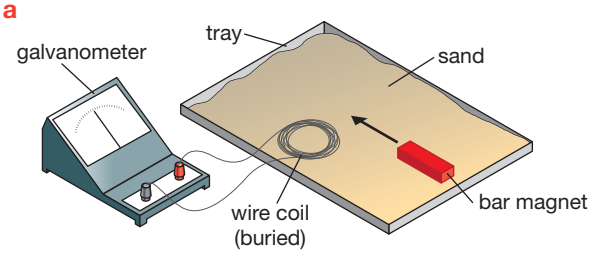
- laboratory tray
- clean sand
- good-quality magnetic compass
- strong bar magnet
- copper coil (ore body)—varnished
- galvanometer
- 4V power supply (or battery)
- 3 electrical leads with alligator clips
- switch

### Procedure

1 Fill the tray with sand and bury the coil just below the surface about 10 cm in from one edge and near the centre of the side. Leave the two ends of the coil sticking above the sand and over the edge of the tray.

2 Connect the two wires from the coil to the galvanometer. A galvanometer is an instrument that detects very small electric currents. Your set-up should look like Figure 9.2.12a.

a




b

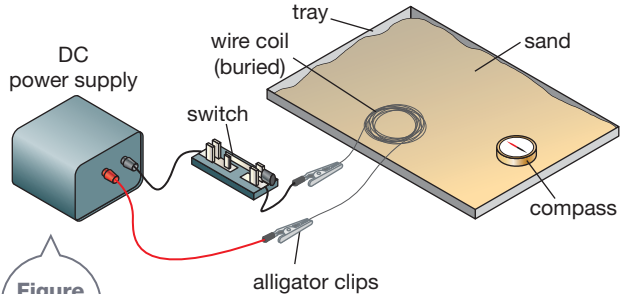



Figure 9.2.12

3 Pick up the magnet and imagine it to be on an aircraft with an electromagnetic (EM) survey system. Start at the end away from the coil. 'Fly' the magnet a few centimetres above the sand and towards the coil (your 'ore body') and watch the galvanometer. You may have to do it a few times to notice any effect.

4 Try 'flying' faster or slower, and higher or lower. Record the readings on the galvanometer each time. Construct a table to record your observations.

5 Disconnect the galvanometer from the coil and connect the coil to DC terminals of the power supply (or battery) with a switch. The power supply represents the eddy currents created in the ore body. Turn the knob on the power supply to 4V. Your set-up should look like Figure 9.2.12b.

6 Pick up the compass and imagine it to be on an aircraft with an EM system. The compass is modelling the detector on the aircraft. Hold the compass flat and start at the end away from the coil.

7 'Fly' the compass just above the sand and towards the coil. Close the switch a few seconds before the compass 'flies' over the coil. Watch the response of the compass. Turn off the switch as soon as the compass passes the coil. You may have to do it a few times to notice any effect. Try 'flying' faster or slower, and higher or lower.

### Results

1 Record your observations of the effect on the compass.

2 Predict what would happen to the compass direction if you turned the coil over in the sand and repeated step 7. Try this and record any observations.

### Discussion

1 **Describe** the effect on the galvanometer of passing a magnetic field through the coil.

2 **Explain** what the changing magnetic field must have done to the coil.

3 **Describe** what the electric current in the coil did to the compass.

4 **Explain** why the electric current in the coil affected the compass.

5 **Compare** this model with a real electromagnetic survey.

# 9.3 Mines and wells



A mine or an oil well is not just a simple hole in the ground. Oil below the sea floor may require a massive drilling platform resting on the sea bottom. Gold may need a hole several kilometres deep with miners working in tunnels. Designing, building and operating mines and wells requires many skilled workers, from geologists and engineers to drillers and mechanics.

## Mining methods

There are many different mining methods. Some methods are specific to a particular mineral or a specific type of coal. The method of mining chosen depends on three main factors:

- the type of mineral
- the geology of the area
- the cost and how much the mineral is worth.

Some of the more common mining methods are surface, underground, dredging and leach mining. Other methods exist as well. Figure 9.3.1 summarises some of these methods.

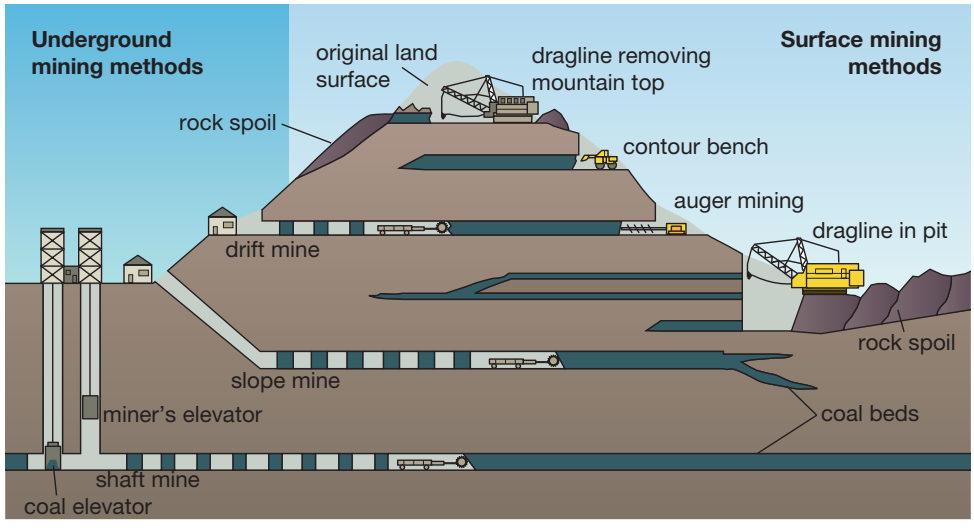



**Figure 9.3.1** Many of the coal mining methods shown here are also used to mine other minerals.

## Surface mining

When the ore body is near the surface, the cheapest option for mining may be to remove the soil and rocks covering it to get to the ore. A large, open working surface is created, often by drilling and blasting the rock with explosives. Removal of this rock creates a large pit or **open-cut** mine. The pit is usually designed with roads around its walls so that trucks and other machinery can be driven down to the working surface and the mined ore can be driven back up to the surface. The ore can be removed in various ways, such as by machines with large shovels, giant drills called augers and drag lines. A good example is the Kalgoorlie gold mine called the 'Super pit', shown in Figure 9.3.2.




**Figure 9.3.2** Three images of an open-cut gold mine in Kalgoorlie, Western Australia

Open-cut mines are suitable for low-grade ores. These are ores with a low concentration of the mineral present. Open-cut mines are also useful for ores that are spread out over a large area. The brown coal reserves of the Latrobe Valley in Victoria are widespread and are found relatively close to the surface. This makes open cut the easiest and cheapest way to mine the coal.

9.5

**SciFile**

### Big pit

The deepest open–pit mine in the world is Bingham Canyon Mine in Utah, USA. It is 1.2 km deep, about twice as deep as the Kalgoorlie super pit. It would take a rock about 15 seconds to fall to the bottom!

## Underground mining

If the ore body is deep, fairly concentrated and confined to a small space or in narrow veins, then it may be too costly to remove the overlying rock. In these cases, underground mining is more suitable. Figure 9.3.3 shows one of the methods used.

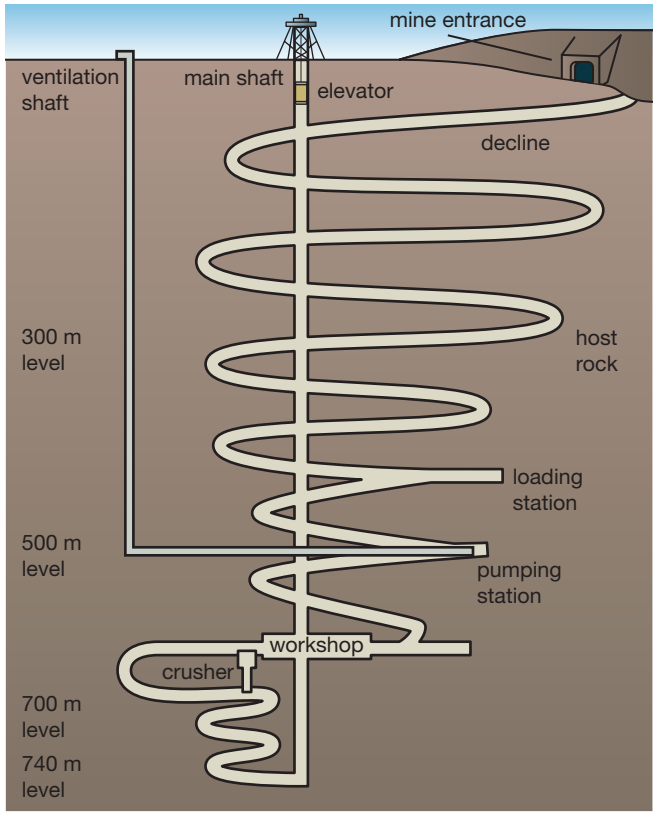



**Figure 9.3.3** Underground mining using a decline enables trucks to drive down to pick up crushed ore and carry it to the surface.

One method uses **vertical shafts** down to the level of the ore body. Horizontal shafts are then dug out into the ore body itself. A hoist connected to a head frame lifts the mined ore to the surface.

Another approach is to use a steady slope (called a **decline**) and drive the ore out by vehicle. The slopes of the tunnels are about 15 degrees.

If the ore body is inside a mountain, it can be reached by horizontal tunnels through the mountainside. These are called **adits**.

### Down deep

SciFile

The deepest underground mine in the world at present is the TauTona Mine in Carletonville, South Africa. It is 3.9 km deep. Without its air-conditioning system, the temperature at the bottom would be about 60°C!

## Dredging

Sand mining uses **dredging** to remove minerals from sand. A large pit is dug and filled with water to create a small lake. Then a dredging boat is floated on the surface. As you can see in Figure 9.3.4, the boat then uses large hoses to suck up the sand. The minerals are heavier than sand and so are easily separated from it when in water. The sand and the water are then pumped back into the lake.



Figure 9.3.4 This boat is dredging for mineral sands at the Gingko Mine, Pooncarie, 220 km south of Broken Hill in New South Wales

## Leach mining

Some materials can be mined by dissolving them in a fluid that is injected into the ore body. The process begins by drilling bore holes into the ore deposit. A solution that will dissolve the ore, called a **leach solution**, is pumped into the ore. The dissolved ore in solution is then pumped to the surface through a second bore hole. You can see this in Figure 9.3.5.

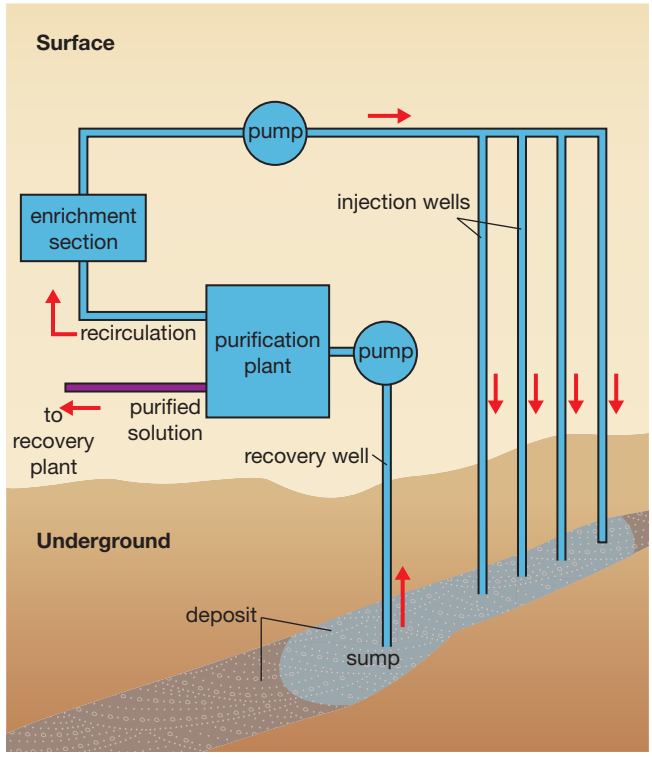



Figure 9.3.5 Leach mining involves injecting a solution to dissolve the ore underground and then pumping it back up to the surface.

The type of leach solution used varies according to the ore deposit. It simply could be water for some salt deposits. For copper ore, acids are generally needed. Copper carbonate ores such as malachite and azurite are recovered in this way. For uranium ores, the leach solution may be acid or sodium hydrogen carbonate.

1 p341

# Petroleum wells

Removing from the ground requires a different method from mining for minerals. **Petroleum** occurs as both a liquid (oil) and a gas, and is usually found trapped within sedimentary rock layers.

Petroleum is recovered by boring narrow holes down into the rock. A steel tower called a derrick is built to support the drilling equipment. This is shown in Figure 9.3.6. A hole is drilled deep into the earth until oil or gas is found, or the company gives up and starts drilling in a new area.

The drill usually has a rotating 'bit' that cuts into the rock. The bit is attached to a length of hollow drill pipe.

As the bit cuts deeper, more pipe is added. A mixture of clay, chemicals and water is continuously pumped through the drill pipe. This cools the drill bit and carries crushed rock to the surface.

When oil or gas is found, the drill pipe and bit are pulled from the **petroleum well**, and a metal casing (a hollow tube) is lowered into the hole and cemented in place. At the upper end of the casing is a system of pipes and valves called a wellhead. This allows the oil or gas to rise up to the surface and into separation and storage tanks.

Sometimes the natural pressure of the oil or gas drops and cannot force the oil to the surface. Then pumps may be used. In some cases, water, steam or gas may be injected into the well to increase the pressure or make the oil flow more freely.

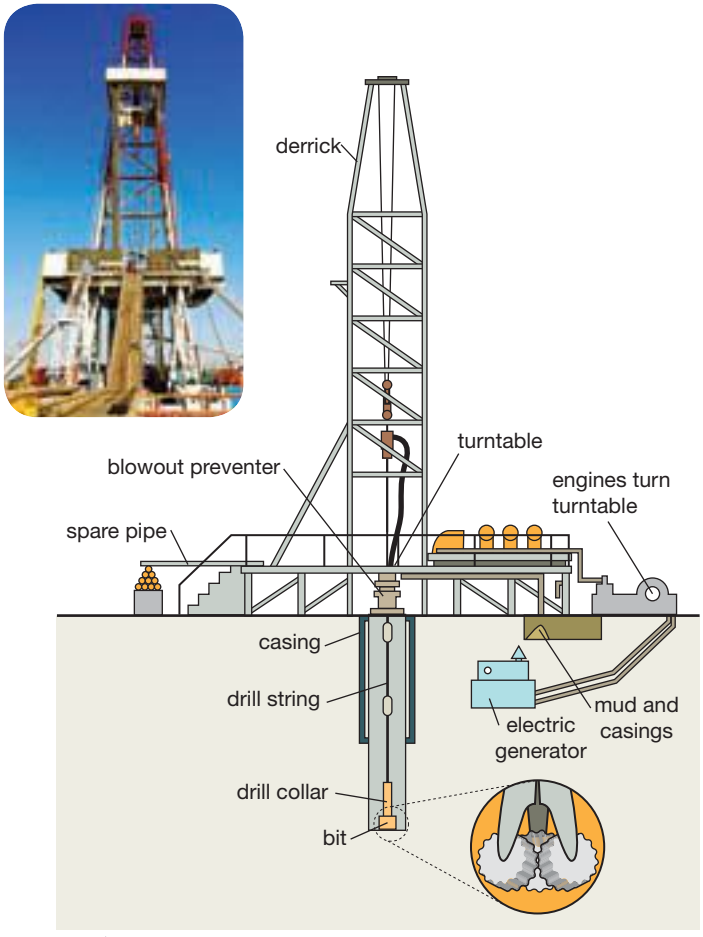



**Figure 9.3.6** An oil derrick is a steel tower that supports the drilling equipment needed to drill an oil well.

## Oil bugs

If oil does not flow easily out of an oil well, geologists have a trick. They pump in bacteria that like eating oil. The bacteria break down the oil molecules into smaller ones that flow more easily out of the rock.

SciFile

Oil and gas rigs in the ocean have a variety of designs. Some, like the one in Figure 9.3.7, rest on the ocean floor. Others are floating platforms tied to the ocean floor by wires. Some are ships that can move from place to place. The oil and gas can be pumped through pipelines on the sea floor to production factories on land. There are also floating ships that can link up to the well and collect the oil and gas for treatment and storage on board.

Oil and gas are flammable and the risk of disaster is high. Oil spills devastate the environment and strict laws exist to make sure that explosions (like the one in Figure 9.3.8) never occur.

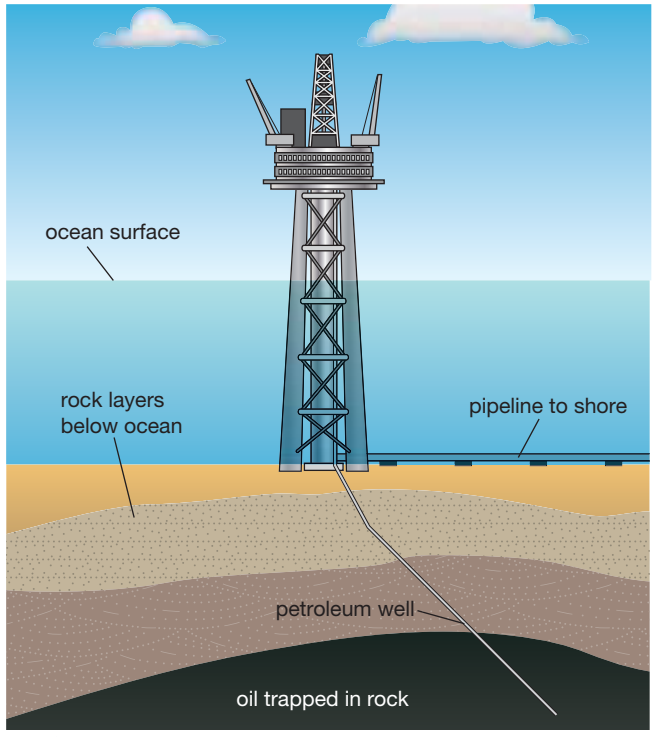



**Figure 9.3.7** An offshore gas platform on the North West Shelf of Western Australia



**Figure 9.3.8** Safety is vital on oil rigs. Accidents such as fires and oil spills can occur.

# SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

## Environmental effects of mining



Figure 9.3.9 Water sprayed over gold ore to reduce dust during loading of a mining truck



Mining and oil exploration provide great benefits to our society. However, without proper laws, monitoring and protection procedures, damage to the environment can occur. Environmental damage can include erosion, subsidence of land, poisoning of soil and water, dust and loss of biodiversity.

Mining and processing of minerals produce large amounts of waste, called tailings. These are often toxic as they may contain acids or poisonous chemicals, such as cyanide from gold mining. Tailings are usually dumped into ponds surrounded by earth walls. Leaks in these ponds are common, with up to five major spills occurring every year worldwide.

In Hungary in 2010, a toxic sludge from a burst pond at an aluminium processing plant (Figure 9.3.10) swept through a village and killed eight people and injured another 150. It also polluted one of Europe's major rivers, the Danube.

In Australia, laws require mining companies to comply with strict procedures. Environmental scientists design and monitor pollution control measures. Dust levels are controlled by spraying water on roads, stockpiles and conveyor transfer points and fitting drills with dust collectors. Often there is an area of vacant land left between the mine and surrounding areas that may be affected by dust.



Figure 9.3.10 This spill at an aluminium processing plant in Hungary in 2010 killed eight people.

Water pollution is controlled by treating it chemically and leaving it to settle out in tailings dams. Clean run-off can be discharged (released) into surrounding watercourses, while other water is treated and re-used for reducing dust.

With underground mines, the surface area can still be used for other purposes such as farming, water reservoirs or urban development. This is obviously not possible with open-cut mines. They have to be rehabilitated (repaired) before they can be used for some other purpose. Rehabilitation may be done while mining is proceeding. In one part of the mine, there may be mining while in another part the area is being repaired. In general, the original top soils that were removed to create the open cut mine are replaced. Figure 9.3.11 shows the same mining site before and after rehabilitation.

The rehabilitation begins by carefully considering the water drainage of the area, so soil erosion can be reduced. This is achieved by ensuring that the slope of the land is not too steep and that vegetation can be planted to bind the soil together. Earthmoving is carried out using diggers to shape the surface to allow for this drainage. Sometimes a dam may be built to serve as a permanent source of water. Then the original topsoil that was kept from before the mining is replaced. The area is fertilised and replanted with plants native to the area. If pollution levels are safe, such areas may become suitable for parks or as refuges for wildlife such as waterbirds.

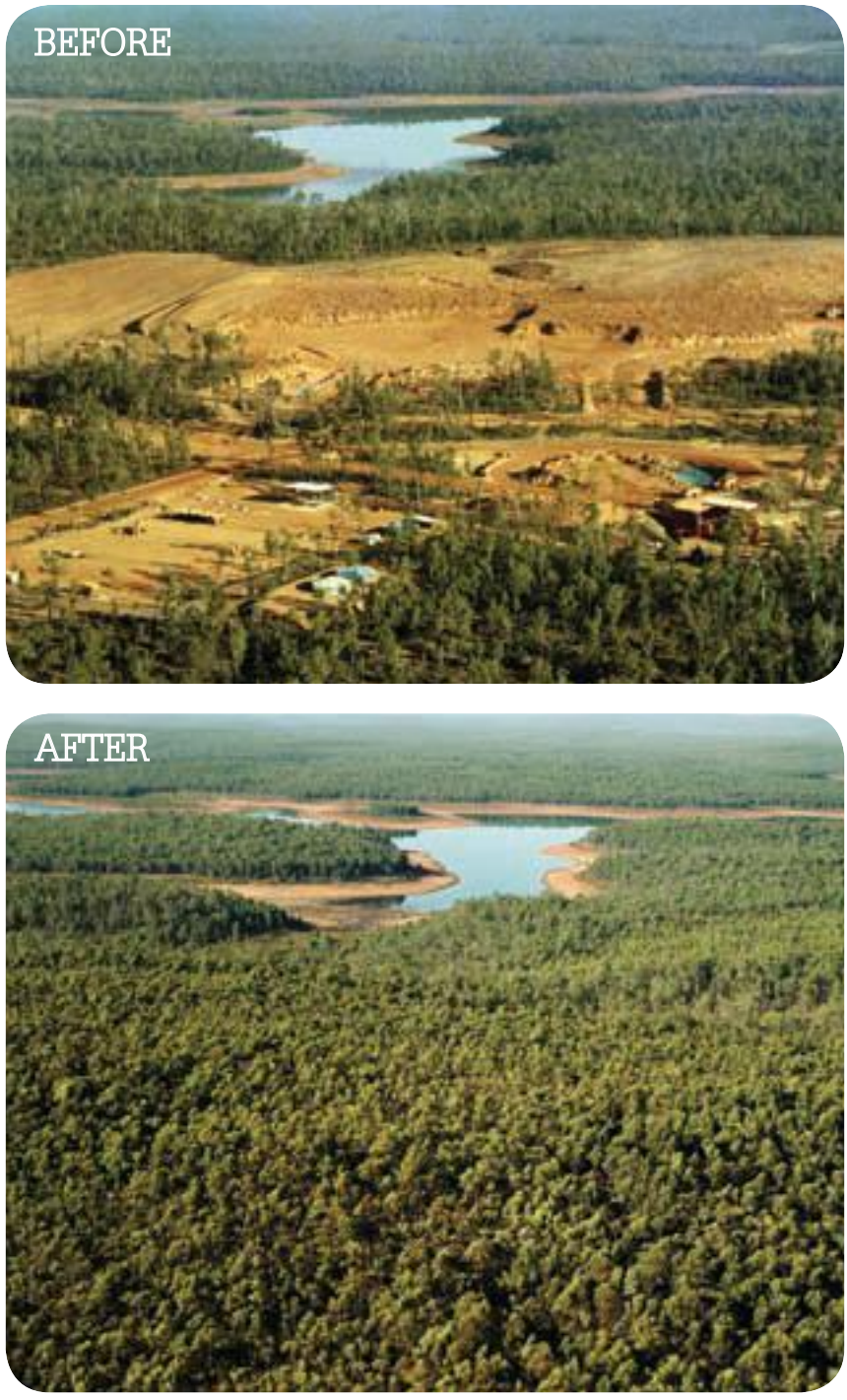



**Figure 9.3.11** These photos show a bauxite mine site in Western Australia before and after the site was rehabilitated.

# 9.3 Unit review

## Remembering

1 **State** the three main factors that determine what type of mining method is chosen.

2 **Name** four methods of mining.

3 **List** five methods of mining coal.

4 **List** five ways in which mining may cause environmental damage.

5 **Name** an example showing that mining can cause environmental damage.

## Understanding

6 **Outline** the process of open-cut mining.

7 **Explain** why a mining company would choose open-cut rather than underground mining.

8 **Outline** the process of dredging mineral sands.

9 **Describe** the process of solution mining of copper ore.

10 **Explain** how petroleum can be removed by drilling a hole.

11 **Explain** how erosion problems may be prevented when designing the rehabilitation of a mine.

## Applying

12 **Identify** the type of mining method you could choose if the ore body was:
- a gold at the surface
- b gold deep below the ground
- c coal in a mountainside
- d coal just below the surface
- e salt deep underground
- f uranium or malachite deep below ground.

13 The flow of oil from a well slows down after it has been in use for a while. **Identify** a method by which the flow may be increased again.

14 **Demonstrate** your knowledge of oil drilling by explaining the function of four key parts in Figure 9.3.6 on page 337.

15 **Demonstrate** your knowledge of mining methods by choosing a mining method shown in Figure 9.3.1 on page 334 and explaining what sort of ore body it would be used for mining.

## Analysing

16 **Compare** adits, vertical shafts and declines as methods of underground mining.

17 **Compare** the leach liquids used in solution mining of salts and copper ore.

18 **Compare** removal of petroleum from the Earth with solution mining of uranium.

## Evaluating

19 Gold miners in the past used shaft mines whereas modern mines on the same sites are open-cut. **Propose** what type of gold deposit the two mines located.

20 **Propose** why drilling rigs used in the ocean are sometimes mounted on board a ship rather than on a platform that is fixed to the ocean bottom.

## Creating

21 **Construct** a diagram of an ore body in the ground that would probably be recovered using:
- a solution mining
- b underground mining
- c surface mining.

## Inquiring

1 Research the advantages and disadvantages of open cut and underground mining methods. Present evidence for both their suitability as mining methods and the environmental effects.

2 Research an important mining or petroleum operation in your state or territory. Discuss the location, mineral or resource being recovered, and any benefits you think it gives your local community.

3 Research three sites where environmental damage has been caused by mining. Some sites you could start with are the Ok Tedi Mine in New Guinea, the Sukinda Valley in India and Kabwe in Zambia.

4 Research the environmental dangers of offshore oil rigs and find at least two examples of disasters.

# 9.3 Practical activities

## 1 Leach mining

### Purpose

To model the process of leach mining.

### Materials

- 500 mL beaker
- 250 mL beaker
- test-tube and rack
- 400 mL fine crushed rock (not soil)
- 2 g copper carbonate
- 5 mL syringe and plastic tube
- 2 × 10 cm plastic tubes, each containing a pencil (for wells)
- filter funnel (plastic)
- retort stand, bosshead and clamp
- 100 mL 0.2 M sulfuric acid
- spoon
- iron nail



**SAFETY**
Sulfuric acid is corrosive.

### Procedure

1. Place 2 g of copper carbonate (your mineral) in the large beaker.
2. Fill the beaker with the fine crushed rock to a few centimetres below the top.
3. Make sure the pencil is not a tight fit in the plastic tube and can be removed easily. Drill a hole down to the copper ore using the plastic tube containing the pencil. This is the injection well. Try to reach the bottom of the beaker. Remove the pencil.
4. Place the filter funnel in a retort stand. Connect the end of the filter funnel to the plastic tube in the beaker. Make sure the lower end of the plastic tube is about half a centimetre off the bottom of the beaker as shown in Figure 9.3.12.
5. Carefully pour about 100 mL of sulfuric acid into the filter funnel, making sure it does not spill over the top of the funnel. Leave to stand for about 2 minutes.
6. Drill another hole down into the beaker using the other plastic tube containing the pencil. Make sure it is about half a centimetre off the bottom of the beaker. Remove the pencil. This is the recovery well.
7. Pass the other end of the plastic tube on the syringe down into the recovery well.
8. Carefully pull the plunger out on the syringe. When you recover some liquid, squirt it into the test-tube. Keep removing liquid until you have about 20 mL. (If you cannot remove any liquid, push the plastic tube of the recovery well down to the bottom of the beaker and try again with the syringe.)
9. Add an iron nail to the test-tube of recovered mineral and observe it for several minutes.

### Results

Record your observations.

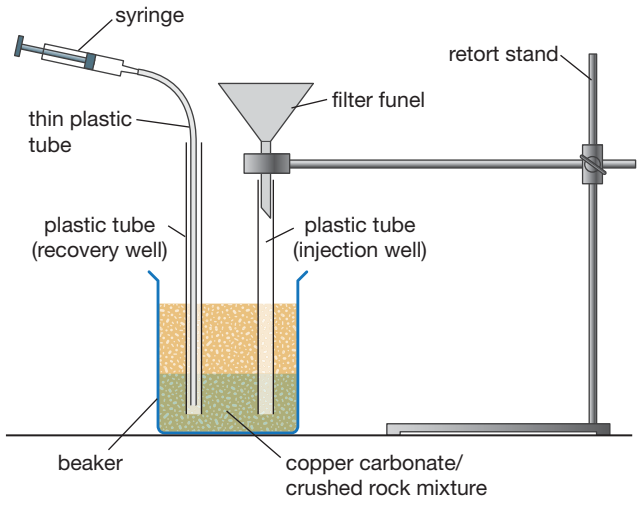



Figure 9.3.12

### Discussion

1. **State** the part of this model that represents the:
   - **a** ore body
   - **b** mineral
   - **c** injection well
   - **d** recovery well
   - **e** leach solution
   - **f** pump.
2. **Describe** how this model showed the process of solution mining using a leach solution.
3. From your observations on this simulation, **propose** what would need to be done to the leach solution after it is pumped out of the recovery well in a real leach mine.
4. **Describe** what happened when the iron nail was placed in the blue solution.
5. **Propose** what substance was formed on the iron nail.

# 9 Chapter review

## Remembering

1 **List** some reasons why mining is important to Australia.

2 **List** ten minerals that are important to Australia.

3 **List** five exploration methods used to locate minerals, coal or oil.

4 **List** the following steps in the correct order when extracting a metal from the Earth: enrichment, mining, exploration, mapping, extracting.

## Understanding

5 **Explain** how iron ore, copper ore, gold and diamonds came to be where they are found.

6 **Explain** how coal and oil are formed.

7 **Describe** three aerial exploration methods used to locate ore deposits.

8 **Describe** how geologists represent ore bodies on a geological map.

9 **Outline** the process of environmental repair in the mining industry.

10 **Describe** five different jobs that enable us to use the resources of the Earth.

11 **Modify** the following definitions to make them correct.

- a A mineral is a naturally occurring substance in the Earth's crust.
- b A streak is the colour when the mineral is crushed to a powder.
- c An electromagnetic survey measures the effect of applying an electric current to the Earth.
- d A seismic survey sends a magnetic field into the ground surface and records the reflected waves.

## Applying

12 Write a procedure to a prac that would **demonstrate** that gravity can separate heavy minerals from the rest of the ore.

13 Steel is harder than copper. Write a method that would **demonstrate** this.

14 Magnetite, cassiterite, tourmaline and haematite often look the same. They are all black minerals. However, one is magnetic. Testing the streak of the three remaining minerals gives one red streak and two white streaks. The two minerals with white streaks have very different densities. **Outline** the tests that would allow you to **identify** which mineral is which.

## Analysing

15 **Compare** the suitability of open-cut mining with that of underground mining for an ore body that starts 20 metres below the surface and runs in narrow channels 2 km into the Earth.

## Evaluating

16 **Propose** a suitable mining method if the ore body is:

- a iron ore at the surface and spread over a large area
- b gold at the surface in narrow veins
- c coal deep below ground
- d salt on the surface.

## Creating

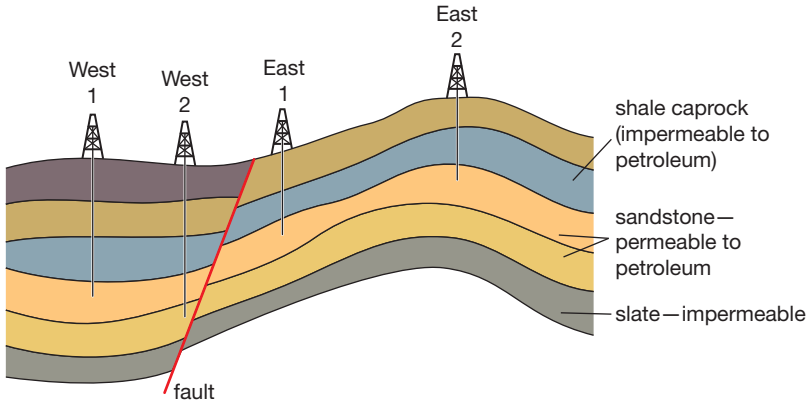
17 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

mineral
hardness
coal
ore
petroleum
exploration
mine
open-cut
well
rehabilitation



# Thinking scientifically

**Q1** Petroleum is less dense than water and so tends to rise up through rock. Consider this diagram showing four possible sites to drill for petroleum.

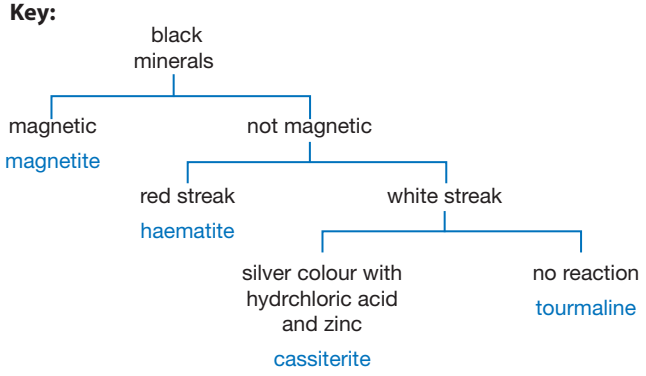



The best place to choose would be:

**A** West 1
**B** West 2
**C** East 1
**D** East 2.

**Q2** Consider the key on the right, which shows how to distinguish between four black minerals.

**Key:**




Which of the following is correct?

**A** Cassiterite can only be distinguished from tourmaline by checking the streak.
**B** Haematite and tourmaline do not react with hydrochloric acid when in contact with zinc.
**C** Tourmaline cannot be distinguished from cassiterite by the streak test.
**D** Magnetite and tourmaline are magnetic.

Questions 3 and 4 refer to the table of mining methods on the right.

| Name | Use | Description |
|---|---|---|
| Shaft | Deep ore body | Vertical tunnel |
| Decline | Deep ore body | Tunnel on a slope |
| Adit | Ore body in a mountain | Horizontal tunnel into mountainside |
| Open-cut | Ore body near surface spread over wide area | Large hole with series of steps down and roads around inside of the sloping walls. Working surface goes deeper as it is mined |
| Dredge | Ore body in soil | Hole flooded and slurry dredged up and separated usually by gravity |
| Strip mining | Shallow resource (e.g. coal) spread over long distance or area | Machine moves along, stripping the surface and gradually going deeper |
| Leach | Soluble ore body | Solution pumped in to dissolve ore and then pumped out again |

**Q3** A suitable mining method for mineral sands at a beach would be:

**A** shaft
**B** adits
**C** decline
**D** dredging.

**Q4** The mining method that would probably not require crushing of the ore after mining would be:

**A** leach
**B** open-cut
**C** decline
**D** strip.

# Glossary

## Unit 9.1

**Flame test:** the colour a mineral glows when heated to a high temperature in a flame

**Hardness:** physical property based on ability to scratch particular minerals

**Hydrothermal fluids:** superheated liquids in the Earth's crust

**Lustre:** how shiny a mineral is

**Mineral:** a naturally occurring liquid or solid in the Earth's crust but not including oil or coal

**Ore:** rocks containing minerals

**Ore body:** large deposit of ore

**Streak:** the colour of the mark left by scraping the mineral on a white unglazed tile



Flame test



Streak

## Unit 9.2

**Core sample:** a drilled sample of rock

**Cross-section:** side view

**Electromagnetic (EM) survey:** a survey that measures the effects of applying a magnetic field to the Earth

**Geochemistry:** the use of chemistry to show what minerals are present in an area



EM survey

**Geological map:** map that shows the geology of an area, including the appearance of the ore bodies from above and from the side

**Gravimeter:** very sensitive instrument that measures small differences in the gravitational pull of the Earth

**Magnetometer:** device that measures magnetic field strength

**Satellite images:** images created using data from satellites that detect electromagnetic radiation from Earth

**Seismic survey:** when a shock wave is sent into the ground surface, and the reflected sound waves are recorded



Satellite image

## Unit 9.3

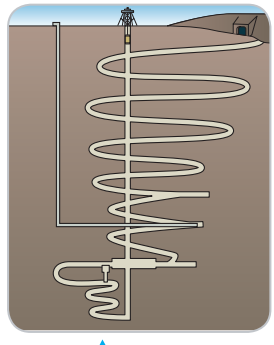
**Adit:** horizontal tunnel through a mountain

**Decline:** underground shaft that is on a slope, allowing vehicles to drive up and down

**Dredging:** process involving a floating platform that mixes water and rocks or soil to separate minerals

**Leach solution:** a solution pumped into the ground to dissolve minerals in the rocks

**Petroleum:** oil and gas occurring naturally in rocks



Decline

**Petroleum well:** narrow hole drilled into the rock, allowing oil and gas to escape to the surface

**Open-cut mine:** a large pit dug into the ground surface

**Vertical shaft:** a narrow tunnel dug vertically downwards into the Earth



Open-cut mine

# Index


## A

abdominal muscles 113
Aboriginal people
    bark paintings of 291
acids 336
acid weathering 291
adits 336, 344
adult stage 133, 134
aerial exploration 326–8
afterbirth 161, 168
aim 37, 38
air 92, 222, 259
air-conditioning 192, 193
aircraft 3, 195–6, 267, 284, 315
aircraft surveys 326–8
alchemy 237–8
alcohol, pregnancy and 162
algae 299
allotropes 252, 275
alloys 216, 236, 260, 275, 316
aluminium 235, 236, 281, 315, 316, 338
aluminium cans 210
aluminium oxide 236, 315, 316
aluminium potassium sulfate 280
alveoli 89, 90, 91, 92, 129
amino acids 83, 119
ammonium nitrate 209
amniotic fluid 160, 161, 163, 168
angina 102, 103
animal bones 116
animal cells 48–9, 52, 58
animals 190
    asexual reproduction in 144
    sexual reproduction in 142
antagonistic muscles 112, 113, 129
anther 140, 141, 145, 167
antimony 329
anti-rejection drugs 104
anus 80, 83, 129, 151
aorta 101
apatite 317
appendicular skeleton 110, 129
appendix 80, 84
Archimedes 224
argon 250
arsenic 329
arteries 99, 129
artificial limbs 169
asexual reproduction 139, 143–4, 167
ash 260
Asian longhorn beetle 136
asparagus 118
asthenosphere 278
asthma 162
atomic numbers 268–9, 275
atoms 231, 238, 244, 246, 249, 251, 257, 266–72, 275
atomic symbols 249
atomic theory of matter 231, 267
atria 101, 102
attention deficit hyperactivity disorder (ADHD) 162
augers 335
aura (rocks) 320
Australia
    economy of 315–16
Australian Customs Service 135
Australian Quarantine Inspection Service (AQIS) 135–6
Australian websites (.au) 13
auxiliary power units (APUs) 183
average measurements 4–6, 38
axial skeleton 110, 129
axons 60, 76
azurite 316, 330, 336

## B

bacteria 43, 51, 57, 62, 68, 76, 82, 83, 104, 135, 145, 322
ball and socket joint 112, 130
balloons 215, 248, 250
banded deposits 319
bark 59
bark paintings 291
barley 145
basalt 281, 282, 283, 330
base metals 237
Bates, Anna 161
batteries 182, 193
battery-controlled car 184
bauxite 301, 316, 339
beltless engine 182
bibliography 14, 20, 38
biceps 112, 113
bicycles 183, 253
bile 82, 119, 129
Bingham Canyon Mine 335
binocular microscope 41, 42, 43, 46, 47, 76
biodiversity 338
biosecurity 135–6, 167
biosensors 322
biotite 283
birds 142
birth 152, 160, 161, 163
bitumen 315
black coal 321
Black Death 145
bladder 70, 120, 130, 151, 153
blastocyst 159, 160, 161, 163
blood 67, 98, 99–100, 102–3, 260, 261
blood cells 60
blood clots 103
blood pressure 121
blood vessels 98, 99–100, 101, 105, 111
bob 30–1, 38
body hair 154
body heat 119
body temperature 60, 102
body waste disposal 118–25
boiling 205, 208, 244
bone marrow 103, 110
bones 65, 66, 109–17, 130
bornite 316
Bowen Basin 321
Boyle, Robert 237
brain 60
Brand, Hennig 237
brass 260
bread 27–8, 80
breakfast cereal 173, 247
breastbone 100, 110
breasts 154
breathing 89–97
breccia 300
bridges 294
brittleness 248, 275
broken bones 113–14
bromine 248
bronchi 89, 90, 129
bronchioles 90, 129
Brown, Robert 52
bruises 100
bubbles 207, 222, 260, 282
buckyball 250, 251, 253
buildings 193, 283, 301
bulbs 143
Bunsen burner 6, 19
buoyancy 17
butterflies 132

## C

calcite 317
calcium 65, 249, 258, 322
calcium carbonate 209, 298
calcium phosphate 111

# Index


calcium sulfate 290, 298, 319
calories 172
cancer 68, 69, 122
canines 81
capillaries 83, 91, 99, 105, 121, 129
caprocks 321
car airbags 208
carbon 196, 232, 236, 248, 249, 251, 252–3, 258, 260
carbon dioxide 49, 60, 91, 92, 93, 100, 119, 160, 206, 208, 209, 232, 234, 258, 259, 260, 291
carbon monoxide 258, 260
cardiac muscle 58, 60, 100, 129
carotid pulse 107
carpals 111
cars 182, 183, 184, 193
cartilage 90, 111, 130
cassiterite 316
cast 114
caterpillar 132, 133
Cayley, George 195
cells 39–77, 79, 102, 129
  respiration and 92–3
cementing 298, 313
cervix 151, 152, 158, 161, 168
chalcopyrite 316
chalk 299
Chang, Victor 105
charcoal 252
cheek cells 50
chemical change 207–9, 244
chemical digestion 81
chemical energy 173, 174, 180, 182, 183, 184, 202, 233
chemical equations 93, 234
chemical properties (atoms) 268
chemical reactions 231–41, 244
chemical sedimentary rocks 298, 300, 313
chemical waste 15
chemical weathering 291, 313
chemistry, alchemy and 238
chert 300
chiropractor 169
chloride 257
chlorine 248, 249, 250, 259, 260
chlorophyll 49, 59, 76, 261
chloroplasts 49, 52, 59, 76
cholesterol 93, 102, 129
chromite 316
chromium 236, 260, 316
chromium oxide 316
circulatory system 79, 92, 98–108, 129
clastic sedimentary rocks 298, 299–300, 313
clavicle 111
clay 292, 293, 294, 305
climate change 12, 190
clitoris 151
clotting 104, 105
clownfish 140
coal 299, 300, 301, 315, 316, 321, 335
coal elevator 334
coarse focus knob 41
coating 235
cold can 206
collagen 111, 113
colloids 260
colour change 207, 208, 232, 318
commercial websites (.com) 13
communicator 29
compact bone 110, 130
complex chemicals 80
complex organisms 65–6
compounds 257–65, 267, 275, 316
compressibility 215
compression (bones) 110
computer models 267
conclusion 20, 38
concrete 222
condensation 205, 206, 209, 216, 244
conduction 59, 249
conglomerate 300
conifers 141
connective tissue 66, 67, 77
conservation of energy, law of 181, 202
consistency (rocks) 313
contact metamorphism 306, 313
contour bench 334
contraction 205, 215, 244, 289
controlled variables 28, 35, 38
cooking oil 223
cooling 194
copper 222, 236, 246–7, 316, 320, 322, 329, 330, 336
copper carbonate 316, 320, 336
copper oxide 236
copper sulfate 280
copper sulfide 316, 328
copulation 142, 158, 167, 168
core 278, 329
cork cells 51
coronary arteries 102
corrosion 235–6
corrugated iron 235
corundum 317
cotyledon 141
Cowper's gland 153
cows, digestion of 84
Cram, Donald 262
cricket 182
cricket pitches 294
cross-fertilisation 145, 167
cross-section 330, 344
crown ethers 262
crushing 204, 205, 210, 335
crust 278, 306
crystal lattices 251, 253, 257, 259, 266
  see also lattices
crystallisation 298, 317, 319
crystals 206, 209, 266, 280, 282, 283, 290, 300, 313, 319
Cullinan diamond 307
Cupriavidus metallidurans 322
Curl, Robert 253
curve of best fit 21, 24, 38
customs 135–6
cyanide 338
cytoplasm 48, 49, 68, 76


## D


dairy products 135
Dalton, John 231, 267
dams 339
Danny Deckchair 224
data presentation and analysis 2–6, 12–13, 14, 18–26, 38
da Vinci, Leonardo 195
decline (mining) 335, 336, 344
deep vein thrombosis 105
defecation 119, 130
deformities 162
dehydration 84
deltoids 113
Democritus 267
density 221–30, 244
dental laser ultrasound 122
deoxygenated blood 100, 101, 105, 129
dependent variable 21, 28, 38
deposition 205, 244, 292, 320
derrick 336, 337
design, energy-efficient 190–9
development 133, 142, 167
developmental retardation 162
diamond 251, 253, 306, 307, 316, 317, 329
diaphragm 89, 92, 120, 129

diarrhoea 84
diatoms 57
diet 24
diffusion 217, 244
digestive system 67, 68, 79–88, 119, 129
dilation 161
diseases 135, 144–5, 190
dispersal 144
displacement 224, 244
dissection 42, 76
dissolution 206–7
DNA 258, 261
dogs 66, 84, 142
dolerite 283, 291
domain 13, 38
dominoes 179
double circulatory system 100, 105
double-glazing 199
drag line 334, 335
drawing (microscope studies) 55
dredging 336, 344
drift mine 334
drills 307, 336–7
drought 206
drugs, pregnancy and 162
dry ice 206
dry washing machines 194
ductility 247, 275
duodenum 80, 82, 129
dust suppression 338, 339

## E

Earth
    shape of 30, 31
    structure of 278
earthworms 142
eaves 193
economy, resources and the 315–16
eddy currents 328
educational institution websites (.edu) 13
eggs 132, 133, 134, 139, 140, 142, 143, 144, 145, 158, 167
ejaculation 158, 168
elastic potential energy 174, 180, 202
electric fan 183
electric motor 184
electric toothbrush 182
electrical energy 172, 180, 181, 182, 183, 184, 192, 202, 253, 301
electromagnetic (EM) survey 328
electronic balance 4
electron microscope 43, 45, 48, 52, 76
electrons 268, 269, 275
electron shells 269, 275
elements 231, 246–56, 258, 267, 275
elephant toothpaste 16
embryo 141, 159, 160, 161, 162, 167, 168
Emons, Amy 169
endometrium 152, 160
endoplasmic reticulum 49, 76
endothermic chemical change 209, 244
energy 60, 92–3, 170–202
energy rating label 191–2, 193, 202
enrichment 321
environment
    mining and the 338–9
    reproduction and the 144–5
enzymes 262
epididymis 153
epiglottis 81, 89
epithelium 66, 77
equipment 11, 29
erectile tissue 153
erosion 292, 308, 313, 338
errors, mistakes and 3–7, 36, 38
eruptions 279, 281
Escherichia coli (E. coli) 121
estrogen 152, 154
eucalypts 134, 143
evaporation 205–6, 209, 216, 244, 298
excretory system 67, 79, 119–21, 130
exercise 93, 105, 107, 209
exhalation 92
exothermic chemical change 209, 244
expansion 205, 215, 244, 289
experiments 21, 36
exploration 314–41
Explorer, MS 226
explosions 209, 335
external development 142
external fertilisation 142
extraction 315, 321
extrapolation 21, 36, 38
extrusive igneous rocks 279, 281, 282, 313
eyes 122

## F

facial hair 154
faeces 83, 84, 119
fair test 28, 38
Fallopian tubes 151, 158, 168
fat cells 60
fats 83, 93, 102
feathers 221
feldspar 281, 283, 317
females 133, 134, 139–40, 142
    reproductive system of 151–3, 154
femur 103, 111
ferns 141, 144
fertilisation 139–40, 142, 159, 160, 167
fetus 122, 160, 161, 162, 168
fibre 50
fibre optics 298
fibula 111
field of view 42, 44, 76
filament 141
fine focus knob 41
fired clay 305
first-hand data 2–10, 15, 38
fish 142
fission 144
flame test 318, 344
flatworms 140
Fleming, Simon 122
flexed muscles 112
flight 195
flint 300
floating 223
floating platforms 337
floors 307
flowers 134, 139, 140–1, 167
fluorescent globes 190–1, 192, 193
fluorine 260, 317
Flyer, The 195
fog 206, 260
foliated rocks 306, 313
follicles 151, 152
food dyes 221
food energy 68, 172, 173
foot 112
foreskin 153
formula equations 234, 244
fossil fuels 183
fossils 298, 299, 300, 321
Foucault's pendulum 30
freezers 205, 216, 244
freezing weathering 290
Fremantle prison 301
frequency 30, 38
friction 182
froglet 134
frogs 134
frontal muscle 113

# Index


fruits 135, 141, 167
FSH 152, 154
fumigation 135
fungal cells 49–50
fungi 50, 62, 144, 145, 153

## G

gabbro 330
galena 316
Galilei, Galileo 31
gall bladder 80
galvanising 235
gametes 139, 140, 142, 144
garden, life cycles in a 133
garnets 305, 307
gases 208, 214, 215, 216, 217, 222, 232, 248, 249, 260
gas exchange 91
gas rigs 337
gastric brooding frog 134
gastric juice 81, 82, 129
gastrochemius 113
gastroenteritis 84
gas weathering 291
gemstones 316
genital pore 140
geochemical surveys 329, 344
geological maps 330, 344
geology 278, 281, 289, 305, 313, 317, 327, 328, 329, 330
geophones 328, 329
geothite 319
geraniums 145
germination 134, 141, 167
gestation 160, 168
gills 134
glacial weathering 290
glaciers 12
glass 181, 307
gliders 195
glomerulus 120
glucose 81, 82, 83, 88, 92, 93, 258
gluteus muscles 113
glycerol 83
gneiss 307
gold 222, 236, 237, 247, 268, 306, 315, 316, 318, 320, 322, 328, 329, 338
Golden Gate Bridge 235
government buildings 301
government websites (.gov or .gov/au) 13
granite 281, 282, 283
graphite 251, 252
grasshopper 133
gravimeter 327, 344
gravitational potential energy 174, 181, 202
gravity 31, 268, 292
gravity surveys 327
Great Plague 145
Great Star of Africa 307
greenhouse gases 26, 190
Greenland 290
grey-scaling 122
groundwater 329
growth 131–69
guard cells 59, 77
guava rust 136
gum trees 134
gut bacteria 58
gypsum 298, 300, 301, 317, 319

## H

haematite 301, 316, 318
haemoglobin 103, 119, 120, 129, 261
hairdressing 169
hairs 41
halite 300, 319
Hamersley Basin 319
hamstring 114
hardness 317, 344
HCG 161
head frame 336
heart 67, 98, 99, 100–2, 105, 122
heartbeat 99, 102
heartburn 84
heart disease 102, 103, 104, 105
heart muscle 93, 102
heart rate 107
heat energy 6, 172, 179, 180, 181, 182, 183, 184, 192, 202, 209, 305, 306
heat transfer 180
helium 222, 224, 248, 250
hen's egg 56
hermaphrodites 140, 142, 145, 167
hertz 30, 38
hinge 130
hinge joint 111
hips 154
hole in the heart 105
honey 222
honey bees 136
Hooke, Robert 51
horizontal shafts 336
hormones 152, 154, 168
hornfels 307
horses 79
host rock 335
hot-air balloons 205, 222
household appliances 184, 191–2, 236
housing efficiency 192–3
human body 258
human cells 50
human digestion 84
human energy 184
human reflex errors 4
human reproduction and growth 142, 151–7, 159
humans 66, 79
humerus 111, 113
humus 293
Hungary 338
Huygens, Christian 31
hybrid cars 193
hydra 143
hydration 141
hydrochloric acid 82, 232–3, 234
hydroelectric energy 183
hydrogen 222, 232–3, 233, 250, 258
hydrogen fuel cell 233
hydrogen peroxide 16
hydrogen sulfide 208
hydrothermal fluids 320, 344
hypothesis 18, 38

## I

ice 226
icebergs 226
ice cubes 205
Iceland 284
ice pack 209
ice weathering 290
igneous rocks 278–88, 300, 306, 308, 313, 319, 320
image 41, 76, 132, 167
immiscibility 260, 275
immune system 60, 103, 104
implantation 152, 159, 168
imprint page 12, 38
incandescent light 184, 190–1, 192
incisors 81
incomplete metamorphosis 133
incompressibility 214
independent variables 21, 28
Indonesia 284
infections, kidney 121

infrared imaging 330
inhalation 92
injuries, muscle 113
inner core 278
input 183
insects 132–3, 142
instrument error 4, 38
insulation 192, 193, 202
intercostal muscles 89
interlocking crystals 281, 313
internal development 142
internal fertilisation 142
intestines 119
intrusive igneous rocks 279, 281, 283, 313
invisible ink 208
involuntary muscles 58, 60, 62
iodine 88, 248
iron 103, 235, 236, 247, 260, 269, 291, 315, 322, 326
iron ore 316, 319, 321
iron oxide 235, 291, 315, 316, 318, 319, 320, 321
iron pyrites 318
irregular solids 224

## J

jade 307
Janssen, Zaccharias and Hans 51
jellyfish 62, 109
jewellery 307
joints 111–12, 130
joule 172, 202

## K

Kalgoorlie 335
kerosene 315
kidneys 104, 119–21, 151, 209
kilojoule 172
kilowatt hours 191–2
kinetic energy 172, 179, 180, 181, 182, 183, 184, 193, 202
Kingsford Smith, Charles 196
kites 195
koalas 58
Kossoff, George 122
Kroto, Harold 253
krypton 250

## L

labia 151
laboratory techniques 19, 238
labour 161, 168
lakes 292
land subsidence 338
lapis lazuli 306, 307
Large Hadron Collider 268
large intestine 68, 80, 83, 129
larvae 132, 135, 167
larynx 89
Latrobe Valley 321, 335
lattices 249, 250, 275
see also crystal lattices
lava 279, 313
lava lamp 221
law of conservation of energy 181, 202
layered rocks 299
leach mining 336
leach solution 336
lead 316
lead sulfide 316, 328
Leaning Tower of Pisa 293
leaves, colour change of 207
LEDs (light-emitting diodes) 194
left atrium 101
left ventricle 101
Lego 246
Lehn, Jean-Marie 262
length 35
lens 41, 44
LH 152, 154
life cycles 132–8, 167
ligaments 66, 111, 112, 114, 130
light energy 172, 181, 182, 202, 209
light microscope 41, 43, 44, 52, 76
Lilienthal, Otto 195
limb deformities 162
limestone 299, 300, 301, 321
limonite 319
Lindbergh, Charles 196
line graphs 21–2, 23–4, 25, 26, 35, 36, 37
line of best fit 21, 24, 38
linear relationship 22
liquid core 278
liquids 214, 215, 216, 217, 222, 224, 226, 249, 260
lithosphere 278
live animals 135
liver 68, 82, 119, 129
living donors 104
longitude 31
low-grade ores 335
lungs 89, 91, 92, 100, 101, 119, 134,
lustre 318, 344
lysosomes 49, 76

## M

McBride, William 162
magma 279, 280, 283, 306, 308, 313, 319, 320
magnesium 232–3, 249
magnesium sulfate 232–3, 280
magnetic fields 326–7, 328
magnetic refrigeration 194
magnetite 319, 327
magnetometer 327, 344
magnification 40, 41, 42–3, 44, 45, 47, 55, 76
malachite 316, 336
males 133, 134, 139–40, 142, 144
reproductive system of 153–4
malleability 247, 275
mammals 142
manager 29
manganese carbonate 317
mantle 278, 279, 306, 313
marble 307, 308
marsupials 142
mass 35, 36, 223, 225, 231, 244
mass number 269, 275
materials list 18
mating 134
measurement 4–6, 10, 36, 38, 43
measuring cylinder 224
meat 84
mechanical digestion 80–1
medulla 120
megajoules 172
megalitres 20
melting 204, 205, 210, 216, 244
membrane 49, 62, 76, 160
menstruation 152–3, 154, 168
mental illness 162
mercury 222, 236, 247, 251
metacarpals 111
metallic elements 247–8
metals 180, 247, 251, 260, 275, 329
metamorphic rocks 280, 305–10, 313, 319
metamorphosis 133, 167
metatarsals 111
methane 234

# Index


method 19, 38
methylated spirits 280
metric system 20, 36, 43, 44, 225
metronome 31
micrometres 43, 44, 76
microscopes 41–3, 45, 46–7, 51–2, 55, 76, 79, 281, 282
milk 260
mine shaft 335
minerals 279, 282, 313, 315, 316–21, 344
mineral sands 336
mining 315, 316, 319, 321, 334–6
  environment and 338–9
mirror 41
miscarriage 162
miscibility 260, 275
mistakes, errors and 3–7, 38
mitochondria 48, 60, 62, 76
mitosis 68, 77
mixing 204, 206–7
mixtures 210, 216–17, 259–60, 275
modelling 64, 88, 275
Mohs scale 317
molars 81
molecular compounds 258
molecular elements 250–1
molecular machines 262
molecules 231, 244, 249, 250, 257, 275
monatomic elements 250, 275
monocular microscope 41, 42, 43, 44, 45, 47, 50, 76
morning sickness 162
morula 159
mosses 141, 144
Mount Eyjafjallajökull 284
Mount Galunggung 284
Mount Oscar 327
Mount Tom Price 319
Mount Whaleback 319
mouse growth 21
mouse's tail 5–6
mouth 68, 81
movement 172
Mt Kosciuszko 2, 3, 7
mucus 82, 89
multicellular organisms 58–9, 77
muscle cells 58, 62, 79
muscles 110, 112–14, 130, 154
muscle tissue 66, 67, 77, 93
mushrooms 144


## N


Nägeli, Karl 52
Naica Cave 319
nanobots 261
nanometre 20, 262
nanotubes 253
nasal cavity 89
National House Energy Rating Scheme 193, 202
native copper 316
natural cements 298, 313
natural gas 316, 321
navigation 31
negative charge 268
neon 250
nephrons 120
nerve tissue 60, 67, 77
nervous system 67
network websites (.net) 14
neutrons 268, 269, 275
New South Wales 336
Newton, Isaac 237
nickel 260, 316, 329
nickel sulfide 316, 330
Nicola, Dr James 169
nitric oxide 232
nitrogen 92, 247, 250, 259, 260
nitrogen dioxide 232
Nobel Prize in Chemistry 262
non-foliated rocks 307
non-interlocking grains 299
non-metallic elements 247–8, 250, 275
non-metallic lattices 251
non-renewable energy sources 183, 190
non-spontaneous reactions 233
North West Shelf 337
nostrils 89
nuclear energy 174, 202
nucleus (cells) 48, 49, 52, 59, 60, 68, 76
nucleus (atoms) 268, 269, 275
nutrients 80, 100, 102, 173
nymph 133, 167


## O


oak 222
objective lens 41, 42, 47, 76
obsidian 223, 282, 283
ochre 291
octopus 142
ocular lens 41, 42, 76
oesophagus 80, 81, 84, 129
oil 315, 316, 321
oil bacteria 337
olivine 281
Olympic Dam 327
onions 55
on-site exploration 328–9
Oodnadatta 327
opal 316
open-cut mining 335, 339
ore 316, 319, 330, 335, 336, 344
organ donors 104
organelles 48, 49, 50, 76
organic photovoltaics 194, 202
organic sedimentary rocks 299, 300, 313
organisation websites (.org) 13
organisms 65–72
organs 65, 67, 77, 79, 129
organ transplants 70, 104
outer core 278
overweight 93
ovulation 140, 141, 152–3, 154, 168
oxygen 60, 67, 89, 91, 92, 93, 100, 102, 103, 222, 232, 233, 234, 235–6, 247, 250, 257, 258, 259, 260, 261, 268, 281, 291, 316
oxygenated blood 100, 101, 105, 129
oxyhaemoglobin 103
ozone 232


## P


pacemaker 100
paint mixing 208
pancreas 68, 80, 82
parallax error 3, 8, 38
parental care 142
parthenogenesis 144, 167
particle model 214, 216–17, 244
patella 111
pectorals 113
Pedersen, Charles 262
pegmatite 320
pelvis 110, 111, 153
pendulum 30–1, 38
penicillin 8
penis 140, 142, 152, 153, 154, 158
pentlandite 316
perfume 217
peridotite 281
period 30, 38, 168
periodic table 248–9, 268, 275

peristalsis 81, 84, 129
permanent colour change 207–8
permeability 294, 313
peroxide 169
petal 141
Petovic, Aldijana 169
petroleum 222, 315, 316, 336–7, 344
phalanges 111
pharynx 89, 129
philosopher's stone 237
phosphorus 237, 250, 258
photosynthesis 49, 59, 76, 173, 202, 261
physical change 204–13, 214–20, 244
physical properties 221, 268
physical weathering 289–91, 313
piezo electricity 283
Pilbara region 315, 319, 327
pins and plates 114
Pistorius, Oscar 174
pivot joint 112, 130
placenta 159, 160, 161, 162, 168
plant cells 49, 52, 58, 59, 62, 64
plant growth 292, 293
plants 134, 190, 321
  asexual reproduction in 143–4
plant weathering 291
plasma 103
plaster of Paris 298
platelets 103, 110
platinum 236
pods 141
pollen 134, 140–1, 145, 262
pollination 140, 167
polystyrene 222
Ponting, Ricky 294
pools 193, 301
pore spaces 293, 313
Portland cement 298
positive charge 268
potassium 236, 249
potassium oxide 236
potatoes 139
potential energy 173–4, 202
power station 184
prac work 18–20, 23, 24, 28–9
precipitates 207, 209, 244
predictions 21, 23, 24, 25, 36, 267
pregnancy 158–64
premolars 81
pressure 215, 305, 306, 319
products 93, 232, 234, 244
properties 247, 257, 275
prostate gland 153
prosthetic running blades 174
prosthetist 169
protein 119
protists 57, 77
protons 268, 269, 275
protozoa 144
puberty 154, 168
pubic hair 151, 154
pulmonary artery 101
pulmonary vein 101
pulse 10, 99, 105, 107
pumice 223, 282, 283
pupa 132, 133, 135, 167
pure water 226
pus 57

## Q

qualitative data 2–3, 36, 38
quantitative data 2–3, 20, 36, 38
quarantine 135–6
quartz 281, 283, 317
quartzite 307, 308

## R

rabies virus 136
radial pulse 107
radio telescope 11
radius 111, 113
radon 250
reactants 93, 232, 234, 244
reaction time 5, 9
reading errors 4, 8, 38
recrystallisation 306
rectangular prism 223
rectum 68, 151
recycling 210
red blood cells 51, 60, 77, 91, 103, 110, 119
red imported fire ant 136
red soils 291
reflex tester 5
regeneration 145
regenerative braking 193, 202
regional metamorphism 306, 313
regular solids 223
rehabilitation (mining) 339
Reith, Frank 322
rejection 104
renal system 120
renewable energy 183–4
replanting 339
reproduction 67, 131–69
research planning 27–35
reservoir rock 321
resources 14, 15, 20, 315–25
respiratory system 67, 79, 89–97, 119, 129, 140
resting pulse rate 107
retort stand 19
rhodochrosite 317
ribosomes 48, 76
ribs 89, 92, 100, 110, 111
RICE (Rest, Ice, Compression, Elevation) method 114
right atrium 101
right ventricle 101
rivers 292
roads 301
Robinson, David 122
robots 261
rock cycle 308, 313
rock erosion 292
rock phosphate 301
rock spoil 334
rocks 277–313
root hairs 59, 77
roots 141, 143
rotifers 57
rubber band 173, 174
rubella 159
ruby 305, 307
Ruska, Ernst 52
rust 233, 235, 260
rutile 316

## S

saddle joint 112, 130
St Elmo's fire 284
St Martin, Alexis 86
saliva 81, 84
salt 120, 257, 259
salt lakes 319
salt weathering 290
sand 257, 259, 260, 292
sandstone 300, 301, 321, 329
SA node 67
sapphire 305, 307
sartorius 113
satellite images 330, 344
scale models 267
scanning electron microscope (SEM) 43, 44, 52

# Index


scanning tunnelling microscope (STM) 246–7, 250, 266, 267, 275
schist 307
Schleiden, Matthias 52
school laboratory 28
Schwann, Theodor 52
scientific data 1–38
scientific model 267
scoria 282, 283
scrotum 153
seasons 132
sea stars 145
seawater 226
second-hand data 5, 11–17, 38
sedimentary rocks 280, 297–304, 308, 313, 319, 320, 321, 336
sedimentation 292, 313
seeds 134, 135, 140–1
seismic surveying 328–9, 344
selenite 319
self-fertilisation 145, 167
SEM 70
semen 153, 168
sepal 141
sex-change animals 140
sexual intercourse 158, 168
sexual reproduction 139, 154, 158, 167
shade 192, 193
shaft mining 334
shale 329
shape 205
sharks 217
shaving foam 260
silica 284, 298, 307
silicon 250, 257, 259, 266, 281
silicon oxide 316
silt 292, 293
silt stone rock 294
silver 236, 237, 250, 316, 328
silver chloride 234
silver nitrate 234
silver oxide 236
sinking 223
skeletal muscles 58
skeleton 54, 67, 79, 109–11, 130, 169
skin 66, 67, 70, 79, 119
skull 110, 111
slate 307, 308, 330
slides 46, 47, 50, 54
slope mine 334
small intestine 66, 68, 80, 82–3, 129
Smalley, Richard 253
smells 217
smoking, pregnancy and 162
smooth muscles 58, 60
snails 142, 145
sodium 236, 249, 250, 257, 259
sodium azide 208
sodium chloride 232–3, 234, 259, 280, 290
sodium hydrogen carbonate 336
sodium hydroxide 232–3, 234
sodium nitrate 234
sodium oxide 236
soft bones 65
soft tissues 109
soils 135, 292, 293–4
soil weathering 289
solar energy 181, 183, 193, 194, 196
Solar Impulse 196
solder 260
solid core 278
solidification 205, 210, 244
solids 207, 214, 215, 216, 222, 223, 226, 232, 248, 249, 260
solubility 318
solutions 206–7, 216, 244
solvents 216
sound energy 172, 180, 181, 182, 202, 209
sparklers 233
specialised cells 77
specimens 41, 42, 43, 44, 47, 76
sperm 134, 139, 140, 142, 143, 145, 151, 152, 153, 154, 158, 159, 168
sphincter 82, 84, 120, 129
spine 67, 100
Spirit of St Louis 196
spongy bone 110, 130
spontaneous reactions 233
spores 144
sporting surfaces 294
sprains 114, 130
spreadsheets 20, 25, 35
stainless steel 236, 260
stains 42
stalactites 319
stalagmites 319
stalk 141
starch 81, 88
star rating 191–2
starting angle 35
state changes 216–17
steam 209
steam engine 184
steel 223, 236, 260
stem cells 69–70
stems 143
stereo microscope 41–2, 43, 44, 76
sterling silver 260
stigma 140, 141, 145, 167
stomach 68, 80, 82, 84
stomata 59, 77
stones 221
stored energy 173–4
strain 114, 130
streak test (minerals) 318, 344
streams 320
striated muscles 58
striped muscles 58, 60
stroke 103
strontium 318
structural cells 59
structure (rocks) 313
style 140, 141, 167
subatomic particles 268, 275
sublimation 205, 206, 208, 244
sudden infant death syndrome (SIDS) 162
sugars 49, 80, 81, 173, 206
sulfides 328, 329
sulfur 248, 250, 258, 322
sulfuric acid 232–3, 258, 284
super-saturated solutions 280
supramolecular chemistry 261–2
surface mining 334, 335
survival of species, reproduction and 139–50
suspension 260
swallowing 81–2
sweating 119, 154
synovial fluid 111, 130
systems 67–8, 78–131


## T


tabular information 25, 26, 35
tadpoles 134
tailings 338, 339
talc 317
tap root 143
tapeworms 140, 142
tare 4, 38
tarsals 111
teamwork 28, 38
tectonic plates 306, 313
teeth 68, 81
television, energy use and 93
temperature 4, 26, 205, 214, 215, 216, 289

tendons 66, 112, 113, 114, 130
tension (bones) 110
testes 140, 153, 154, 168
testosterone 154
texture (rocks) 313
thalidomide 162
thermometer 26, 205
thrombosis 99
thylite 307
tibia 111
TIM 13
timekeeping 31
tin 316
tissues 65–7, 69, 77, 79, 129, 159
Titanic, RMS 226
titanium 316
toads, life cycle of 134
toilet paper 29
tongue 81
topaz 317
toxic sludge 338
trachea 89, 90, 129
transmission electron microscope (TEM) 43, 44
trees 58, 59, 291
triceps 66, 112, 113
turntable 337
turquoise 306, 307
Twelve Apostles 290

## U

ulexite 298
ulna 111, 113
ultramafic rocks 330
ultrasound imaging 122
umbilical cord 159, 160, 161
unbanded rocks 307
uncanned meat 135
underground mining 334, 335–6
underground stem 143
unicellular organisms 57, 62, 68, 77
unit conversion 23, 225
upper mantle 279
uranium 316, 329, 336
urea 119–20, 130, 160
ureters 120, 130, 151, 153
urethra 120, 121, 130, 151, 153
urine 118, 120, 121, 153, 237
URLs 13–14, 38
useful energy 182–3
U-shaped valleys 290
uterus 151, 152, 158, 159, 160, 161, 168

## V

vaccines 69
vacuole 48, 49, 76
vagina 151, 152, 153, 158, 168
valves 99–100, 101, 102
van Leeuwenhoek, Antonie 43, 51–2
variables 27–8, 29, 31, 38
varroa mites 136
vas deferens 153, 168
vegetable oil 222, 257
vegetables 135, 193
vegetative reproduction 143
veins (body) 99–100, 129
veins (rocks) 320, 335
vena cava 101
ventilation 193
ventilation shaft 335
ventricles 101, 102
vertebral column 110, 111, 151
vertical shaft 336, 344
vibrations 172, 214, 215, 216
vibrator truck 328–9
villi 83, 129, 160
Virchow, Rudolf 52
viruses 52, 104, 135
voice 154
volcanoes 279, 282, 284, 306
voltage 184
volume 223–4, 225, 244
voluntary muscles 58, 62
vomiting 84
vulva 151

## W

wanderer butterfly 132–3
Wang, David Hsiao-chuan 122
washing detergent 267
wasted energy 182–3
water 49, 59, 83, 84, 92, 93, 102, 119, 121, 217, 222, 223, 224, 226, 232, 233, 234, 257, 258, 259, 260, 294, 329
water-holding capacity 294, 313
water level, candles and 25
water pollution 339
water saving 193
water temperature 21
water weathering 290, 291
wave weathering 290
weathering 289–96, 298, 308, 313
weevils 135
weight, mass and 223
wells 316, 336–7, 344
Western Australia 319, 327, 337, 339
wet mount 46
white blood cells 57, 60, 77, 103, 110
White Cliffs of Dover 299
white fat cells 60
white sand 294
Whittle, Frank 196
wind energy 183
wind weathering 291
window shading 193
windpipe 81
womb 151, 152, 168
word equation 234, 244
work 171, 202
World Health Organization 24
World War I 248
world wide web 13–14
wrasse fish 140
Wright, Orville and Wilbur 195

## X

xenon 250
x-rays 135

## Y

yolk sac 160

## Z

zero emissions house 192
zero error 4, 38
zinc 235, 236, 316, 322, 329
zinc oxide 236, 328
zirconium 316
zygote 139, 159,167