PEARSON science

NEW SOUTH WALES

S.B.

AUSTRALIAN CURRICULUM

It's an exciting time to be in education.

We are embarking on a journey that unites two significant educational initiatives: the implementation of the NSW Syllabus for the Australian Curriculum and the ever-increasing use of technology in our students' educational experience.

Pearson Australia is pleased to introduce their solution for the NSW Science Syllabus: **PEARSON science NEW SOUTH WALES**. It has been written from the ground up for the Australian Curriculum and developed specifically for the NSW Syllabus, and has been tested in focus groups and trialled in classrooms throughout Australia.

Whether you choose to use a printed book or a digital delivery medium, the **PEARSON science NEW SOUTH WALES** series can provide the content that you and your students need.

We hope you enjoy the journey you are about to take as much as we have enjoyed preparing for it. We look forward to working with you to implement the NSW Syllabus for the Australian Curriculum and to helping you manage your digital aspirations.

We would like to thank our authors for their extraordinary dedication and their contribution to the development of this project.

A slot canyon is formed over time when rapidly flowing water erodes sedimentary rock. A slot canyon is much deeper than it is wide. This one is in Antelope Canyon, Arizona.

Pearson Australia
(a division of Pearson Australia Group Pty Ltd)
707 Collins Street, Melbourne, Victoria 3008
PO Box 23360, Melbourne, Victoria 8012
www.pearson.com.au

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First published 2014 by Pearson Australia
2018 2017 2016 2015
10 9 8 7 6 5 4 3

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Publishers: Catriona McKenzie, Ross Laman and Alicia Brown
Project Editors: Jane Sunderland and Michelle Hessels
Editors: Kay Waters and Catherine Greenwood
Series Cover Designer: Glen McClay
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Printed in China

National Library of Australia Cataloguing-in-Publication entry
Author: Rickard, Greg, author.
Title: Pearson Science New South Wales. Student Book 8/ Greg Rickard, Warrick Clarke, Jacinta Devlin, Greg Linstead, and Maggie Spenceley.
ISBN: 9781 4425 6561 6 (paperback)
Subjects: Science--Study and teaching (Secondary)
Science--Textbooks.
Includes index.
Other Authors/Contributors: Warrick, Clarke, author. Devlin, Jacinta, author. Linstead, Greg, author. Spenceley, Maggie, author.
Dewey Number: 500
Pearson Australia Group Pty Ltd ABN 40 004 245 943

Acknowledgement
NSW Science 7–10 Syllabus © Board of Studies NSW for and on behalf of the Crown in right of the State of New South Wales, 2012.

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PEARSON science NEW SOUTH WALES

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NEW SOUTH WALES

Student Book

Written from the ground up for the Australian Curriculum and developed specifically for the NSW Science Syllabus for the Australian Curriculum, the student book acts as a guide for both student and teacher.

- Developed specifically for the NSW Science Syllabus
- Utilises an inquiry approach throughout
- The content is presented in a range of contexts within the interrelated strands of Knowledge and Understanding and Working Scientifically.

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 New South Wales** package together
- Includes all answers to the student and activity book.

EAL/D Activity Book

The EAL/D activity book incorporates tailored language and vocabulary support for English as an Additional Language or Dialect (EAL/D) learners. With activities matching page-for-page, the EAL/D activity book can be used alongside the standard activity book.

AUSTRALIAN CURRICULUM

ALWAYS LEARNING

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How to use this book

PEARSON science NEW SOUTH WALES 8 Student Book

PEARSON science NEW SOUTH WALES 8 has been designed for Stage 4 of the NSW Science Syllabus for the Australian Curriculum. It includes content and activities that cover all learning outcomes within the interrelated strands of Knowledge and Understanding, and Working Scientifically. The content is presented through a range of contexts to engage students and assist them to make connections between science and their lives.

Additional syllabus content is clearly identified and carefully placed in the flow of core content. Learning Across the Curriculum content is addressed throughout the series and indicated using icons.

PEARSON science NEW SOUTH WALES 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.

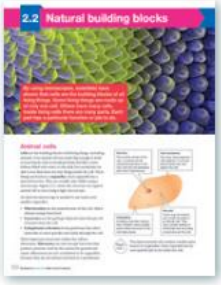
Chapter opening page

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

The key ideas reflect the syllabus content 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.

science4fun

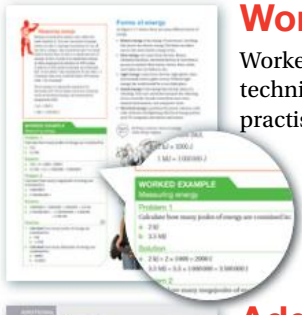
Inquiry-based activities using everyday materials assist students to understand key concepts under development.

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 practise key skills.

Additional content

Additional syllabus content is clearly identified using shading and icons.

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 research additional syllabus content and to go beyond the unit content.

Practical investigations

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

A Student-design icon indicates that an activity includes student input and design.

Safety boxes highlight significant hazards.

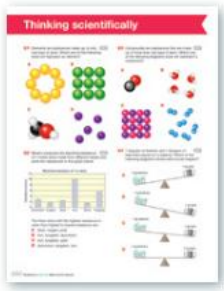
A safety glasses icon reminds students when appropriate to wear safety glasses.

Learning Across the Curriculum

Learning Across the Curriculum content is addressed throughout the Student Book using icons and in Learning Across the Curriculum spreads. A full list of Learning Across the Curriculum icons can be found on page xiii.

Chapter review

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

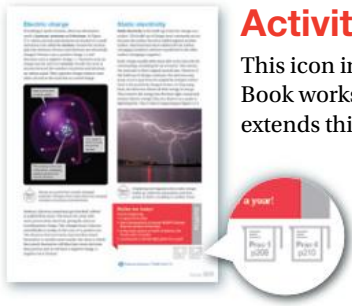


Thinking scientifically

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

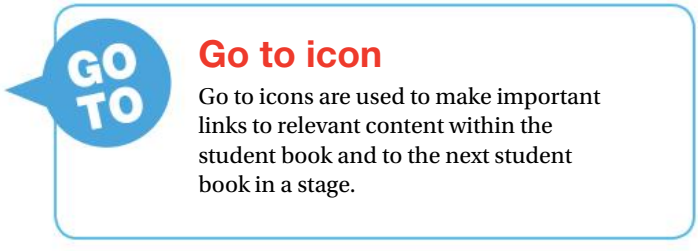
Glossary

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.



Go to icon

Go to icons are used to make important links to relevant content within the student book and to the next student book in a stage.

The PEARSON science NSW 8 package

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

- Activity Book
- EAL/D Activity Book
- eBook 3.0
- Teacher Companion
- Pearson Assess New South Wales

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. The verbs in black are consistent with the key verbs used in NSW syllabuses and examinations. The verbs shown in blue in this list may also feature throughout the book and are provided for additional support to teachers and students.

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
construct	Prepare or devise something, such as a key or diagram
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 steps for an experiment or procedure
investigate	Plan, inquire into and draw conclusions about
synthesise	Put together various elements to make a whole

Learning Across the Curriculum

NSW Syllabus Learning Across the Curriculum content is addressed throughout the series and is identified using the following icons.

Learning Across the Curriculum icons	
AHC	Aboriginal and Torres Strait Islander histories and cultures
A	Asia and Australia's engagement with Asia
CC	Civics and citizenship
CCT	Critical and creative thinking
DD	Difference and diversity
EU	Ethical understanding
ICT	Information and communication technology capability
IU	Intercultural understanding
L	Literacy
N	Numeracy
PSC	Personal and social capability
S	Sustainability
WE	Work and enterprise

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.

1 Working with scientific data

Have you ever wondered ...

- what the difference is between a mistake and an error?
- why scientists take multiple measurements?
- how to run a fair test?

After completing this chapter students should be able to:

- propose the type of data that is needed, including first-hand and secondary data N CCT
- conduct a range of investigation types N EU
- apply simple numerical procedures such as calculating means N
- use scientific language and representations L ICT
- research information from a range of sources ICT L
- compare the reliability of gathered data with that from other sources CCT
- use a recognised method to acknowledge sources of data L
- record measurements accurately, using appropriate units L
- use, construct and analyse information from graphs, tables, other texts and multimedia resources ICT N L EU
- identify variables to be measured and controlled EU PSC
- describe safety and ethical guidelines EU PSC
- assess the method used and identify improvements WE PSC

ADDITIONAL

- outline the history of pendulum-motion studies and its connection with timekeeping and setting standards of length.

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 investigations. First-hand data is collected from experiments, surveys and fieldwork. 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 can be described by your personal data. This includes 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 includes 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 includes 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 (secondary data)** is data that comes from the work of other people. Second-hand data includes 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.

1.1 1.2

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), wrongly 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 (changes) 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.

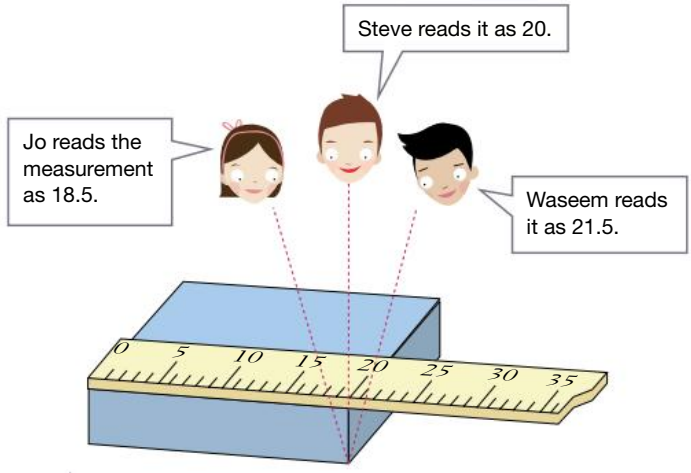


Figure 1.1.3 Parallax errors can be reduced by keeping your eye in line with the measurement.

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!

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!

SciFile

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

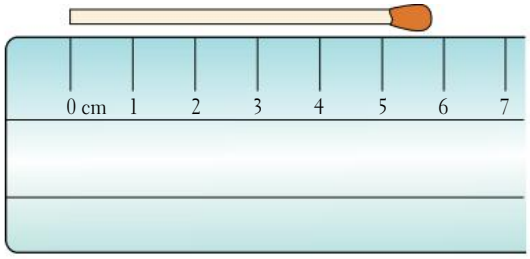


Figure 1.1.4 This match is not quite 6 cm long, but is it 5.7, 5.8 or 5.9 cm?

- **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.

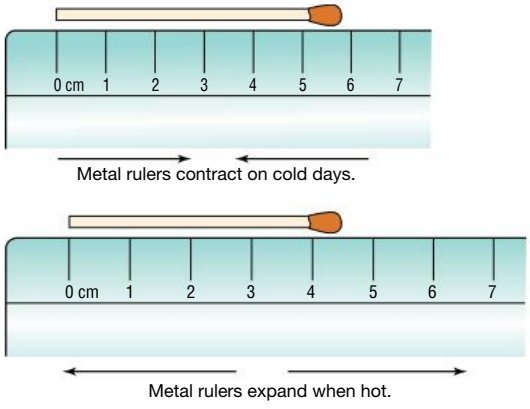


Figure 1.1.5 Metal rulers give different measurements at different temperatures. Although exactly the same, this match will appear 'longer' on cold days.

- **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.

Prac 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.

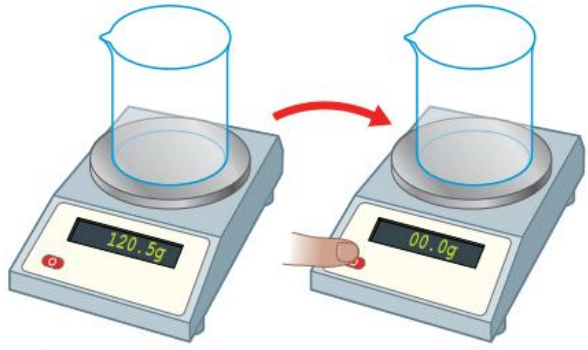


Figure 1.1.6 The tare button on an electronic scale re-sets its zero so that you don't have to worry about the mass of the beaker that is on it.

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.

Prac 2 p10

GO TO Pearson science NSW 7 Unit 1.3

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.

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
Finding averages

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.

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

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

Solution

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:

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

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.

Practice

N

Use the above procedure to **calculate** the average for each of the following sets of data.

1 9, 10, 6, 13, 12, 10, 11, 15, 12

2 0.72, 0.57, 1.02, 0.34, 0.74, 0.89

3 135, 137, 134, 138, 136, 136, 137, 135

4 1.22, 1.25, 1.18, 1.15, 1.20, 1.16, 1.24

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 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.

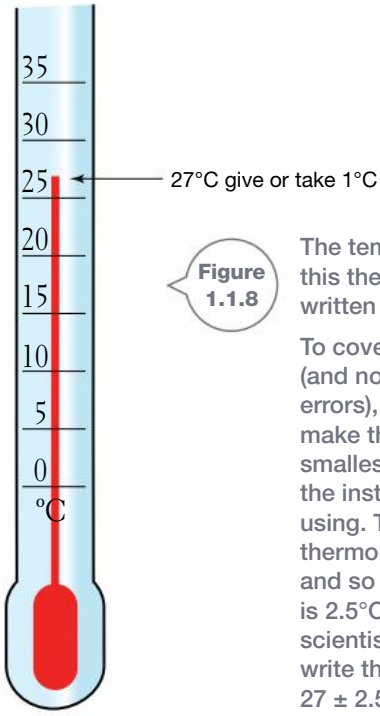


Figure 1.1.8 The temperature shown on this thermometer might be written as 27 ± 1°C.

To cover all types of errors (and not just reading errors), scientists usually make the error half of the smallest of the divisions of the instrument they are using. The markings on this 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.

Practice

N

State the answers to the practice questions in the previous Worked example as average ± error.

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.
- Always tie back long hair before heating something. Otherwise it's a fire risk!
- If you need to leave a lit Bunsen burner, 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, **list** 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 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. N
   - **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 **Define** the term *tare*. L

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

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

9 **Outline** how the mean of a set of measurements is calculated.

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

Applying

11 For each set of data below, eliminate the highest and lowest measurements and then **calculate** the average of the remaining 'good' measurements. N
   - **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.

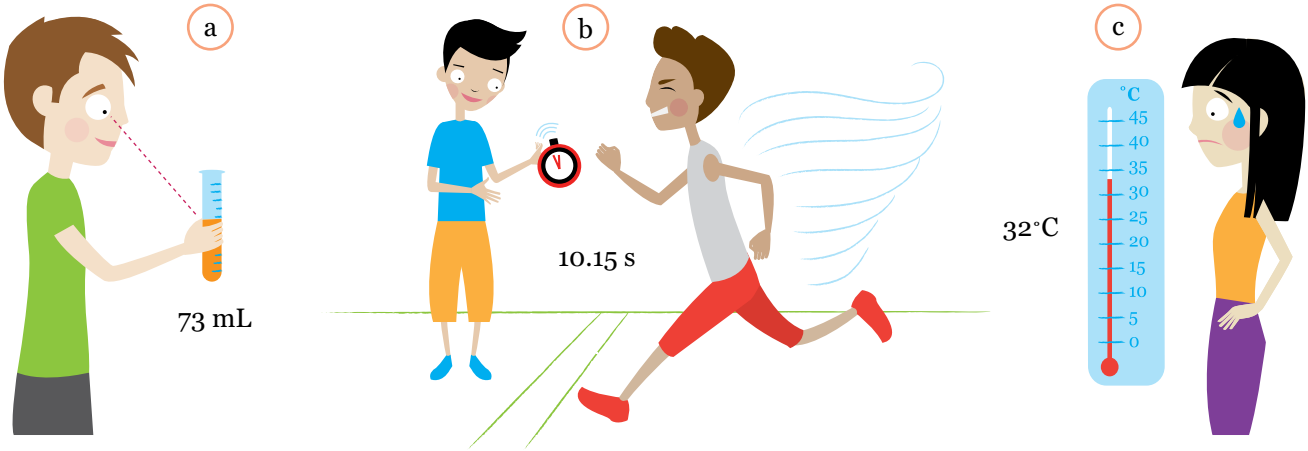
12 The time a ball took to drop down a 15.0 m cliff was measured by different members of a prac team. Their results are shown below.

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. N
   - c **Identify** the type of error that would have had the biggest effect on the results of this experiment.

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

Figure 1.1.10



1.1 Unit review

Analysing

14 **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.

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

Evaluating CCT

16 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.

17 **a** **Identify** whether the measurement made with a metal ruler will be too high or too low on a:

- **i** hot day
- **ii** cold day.

b **Justify** your answers.

18 **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 after turning them off and before packing them away.
- **d** always point test tubes away from everyone when heating.

Creating CCT

19 **Construct** diagrams to explain these types of errors:

- **a** parallax errors
- **b** reading errors.

Inquiring

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

2 In 1983, Air Canada flight AC143 ran out of fuel and glided to a safe landing at an abandoned air force base at Gimli, Canada. Research this flight to find:

- details of its descent and landing
- images/video of the flight
- how the conversion between litres (a metric unit) and gallons (an older imperial unit) led to the aircraft running out of fuel
- what else went wrong when landing and how this assisted the aircraft
- whether there were any injuries or deaths.

Present your research in digital form. In your presentation, classify the problems the flight crew had with their unit conversions as mistakes or errors. Justify your decision. ICT

3 Accidents caused the following discoveries to be made or caused another use for them. Research one of them:

- penicillin (Alexander Fleming) (Figure 1.1.11)
- Bakelite™ (Leo Hendrik Baekeland)
- Coca-Cola® (John Pemberton)
- heart pacemaker (Wilson Greatbatch)
- microwave oven (Percy L. Spencer)
- 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.

Present your research as a biography outlining the life of the discoverer and their accidental discovery.

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 investigations

1 Reaction times

Purpose

To determine your reaction time.

Hypothesis

How long do you think it takes for you to react—a second, half a second or less? Before you go any further with this investigation, write a hypothesis in your workbook.

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.

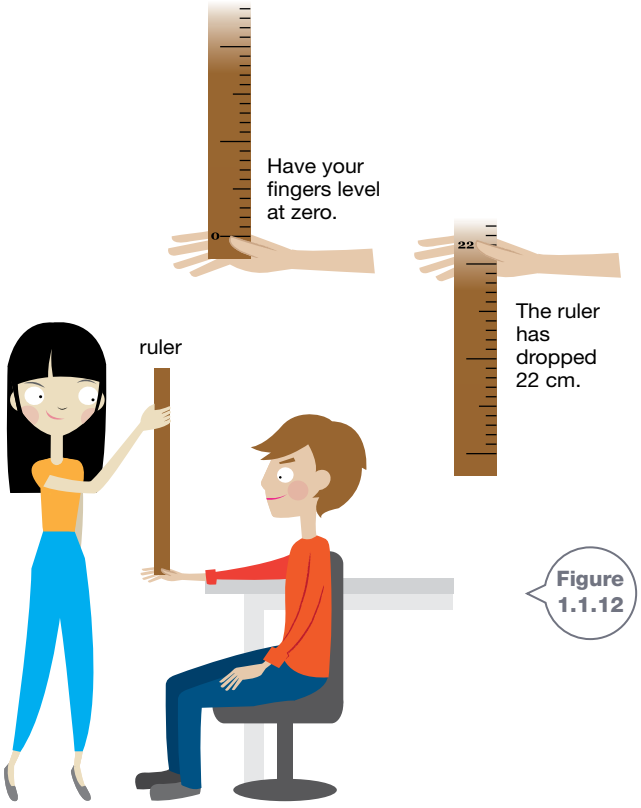


Figure 1.1.12

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.
5. Have two trial runs and then record in your table the distance dropped for the next three runs.
6. Repeat the experiment, but this time count down the ruler drop.
7. 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 the average distances the ruler dropped in each experiment. Add your own answers to the table. N
3. Calculate your average reaction time using the mathematical formula: N

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

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. Add your times to the table.

Reaction times continued on next page

Reaction times continued

Practical review

1. If you have already measured your reaction time using interactive games on the internet, then **compare** the result you obtained there with the result you obtained in this prac.
2. Of the different methods you tried, **assess** which is the most reliable way of measuring reaction time.
3. Digital stopwatches normally measure to the nearest 0.01 second. **Compare** this with your reaction time.
4. Your measurements using a stopwatch should never be thought of as perfect. **Explain** why.
5. **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

1. Copy the table below into your workbook.
2. 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

Results

1. Use your Results table to record all the measurements of your prac team.
2. If you have five or more measurements then cross out the highest and lowest measurement for each.
3. Calculate the average of the remaining 'good' measurements (if you have less than five measurements then use all the measurements you have).
4. State each measurement as an average ± error. Include the units you used.

Practical review

1. **Explain** why scientists repeat their measurements instead of taking just one.
2. **Calculate** the average for each measurement. N
3. **State** each measurement as average ± error.
4. **Contrast** an error with a mistake.
5. **Explain** why errors happen in every measurement.
6. **List** the likely sources of errors in each measurement you took in this investigation.
7. **Classify** the errors in your list in Question 6 as parallax, reading, instrument or due to human reflex.
8. For each measurement, **assess** which of these errors was the most important.

	Measurement					Average measurement	Average ± error	Units
	#1	#2	#3	#4	#5			
Length of laboratory								
Temperature of tap water								
Number of heartbeats in a minute								
Time for a pen to drop 2 m to floor								
Time for flat paper to flutter 2 m to floor								

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 at university. You learn a bit more each year, allowing you to run more and more of your own investigations 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 must use second-hand data 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. For example, ice 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, many glaciers are melting fast and data describing them must be as recent as possible for it to be accurate: data from a year ago can be 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.

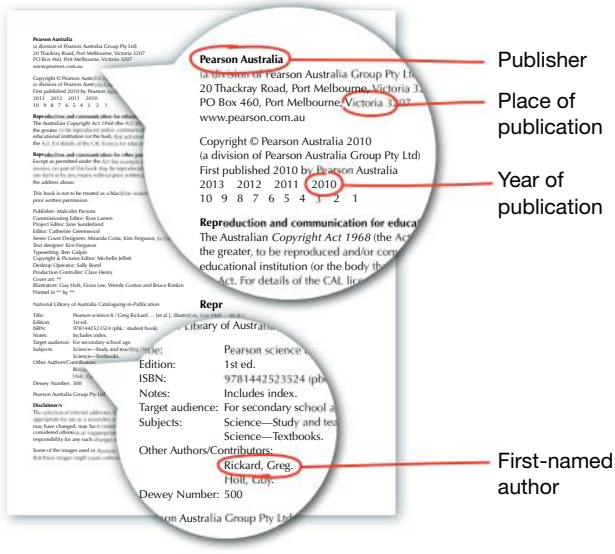


Figure 1.2.3 The imprint page shows who published the book or magazine and when it was published.

Where did it come from?

Encyclopedias, scientific journals and science textbooks can usually be trusted to provide accurate data. 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

TIM and the www

SciFile

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!

Mentos + Diet Coke = nothing!

SciFile

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.

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

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.

Other .org sites that can be trusted are the Australian Red Cross, the United Nations, zoos such as Taronga Zoo (New South Wales) 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 vaccination, evolution, stem cell research and abortion are often biased for or against the issue and so they need to be treated with care.

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 to gather material from at least one:

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

Resource lists

Ethics is the study of what is right and wrong. Ethics influences how we treat each other and how we want to be treated ourselves. Part of ethics is honesty and respect. We all want to be treated honestly and with respect but this means we also need to treat others the same way.

As scientists, we must be ethical in whatever we do. It is unethical for a scientist to pretend that data is theirs when it actually came from the work of someone else. We need to be honest and need to respect the scientist or team that originally found the data. For this reason, scientists include a resource list that shows where their information has come from.

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 its 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 1.2.4.

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: We Care For Rabbits Society, www.wecare4rabbits.com/rabbits.asp, updated 13 March 2013.

Figure 1.2.4 Entries in a resource list

Prac 1 p16 Prac 2 p17

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

4 **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.

5 You should use a range of resources to collect second-hand data. **Explain** why.

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 the 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.

8 **Assess** the following magazines could be trusted to give accurate scientific data.
- a *New Idea*
- b *COSMOS*
- c *Top Gear*
- d *Popular Scientist*
- e *Dolly*
- f *Men's Health*

Evaluating CCT

9 **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

Creating CCT

10 Gary used the resources shown in Figure 1.2.5 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 1.2.5

Inquiring

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

2 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.

Present your findings as a summary.

1.2 Practical investigations

1 Elephant toothpaste

Purpose

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

Materials

- 100 mL 3–6% solution of hydrogen peroxide
- squirt dishwashing detergent
- 3–4 drops food colouring
- 1 large spatula live powdered yeast
- 40 mL very warm water

SAFETY

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

- empty 500 mL plastic soft-drink or water bottle
- 100 mL measuring cylinder or plastic cup
- stirring rod
- funnel
- beaker
- newspaper or tray to 'catch' the toothpaste
- safety glasses

Procedure

1. Place the tray on your workbench or cover the bench with newspaper. Alternatively, perform the prac outside.
2. Place about 40 mL of very warm water into the beaker and add about 1 large spatula of yeast powder. Mix with the stirring rod 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.

Practical review

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. Three different ways you can do this are:
   - draw water into the eye-dropper
   - attach Blu-Tack to the end of the lid of the ballpoint pen as shown in Figure 1.2.6
   - bend the plastic straw over and hold it in place with the paperclip as shown in Figure 1.2.6. 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.

Practical review

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.

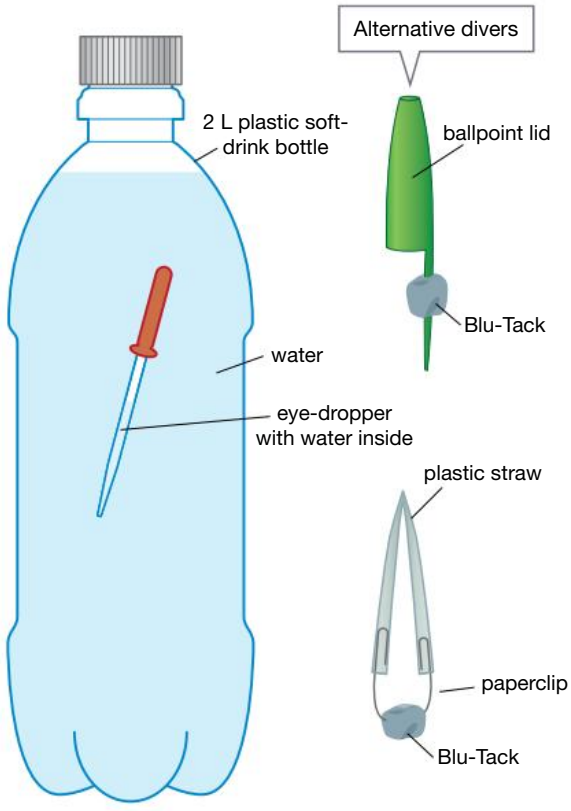
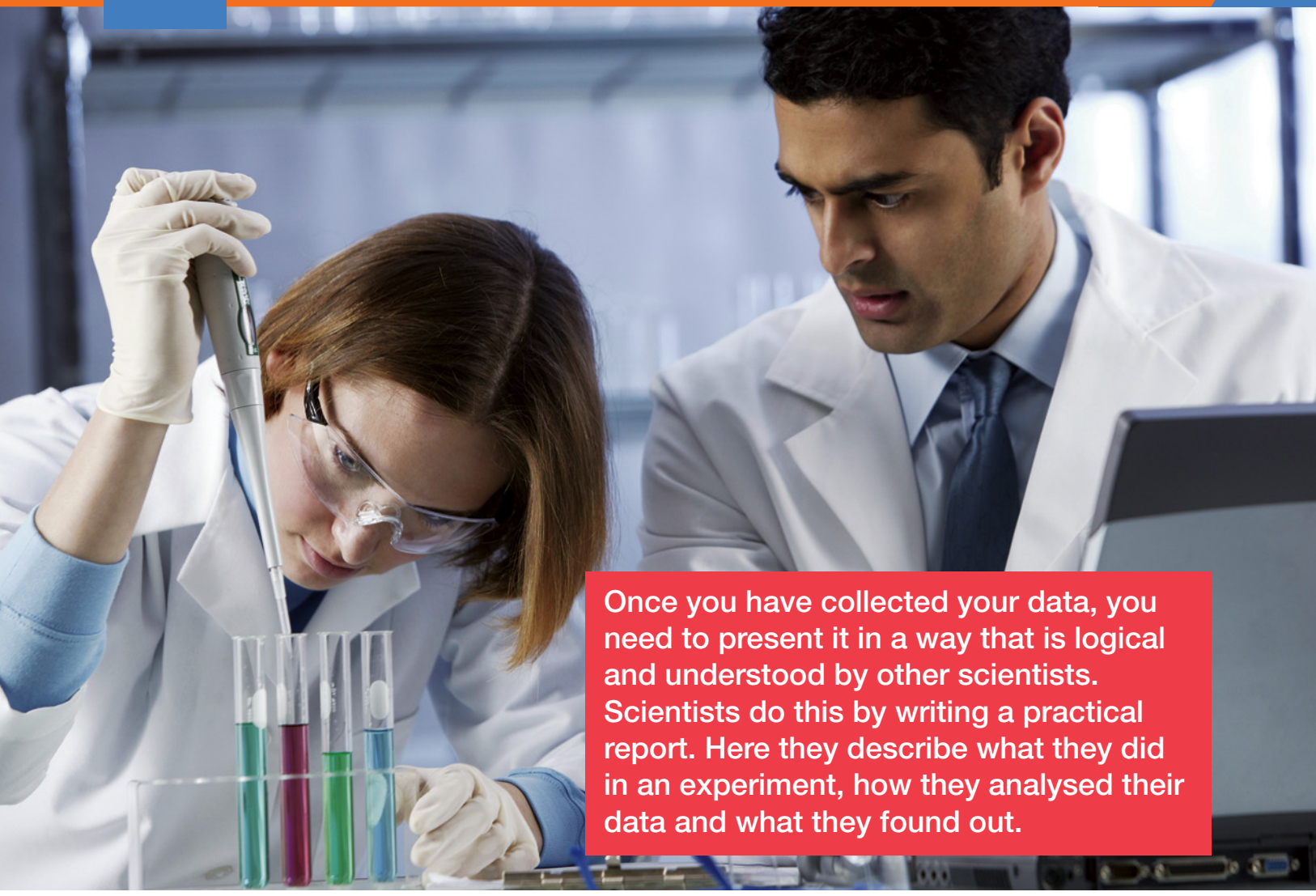


Figure 1.2.6

1.3 Processing 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(s) of the investigation and a list of partners who were in your team.

Purpose

The **purpose** (or aim) 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

This is a comprehensive list of everything that you used in the investigation.

It includes all:

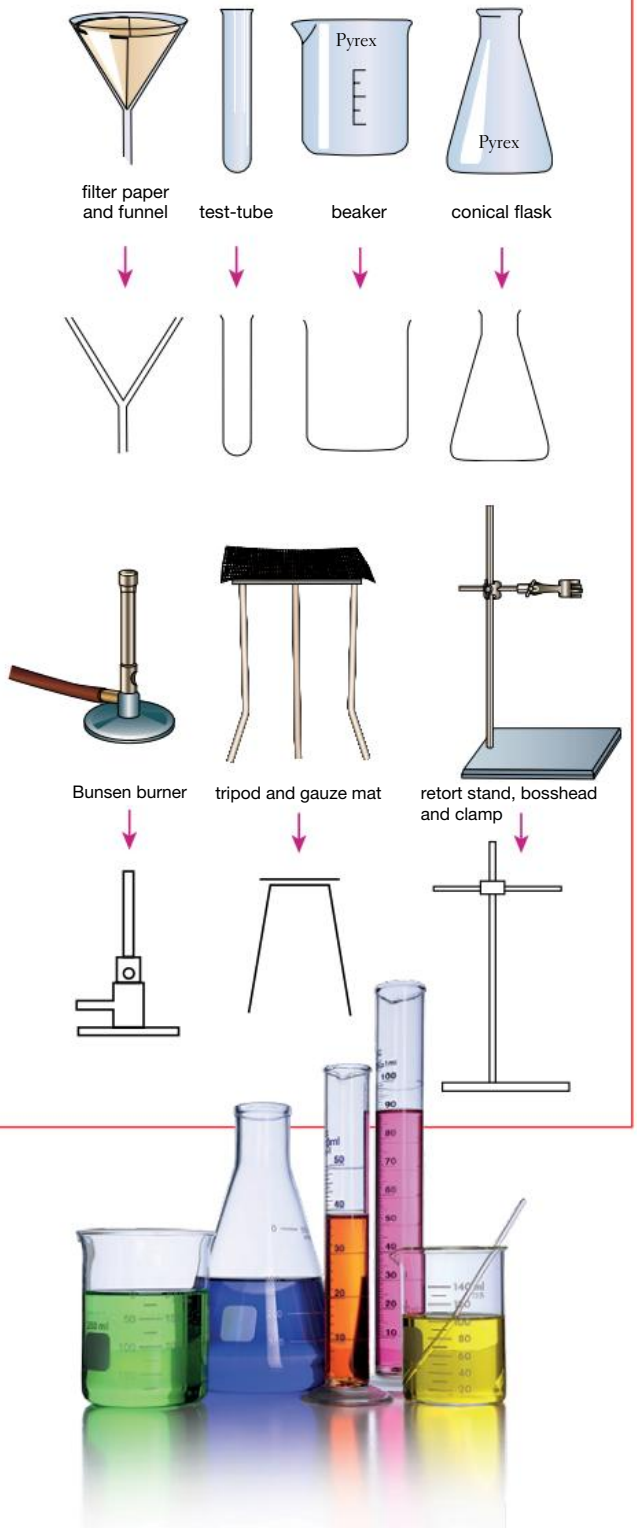
- chemicals used—give all chemicals their correct names, chemical formulas (if known), their concentration and the quantity of each (for example, 25 g sodium chloride NaCl or 50 mL 0.5 M hydrochloric acid HCl)
- equipment or apparatus used—give all pieces of equipment their correct names. If the equipment comes in different sizes then specify the size used (for example, 100 mL beaker or 250 mL conical flask).

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 scientific diagram.

1.3

Figure 1.3.1 Scientific equipment is normally drawn simply and in two dimensions.



Procedure

The **procedure** (or method) is a description of everything that you did in the investigation, 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

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. ✗

Results

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

This is also where you may start analysing your data, such as calculating averages. You might also present your data in different ways such as in spreadsheets, diagrams or by plotting graphs.

Practical review

This section is sometimes called the *Discussion*. This is where you discuss your experiment, often by answering a set of questions. In the practical review, you:

- describe what happened in your investigation and explain why it happened
- discuss what you think your results show
- include second-hand data that relates to your investigation
- describe the problems encountered and what was done to overcome them
- construct a **conclusion**, a brief summary of what you found out in the investigation
- assess your investigation. This includes assessing whether your hypothesis was accurate or not, suggesting alternative procedures that might improve the investigation and ideas for further experiments.

Resource list

If second-hand data was used then a report should end with a list of all resources used in gathering information about the investigation. This list is sometimes called a **bibliography**.

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. ✗

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 and spreadsheets are useless unless you specify the units they are measured in. In science, most of your measurements will use 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. However, measurements will sometimes be too big or too small to be sensibly measured with these units (Figure 1.3.2). This is when units with prefixes are used. **Prefixes** are letters or words that sometimes appear before unit symbols and unit names. The most common are milli (prefix m), centi (c) and kilo (k). These are shown in Table 1.3.1.

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 1.3.2 shows you how to make some conversions.

Table 1.3.2 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)

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

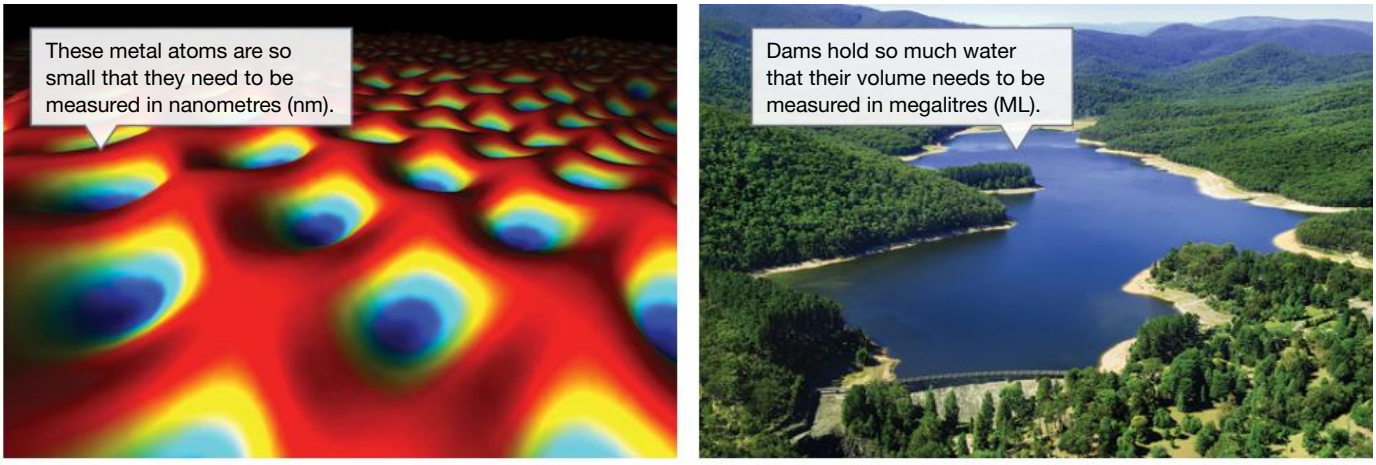


Figure 1.3.2 Prefixes allow scientists to measure extremely small and extremely large quantities.

Graphing data

Graphs are better than tables at showing patterns in data. Five different types of graphs are shown in Figure 1.3.3.

- Bar graphs and column graphs have a set of continuous numbers along one axis, and discrete (non-continuous) quantities like colours or materials along the other axis.
- Histograms have a set of continuous numbers along one axis and a set of continuous number ranges along the other axis.
- Sector graphs or pie charts show the proportions or percentages of different discrete quantities.
- Line graphs have sets of continuous numbers along both axes.

Sector graphs, histograms 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.

GO TO Pearson science NSW 7 Unit 1.4

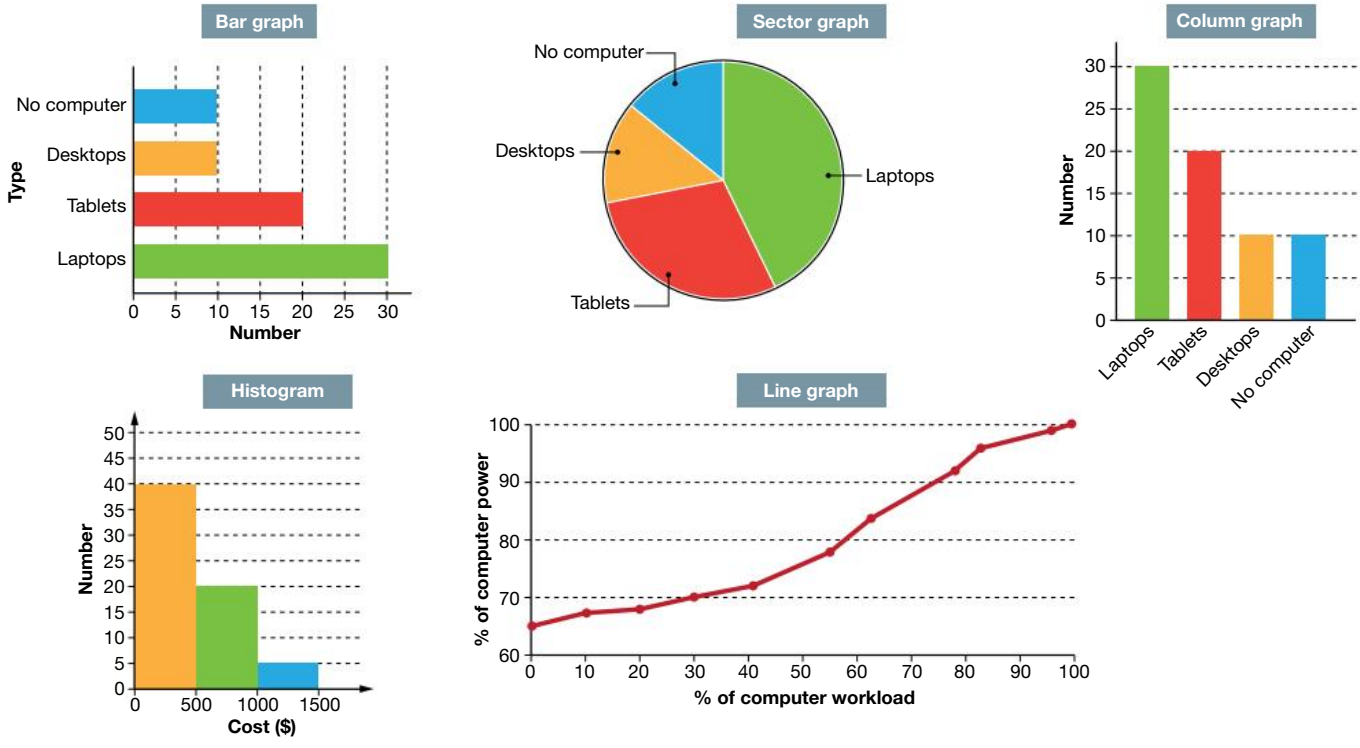


Figure 1.3.3 Depending on the data, scientists plot different types of graphs.

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 1.3.4 shows a graph that plots how the baby mouse in Figure 1.3.5 grew during its first week or so of life. The pattern in this data is shown by a line of best fit.

A line of best fit doesn't explain the cooling of water. Figure 1.3.6 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 Baby mice grow quickly. A line graph best displays their growth.

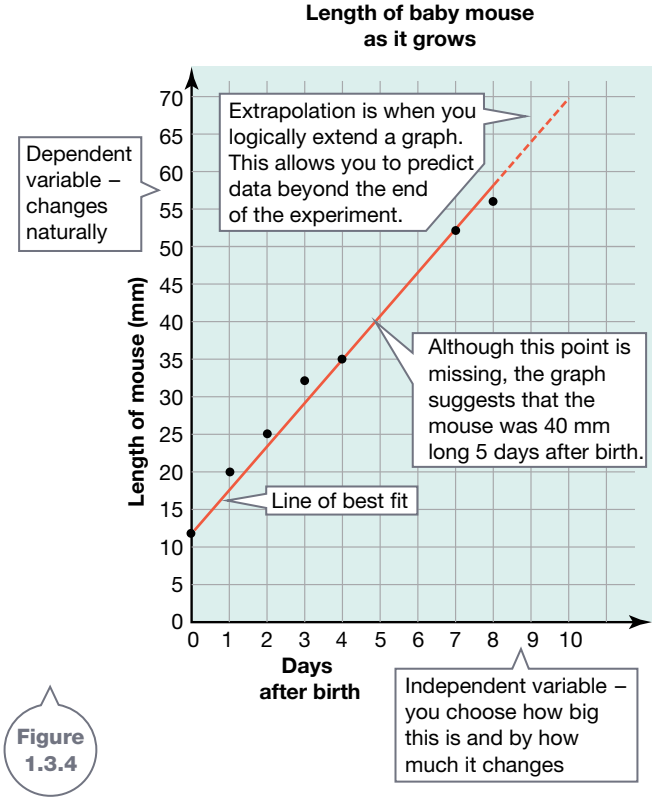


Figure 1.3.4 Do not connect the points up dot to dot. Instead, draw a straight line or curve through their 'centre'. This gives you a line of best fit.

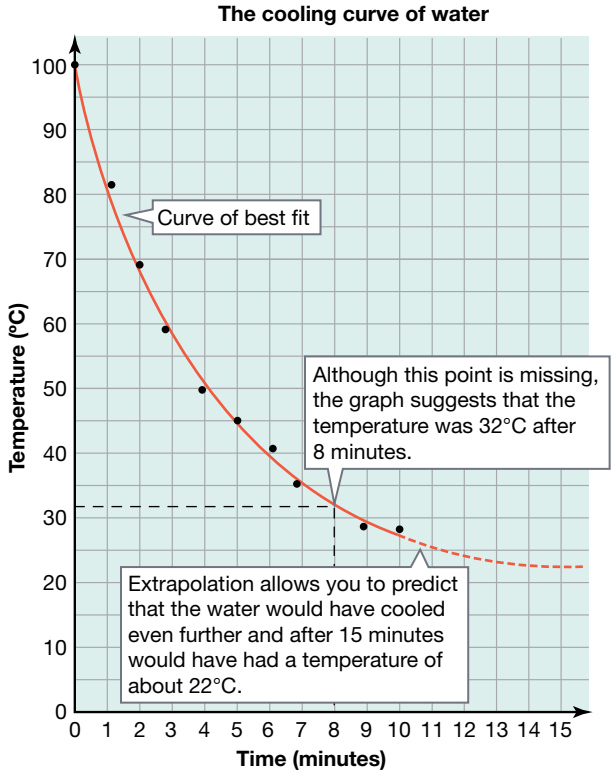


Figure 1.3.6 Lines and curves of best fit can be used to predict data that was never actually collected in the experiment.

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 1.3.7. It also shows the correct way of plotting them.

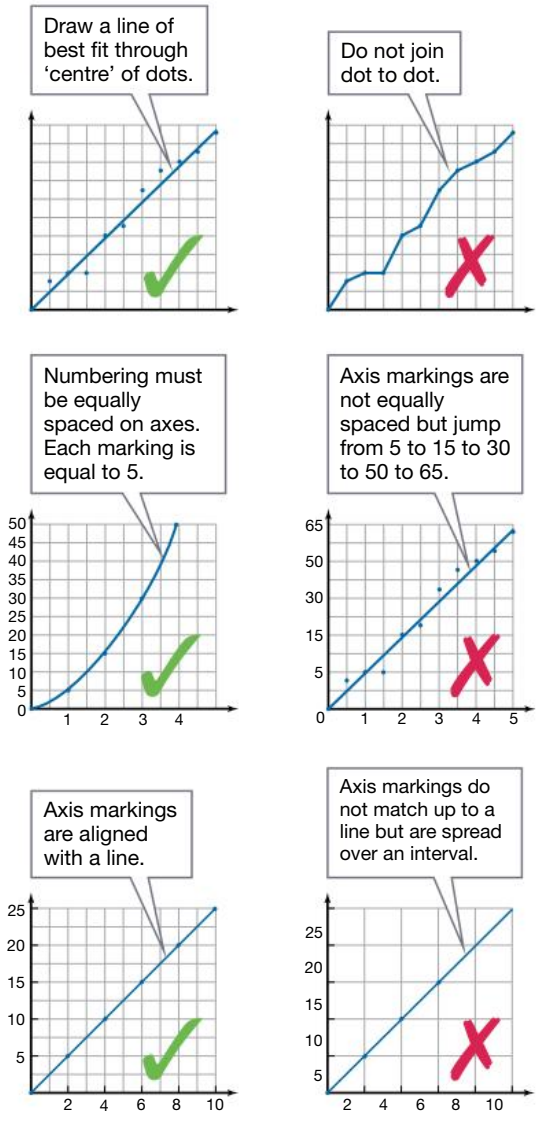


Figure 1.3.7 Correct and incorrect ways of plotting line graphs

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 1.3.8.

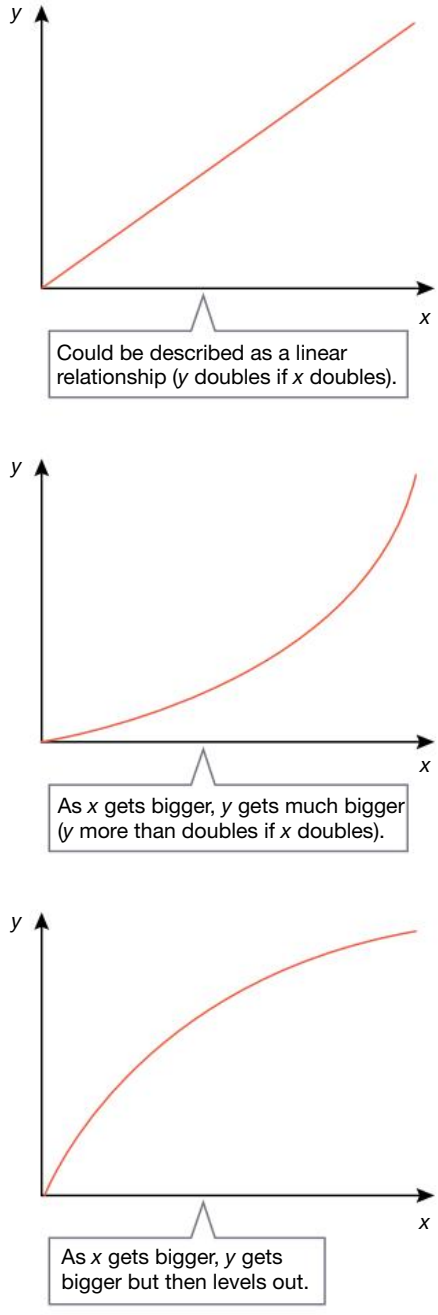


Figure 1.3.8 Three ways of describing the shape of a line graph

Prac 2 p27 Prac 1 p26 1.6

1.3 Unit review

Remembering

1 **Name** the standard metric unit and state its symbol for:
- a length
- b mass
- c time
- d liquid volume.

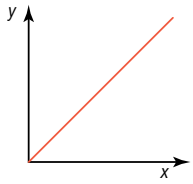
2 **List** the main advantage that line graphs have over other types of graph.

Understanding

3 **Explain** why lines of best fit are drawn through points on a line graph instead of connecting the points up dot to dot.

4 **Describe** the shape of the line graphs in Figure 1.3.9.

a



b

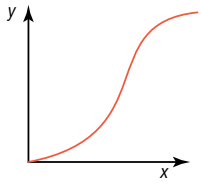


Figure 1.3.9

Applying

5 Below are four similar sentences that could be used in a procedure. **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.

6 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.

7 **Use** the graph in Figure 1.3.4 on page 22 to **predict**: N
- a how long the mouse is likely to be after 10 days
- b when the mouse is likely to be 45 mm long.

8 **Use** the graph in Figure 1.3.6 on page 22 to **predict** the: N
- a likely temperature of the water at 4.5 minutes
- b time at which the temperature was likely to be 25°C.

9 a **Identify** the point that is probably a mistake in the graph in Figure 1.3.10.
- b Ignoring this mistake, **describe** the shape of the graph.

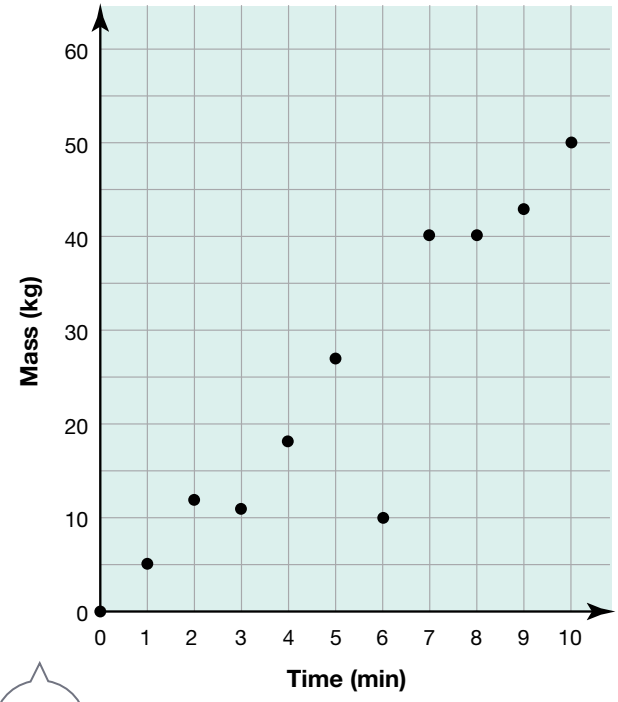


Figure 1.3.10

Analysing

10 **Calculate** what the following quantities would be when converted into the units indicated. N
- a 3000 mm in metres
- b 4.5 km in metres
- c 375 mm in centimetres
- d 2850 cm in metres

11 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 1.3.11.

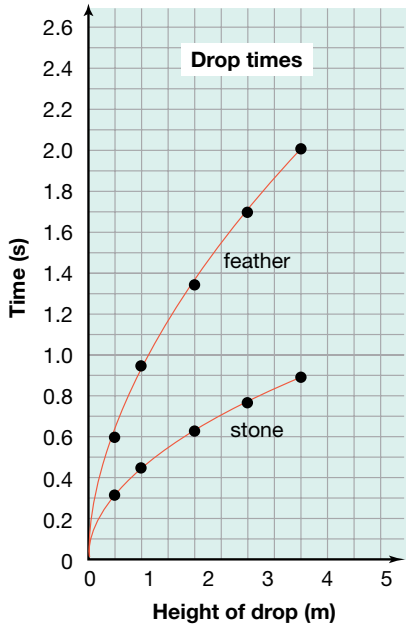
a **Use** her graph to **predict** the drop time for the feather and stone from: N

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. N

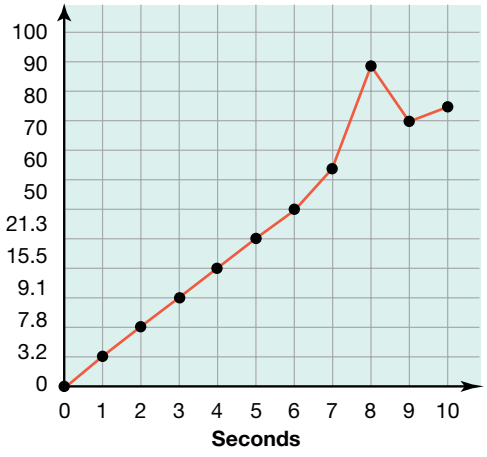
i 0.5 s **ii** 0.8 s **iii** 1.0 s

Figure 1.3.11



12 **Analyse** the graph in Figure 1.3.12 and **identify** five things that are wrong about it and the way it is plotted.

Figure 1.3.12



Evaluating CCT

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

a **Calculate** what these numbers represent in joules. N

b **Use** this information to **assess** the diet of Australians. Do we eat too little, just enough or too much?

Creating CCT

14 **Construct** 2D scientific diagrams that show how to set up the equipment required to:

a boil water in a beaker over a Bunsen burner

b filter a mixture of sand and water, the filtrate passing into a conical flask.

15 **Construct** diagrams to **compare**:

a bar graphs and column graphs with histograms

b line graphs with sector graphs.

Inquiring

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

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

Present your findings as:

- a print copy or recording of the advertisement
- a summary of the data used
- a description of how that data was used to convince people to buy whatever product or service is being advertised.

1.3 Practical investigations

1 Candles and rising water

Purpose

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

Hypothesis

In this experiment, the water level in the glass will rise as the candle burns. What do you think will happen if you double the number of candles—do you think the rise in water will double too? Before you go any further with this investigation, write a hypothesis in your workbook.

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 1.3.13. If using a beaker, ensure that the water level is well over its pouring lip.

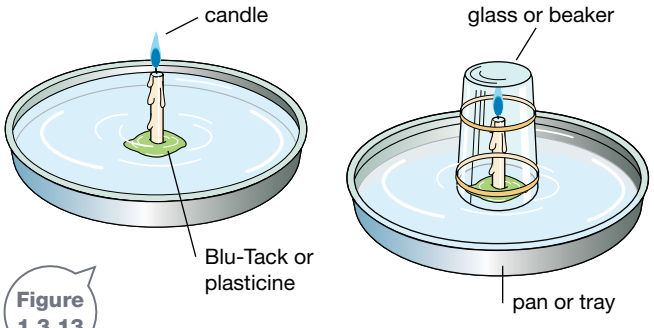


Figure 1.3.13

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.

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.

Practical review

1. **Describe** the shape of the graph you plotted.
2. a **Analyse** your graph. Does it suggest a relationship between the number of candles and the rise in the water level?
   b **Justify** your answer.
3. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
4. **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.
5. **Propose** a reason why the water rose in this experiment.

2 The greenhouse effect

Purpose

To demonstrate the greenhouse effect.

Hypothesis

Which do you think will heat up faster when placed in sunlight and which do you think will cool the fastest—a thermometer in a sealed plastic bag or one in the open? Before you go any further with this investigation, write a hypothesis in your workbook.

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 1.3.14. 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.

Practical review

1. **Identify** the thermometer that showed the faster increase in temperature.
2. **Identify** the thermometer that showed the faster drop in temperature.
3. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
4. **Describe** the shapes of each graph.
5. **List** the errors involved in this experiment.
6. 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.

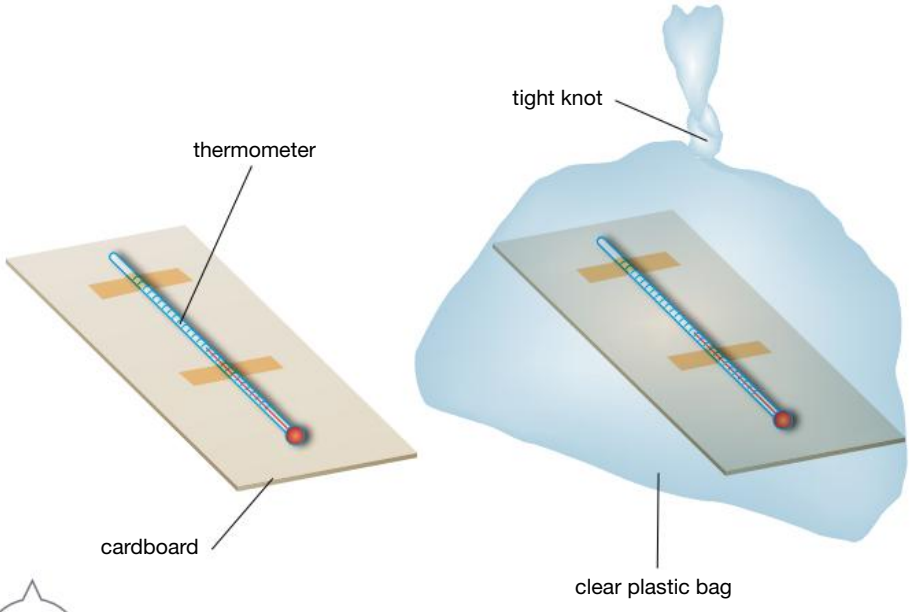


Figure 1.3.14

1.4 Planning investigations

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 variables (Figure 1.4.1).

A few variables 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?)

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 (Figure 1.4.2) and the type of toaster. The cleanliness and age of the toaster will have some effect but probably not as much as other variables.

GO TO Pearson science NSW 7 Unit 1.5

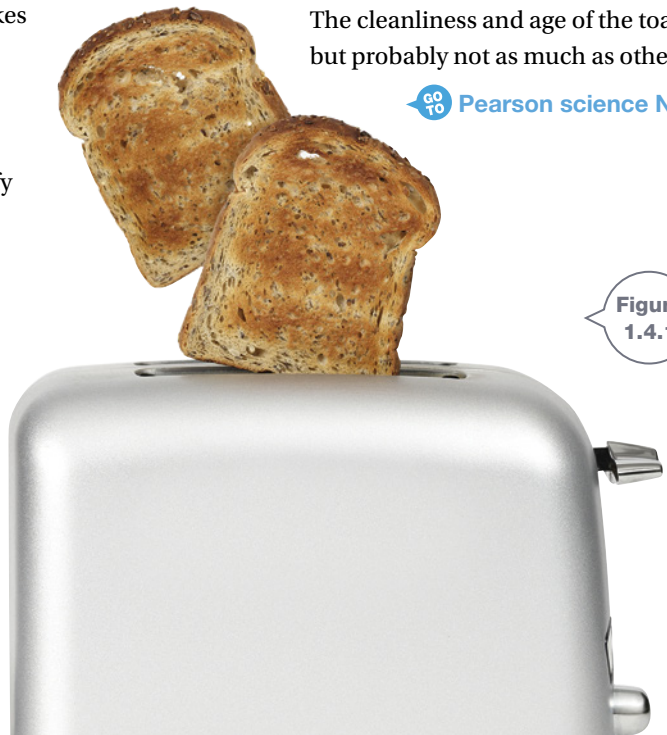


Figure 1.4.1 Many factors influence the time it takes to toast some bread. These factors are known as variables.

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

Independent variable

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.

Dependent variable

What you are trying to test and about to measure is known as the **dependent variable**. This is 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 managerial 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.

Ethical guidelines

Scientists must be ethical in their research and so must you. Any investigation that you carry out needs to:

- be safe—assess all risks before carrying out any prac work and take steps to minimise those risks. Take care with equipment and chemicals and follow all laboratory safety rules
- be careful—avoid silly mistakes and make sure that all data is recorded accurately
- be honest—run fair tests and analyse your data accurately and fairly. If you use the data of someone else, then acknowledge them in a resource list
- be respectful—respect the work of others, whether they are part of your prac team, your teacher, the laboratory technician or someone who has provided second-hand data
- take care of the environment—chemicals can harm the environment, so dispose of them as instructed by your teacher or laboratory technician. If an experiment requires samples of soil, leaves, plants or animals then take only what you need and no more
- take care of animals—do not carry out unnecessary experiments on animals. If you do need to use animals (even insects and snails), then treat them with care and respect. If possible, return the animals to their habitat when you have completed your work.

INQUIRY science 4 fun

Pendulum pictures

If a pendulum starts swinging 'off-line' (not directly under its support), then it will trace out loops and circles. Can you use it to draw pictures for you?

Collect this ...

- empty coffee can or similar
- hammer and nail or hole punch
- string
- fine sand

Do this ....

1. Punch a hole in the base of a can and another three holes near its upper edge. Weave string through the three upper holes and tie it as shown below.
2. Tie the can to a support.
3. Place your finger over the bottom hole and fill the can with fine sand.
4. Pull the can sideways and let go, trying different starting positions.

Record this ....

Describe what happened.

Explain why you think this happened.

Prac 1 p35 Prac 2 p36 1.7

LEARNING ACROSS THE CURRICULUM

CRITICAL AND CREATIVE THINKING

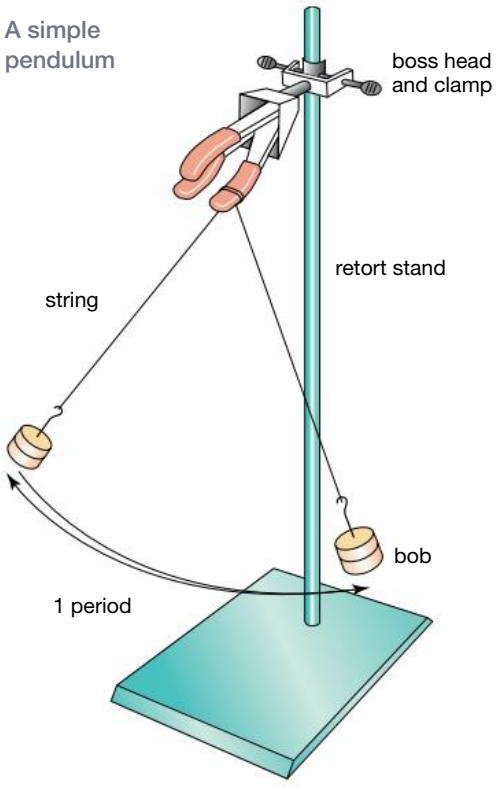
Figure 1.4.4 Pendulums are used in metronomes and some clocks.

THE PENDULUM

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 1.4.4. The **period** of a pendulum is the time it takes to complete one entire swing, back and forth, as shown in Figure 1.4.5. Period is measured in seconds (unit symbol s).

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 a Foucault's pendulum and it is evidence that Earth is spinning.

SciFile

PENDULUM VARIABLES

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

- length of the string
- 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. Gravity is the force that causes the bob to swing back and forth. Without gravity, a pendulum would never swing. The higher the gravity, the faster the bob will swing (giving a shorter period).

It might seem obvious that the mass of the bob would affect the period of a pendulum, but it doesn't. Changing its mass has little or no effect.

Go to Pearson science NSW 7 Unit 7.3

Prac 3 p36 Prac 4 p37 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 that gave scientists a way of:

- measuring time accurately
- determining how long a metre was, regardless of where they were on Earth
- proving that the Earth was not perfectly spherical but a little wider around the equator.

The pendulum also gave explorers a way of determining their longitude and therefore their position on Earth.

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 ten seconds per day.

Other important achievements were in:

- 1670—English clockmaker William Clement created the first grandfather clock with a minute hand. He placed a pendulum nearly one metre long in a wooden case to minimise the effect of any air movements. This pendulum swung with a period of exactly one second and is commonly known as the seconds pendulum
- 1721 to 1726—the length of a pendulum changes slightly as its temperature changes throughout the day. This changes the period and therefore its timing. Two English clockmakers found a way to compensate for these changes. George Graham developed a mercury pendulum in 1721 and John Harrison developed a pendulum made of brass and iron rods in 1726. Their clocks were accurate to within one second per day.
- 1889—German instrument maker Sigmund Riefler developed a spring mechanism that gave the pendulum a slight push once every swing to overcome the natural slowing of the pendulum due to friction. His clocks were accurate to within 10 milliseconds per day.

Pendulums are still used to regulate the timing of grandfather and older-style mantle clocks today. 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.

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.

Figure 1.4.7

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

STANDARDS OF LENGTH

Scientists, builders and traders all over the world need to know the exact length of one metre. They need a standard length that doesn't change. One early method of setting the standard length of one metre was suggested by French scientist Gabriel Mouton around 1630. His method used a seconds pendulum. Gravity is roughly the same everywhere on Earth, and so the seconds pendulum swings the same way wherever it is located. To achieve a period of one second, a pendulum needs to be one metre long. Hence, anyone with a pendulum has an accurate way of measuring the length of one metre. Although convenient, this method of defining the length of a metre was abandoned in favour of other (non-pendulum) methods.

1.9

REVIEW

1 **Define** the term *period*. L

2 **Outline** how the seconds pendulum can be used for:
   a accurate timekeeping
   b measuring the length of one metre.

1.4 Unit review

Remembering

1 **Recall** what a fair test is.

2 **List** the variables that influence how long it takes to toast a slice of bread.

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

independent	fixed
dependent	changes naturally
controlled	changed by you

4 **List** six ethical guidelines that you need to follow when carrying out scientific research.

Understanding

5 **Define** the term *variable*. L

6 a **State** how many variables should be changed in the one experiment.

b **Explain** why.

Applying

7 Imagine aliens land on Earth and begin to carry out experiments on humans.

a **Identify** the ethical guideline that you really hope they follow.

b **Explain** how this relates to what you do in the school laboratory.

8 **Predict** the pattern that would form in the science4fun on page 30.

Analysing

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

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.

Evaluating CCT

11 **Propose** advantages that the managerial model brings to the:

a team

b teacher.

12 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.

Creating CCT

13 Benji and Bianca carried out an experiment to test how long it took to toast a slice of bread. They repeated the experiment and calculated average times. Their results are shown in the table below.

a For this experiment, **identify** the:

i independent variable

ii dependent variable

iii controlled variables.

b **Identify** which type of graph below would best represent the above data.

A line graph

B histogram

C bar graph

D pie chart/sector graph.

c **Design** an experiment that tests which of five different toasters toasts a slice of bread the quickest.

Toaster make	Setting	Bread type	Slice thickness	Fresh or stale	Average time (s)
Toastie	High	Wholemeal	Thick	Fresh	40
Toastie	High	White	Thick	Fresh	31
Toastie	High	Seeded	Thick	Fresh	45
Toastie	High	Wholegrain	Thick	Fresh	44
Toastie	High	Sourdough	Thick	Fresh	38

1.4 Unit review

Inquiring

1 Search the internet to find videos showing: ICT
   - how pendulum clocks work
   - parachute drops and skydiver formations.

2 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.

3 Research the development of different standards for the length of one metre. Find: N
   - what the *toise* was
   - the problems associated with the toise
   - how the size of Earth was used to define the metre
   - how modern scientists define the length of one metre.

   Present your findings as answers to the above tasks.

Figure 1.4.8 Skydivers in formation

1.4 Practical investigations

STUDENT DESIGN

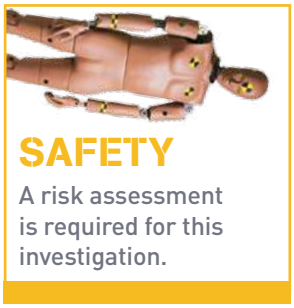
1 Parachute drop time

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



SAFETY

A risk assessment is required for this investigation.

- access to a hole punch
- sticky tape
- small masses (plasticine or paperclips are ideal)
- access to an 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 several different ways to test each of your selected variables. Select the best procedures and write them in your workbook.
4. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Hints

1. Only change the variable you have chosen to test. Keep all the other variables the same.
2. When constructing your chutes, reinforce the string holes with patches of sticky tape like the one shown in Figure 1.4.9.
3. Drop your chutes from a height of at least 2 metres.
4. Make repeated measurements of the time they take to hit the ground, recording them in a table or spreadsheet.

Results

Construct a table and a line graph for each experiment.

Practical review

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.
5. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

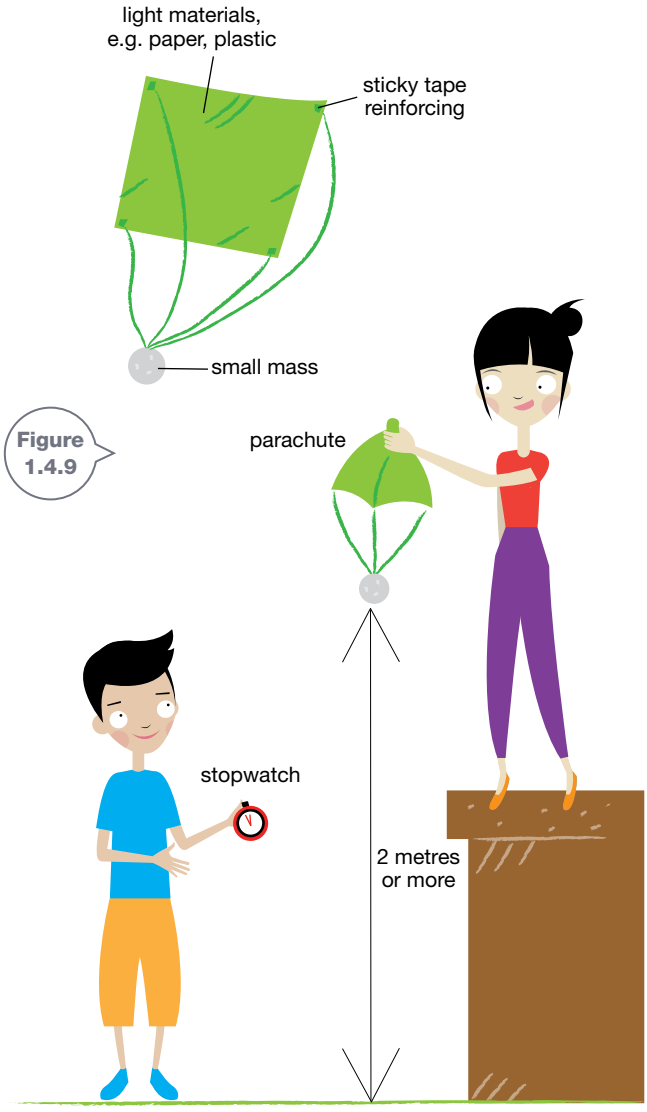


Figure 1.4.9

1.4 Practical investigations

STUDENT DESIGN

2 Testing absorbency of paper

Purpose

To determine the variables that determine the absorbency (amount of water soaked up) of paper towel and/or toilet paper.

Materials

- a collection of different absorbent paper towels and toilet papers
- equipment as chosen by students (such as beakers, measuring cylinders, eyedroppers)

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Brainstorm the variables that would affect how absorbent paper towels and/or toilet papers are.
2. Design and run two pracs that will test two of these variables.
3. Write your procedure in your workbook.
4. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Hints

Only change one variable at a time.

Results

Construct a table to display your results.

Practical review

1. **Construct** a conclusion for each of the variables you tested.
2. **Assess** your procedure and propose changes that would improve it.

STUDENT DESIGN

3 The pendulum and length

The time it takes for the pendulum to complete one swing (back and forth) is known as its period.

Hypothesis

What do you think will happen to the period of a pendulum when its length is increased—will the period increase, decrease or stay the same? Before you go any further with this investigation, write a hypothesis in your workbook.

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)

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that tests what happens to the period of a pendulum when its length is changed.
2. Write your procedure in your workbook.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Hints

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 mass and angle you will use, and keep them fixed.
2. Decide on the lengths that you will test. At least five different lengths should be tested.
3. Don't attempt to measure the time of a single swing. Instead, measure the time for five or ten complete swings.

4 You need to repeat measurements for the time taken for ten complete swings. Decide how many times you will repeat each experiment.

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). N

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 √ 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 1.4.10.

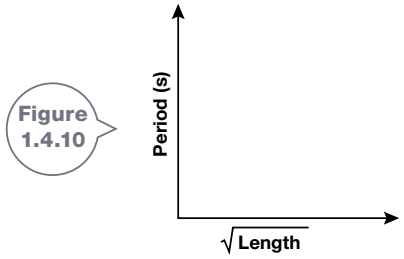


Figure 1.4.10

Practical review

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 a **Construct** a conclusion for your investigation.
b **Assess** whether your hypothesis was supported or not.

STUDENT DESIGN

4 The pendulum, mass and starting angle

Purpose

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

Hypothesis

What do you think will happen to the period of a pendulum when its mass is increased or if it is swung from a bigger angle—do you think the period will increase, decrease or stay the same? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- materials to construct a pendulum

- stopwatch
- protractor

SAFETY

A risk assessment is required for this investigation.

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 Write your procedure in your workbook.

3 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Results

Construct a table and a line graph to display your results.

Practical review

1 **Explain** how you controlled all the variables other than the starting angle in this experiment.

2 a **Construct** a conclusion for your investigation.
b **Assess** whether your hypothesis was supported or not.

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.

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

Understanding

5 **Define** the following terms. L
- a purpose
- b hypothesis
- c conclusion
- d bibliography

Applying

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

7 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. N

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

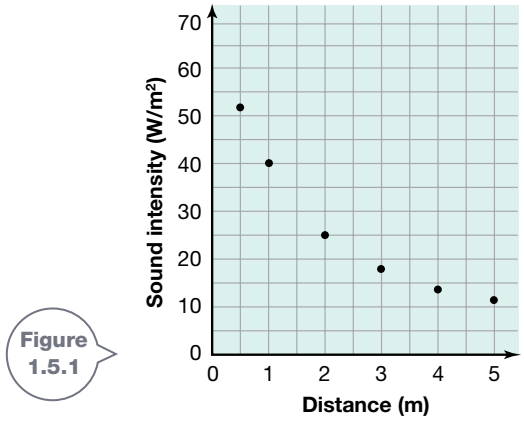


Figure 1.5.1

9 **Identify** the variables that could logically influence:
- a how quickly iron rusts
- b how quickly a banana ripens
- c how often you go to the toilet to urinate
- d how good you are at sport.

Analysing

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

Evaluating CCT

11 a **Determine** whether you can or cannot answer the questions on page 1 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

Creating CCT

12 **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		

1.10

Thinking scientifically

Anila ran an experiment in which she measured the period of a pendulum. The period 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. CCT

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

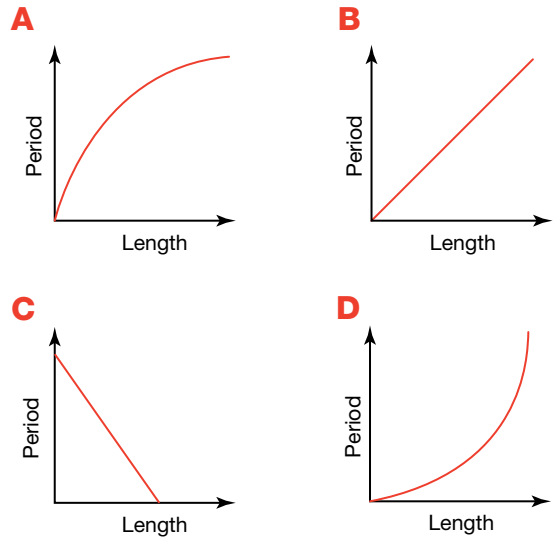
Q2 State which is the most likely aim for her experiment. CCT

- **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. CCT

- **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. CCT



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

- **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 L

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

Human reflex: the quickest time that you can react to something, for example, pressing a stopwatch to record a race time.

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

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

First-hand data

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 (secondary 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 L

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

Ethics: the study of what is right and wrong

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

Resource list: a list of all resources used in gathering data for an experiment or report

URL: website address

URL

Unit 1.3 L

Bibliography: resource list

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

Extrapolation: logical extension of a line graph

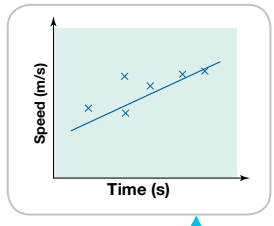
Hypothesis: an 'educated guess' about what might happen in an experiment

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

Procedure: a description of what you did in an experiment

Prefixes: letters in front of standard unit symbols, e.g. *m* for milli, *c* for centi, *k* for kilo

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



Line of best fit

Unit 1.4 L

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

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

2 Cells

Have you ever wondered...

- what your skin and hair would look like if they were magnified?
- why you have different parts to your body?
- 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:

- identify that living things are made of cells
- identify structures within cells and describe their functions
- identify that new cells are produced by cell division
- outline the role of cell division in growth and repair
- distinguish between unicellular and multicellular organisms
- identify that different types of cells make up tissues, organs and organ systems
- identify the materials required for photosynthesis
- explain how organ systems work together to provide cell requirements L
- describe the role of the root, stem and leaf in plants L CCT
- research how changes in scientific knowledge have contributed to finding a solution to a human health issue CCT EU
- recall how scientific discovery has contributed to solving a real-world problem CCT EU
- describe how technology has contributed to finding solutions to a contemporary issue ICT L
- describe how people can hold different ideas about the application of a solution to a contemporary issue CCT DD PSC EU

2.1 Making things bigger

Some 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, such as the details of this bread mould.

INQUIRY

science 4 fun

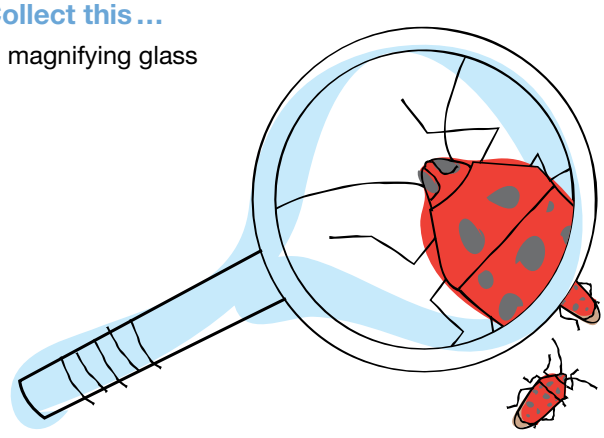
It looks different!

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 photos in 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.

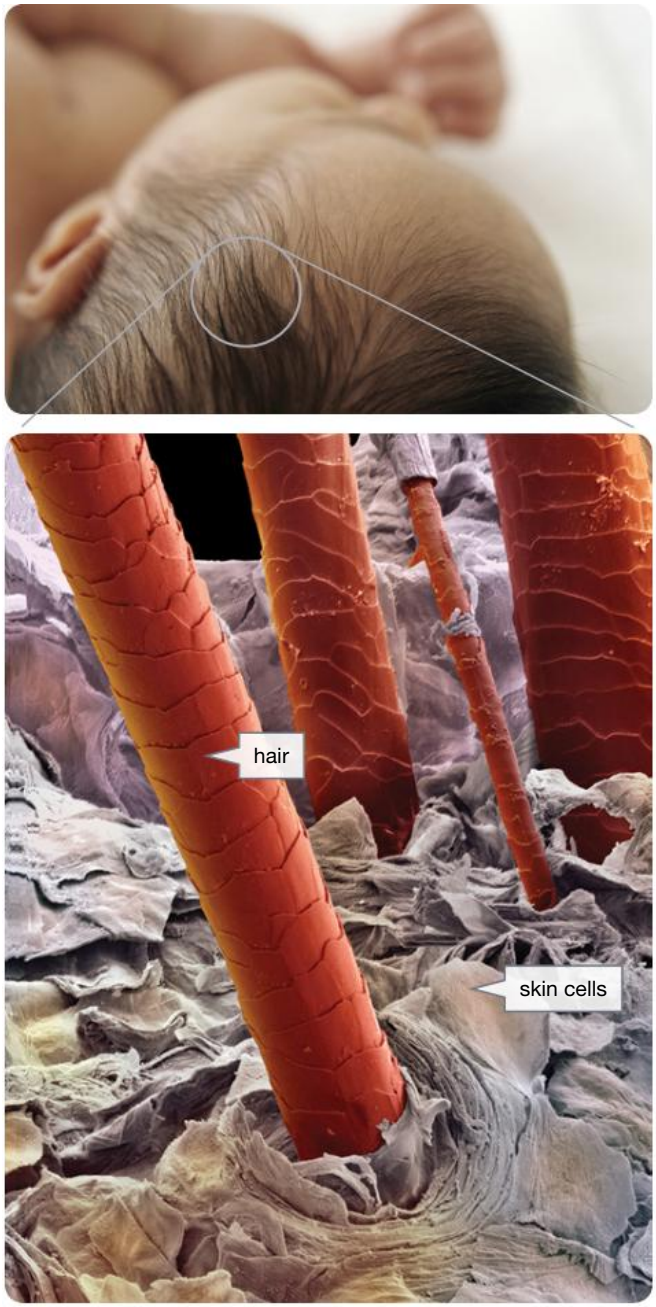


Figure 2.1.1 With a microscope you can see much more than you can with your naked eye. Using a very powerful microscope, you can see single hairs surrounded by skin cells of this baby's scalp.

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 causes 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**.

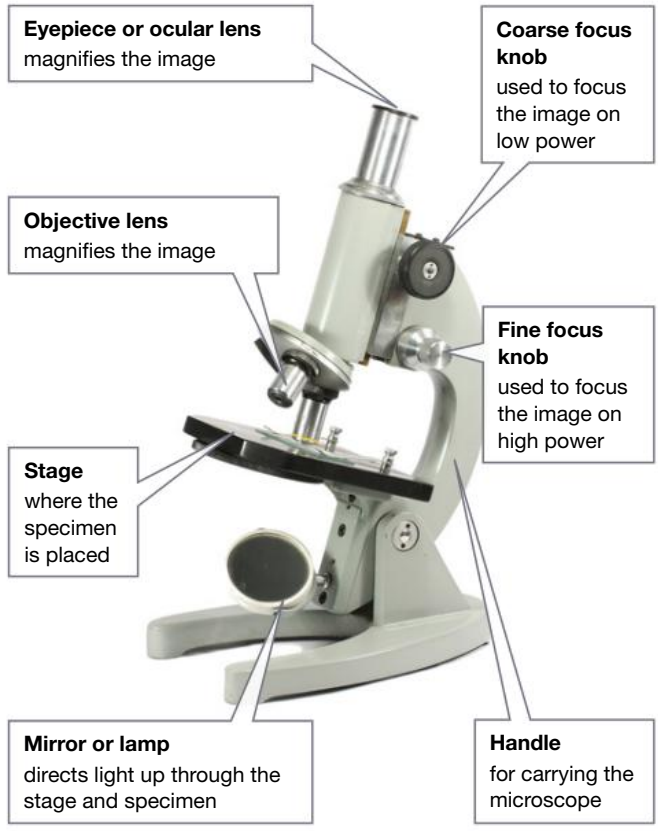


Figure 2.1.2 How the parts of a microscope are organised

Prac 1 p48
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 in three dimensions.

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 so 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.

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.

When you move a specimen under a stereo microscope, the image moves 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. 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*.

As the magnification increases, 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.

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) are used 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 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 they 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.

Calculating magnification

The microscope in Figure 2.1.2 on page 43 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.

WORKED EXAMPLE

Calculating magnification

Table 2.1.2 shows examples of how magnification is calculated.

Table 2.1.2 Calculation of common magnifications

Ocular lens magnification	Objective lens magnification	Total magnification
×10	×4	× 10 × 4 = ×40
×10	×10	× 10 × 10 = ×100
×10	×40	× 10 × 40 = ×400

Problem

If a microscope has an ocular lens magnification of ×5 and an objective lens magnification of ×10, what is the total magnification?

Solution

To calculate total magnification, multiply the ocular lens magnification by the objective lens magnification.

ocular lens magnification × objective lens magnification
= ×5 × 10
= ×50

Practice

N

Calculate the magnification for each of the following combinations of lenses.

Ocular lens magnification	Objective lens magnification	Total magnification
×2	×5	
×10	×5	
×2	×10	

Prac 2 p49

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 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.

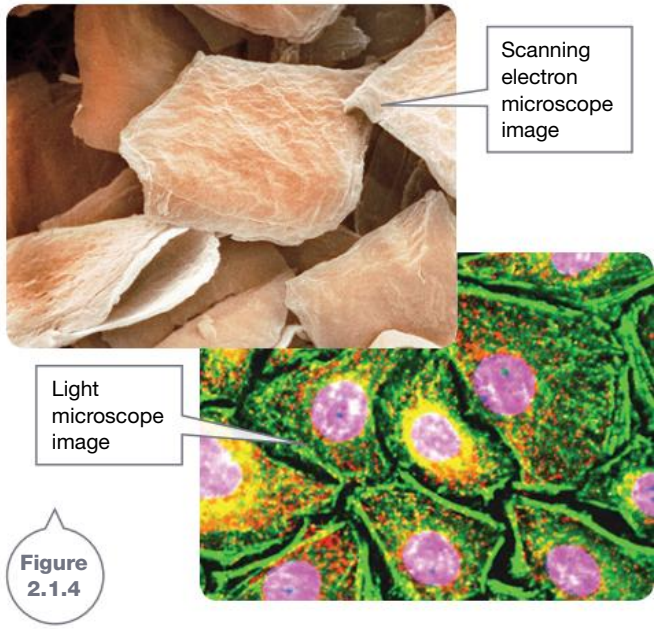


Figure 2.1.4

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

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 such as 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.

Discovering bacteria

SciFile

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

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. L
- 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.

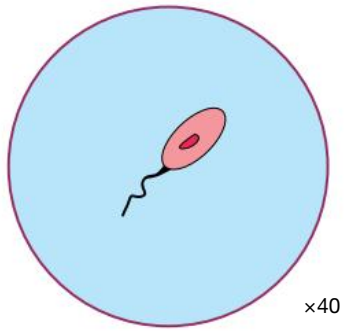
Applying

11 **Calculate** the total magnification in the following examples. N

	Ocular lens	Objective lens
a	×4	×10
b	×10	×100
c	×4	×40

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

Figure 2.1.5



Analysing

13 **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. N

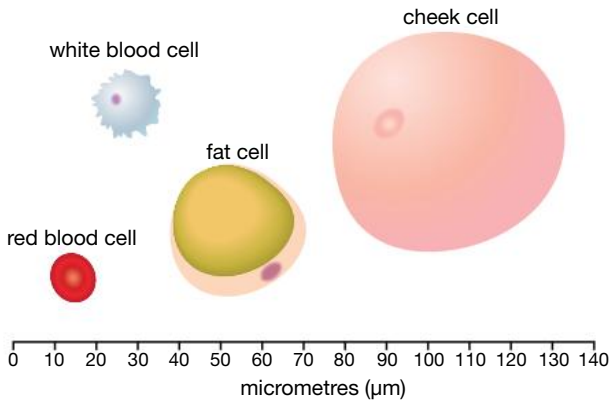


Figure 2.1.6

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

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

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

17 Figures 2.1.7 and 2.1.8 show the same type of mosquito under very different magnifications. **Compare** both images and **list** the extra information that greater magnification brings.

Figure 2.1.7 A mosquito seen with a little magnification (like that obtained with a magnifying glass)

Figure 2.1.8 A mosquito seen with an electron microscope

Evaluating CCT

18 a **Identify** the type of microscope that most likely produced the image shown in Figure 2.1.9.

b **Justify** your answer.

Figure 2.1.9

Creating CCT

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

Inquiring

1 Research different types of microscopes to find:

- images of each type
- what each type is used for
- the advantages and disadvantages of each type
- their maximum magnifications.

Present your research as a poster.

2 Research the electron microscope. Find:

- when the first one was built
- who built it
- how different electron microscopes are used in different workplaces.

Present your findings in digital form. ICT

2.1 Practical investigations

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 2.1.10.
3. Soak up any excess water or stain with a piece of filter paper or tissue.

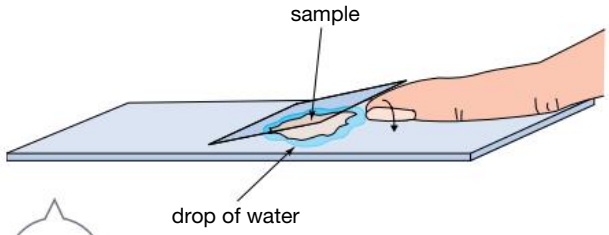


Figure 2.1.10

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 pages 48 and 49.

Purpose

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

Materials

- a section of newspaper containing small print

- monocular microscope
- microscope lamp (if needed)
- 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 newsprint 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.

Practical review

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.

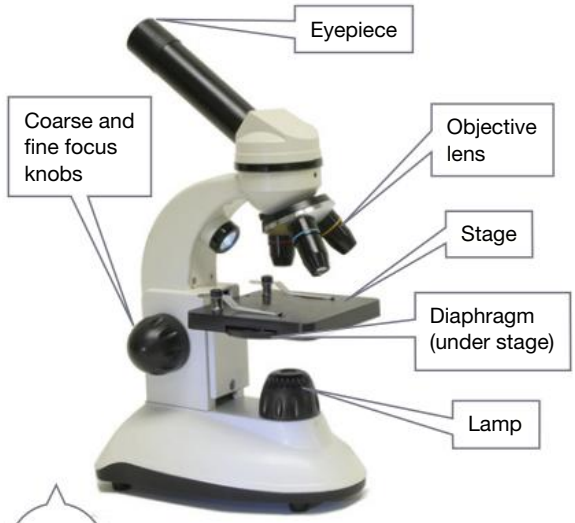


Figure 2.1.11

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.

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

Materials

- 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.

- monocular or binocular microscope
- microscope lamp
- glass microscope slides
- cover slips
- eye-dropper

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.

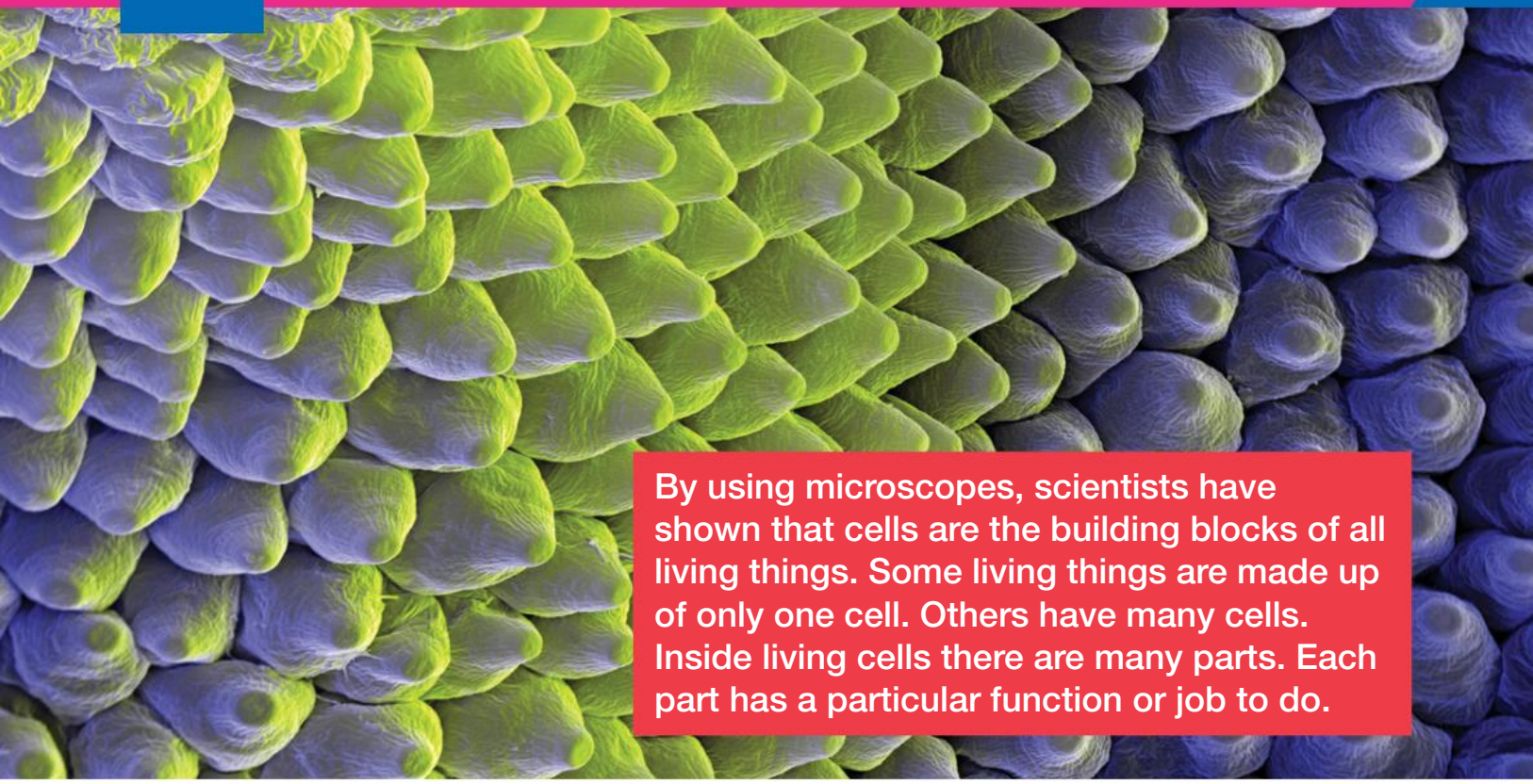
Results

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

Practical review

1. **Describe** how each specimen appeared. In your description note observations that were not possible without the microscope.
2. a **State** which specimen you found most interesting.
   b **Explain** why you found it interesting.

2.2 Natural building blocks



By using microscopes, scientists have shown that cells are the building blocks of all living things. Some living things are made up of only one cell. Others have many cells. 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 known as **organelles**. Each organelle has a special function. Organelles are usually only visible using a microscope. Figure 2.2.1 shows the structure of a typical animal cell as seen using a light microscope.

An electron microscope is needed to see some even smaller organelles such as those in Figure 2.2.2:

- **Mitochondria** are the powerhouses of the cell, which release energy from food.
- **Lysosomes** are the garbage disposal units that get rid of wastes from the cell.
- **Endoplasmic reticulum** forms pathways that allow materials to move quickly and easily through the cell.

Other important structures within the cell are ribosomes. **Ribosomes** are microscopic factories that produce proteins used by the animal for growth and repair. Ribosomes are not considered to be organelles, because they are not always enclosed in a membrane.

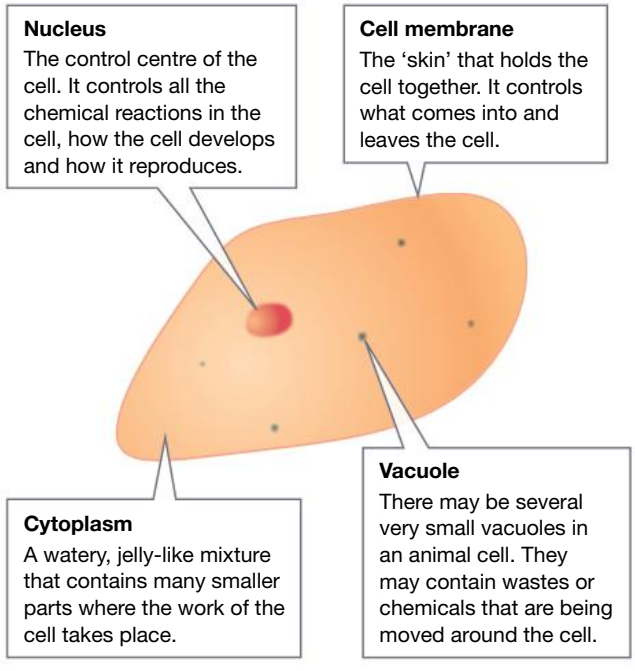


Figure 2.2.1 This is an example of a typical animal cell. The cell contains smaller parts known as organelles. Each organelle has its own specific job to do within the cell.

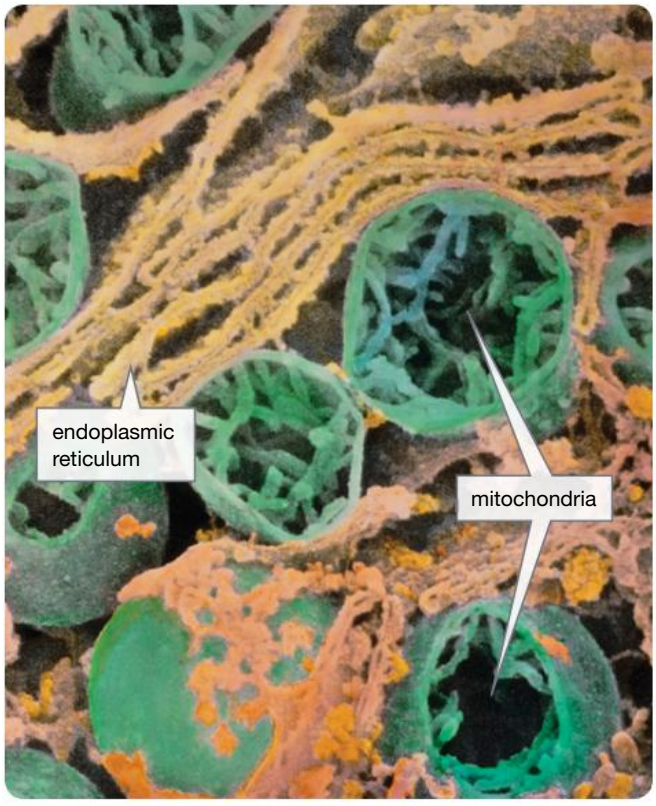


Figure 2.2.2 Some organelles within a cell are so small that they can only be seen clearly with an electron microscope at magnifications of over ×100 000.

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 found in the green parts of plants. Plants cannot go hunting for their food. Instead, they make it themselves using energy from the Sun to chemically combine water and carbon dioxide from the air to make a sugar called glucose. This process is called **photosynthesis**. It takes place in chloroplasts.

Prac 1 p58 | Prac 2 p59 | 2.2 | 2.3

INQUIRY

science 4 fun

Human cells

NO

What do your cells look like?

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.

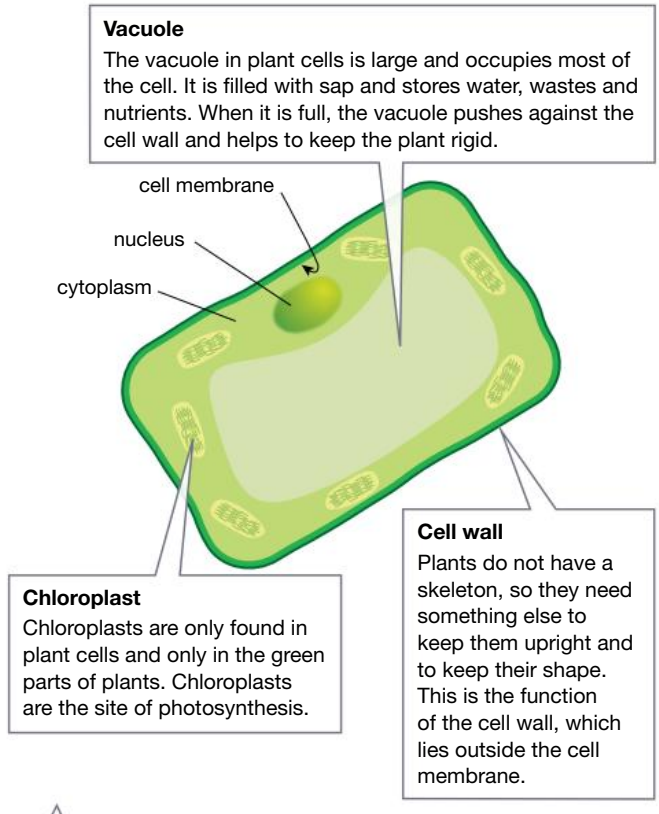


Figure 2.2.3 A typical plant cell has all the organelles that an animal cell has, as well as chloroplasts and a cell wall.

Tough stuff

SciFile

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.

Fungal cells

Fungi are a group of organisms that can be made of just a single cell (such as yeast) or many cells (such as the toadstool in Figure 2.2.4).

Figure 2.2.4

This toadstool is a fungus made up of many 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.

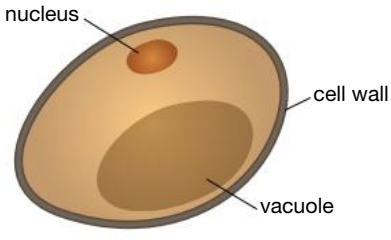


Figure 2.2.5

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.

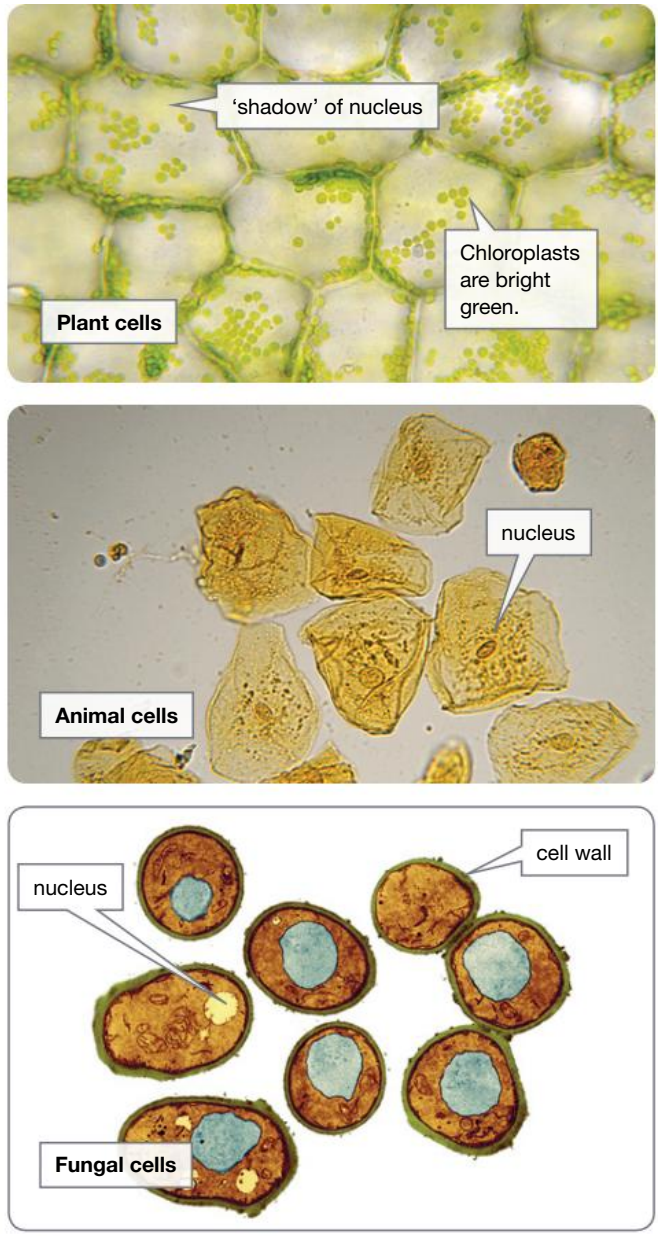


Figure 2.2.6

A nucleus is present in all cells: plant, animal and fungal.

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 2.2.7. Others live on and in your body and help you to stay healthy. Bacteria are also used in the production of cheese and yoghurt.

Figure 2.2.7 The yellow pus on infected wounds is an accumulation of dead white blood cells that have died trying to fight harmful bacteria.

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 2.2.8. Unicellular organisms belong to a group called the protists. Most protists are harmless, but some can make you very sick. For example, giardia is an infection caused by the protist *Giardia lamblia*. This unicellular organism is found in the faeces of humans and other animals. A person becomes infected when they swallow the parasite from their unwashed hands or drink infected water. The water that comes through the taps has been treated to kill any harmful organisms such as *Giardia*. If you are in the bush and using untreated water, then for your health's sake it is best to boil the water before you drink it.

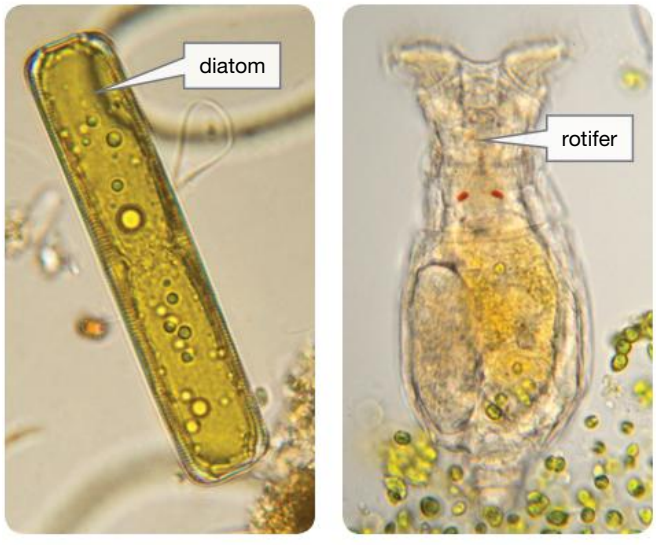


Figure 2.2.8 Microscopic organisms such as diatoms and rotifers are found in pond water.

Prac 3 p60

Dividing cells

Unicellular organisms reproduce by their cell dividing to produce two new identical cells; that is, two new organisms. This type of cell division is called mitosis. **Mitosis** is cell division that produces two new identical cells. This process is happening in Figure 2.2.9.

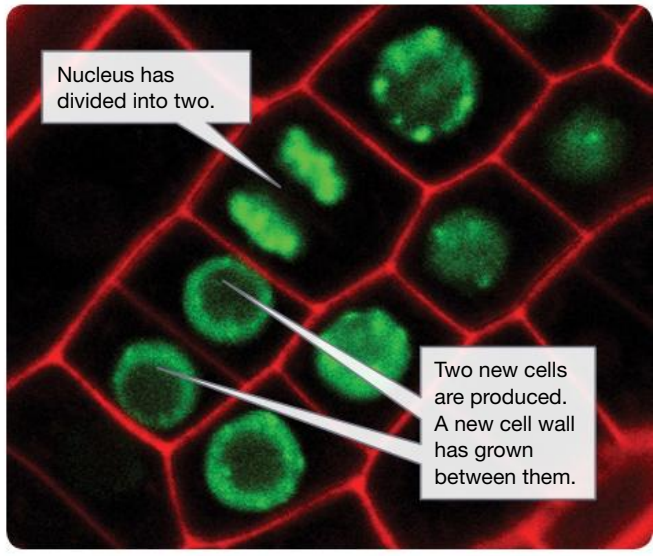


Figure 2.2.9 These plant cells are dividing by mitosis.

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.

Like all other organisms made up of many 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.

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.

How many and what do they do?

SciFile

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.

2.4

LEARNING ACROSS THE CURRICULUM

CIVICS AND CITIZENSHIP

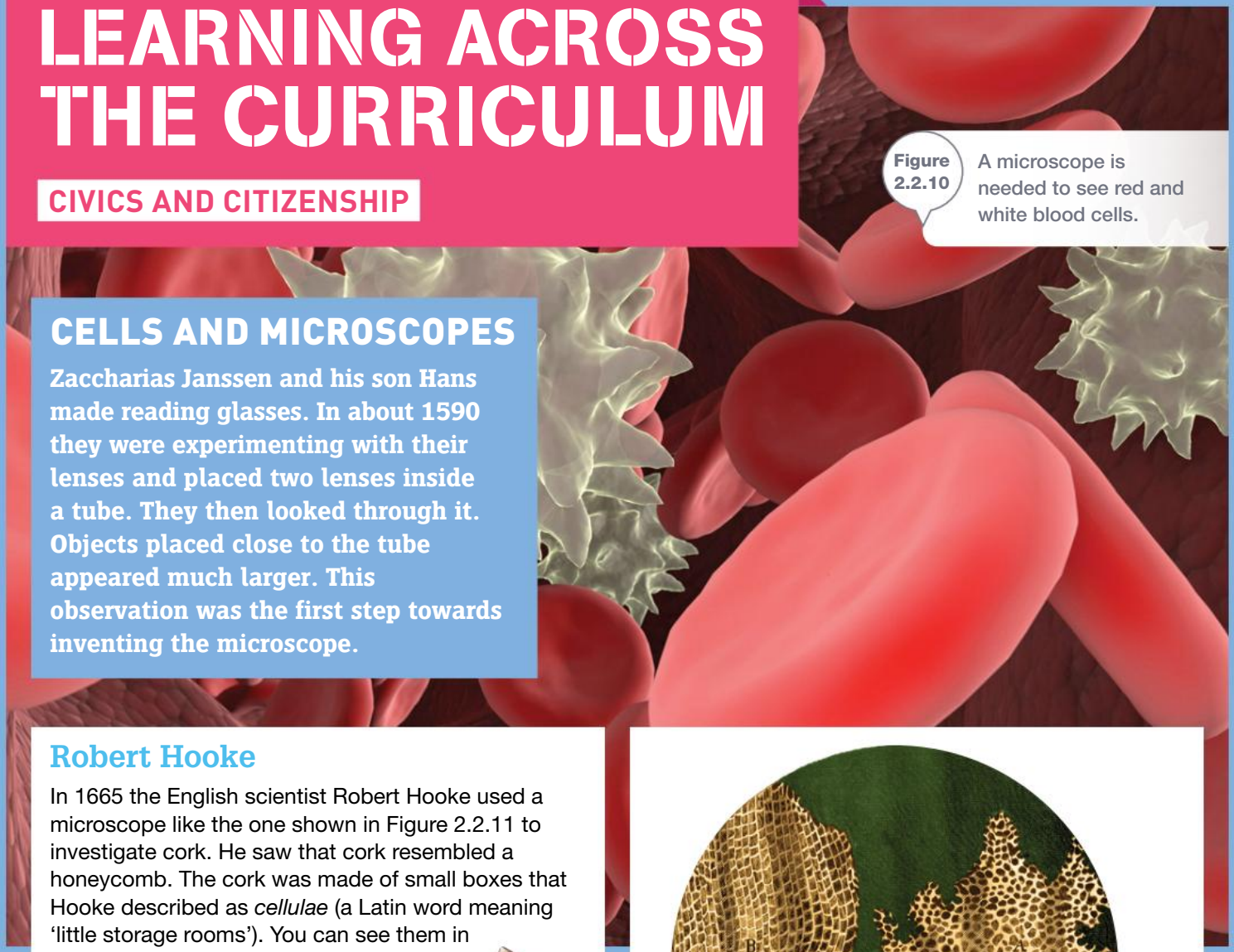


Figure 2.2.10 A microscope is needed to see red and white blood cells.

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.

Robert Hooke

In 1665 the English scientist Robert Hooke used a microscope like the one shown in Figure 2.2.11 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 2.2.12. 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.

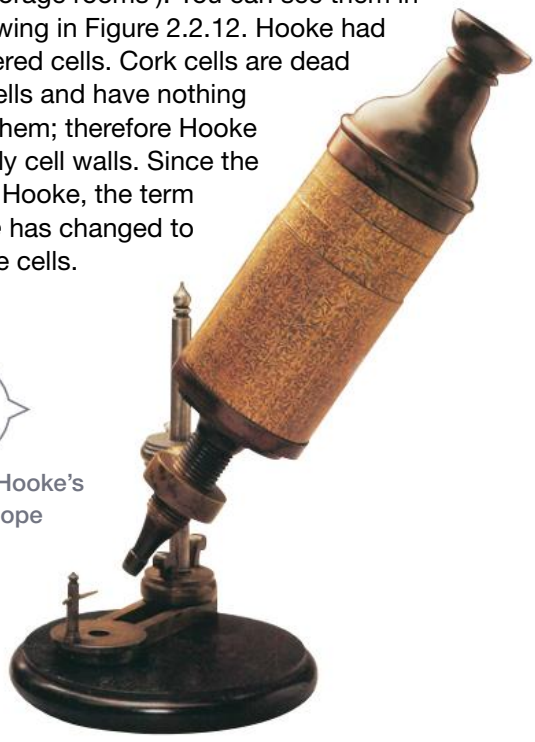


Figure 2.2.11 Robert Hooke's microscope

Figure 2.2.12 Hooke's original 1665 drawing of cork cells

Antonie van Leeuwenhoek

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.

Cell theory

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 2.2.13.

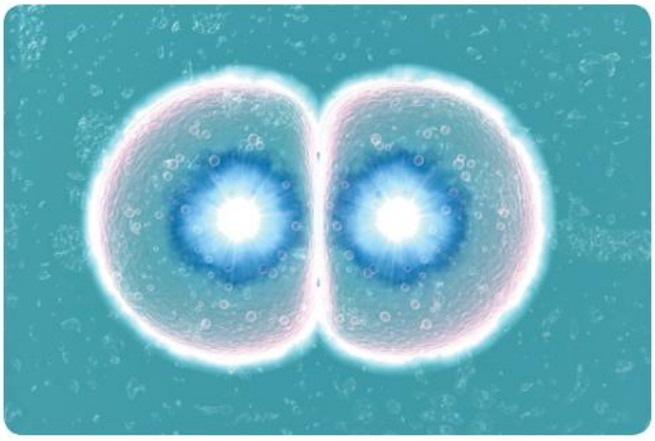


Figure 2.2.13 One cell dividing to produce two cells

Seeing viruses

In 1931 the German engineer Ernst Ruska (Figure 2.2.14) 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.

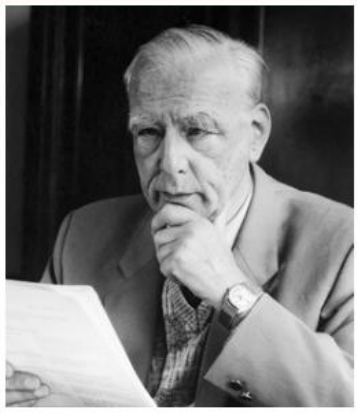


Figure 2.2.14 Ernst Ruska

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 2.2.15.

Figure 2.2.15 A scanning electron microscope

2.5

REVIEW

1 **Outline** the main points of the cell theory.

2 **Compare** the cells that Hooke studied in 1665 with the cells that Leeuwenhoek observed in 1674.

3 **Compare** the magnification of the microscope Leeuwenhoek used with the magnification of modern electron microscopes.

4 **Construct** a timeline showing the main advances in scientists' knowledge of cells from the time that Janssen and his son were working with lenses until the present.

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 2.2.16.

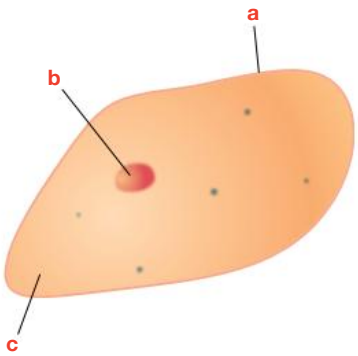


Figure 2.2.16

4 **Name** the parts of the cell labelled a, b and c in Figure 2.2.17.

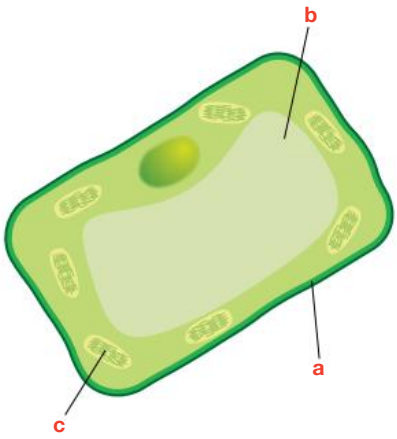


Figure 2.2.17

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

6 **State** the meaning of the prefix *uni* in the word unicellular. L

7 **List** the features that you would expect to see in cheek cells observed in the science4fun on page 51.

Understanding

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

9 **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 chloroplasts.

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

11 a **Name** two unicellular organisms that are commonly found in water.
- b **Explain** why you should boil river water before drinking it.

12 You began as a single cell but now your body is made of billions of cells. **Explain** how one cell became billions of cells.

Applying

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

14 **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.

15 **Use** your skills in drawing from a microscope to **draw** four cells from Figure 2.2.19.

Analysing

16 **Compare** plant and animal cells.

17 **Contrast** plant and fungal cells.

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

Evaluating CCT

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

20 **Draw** a Venn diagram like that shown in Figure 2.2.18. From the descriptions of cells on pages 50 to 51, **select** the characteristics that would go in each part of the diagram.

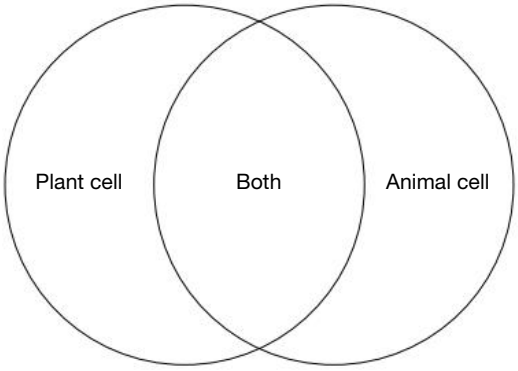


Figure 2.2.18

21 a **Classify** the type of cell shown in Figure 2.2.19 as a plant cell or an animal cell.

b **Justify** your answer.

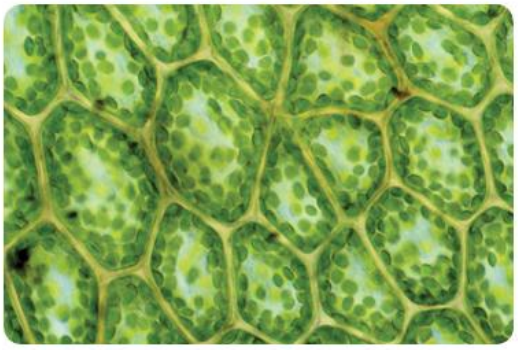


Figure 2.2.19

22 a **Classify** the cell shown in Figure 2.2.20 as an animal cell or a fungal cell.

b **Justify** your answer.

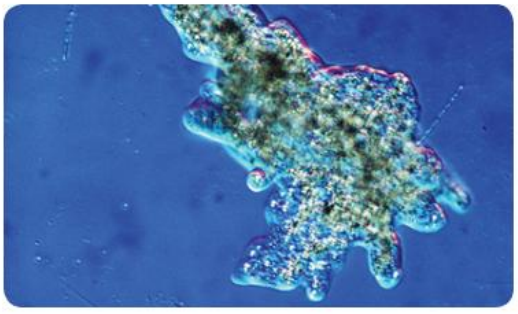


Figure 2.2.20

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

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

25 A student was using a microscope to examine unicellular organisms. Figure 2.2.21 shows what was visible when the student changed from low power to high power. **Propose** what the student should have done in order to view the complete organism.

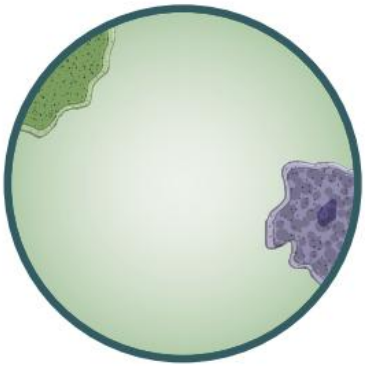


Figure 2.2.21

High magnification

Creating CCT

26 As large organisms such as humans grow, they make more and more very tiny cells. What if these organisms 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

The invention of the light and electron microscopes led to the discovery of cells, bacteria and viruses. These discoveries provided evidence that some unicellular organisms were often the cause of disease. This led to techniques that killed the unicellular organisms or minimised their spread. Research:

- how the microscope led to the discovery of unicellular organisms
- how these discoveries helped minimise the spread of the diseases that unicellular organisms caused
- the main people involved in these discoveries.

Present your findings as a timeline.

2.2 Practical investigations

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

- slices of onion and rhubarb leaf stalk
- a few drops iodine
- a few drops water
- microscope and lamp
- filter paper
- microscope slide and cover slip
- eye-dropper
- 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.

Practical review

1. Refer back to the diagram of the typical plant cell shown in Figure 2.2.3 on page 51. 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. a **List** the parts you could not see.
   b **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.

Hypothesis

What do you think will happen to an egg that has no shell when left in salt water and in distilled water? Before you go any further with this investigation, write a hypothesis in your workbook.

Purpose

To observe a membrane at work.

Materials

- 2 eggs
- 500 mL white vinegar
- 1 tablespoon 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. 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 water (mL)		
	Day 0	Day 3	Change
Distilled water	200		
Salt water	200		

Practical review

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 hypothesis.

3 Looking at pond water

Purpose

To observe microscopic organisms in pond water.

Materials

- pond water

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

SAFETY

Do not drink pond water. Wash your hands thoroughly after the activity.

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 they also appear to be moving faster.

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 2.2.22 to identify the organisms you saw.

Practical review

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.

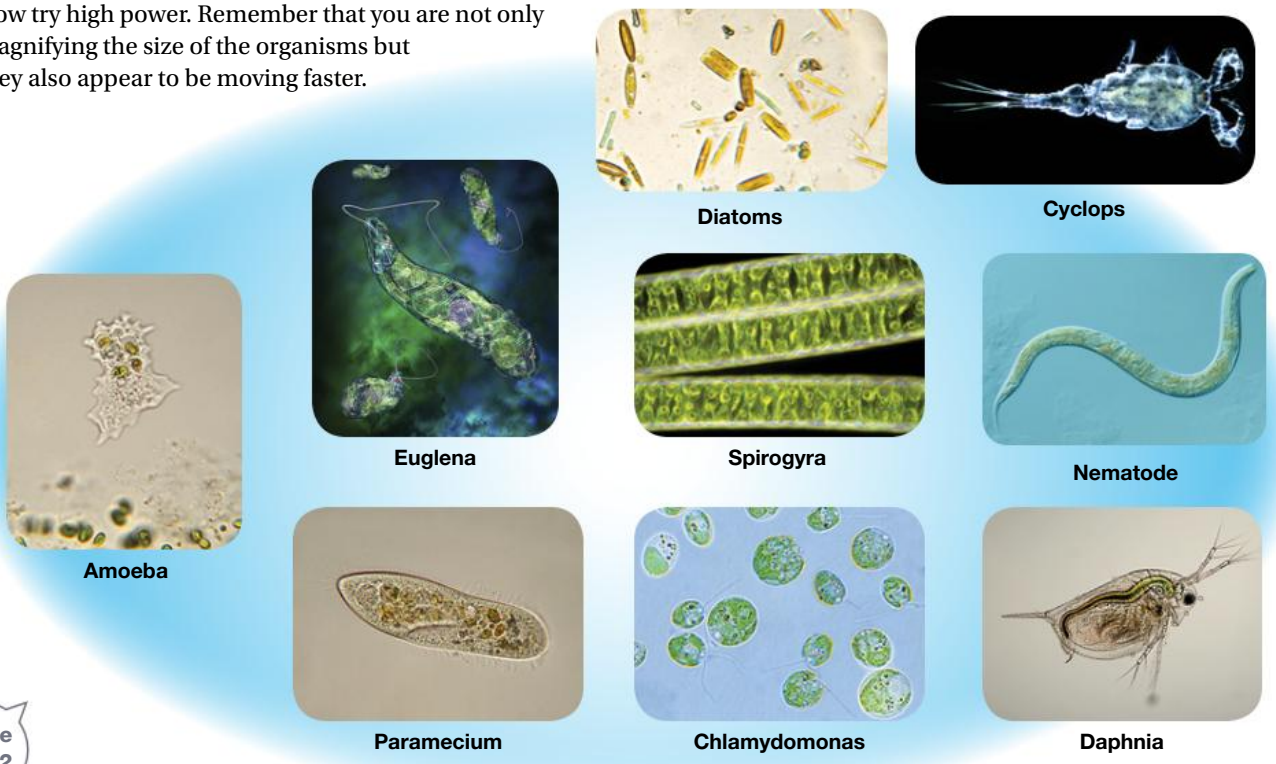
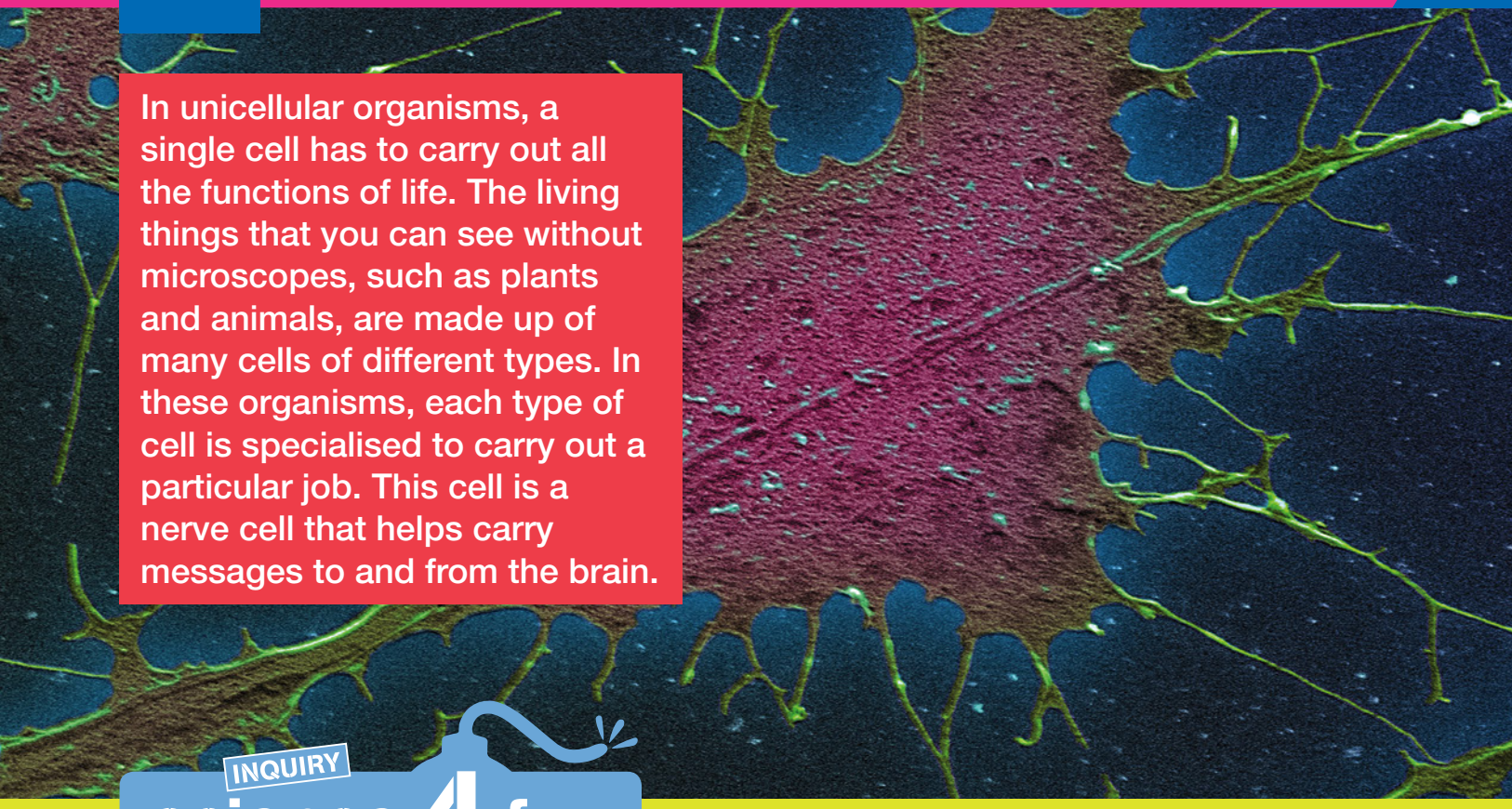


Figure 2.2.22

2.3 Specialised cells



In unicellular organisms, a single cell has to carry out all the functions of life. The living things that you can see without microscopes, such as plants and animals, are made up of many cells of different types. In these organisms, each type of cell is specialised to carry out a particular job. This cell is a nerve cell that helps carry messages to and from the brain.

INQUIRY science 4 fun

Where the water goes

YES

Where does the water go in a plant?

Collect this …

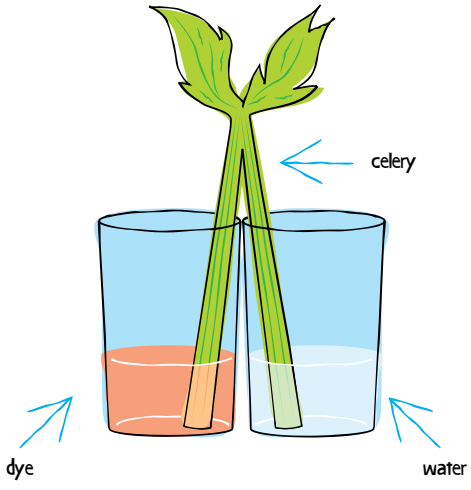
- celery stick
- food colouring
- two yoghurt containers or glasses
- knife

SAFETY

Take care when using a knife.

Do this …

1. Fill both containers with water until they are about one-third full.
2. Add a few drops of food colouring to one container to give it a strong colour.
3. Carefully cut the celery lengthwise from the end of the stalk to just under the leaf blades, as shown in the diagram.
4. Cut across the end of the stalk to remove the dried end.
5. Place one half of the celery stalk in the water and the other half in the water with food colouring, as shown.



6. Leave the containers in a safe place for one to two hours.
7. Cut across the stalk about half-way up.

Record this …

Describe any changes to the leaf blades and at the newly cut end of the stalk.

Explain why you think this happened.

Multicellular organisms

Living things such as humans, fish and the tree and koala in Figure 2.3.1 are made of millions and millions of cells. They are known as **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.

Figure 2.3.1 This koala and the tree in which it is sitting are both multicellular organisms.

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

Specialised animal cells

Animals are complex multicellular organisms with a large number 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 2.3.2.

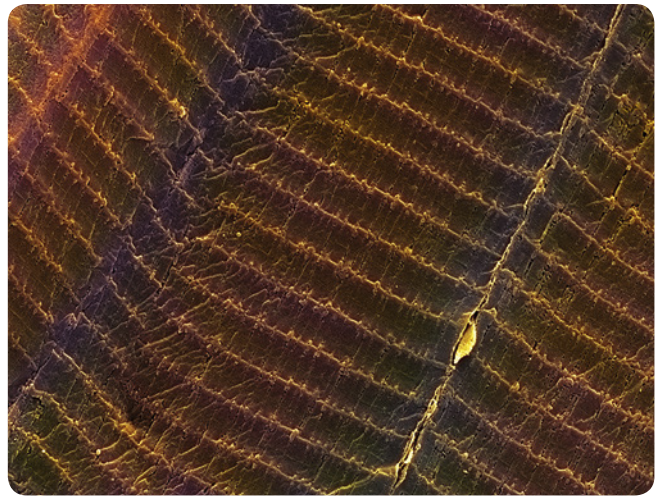
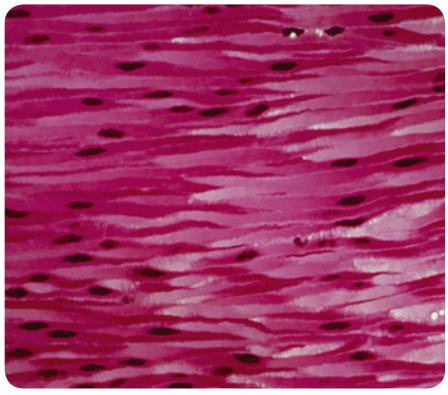


Figure 2.3.2 The voluntary muscles (skeletal muscles) attached to our bones have a striped appearance and are also known as striated (striped) muscles.

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 2.3.3.

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.

Figure 2.3.3



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

Cardiac muscle (Figure 2.3.4) 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 2.3.4

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 2.3.5 shows, some nerve cells have very long fibres extending from the cell. These fibres are called **axons**—they 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.

Blood cells

Figure 2.3.6 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 2.3.5

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

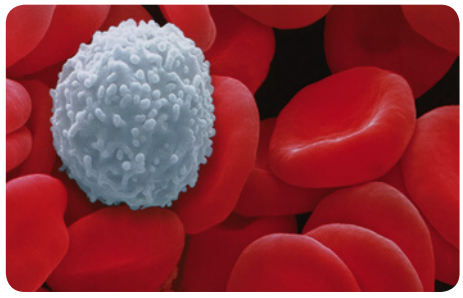


Figure 2.3.6

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

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.

SciFile

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 2.3.7 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.

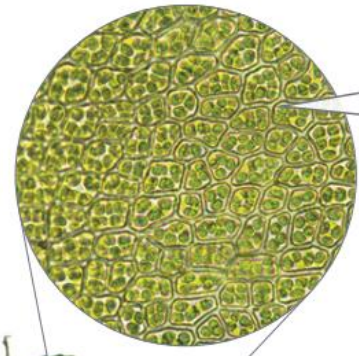
Figure 2.3.7

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

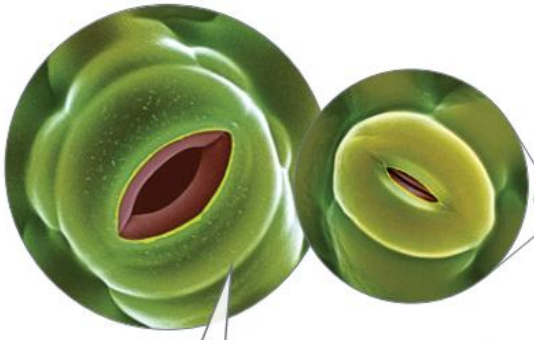
Specialised plant cells

Like animals, plants are multicellular organisms. Plants have specialised cells of different shapes and sizes, but they do not have as many different types of cells as animals.

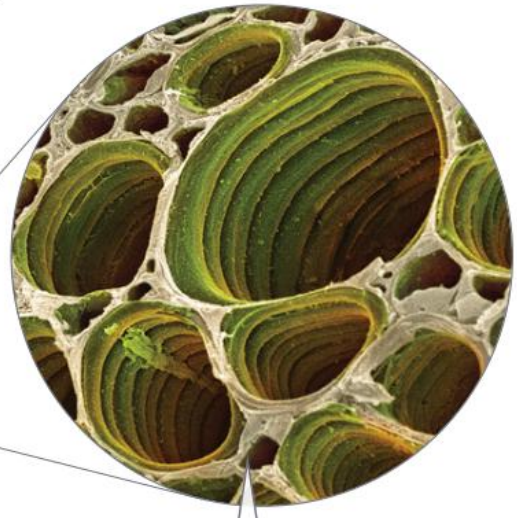
Each type of cell is specialised to carry out a different function within the plant. Figure 2.3.8 shows some plant cells that have different functions.



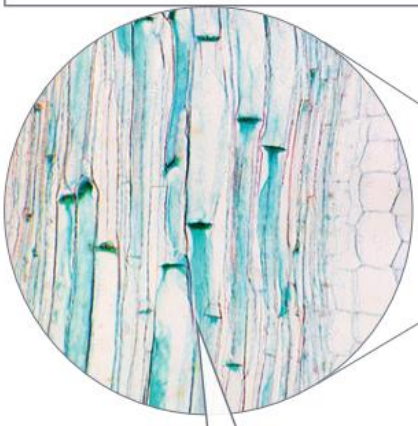
Photosynthetic cells
Cells near the surface of the green parts of stems and leaves have large numbers of chloroplasts. In the chloroplasts is a green chemical called **chlorophyll**. This chemical traps the Sun's energy, which the plant then uses in photosynthesis. Plant cells that are not exposed to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



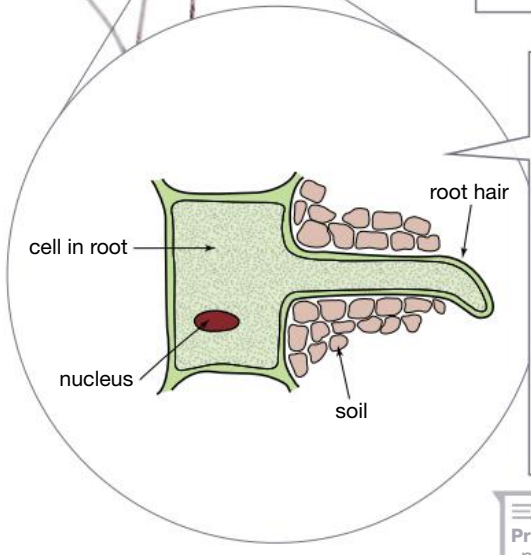
Guard cells
Guard cells are found on the leaves and stems of plants. Guard cells work in pairs to open and close very tiny pores (or holes) in the leaves called **stomata**. Gases needed by the plant enter through open stomata. Unwanted gases leave the same way. Guard cells close the stomata when plants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



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 inside the bark.



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 are cells that are specialised for transporting 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.

Figure 2.3.8 Different plant cells have different jobs to do.

Prac 1 p67 | Prac 2 p67 | 2.6 | 2.7

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 prefix *multi* means in the word multicellular. L

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 entering 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*. L
- b **Explain** why the cells of multicellular organisms are not all the same.

8 Once water has entered the root of a plant, **explain** how it is able to get to the leaves where it is needed.

9 **Predict** what will happen in each side of the celery stick in the science4fun on page 61.

Applying

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

Analysing

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 CCT

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 CCT

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 **Construct** a diagram 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.

2.3 Unit review

Inquiring

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

Present your research as a poster.

Figure 2.3.9 Jellyfish have specialised stinging cells. These cells assist in their survival.

2 Red blood cells have no nucleus. Research red blood cells. Find:

- images of red blood cells
- what they do in the human body
- where they are made
- what happens if you don't have enough of them
- why their lack of a nucleus is an advantage.

Present your findings as a digital slideshow. ICT

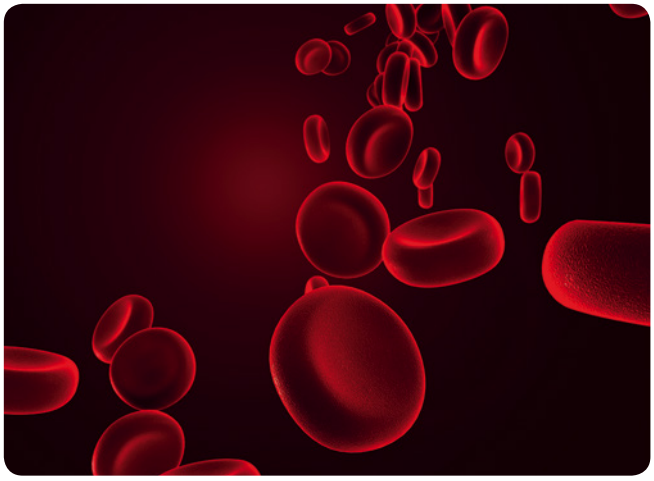


Figure 2.3.10 Red blood cells are the only cells in the human body that do not have a nucleus.

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

Present your research as an annotated diagram showing where different bacteria live in the body and what each type of bacterium does.

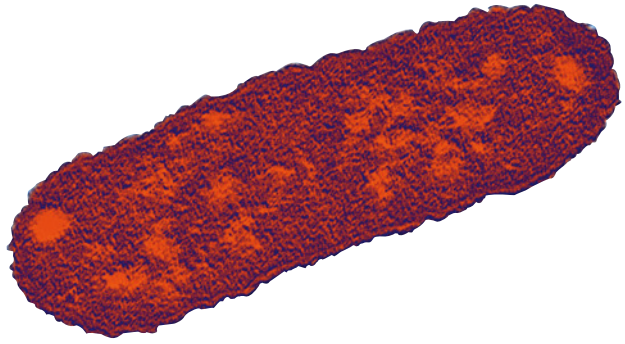


Figure 2.3.11 Bacteria are very small organisms made of just one cell. A bacterium is so simple that it has no organelles.

2.3 Practical investigations

1 Modelling water transport cells

Purpose

To model the effect of very thin tubes on the movement of water in plants.

Materials

- food colouring
- 125 mL water

- 500 mL beaker
- 1 × 30 cm length of capillary tubing
- 2 × 20 cm lengths of glass tubing with different diameter bores, both larger than the capillary tubing

Procedure

1. Place the water into the beaker and add enough food colouring to give the water a distinct colour.
2. Hold the three pieces of glass tubing upright in the water as shown in Figure 2.3.12. Make sure the tubing is touching the bottom of the beaker.

Figure 2.3.12

Results

1. Observe the height to which the water has risen in the different tubes.
2. Construct a diagram showing the apparatus and the results.

Practical review

1. The bore is the hole in the middle of the tube. **Explain** how the diameter of the bore affects the level of water in the tube.
2. The bore of the water-carrying tubes in a plant are many times smaller than the capillary tube. **Propose** the effect this would have on the water level.

STUDENT DESIGN

2 My cell

Purpose

To construct a model of a cell.

Materials

You can decide on 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

A risk assessment is required for this investigation.

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.

Practical review

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.

2.4 Cell to organism

Wombats and wallabies, 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

YES

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.

Animal 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 (like those in Figure 2.4.1) there are several different levels of organisation. These levels are shown in Figure 2.4.2.

- **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 working together to complete a task.
- **Organ systems**: Organs are arranged into organ systems. Organ systems have two or more different organs that work together.

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

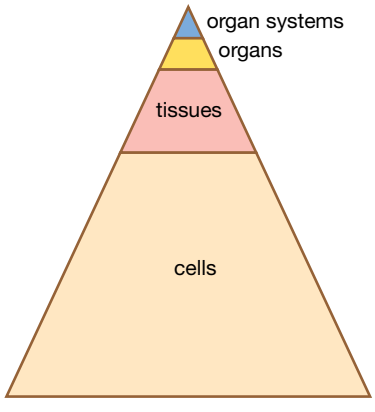


Figure 2.4.2 In a complex organism, there are many more cells than there are tissues, many more tissues than organs, and many more organs than systems.

Tissues

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

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

Epithelium is 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.

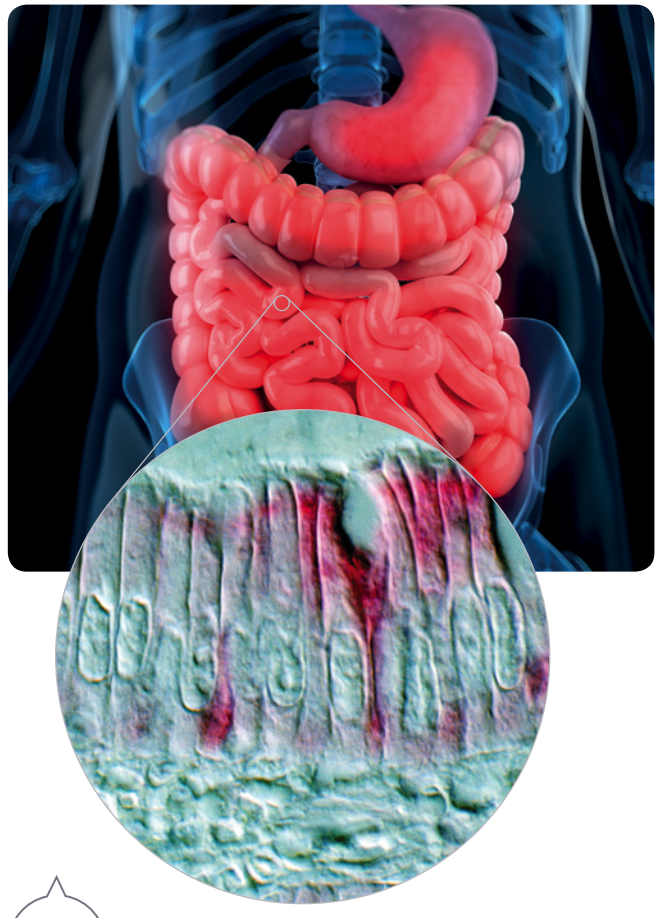


Figure 2.4.3 Column-shaped cells make up the epithelium lining your small intestine.

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 on page 70. 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 contracted. 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.

Prac 1 p77

Figure 2.4.4

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

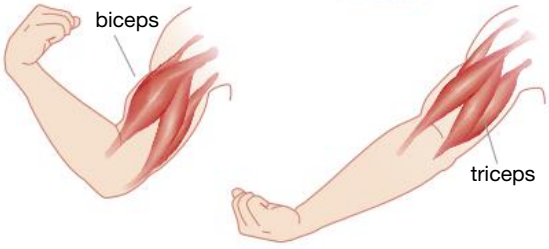


Figure 2.4.5

Muscles in the front of the arm (biceps) 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.

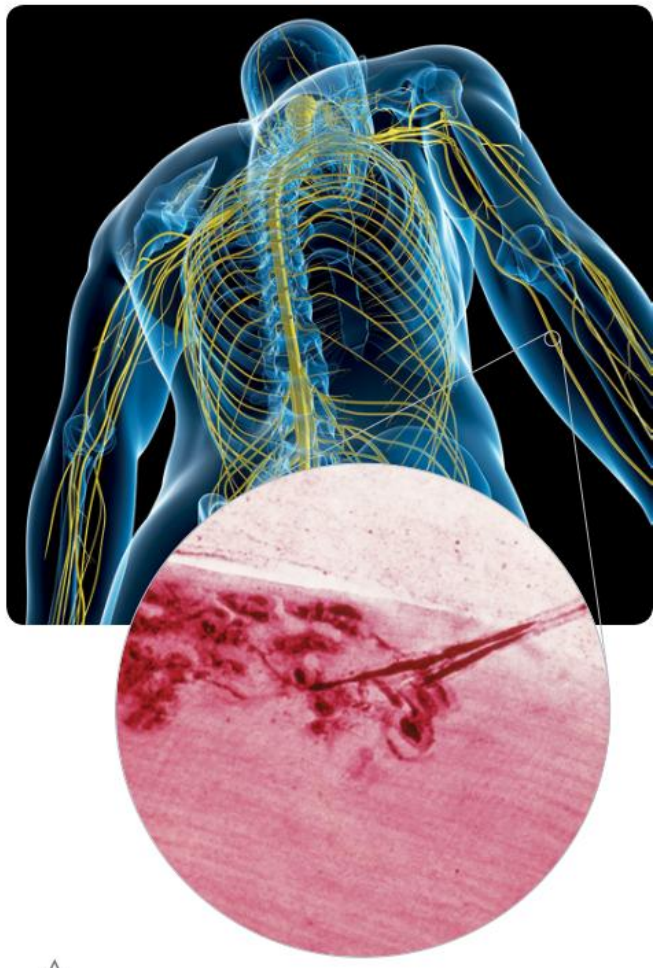


Figure 2.4.6

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, the skin has many different parts.

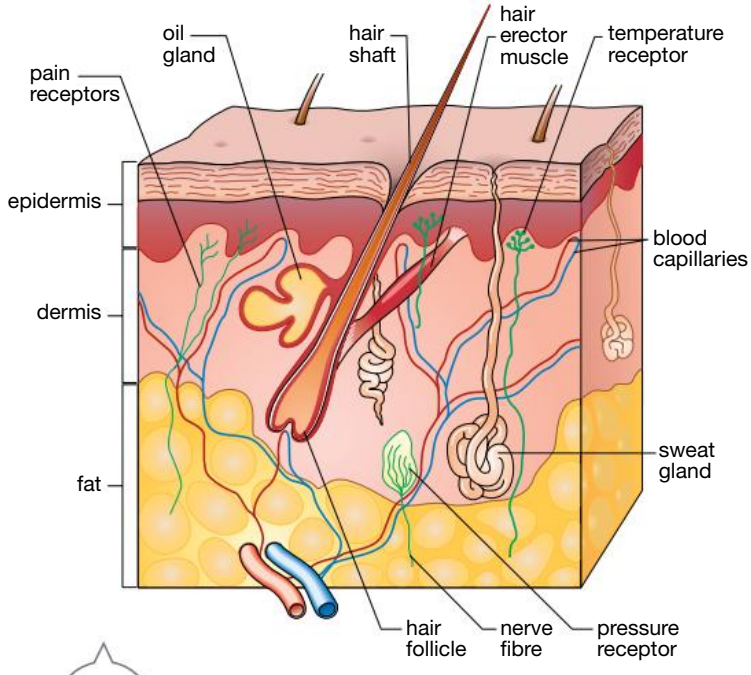


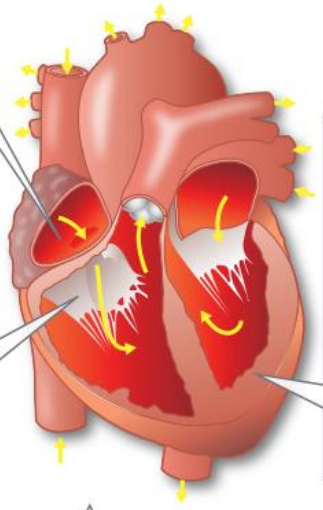
Figure 2.4.7

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 around your body, carrying to the cells all the things they need to function. Your blood also carries away wastes that could harm your cells.

Prac 2 p77

Nerve tissue generates the signal that causes the heart to beat. A group of nerve cells in the right atrium, known as the SA node, triggers each heartbeat. Nerve signals from the SA node are transmitted through the heart, controlling the frequency with which the heart beats.



Most of the heart is muscle tissue. The contraction and relaxing of the cardiac muscles create the heartbeat that pushes the blood from your heart around your body.

Connective tissue forms the heart valves. The tissues of the valves must be flexible enough to let the valve open, allowing the blood to flow through. They must also be strong enough to hold back the flow of blood when the valve is closed.

Figure 2.4.8 The heart is an organ made of different tissues.

Organ 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 form an organ system. For example, a series of organs work together to change the food you eat into a form that your body can use. This system digests the food. For this reason the system is called the digestive system. It is shown in Figure 2.4.9.

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.

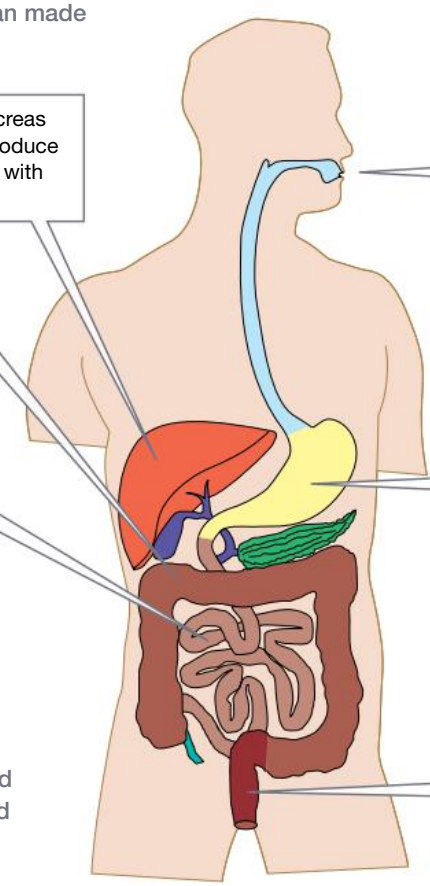
GO TO Chapter 3 GO TO Unit 4.3

The liver and pancreas are organs that produce chemicals to help with digestion.

In the mouth, food is broken into smaller pieces by the teeth, making it easier to swallow and digest.

In the large intestine, water is removed from the waste (mostly food you have not been able to digest).

As it passes along the small intestine, the digested food is absorbed into the bloodstream.



In the stomach and the small intestine, food goes through chemical changes so that it can be used by the body.

Wastes are stored in the rectum until they are passed out of the body.

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.

Plant tissues and organs

Although flowering plants are simpler than animals, they have tissues and organs too. These tissues and organs enable the plant to carry out essential functions such as photosynthesis, transport and reproduction. For example, many plants use flowers to reproduce and so flowers are their reproductive organs.

GO TO Unit 4.2

Transport tissue

Materials are transported around plants in two types of cells:

- **Xylem** carries water from the roots. Xylem cells are long thin tubes with strong walls that also form an important part of the skeleton of the plant. You can see them clearly in Figure 2.4.10.
- **Phloem** carries glucose from the leaves to all other plant parts.

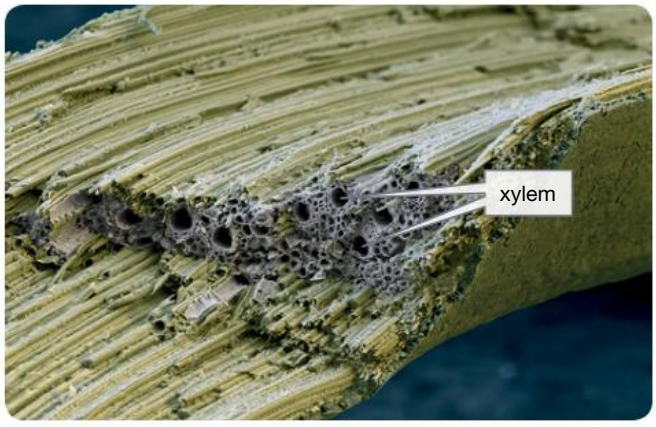


Figure 2.4.10 A piece of bamboo showing the long bundles of xylem cells that carry water throughout the plant

Phloem and xylem together form a network of vascular tissue throughout the plant. The vascular tissue in a leaf can be seen in Figure 2.4.11.

Figure 2.4.11 The network of vascular tissue can been seen in this leaf. This transport system extends throughout the stem and roots as well.

Plant organs

The main organs of a plant are its roots, stems and leaves. These organs work together to bring together the raw materials required for photosynthesis. **Photosynthesis** is the process by which plants make glucose. Plants use energy from glucose for their own life processes; without it they could not survive. For photosynthesis to take place, water, sunlight, chlorophyll and carbon dioxide are needed. Oxygen is produced as a waste product.

The root is the plant organ that takes water into the plant from the soil. The structure of the root is shown in Figure 2.4.12. Water moves through cells to the vascular tissue. It moves up the xylem to the stem.

The stem is the organ that holds the leaves of the plant up to the light. Stems also carry water from the root to the leaves and transport glucose to all parts of the plant.

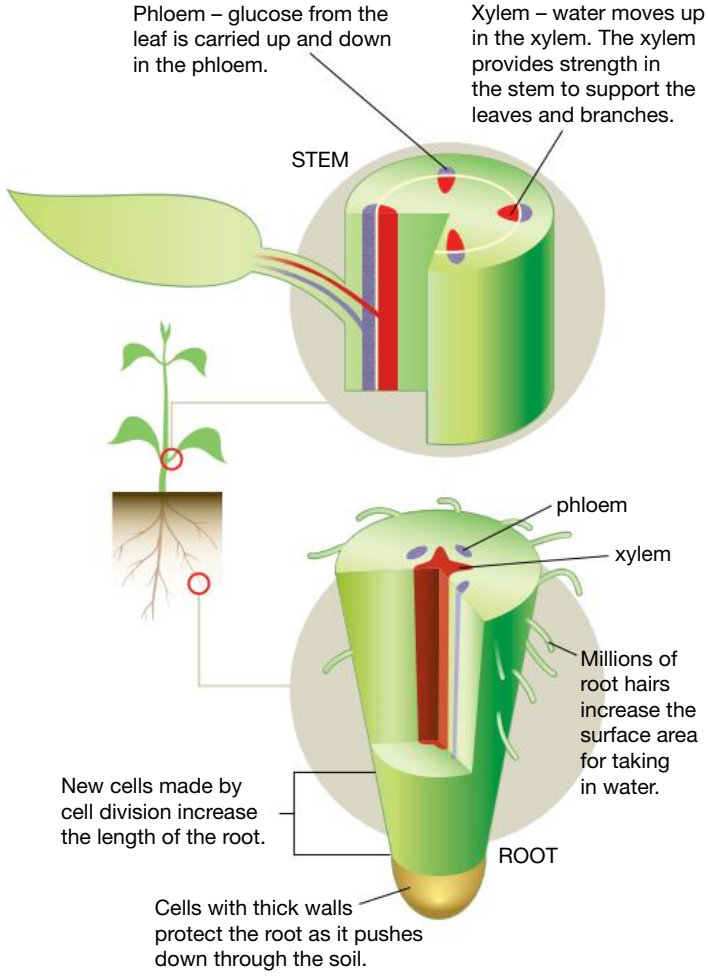
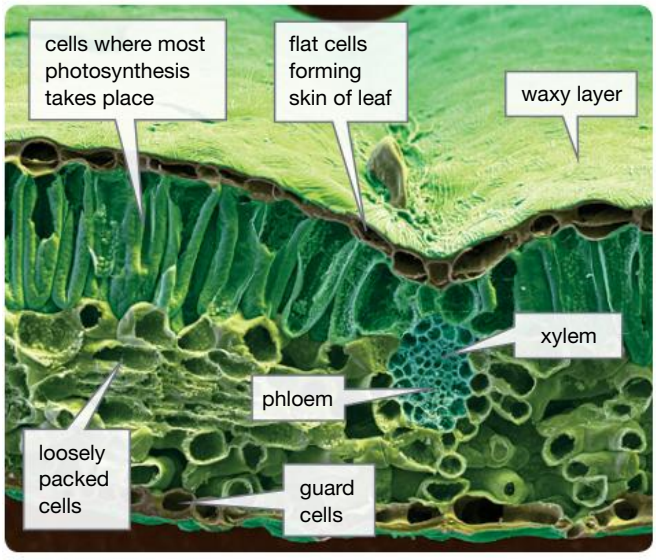


Figure 2.4.12 The roots and stem are plant organs that help get the water necessary for photosynthesis up to the leaves.

The leaves are the organs in plants that carry out photosynthesis. Leaves have:

- a large surface area to capture as much light as possible
- cells near the surface that have large numbers of chloroplasts to trap energy from the Sun
- stomata (holes) in the leaf surface to let carbon dioxide into the leaf and let water vapour and oxygen out
- air spaces within the leaf that allow gases to move quickly through the leaf to the cells where they will be used or away from the cells that produced them as waste
- large amounts of vascular tissue to carry water to the cells and to carry glucose away from the cells to other parts of the plant.

You can see these different parts in Figure 2.4.13.



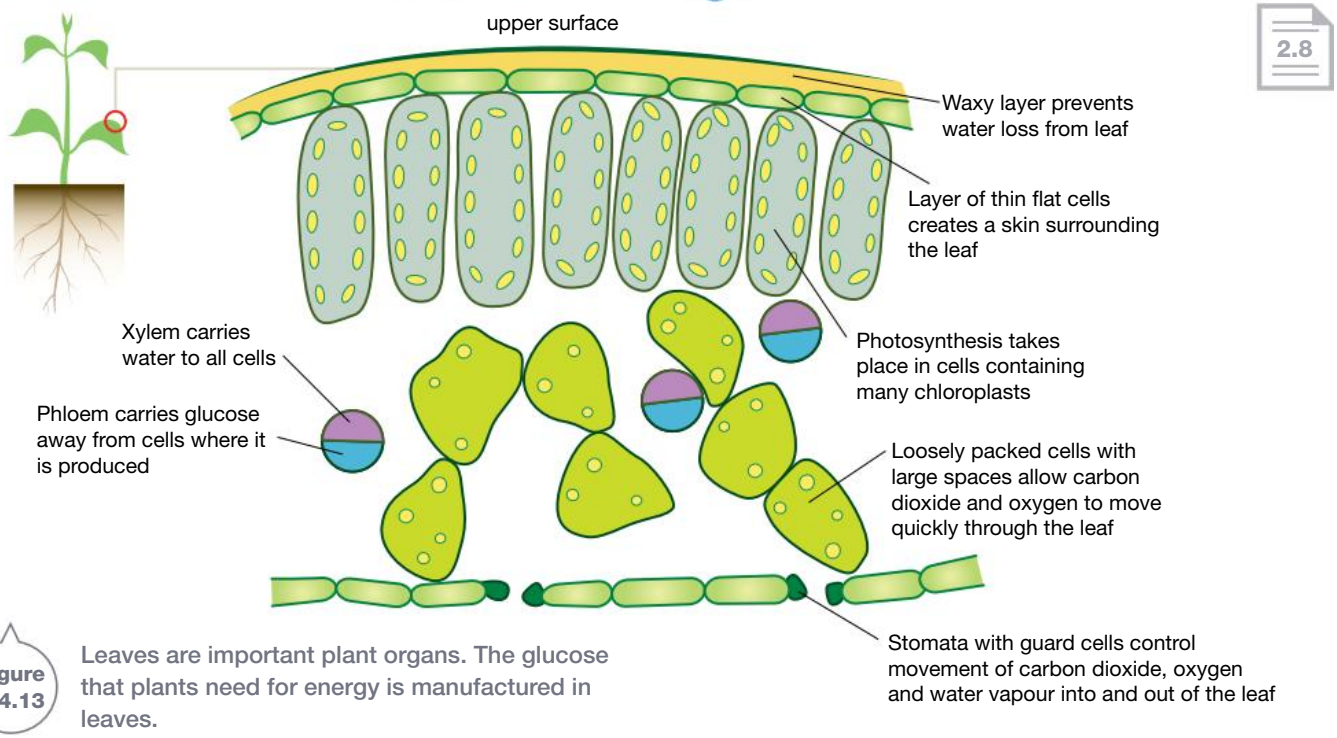


Figure 2.4.13 Leaves are important plant organs. The glucose that plants need for energy is manufactured in leaves.

Photosynthesis

Photosynthesis uses carbon dioxide from the air and water from the soil. The carbon dioxide and water react together to produce glucose, a sugar plants use as their source of energy. Sunlight is needed for photosynthesis to take place. Light energy from the Sun is converted into chemical energy and stored in the glucose that is produced. Chlorophyll is also needed for the reaction. Chlorophyll is a chemical that converts the Sun's energy into chemical energy the plant can use.

The process of photosynthesis is summarised in Figure 2.4.14.

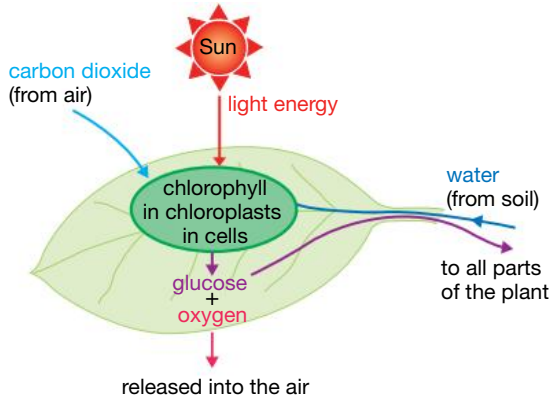


Figure 2.4.14 Before photosynthesis can take place, all the raw materials need to be brought together in the chloroplasts of leaf cells.

GO TO Unit 7.3

2.8

LEARNING ACROSS THE CURRICULUM

CIVICS AND CITIZENSHIP

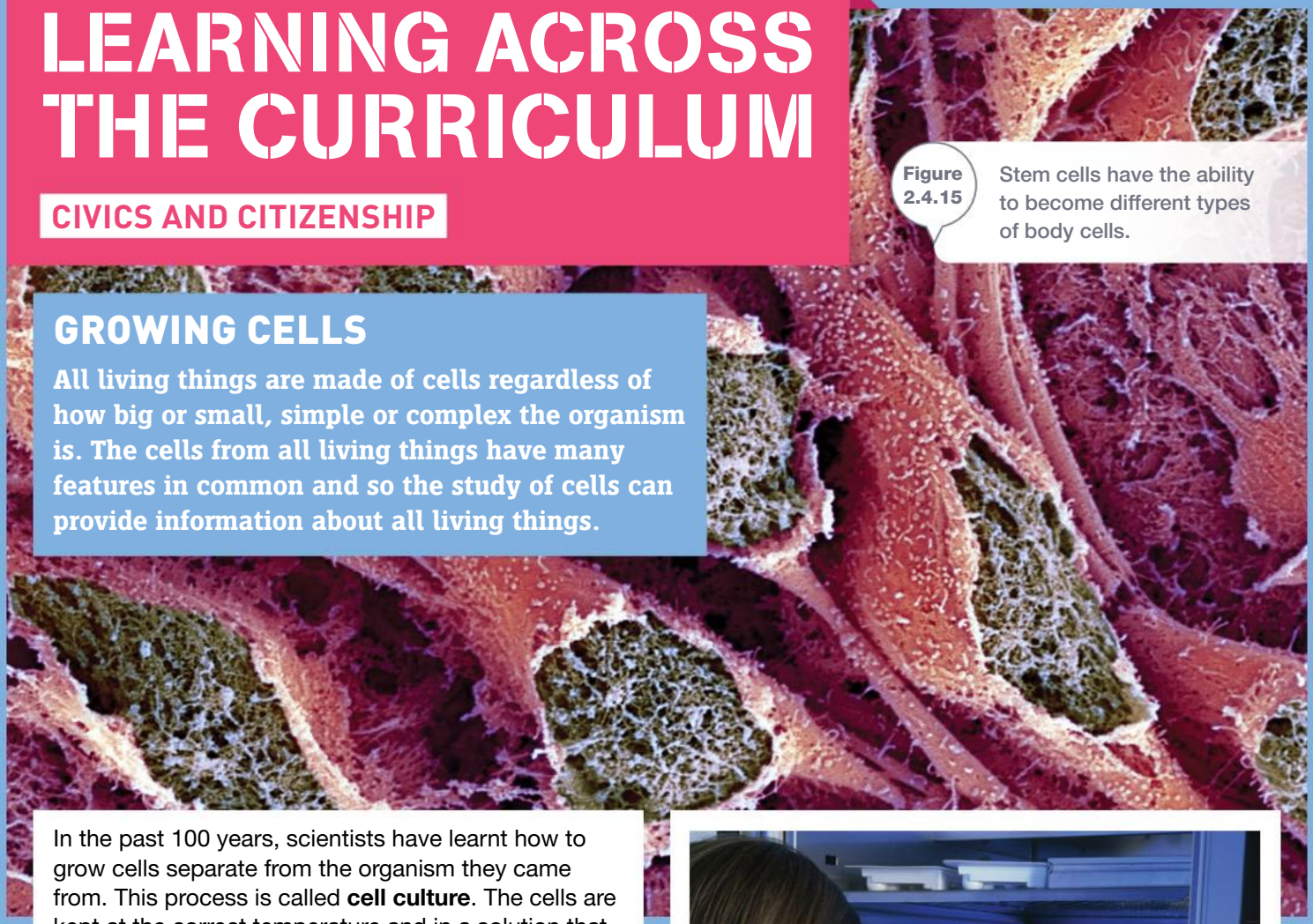


Figure 2.4.15 Stem cells have the ability to become different types of body cells.

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 past 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.

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 (grown).

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 a scanning electron microscope image of some stem cells in Figure 2.4.15.

Figure 2.4.16 Tissues are cultured in flat bottles like these.

Stem cells extracted from the hair root are grown in culture for about two weeks in flat bottles like those in Figure 2.4.16. They are 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 2.4.17.

Figure 2.4.17 A strip of skin is held above the culture medium.

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?

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. 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.

The experiment shown in Figure 2.4.18 suggests that it may be possible to grow body parts in the future.

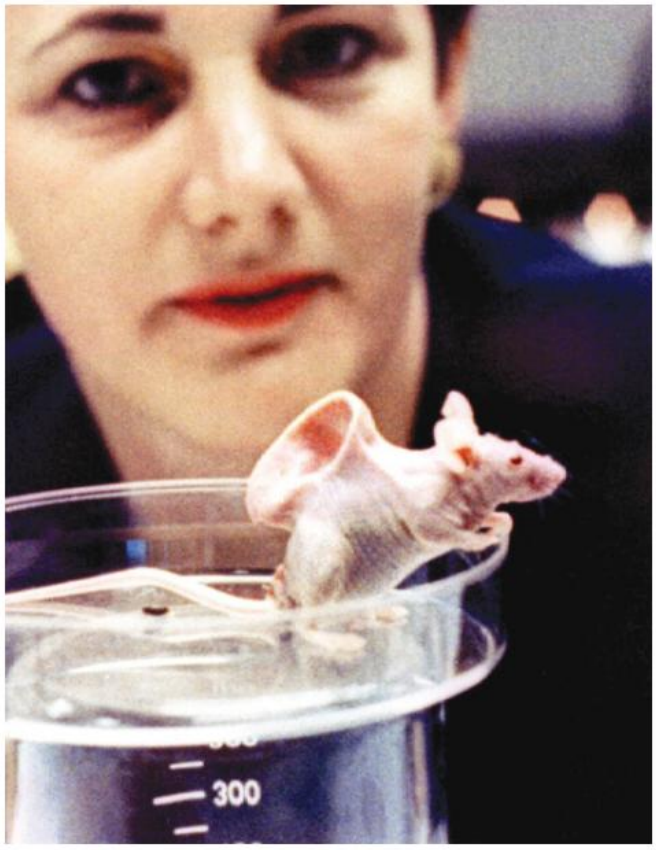


Figure 2.4.18 The ear on the back of this mouse was grown from cartilage cells from a cow, implanted on a mould in the shape of an ear.

2.9

REVIEW

1 **Explain** what the following terms mean.
   - **a** cell culture
   - **b** stem cells

2 **Recall** a place in the body where stem cells are found.

3 **Describe** one use for skin cells grown in culture.

4 **Describe** some possible uses for cell culture technology in the future.

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 plant organ:
- a in which most photosynthesis takes place
- b through which water enters the plant.

Understanding

6 **Describe** what is meant by the term *system* as it relates to the human body.

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

8 **Explain** how root hairs make roots more efficient.

Applying

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

10 Sketch a diagram to **demonstrate** the path water travels from the soil to the cells where photosynthesis takes place.

Analysing

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

12 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.

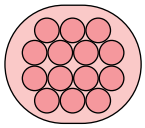
13 **Compare** cardiac muscle and skeletal muscle.

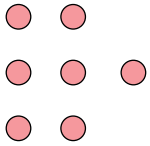
Evaluating CCT

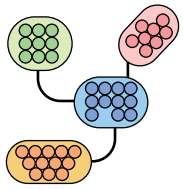
14 **Propose** how the amount of photosynthesis taking place in a leaf would change if:
- a the stomata were closed
- b the number of chloroplasts was reduced by half.

15 In 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 

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

17 In the science4fun on page 68, vinegar (an acid) slowly removed calcium from chicken bones.
- a **Propose** what might happen to your bones if they lost calcium.
- b **Predict** how the functioning of your skeleton might change if you do not have enough calcium in your diet.

Creating CCT

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

Inquiring

Research stem cells and the advantages and disadvantages that their use in the future may bring. Your research should:
- include images of stem cells
- compare embryonic stem cells with adult stem cells
- list the advantages and disadvantages of the use of embryonic and adult stem cells
- find reasons why some people support the use of embryonic stem cells while others argue against their use
- propose why supporting scientific research in new areas such as stem cells is important.

Present your research in a digital form. ICT

2.4 Practical investigations

1 Muscles get tired

Purpose

To find out what contributes to muscle fatigue.

Hypothesis

What do you think will cause your muscles to fatigue (become tired) more quickly—squeezing a ball at waist height or with your arm held above your head? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- soft foam or rubber ball
- stopwatch

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 like the one in the Results section.

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		

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

Practical review

1. **Analyse** your results for Parts A and B. **Describe** any evidence that your muscles were becoming tired.
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. a. **Construct** a conclusion for this investigation.
   b. **Use** this to **assess** whether or not your hypothesis is supported.

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. List all the parts you know are inside your body.
3. Think about the position in the body and size of the organs. Draw 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.

Practical review

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 a **List** the parts of an animal cell that can be seen under a light microscope.
b **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.

Understanding

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

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

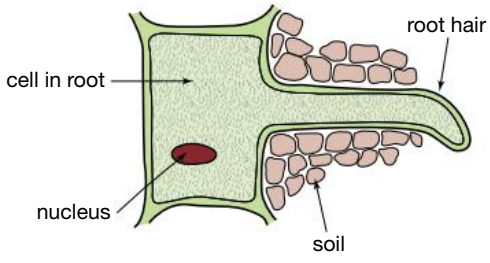
6 **Describe** what happens to the field of view when a microscope is changed from low power to high power.

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

8 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.

9 Study the diagram in Figure 2.5.1, 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.

Figure 2.5.1



Applying

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

11 The term *organelle* means *little organ*. Organs and organelles are very different. **Demonstrate** why organelle is an appropriate name for these structures.

12 **Calculate** the missing numbers in this table. N

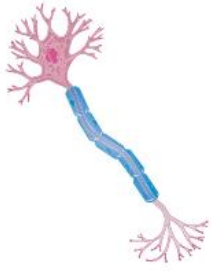
Ocular lens	Objective lens	Total magnification
×4		×40
	×10	×100
×4	×100	
×10	×40	
×10		×1000

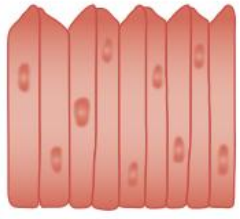
13 The field of view of a microscope was measured and found to be 3 mm using a magnification of ×10. N

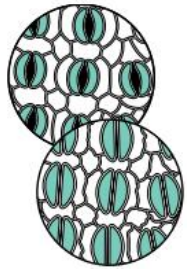
Calculate the diameter of the field of view at the following different magnifications and using the two different units.

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

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

a 

c 

b 

d

Analysing

15 **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

16 **Compare** the outer layer of plant cells and:
- a animal cells
- b fungal cells.

17 **Compare** unicellular and multicullular organisms.

18 **Classify** each of the organisms in Figure 2.5.2 as unicellular or multicellular.

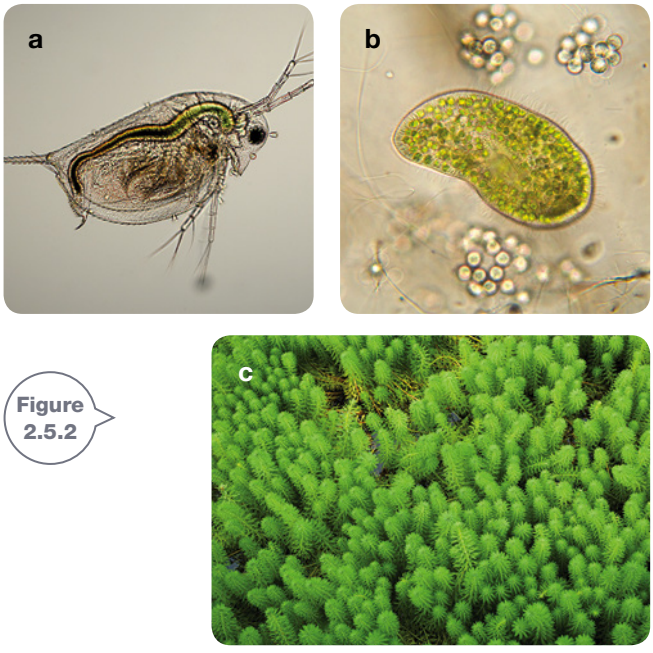


Figure 2.5.2

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 2.3.4 on page 63, 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.

22 Many plants have leaves that are thin and flat. **Propose** how changing the shape of a leaf to a cube would affect the functioning of the leaf as an organ of photosynthesis.

23 a **Determine** whether you can or cannot answer the questions on page 41 at the start of this chapter.
b **Assess** how well you understand the material presented in this chapter.

Creating CCT

24 **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

2.10

Evaluating CCT

19 **Use** Figure 2.5.3 to:
- a **compare** the size of plant cells and animal cells.
- b **propose** a reason for plant cells being the first cells to be seen
- c **propose** a reason why bacteria were not discovered until long after plant cells.

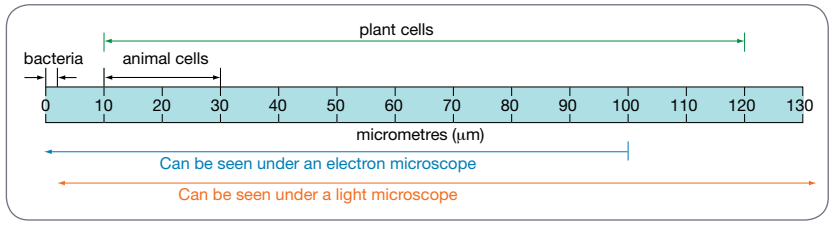
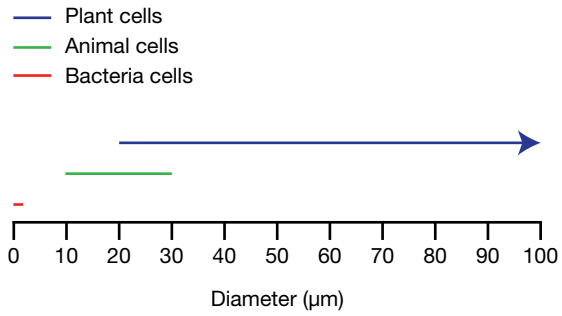


Figure 2.5.3

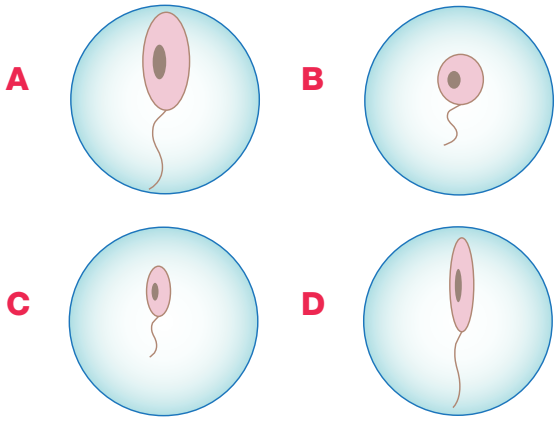
Thinking scientifically

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

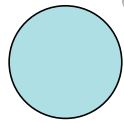


A 100 μm **B** 2 μm
C 15 μm **D** 45 μm

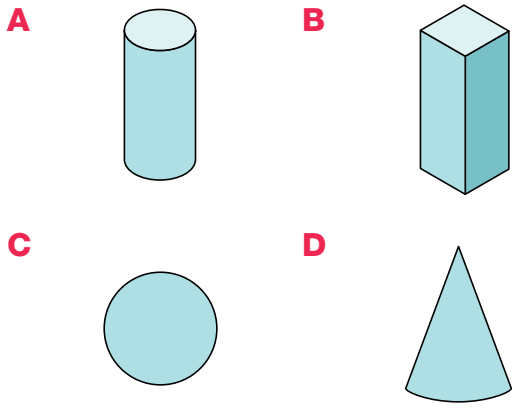
Q2 The unicellular organism shown here was viewed under a microscope with a magnification of ×2. Which diagram represents the image you would see? CCT



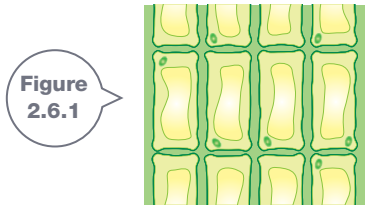
Q3 When a cell was cut from a section of a plant stem and viewed under a microscope, it appeared as a circle, as shown. CCT

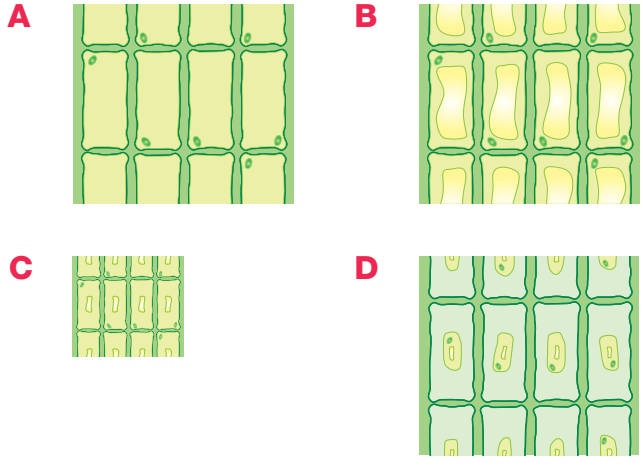


Which one of the following could *not* be the three-dimensional shape of the cell?



Q4 Figure 2.6.1 shows some normal plant cells. What would the cells look like if the plant they came from had no water for 3 days? CCT





Glossary

Unit 2.1 L

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)

Binocular microscope

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

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

Monocular microscope

Unit 2.2 L

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

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

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

Mitosis: cell division that produces two identical cells

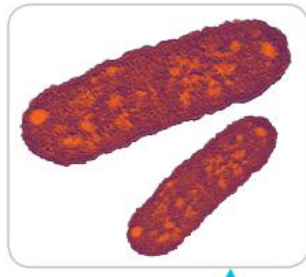
Nucleus: the control centre of a cell

Organelles: the smaller parts of a cell

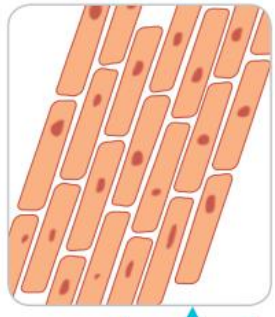
Photosynthesis: process used by plants to make food from water and carbon dioxide using energy from the Sun

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

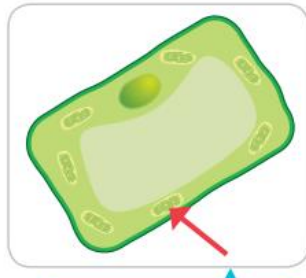
Ribosomes: structures that produce proteins



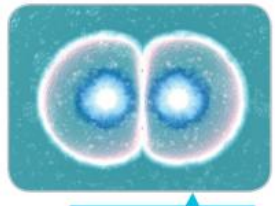
Bacteria



Cells



Chloroplast

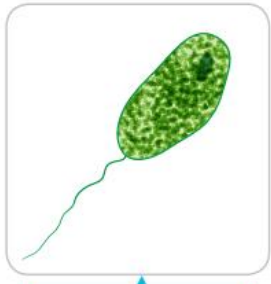


Mitosis

Glossary

Unicellular organisms: living things made up of only one cell

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



Unicellular organism

Unit 2.3 L

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

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

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

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

Unit 2.4 L

Cell culture: growing cells separately from organisms in the laboratory

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

Epithelium: skin

Muscle tissue: specialised tissue that can contract

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

Muscle tissue

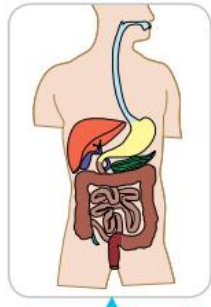
Organ system: two or more different organs that work together

Phloem: cells in a plant that carry glucose from the leaves to all other parts of the plant

Stem cells: cells that can become different types of cells under specific conditions

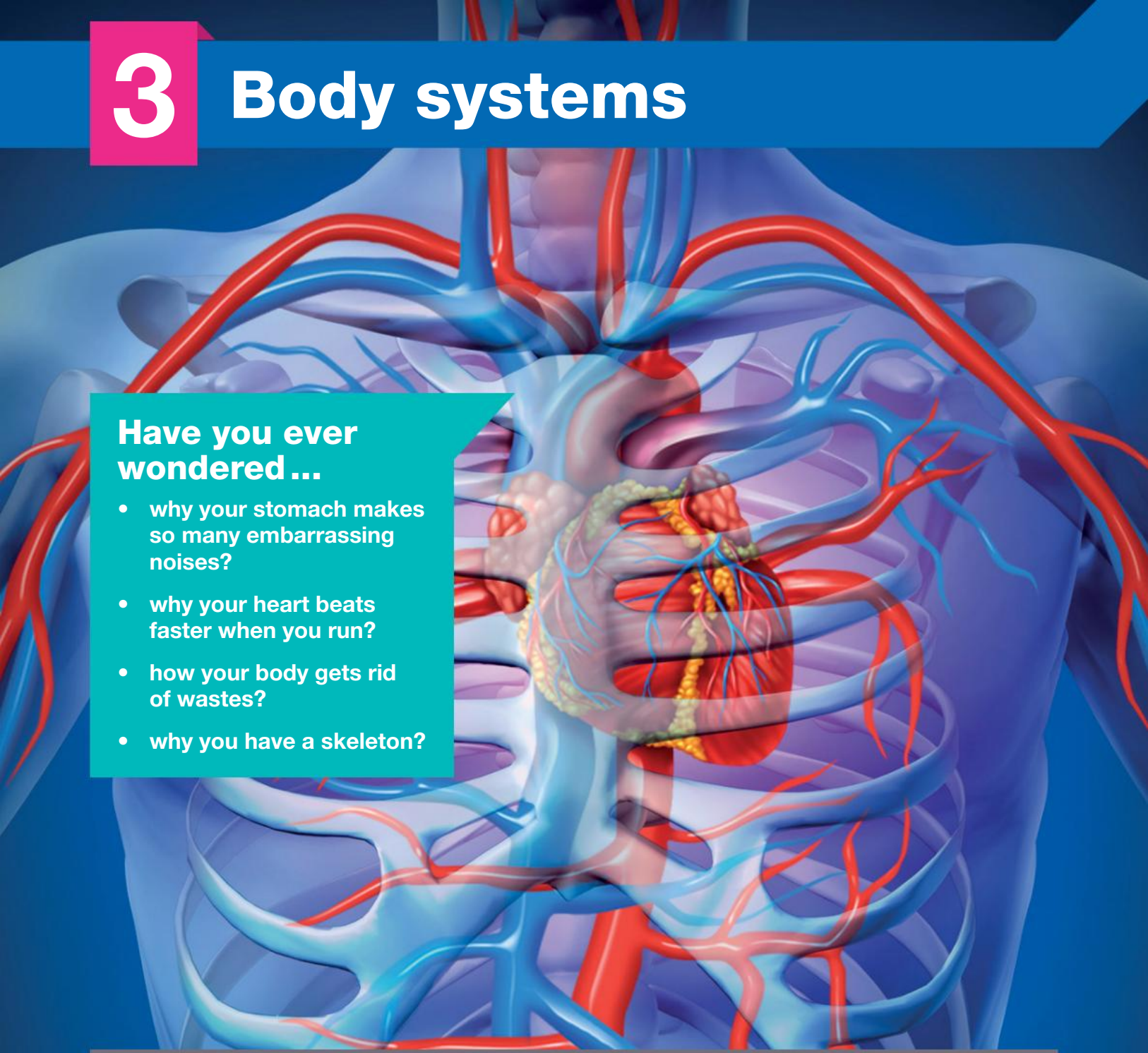
Tissue: groups of cells that perform the same function in the body

Xylem: cells in a plant that carry water from the roots to the rest of the plant



Organ system

3 Body systems



Have you ever wondered...

- why your stomach makes so many embarrassing noises?
- why your heart beats faster when you run?
- how your body gets rid of wastes?
- why you have a skeleton?

After completing this chapter students should be able to:

- describe the role of the human digestive, circulatory, excretory, skeletal/muscular and respiratory systems L
- explain how systems work together to provide cells with gases, nutrients and water, and to remove cell wastes L
- identify the materials required for respiration
- outline how respiration provides energy for cells
- research how changes in scientific knowledge have contributed to finding a solution to a human health issue CCT EU
- recall how scientific discovery has contributed to solving a real-world problem L PSC
- describe how technology has led to organ transplants, artificial joints/limbs and treatments for asthma, kidney and heart disease ICT L
- describe how people can hold different ideas about the application of a solution to a contemporary issue CCT DD PSC L

ADDITIONAL

- propose reasons why society should support biological research. CCT PSC L

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

Humans are multicellular organisms. Our bodies are made up of millions 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 wastes.
- The skeletal system supports the body and enables it to move.

Figure 3.1.1 The millions of cells that make up the jockey and the horse are organised into tissues. Tissues are organised 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 roll 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 roll looks good and probably tastes good, but it has to be digested before you can use the nutrients it contains.

INQUIRY science 4 fun

Where's the sugar?

Is there sugar in bread?

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 taste.
Explain why you think this happened.

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 to assist with digestion.

The human digestive system is shown in Figure 3.1.3.

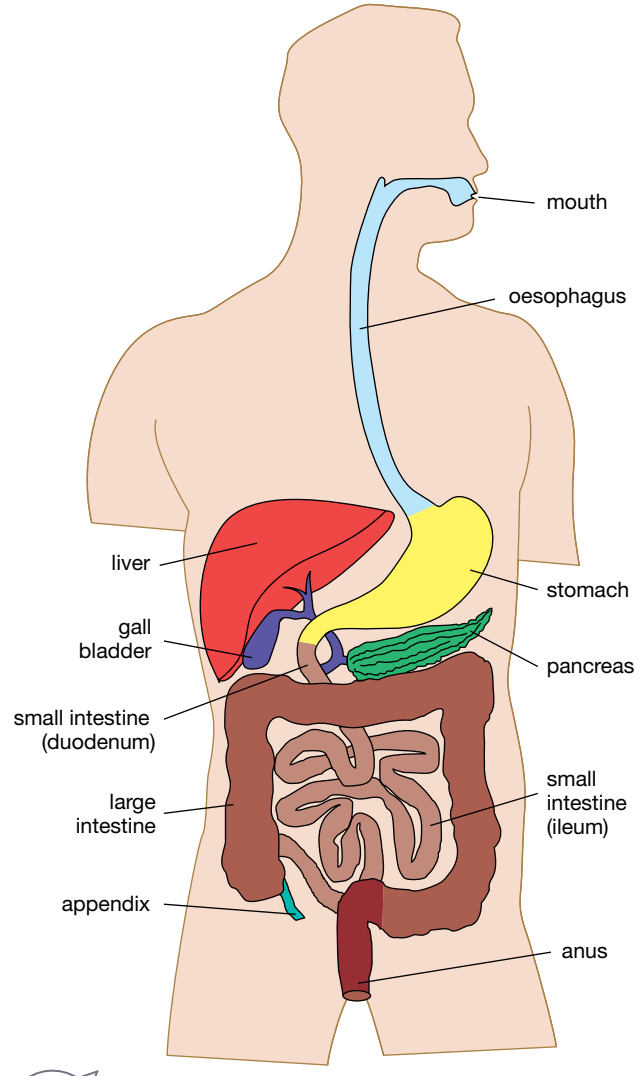


Figure 3.1.3 The human digestive system

3.1

Types of digestion

There are two different types of digestion:

- mechanical digestion
- chemical digestion.

Mechanical digestion is when the food is broken down into smaller pieces, as shown in Figure 3.1.4 on page 86.
It is like cutting a slice of bread or a piece of meat into smaller pieces. Mechanical digestion is a physical change because no new substances are made.

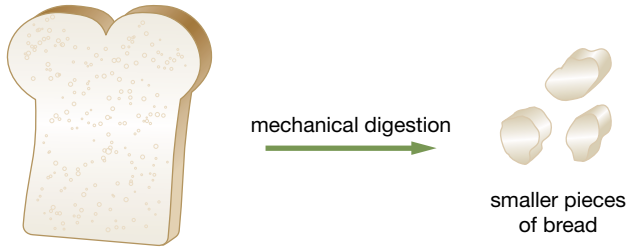


Figure 3.1.4 Mechanical digestion happens when you tear and chew food with your teeth.

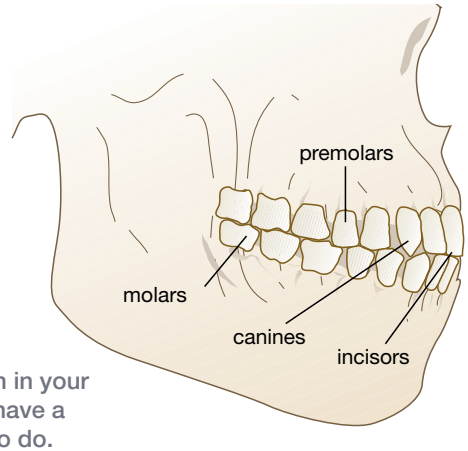


Figure 3.1.6 The different types of teeth in your mouth each have a specific job to do.

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.

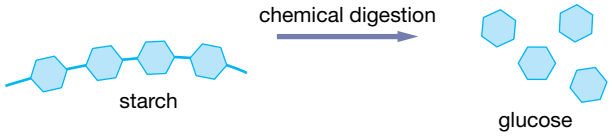


Figure 3.1.5 Chemical digestion happens when saliva in your mouth and gastric juice in your stomach break down your food.

3.2

In the mouth

The process of digestion starts with your teeth. As Figure 3.1.6 shows, you have four types of teeth:

- incisors
- canines
- premolars
- molars.

The incisors are the four pairs of teeth at the front. 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.

In humans, the canine teeth have no 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.

Tongue tied

Your tongue is a muscle that is unique. All your other muscles (such as your biceps and pectorals) attach to bone at both ends, whereas your tongue only attaches at one end.

SciFile

Swallowing

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.

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. A second sphincter separates the stomach from the small intestine. You can see it in Figure 3.1.8.

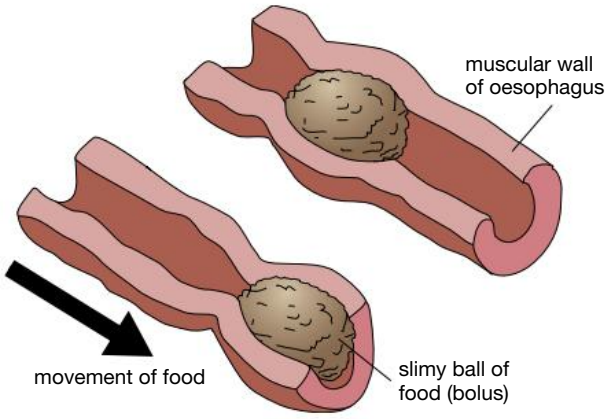


Figure 3.1.7 Peristalsis is the rhythmic contracting and relaxing of the muscles of the oesophagus that keeps food moving through the oesophagus and other parts of the digestive system.

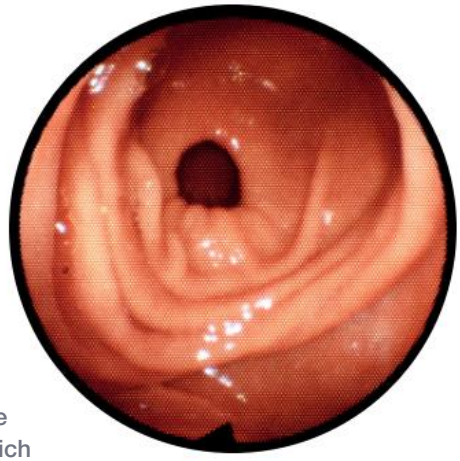


Figure 3.1.8 A sphincter is a ring-like muscle. Sphincters are located throughout the digestive tract. This photo shows the pyloric sphincter, which controls the release of digested food from your stomach into your small intestine.

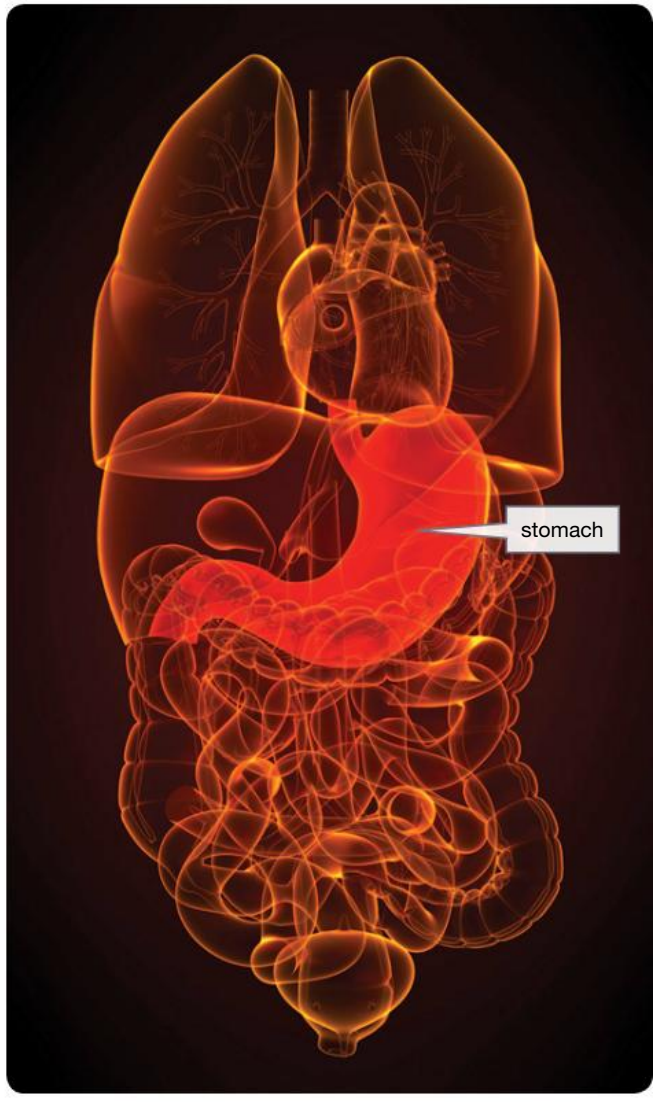


Figure 3.1.9 In the stomach, food is digested both mechanically and chemically. The food is turned into a thick, acidic soup.

Stomach

The stomach is shaped like a bag. It is the big red shape in the middle of Figure 3.1.9. 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—contain chemicals that start the digestion of protein, the main nutrient found in meat.

Small intestine

The **small intestine** 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.

The **duodenum** is the first part of the 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 and 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—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 mechanical digestion of fats. It acts in a similar way to dishwashing detergent. In 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 food to be broken down into tiny pieces so that they can be digested more easily. Figure 3.1.10 shows the liver and adjacent organs.

Prac 1 p92

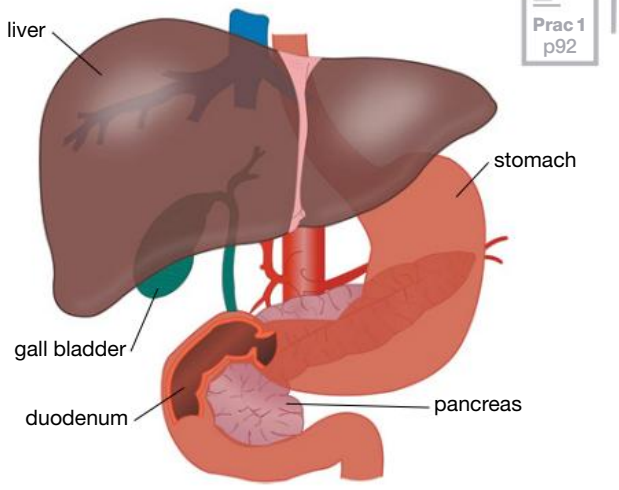


Figure 3.1.10 Blood carrying nutrients from the digestive system travels to the liver before it goes anywhere else. The liver removes toxins such as alcohol from the blood and also acts as a short-term store for glucose. Glucose is a simple sugar produced by the digestion of carbohydrates.

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 food. The digestive chemicals change the remaining foods into forms that can be used by the body. When the food passes into the lower part of the small intestine (known as the **ileum**), it is in the form of very tiny particles that can be absorbed by (taken into) the body.

It is in the ileum that the digested food is absorbed into the body. On the inner lining of the ileum 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 only travel a very tiny distance as they move from the digestive system into the blood system—this distance is about one-hundredth of the diameter of a full stop! Figure 3.1.11 shows the detailed structure of villi.

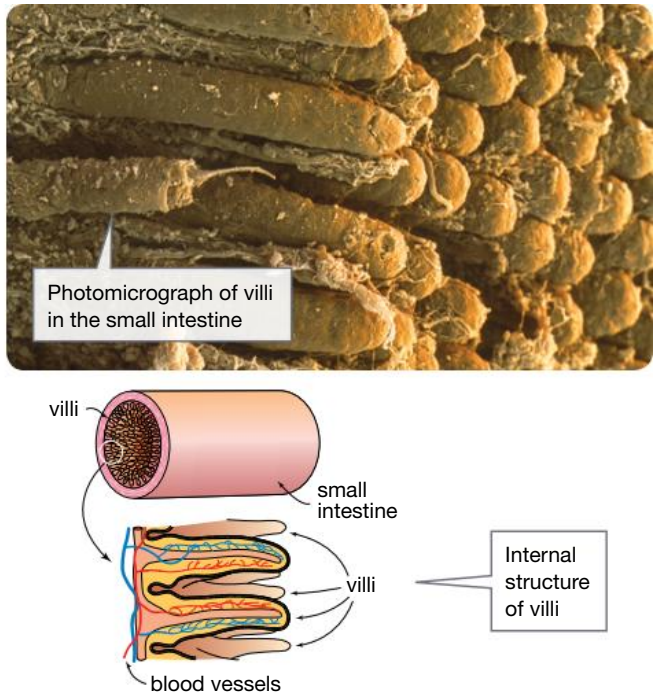


Figure 3.1.11 Villi greatly increase the surface area through which nutrients can be absorbed from the small intestine.

3.3

The nutrients that pass from the small intestine are:

- fatty acids and glycerol produced from the 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 3.1.12 summarises the major changes that occur in the digestive system.

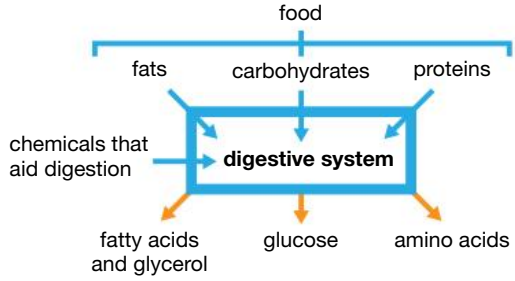


Figure 3.1.12 Many different things happen to food in the digestive system.

Prac 2 p93

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 to 7 cm in diameter. The large intestine is shown in red in Figure 3.1.13. 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**. The anus is a sphincter muscle at the end of the digestive tract. As Figure 3.1.14 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 3.1.13 The large intestine is the part of the digestive system where wastes from the food you eat are processed into faeces.

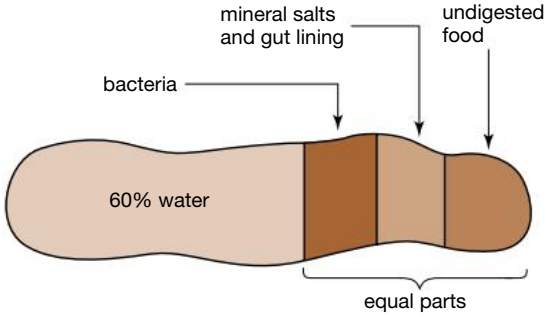


Figure 3.1.14 A large percentage of faeces is water. If the proportion of water decreases too much, then stools become dry, very firm and difficult to expel from the body.

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 can cause the lining of the small intestine to become inflamed so that it can no longer absorb water from the faeces. The faeces are loose, putting the body at risk of dehydration. 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 the 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, creating the sensation of heartburn. Lying down or bending over can also 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 ruptures (bursts) and causes even more severe infection.

The appendix

SciFile

It was once thought that the appendix had no function in humans. However, it is now 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 your body fight disease.

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

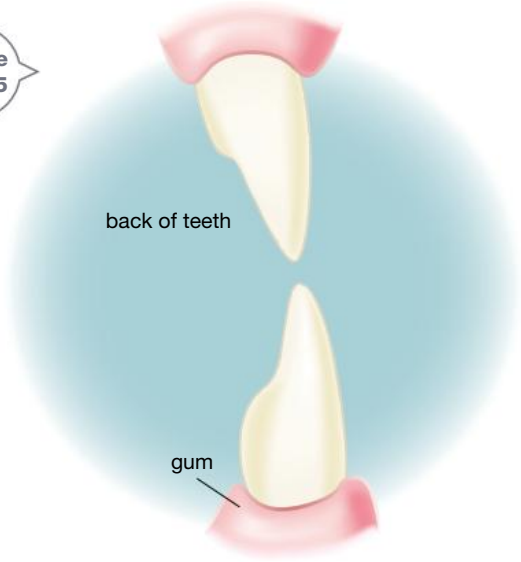
b small intestine

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 shows the shape of the incisor teeth.

Figure 3.1.15

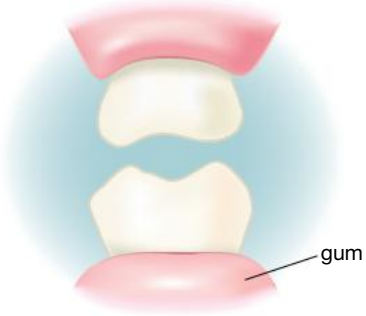


a **Describe** the shape of the teeth.

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

11 a **Identify** the part of the digestive system shown in Figure 3.1.17.

b **Use** the diagram to **demonstrate** how these structures increase surface area.

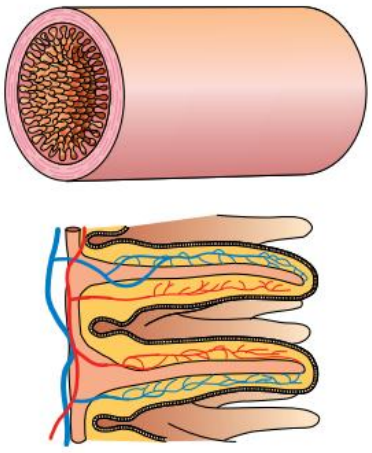


Figure 3.1.17

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.

14 **Compare** the duodenum and the ileum by listing their similarities and differences

Evaluating CCT

15 A dry biscuit or a piece of bread doesn't taste sweet when you start chewing, but after a while it does.

Propose reasons why.

16 **Propose** what would happen if the length of the small intestine was halved.

17 Figure 3.1.18 shows the digestive system of a snake.

- a **Use** the human digestive system as a model to **propose** the names of the parts labelled A, B and C.
- b **Justify** your answer.

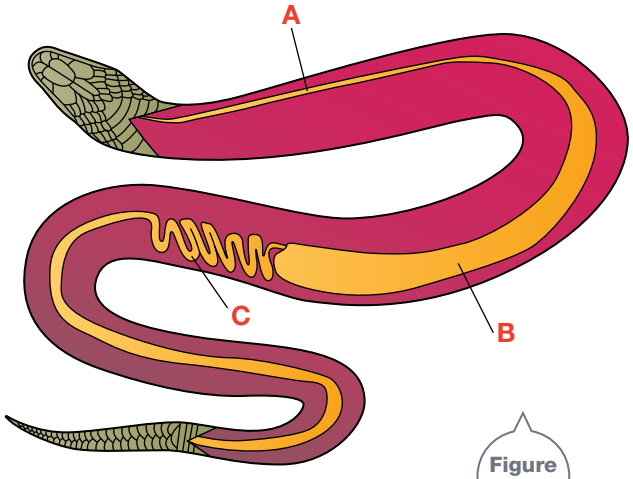


Figure 3.1.18

Creating CCT

18 a **Construct** a diagram of the digestive system.

b **Label** the parts and **identify** the function of each part.

19 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.

20 Digestive enzymes can be purchased for use in experiments. **Design** a prac investigation 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.

Present your findings as a pamphlet.

2 Research body mass index (BMI). Find:

- how BMI is calculated
- the spread of BMI numbers that represent underweight, healthy weight, overweight and obese
- how doctors, nutritionists and gym instructors use BMI
- why age and gender need to be considered when calculating BMI
- why some professional sportspeople have BMIs that place them in the overweight or obese categories
- concerns about the use of BMI as an indication of weight problems.

Present your findings as a pamphlet to be placed in a doctor's waiting room or at the gym.

3 Before modern technology, scientists had great difficulty finding out what happened inside the body. Alexis St Martin contributed a great deal to knowledge of the human digestive system. Find out how he was able to contribute so much.

Present your research as a report for a science magazine aimed at young teenagers.

4 Investigate the structure of teeth and why problems develop if plaque is allowed to build up on them.

Present your findings as a poster to be displayed in a dentist's waiting room.

3.1 Practical investigations

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
- 600 mL warm water at about 38°C

SAFETY
Wash your hands thoroughly after the activity.

- 10 mL measuring cylinder
- 200 mL measuring cylinder
- 4 stirrers
- 4 labels

Procedure

1. In your workbook, draw up a table like the one in the Results section.
2. Label the beakers 'Fat', 'Fat and detergent', 'Oil' and 'Oil and detergent'.
3. Cut the block of animal fat in half and add one piece to each of the beakers labelled 'Fat' and 'Fat and detergent'.
4. Using the 10 mL measuring cylinder, add 5 mL of oil to each of the beakers labelled 'Oil' and 'Oil and detergent'.
5. 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'.
6. Using the 200 mL measuring cylinder, add 150 mL of warm water to all four beakers.
7. Using a clean stirrer for each beaker, stir the contents gently to mix them together.
8. Stop stirring and after 3 minutes observe any changes in the beakers.

Results

Record all observations in your table.

Beaker contents	Observations after 3 minutes
Oil	
Oil and detergent	
Fat	
Fat and detergent	

Practical review

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.

Hypothesis

What do you think will happen in each of the beakers in Figure 3.1.19—do you expect the starch or the glucose to move out of the dialysis tubes into the surrounding water? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

SAFETY
Iodine stains. Avoid contact with skin and clothes.

- starch solution
- glucose solution
- 10 mL iodine solution
- water

- 2 × 500 mL beakers
- 2 × 20 cm lengths of dialysis tubing
- 2 × 10 cm lengths of thin string
- Tes-Tape

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 3.1.19.

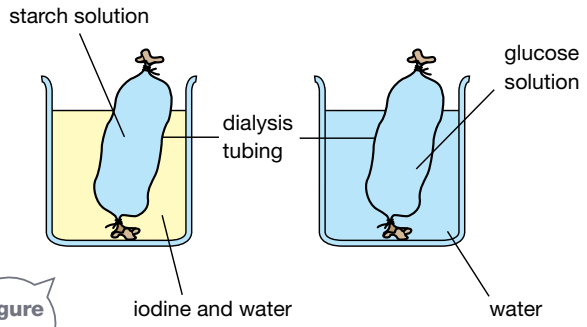


Figure 3.1.19

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'.

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.

Practical review

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. a **Describe** the changes that took place in the beaker labelled 'Starch'.
   b **Infer** what happened to cause the changes.
4. a **Describe** the changes that took place in the beaker labelled 'Glucose'.
   b **Deduce** 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.
7. a **Construct** a conclusion for your investigation.
   b **Assess** whether or not your hypothesis was supported.

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. The lungs and trachea, parts of the respiratory system, are shown here in red.

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.

3.4

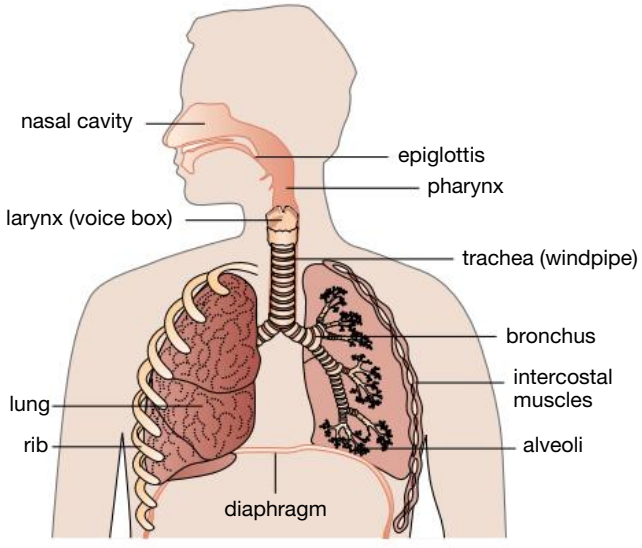


Figure 3.2.1 Structure of the human respiratory system

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. You can see some of these in Figure 3.2.2.

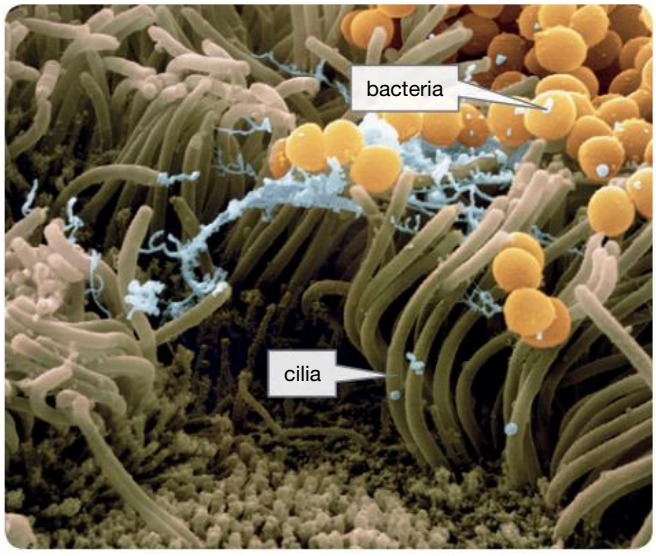


Figure 3.2.2 Cilia are fine hairs that line your nostrils. Together with mucus they trap dust, preventing it from going into your lungs. They also trap some bacteria, like these *Staphylococcus aureus* bacteria.

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.

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 3.2.3. 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** (singular: alveolus) in the lungs.

Alveoli are microscopic in size and about 600 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 3.2.4 shows the alveoli in a section of a lung. Figure 3.2.5 on page 96 shows a magnified view of lung tissue.

Figure 3.2.3 Ridges of stiff flexible cartilage can be seen clearly in this photograph of a trachea.

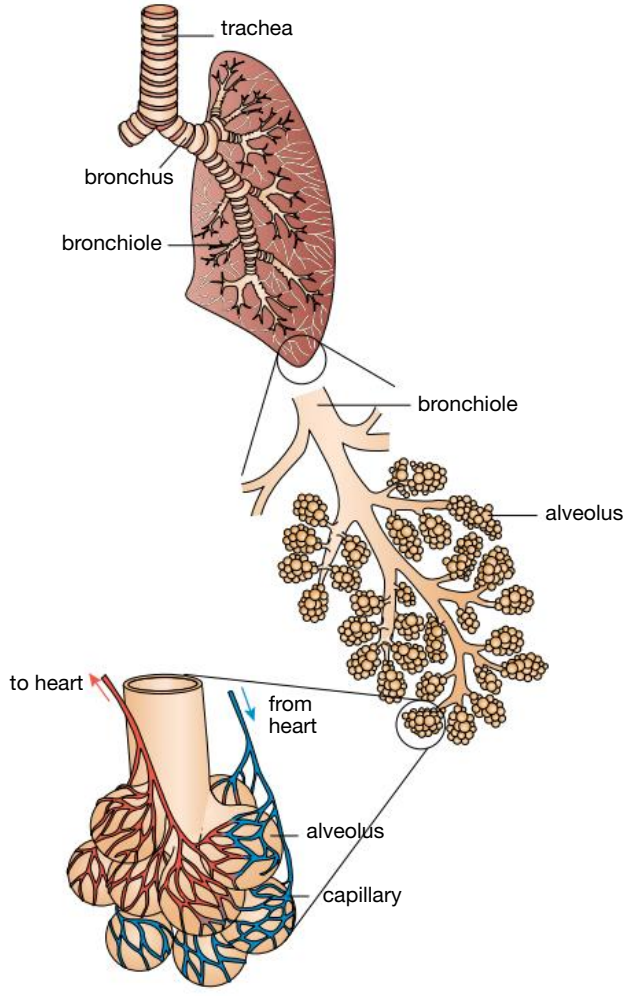


Figure 3.2.4 The air follows a path that starts with the trachea, a tube about the same diameter as a garden hose, and finishes in a microscopic sac called an alveolus.

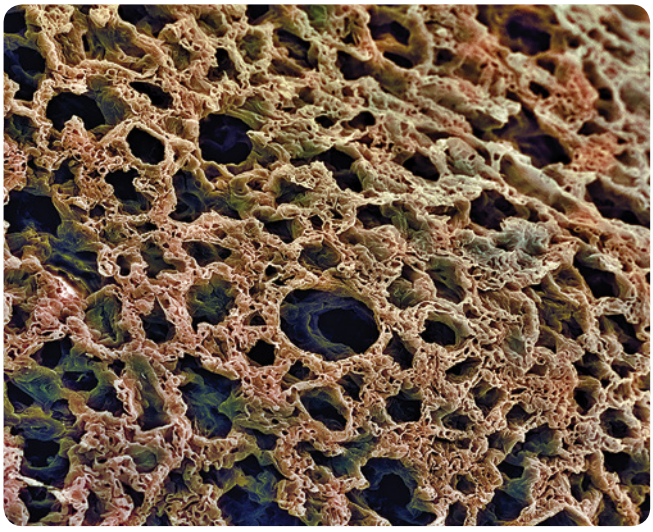


Figure 3.2.5 The alveoli within the lung are closely packed, making the lung like a sponge.

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.

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 3.2.6 illustrates this process.

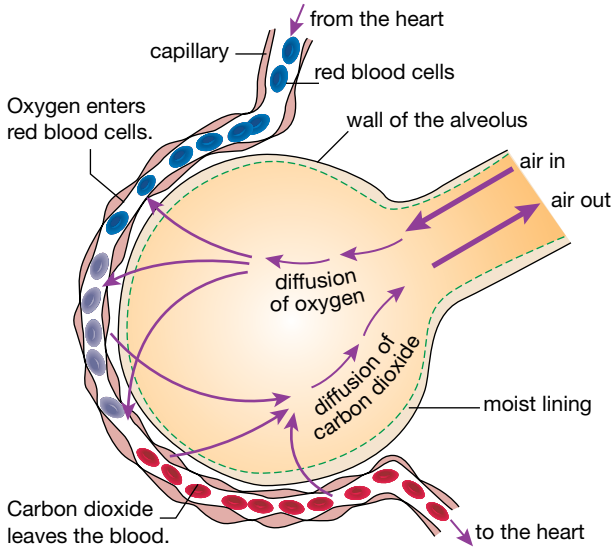


Figure 3.2.6 The walls of alveoli are only one cell thick. So are the walls of blood capillaries. Gases are exchanged where the surface of the alveolus and the blood capillary are in contact.

INQUIRY

science 4 fun

How big?

YES

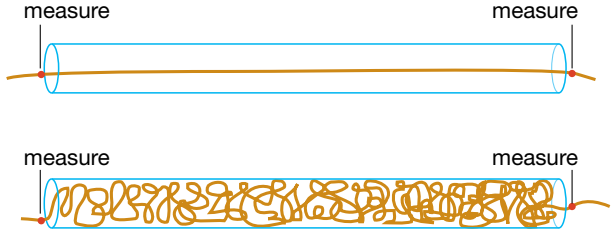
The lungs have a large surface area, but what does that mean?

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 why the twisted piece of string has the larger surface area.

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 alveoli, where it mixes with the remaining air. It then leaves the body with your 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 3.2.7.

Table 3.2.1 The composition of air when 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

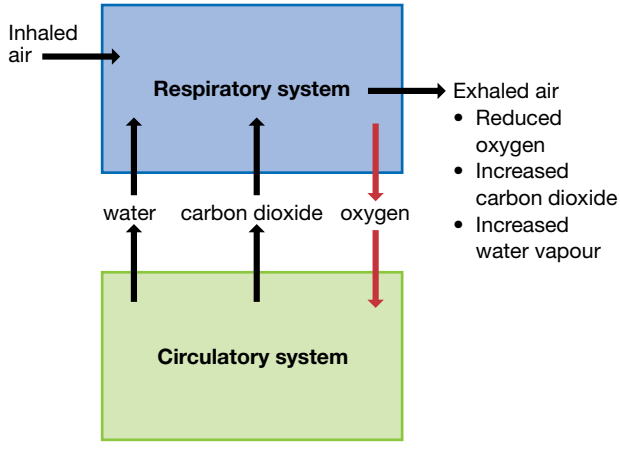


Figure 3.2.7 Summary of what happens in the respiratory system

Prac 1 p101

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 3.2.8.

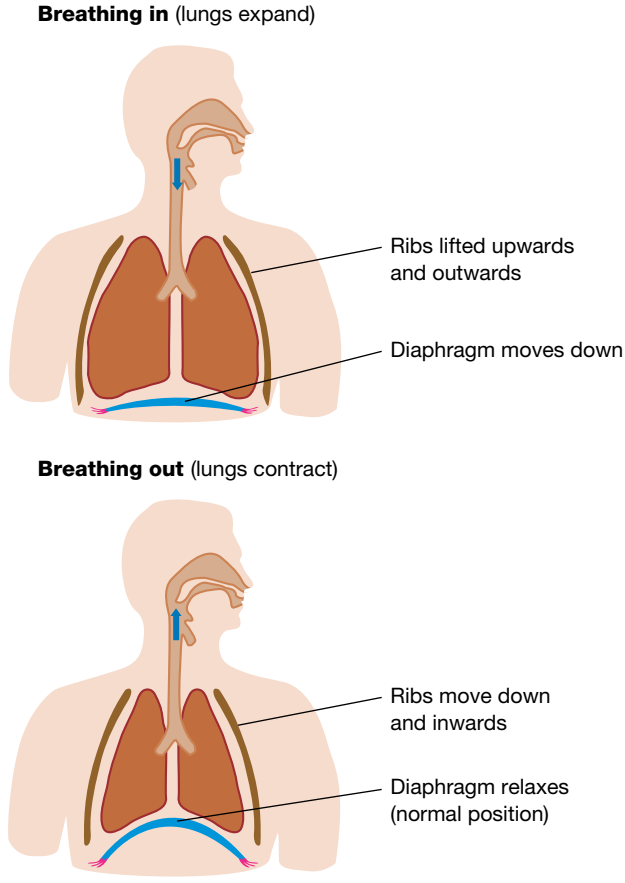


Figure 3.2.8 When you breathe in, your diaphragm flattens and your lungs expand. When you breathe out, the opposite happens.

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.

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. This forces air out of the lungs, to exit through the nose and mouth.

In the cells

Respiration begins once the oxygen and glucose are together in the cells, where 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 3.2.9).

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.

Prac 2 p102

Word equations

A word equation is one way of recording what happens when chemicals react together. On one side are the chemicals that react together. These are known as the reactants.

On the other side are the chemicals that are produced. These are known as the products.

Between the reactants and products is an arrow indicating the direction of the change. The chemicals to which the arrow is pointing are the products. For example in the equation:

reactants → products

A + B → C + D

A and B are the reactants and C and D are the products.

WORKED EXAMPLE

Word equations

Identify the reactants and products in the word equation for respiration:

oxygen + glucose → carbon dioxide + water + energy

Solution

Reactants are substances on the left side of the arrow. Products are on the right.

Reactants = oxygen, glucose.

Products = carbon dioxide, water. (Energy is not a product, because it is not a chemical.)

Practice

Identify the reactants and products in the following word equations.

a iron + oxygen → iron oxide

b lead nitrate + sodium chloride → lead chloride + sodium nitrate

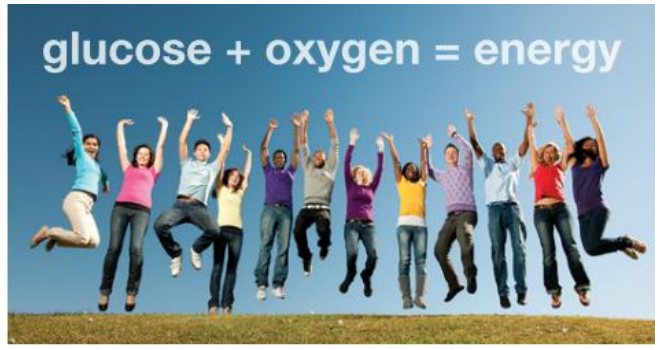


Figure 3.2.9 Glucose and oxygen are both required to provide the energy your body needs.

Energy and oxygen

The amount of energy you consume in your food needs to balance the amount of energy you use. 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.

Prac 3 p103

Couch potato!

SciFile

You use about 250 kilojoules every hour you sleep, but use as little as 200 joules every hour you watch TV. This means you use more energy per hour while sleeping than while watching TV!

3.2 Unit review

Remembering

1 **State** the word equation for respiration.

2 **List** in order the parts of the respiratory system that air passes through as it is 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.

10 **Explain** how the science4fun on page 96 relates to the working of the lungs.

Applying

11 The following letters form a word equation.

$$R + S \longrightarrow T + U + V$$

a **Identify** the products in this equation.

b **Identify** the reactants in this equation.

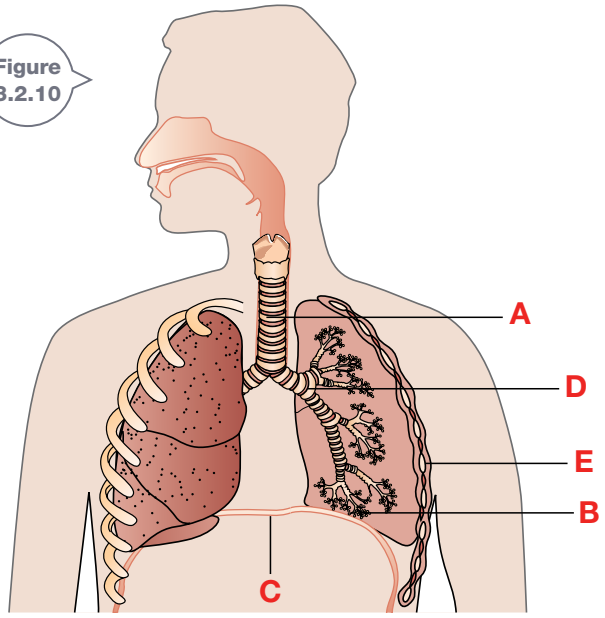
12 a Adult lungs are capable of holding about 6 litres of air. However, only about 500 mL is breathed in and out in a normal breath. **Calculate** the percentage of the lungs that is used for normal breathing. N

b **Use** the table below to **calculate** the volume of oxygen that enters the blood from each inhalation. N

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

13 **Identify** each of the parts labelled A–E in Figure 3.2.10.

Figure 3.2.10



14 Figure 3.2.11 shows a model that is often used to **demonstrate** how the lungs work.

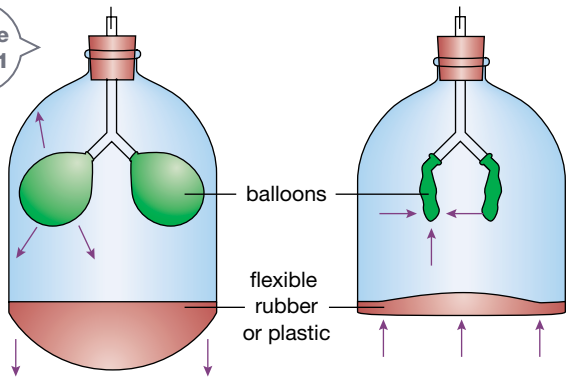
a In this model, **identify** what represents:

i the lungs

ii the diaphragm.

b **Use** this model to **explain** how your diaphragm allows you to breathe.

Figure 3.2.11



3.2 Unit review

Analysing

15 **Contrast** breathing and respiration.

16 Figure 3.2.12 represents the lungs of a frog.

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.

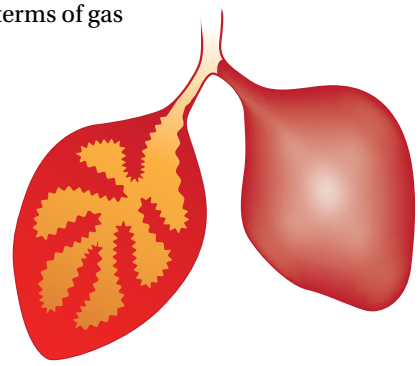


Figure 3.2.12

Evaluating CCT

17 a Limewater is a clear liquid that turns milky when carbon dioxide is bubbled through it. You can see this happening in Figure 3.2.13. **Deduce** what would happen to limewater if:

i air that you were about to breathe in was bubbled through it

ii you blew air into it through a straw.

b **Justify** your answers to part a.

Figure 3.2.13 Limewater turns milky in the presence of carbon dioxide.

18 Propose the advantage for your body of having many blood capillaries surrounding the alveoli.

19 Some lung infections cause a build-up of fluid in the lungs, and the infected person becomes short of breath. **Propose** a reason for this symptom.

20 **Propose** which part of the respiratory system is affected by bronchitis.

Inquiring

1 Research asthma. Find out what:

- happens in the lungs when a person has an asthma attack.
- asthma inhalers such as Ventolin® do.
- causes asthma
- a peak flow meter is and what it does.
- first aid measures should be taken if someone near you has an asthma attack.

Present your research as a poster to be displayed in doctors' waiting rooms.

2 Research to find out what hiccups are and what causes them.

Present your findings as a short piece of writing.

Figure 3.2.14 Inhalers like this one can be used to control asthma.

3.2 Practical investigations

1 Changing air

Bromothymol blue is an indicator that changes from blue to yellow-green in the presence of carbon dioxide.

Purpose

To compare inhaled and exhaled air.

Hypothesis

The two flasks in Figure 3.2.15 contain water and bromothymol blue. What do you think will occur in both flasks when you breathe in and out using the apparatus—do you think they will stay as they are, or will they turn yellow-green? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- few drops bromothymol blue
- disposable straw
- flasks or large test-tubes and glassware as shown in Figure 3.2.15
- 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.

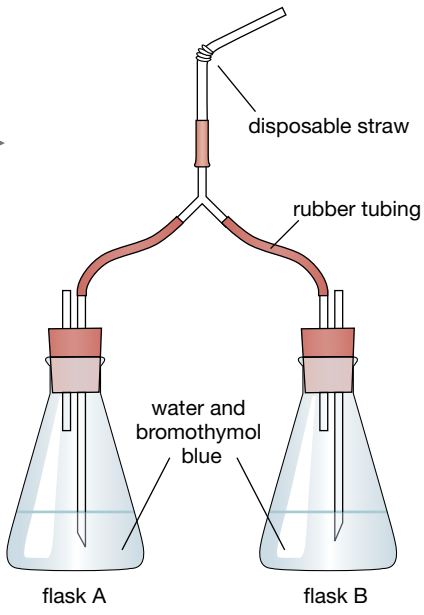


Figure 3.2.15

Procedure

1. Set up the equipment exactly as shown in Figure 3.2.15. 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.

Practical review

1. **Identify** the flask in which any colour change occurred. Was it the flask through which air was inhaled or exhaled?
2. **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.
4. a **Construct** a conclusion for your investigation.
   b **Assess** whether or not your hypothesis was supported.

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.

Hypothesis

In which thermos flask in Figure 3.2.16 do you think most heat will be produced—the one with living seeds or the one with killed seeds? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- 40 germinating pea or bean seeds
- boiling water
- mild disinfectant

- 2 wide-mouthed thermos flasks
- 2 thermometers
- cotton wool
- 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 3.2.16.
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

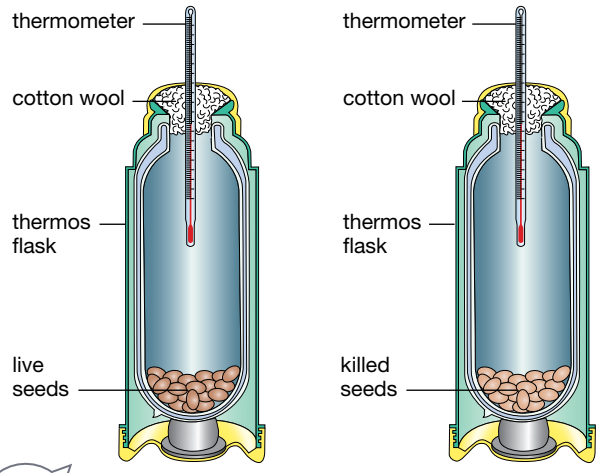


Figure 3.2.16

Practical review

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 in the body.
7. a **Construct** a conclusion for your investigation.
   b **Assess** whether or not your hypothesis was supported.

STUDENT DESIGN

3 Breathing rate

Purpose

To test the effect of exercise on breathing rate.

Hypothesis

What do you think will happen to your breathing rate as you exercise—will it stay the same, increase or level out? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- as selected by students

SAFETY

A risk assessment is required for this investigation.

Do not test students with asthma, as the exercise might trigger an attack.

Procedure

1 Design an experiment that tests the effect of exercise on breathing rate.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you will need, and construct a table in which you intend to record your results.

3 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hints

Choose an exercise that can easily be done for 5 minutes.

Results

Record your results in your table.

Practical review

1 a **Construct** a conclusion for your investigation.

b **Assess** whether your hypothesis was supported or not.

2 **Use** a word equation to help you **explain** why you need more oxygen as you exercise.

3 **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

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. Some of these 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

There are three types of blood vessels in your body:

- arteries
- veins
- 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.

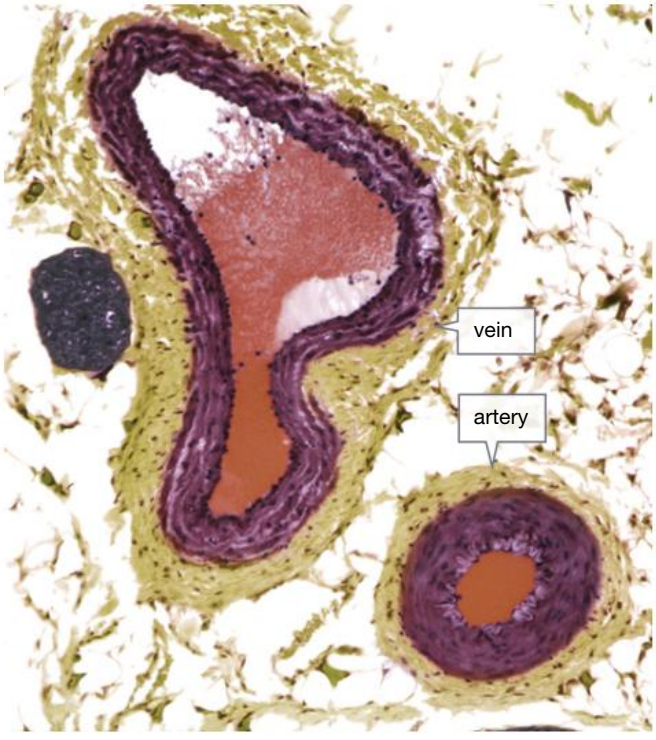


Figure 3.3.2 The walls of arteries have thick layers of muscle and elastic tissue. The thick-walled artery is a sharp contrast to the vein beside it.

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!

SciFile

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 back together to form larger and larger blood vessels called veins. This is shown in Figure 3.3.3.

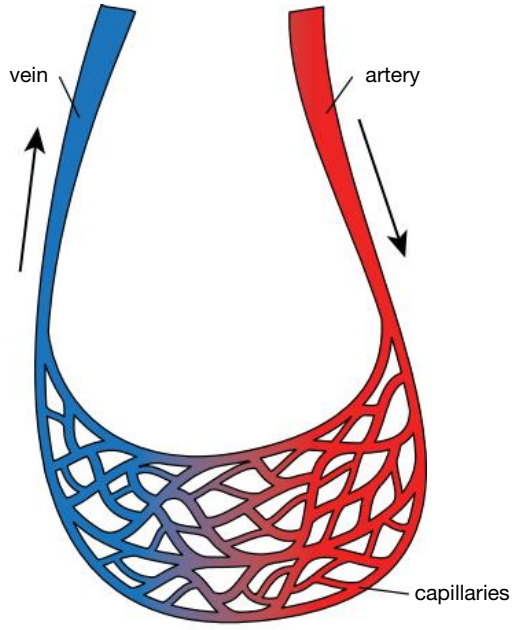


Figure 3.3.3 The capillaries are a network that joins the arteries and veins, allowing blood to flow continuously.

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 towards the heart and close if the blood flows away from it. This is shown in Figure 3.3.4 on page 106. 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.

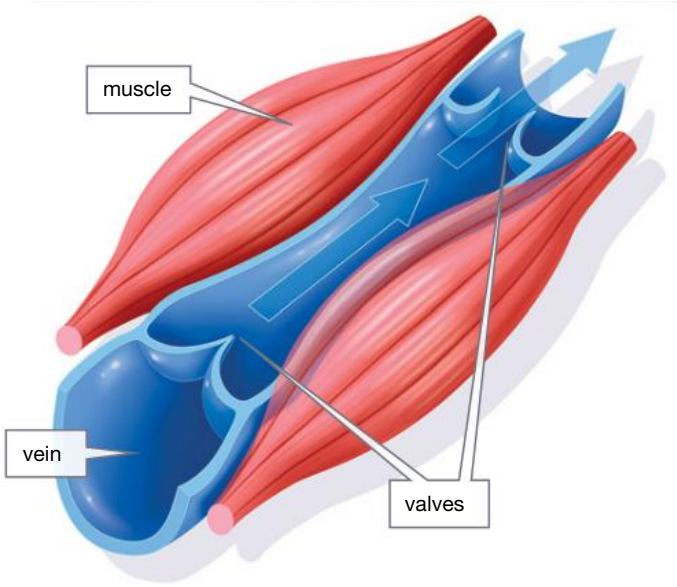


Figure 3.3.4 Blood flowing along the vein towards the heart forces the valves against the vein wall and the blood can flow freely. The valves close preventing blood flow in the opposite direction.

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.

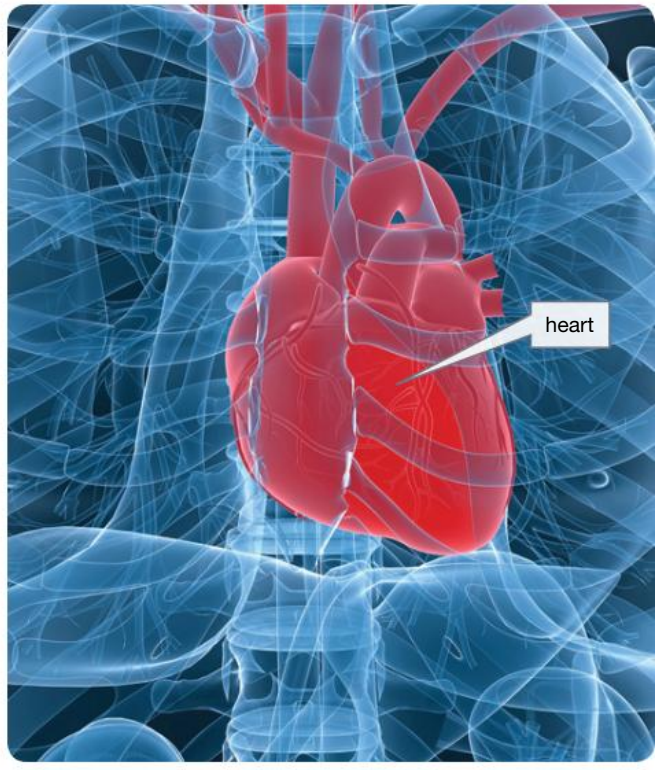


Figure 3.3.5 Your heart lies within your chest protected by your breastbone, ribs and vertebral column (spine).

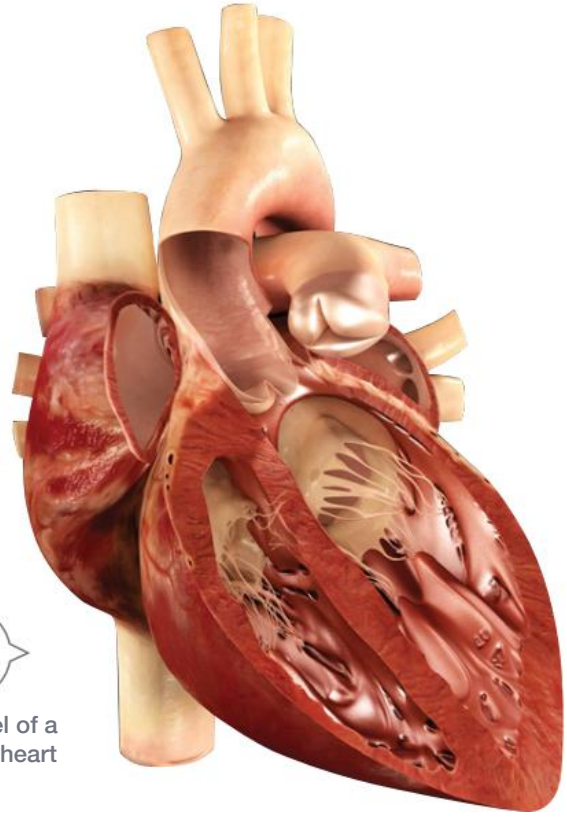


Figure 3.3.6 A model of a human heart

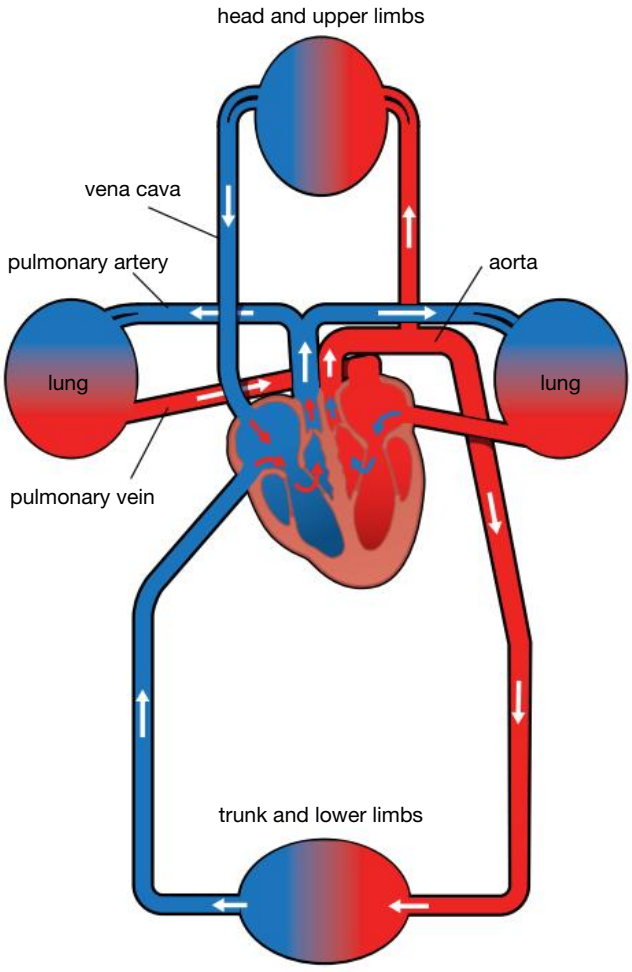


Figure 3.3.7 Your blood follows two separate pathways in your body. One pathway is from the heart to the body and back to the heart. The other pathway is from the heart to the lungs and back to the heart again.

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. As Figure 3.3.8 shows, 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.

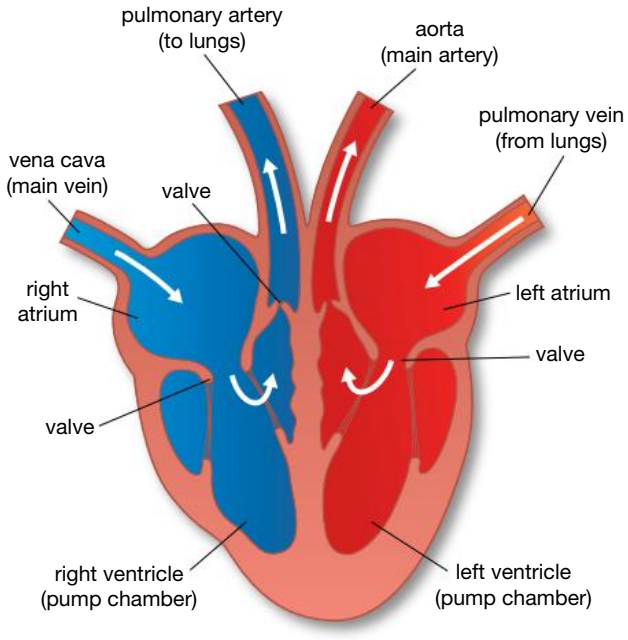


Figure 3.3.8 One side of the heart collects and pumps out deoxygenated blood (shown here in blue). The other side of the heart is completely separate. It collects and pumps out oxygenated blood (red).

3.5

INQUIRY

science 4 fun

No blood

YES

Can you make the blood stop flowing in your veins?

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.

1 The two atria (plural of atrium) contract, pushing blood down into the ventricles.
2 The ventricles contract, forcing blood out of the heart to the body and lungs.
3 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.

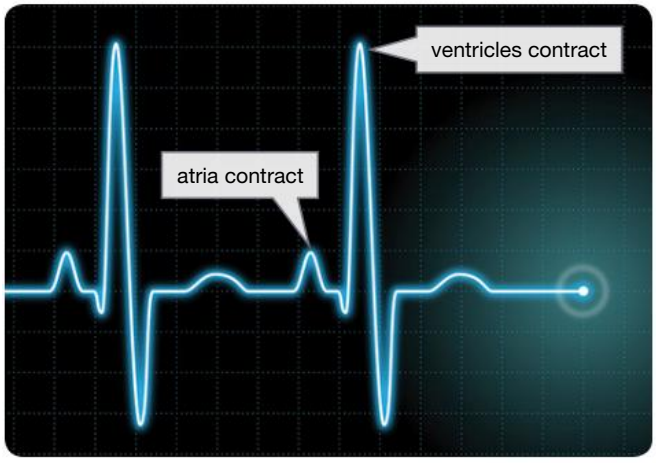


Figure 3.3.9 An electronic recording of a heartbeat. Contraction of the atria creates a small peak followed by a large peak as the strong muscles of the ventricles contract. Between the contractions, the heart is resting.

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Heart disease

Coronary arteries supply the muscles of the heart with blood. The inner wall of healthy arteries is smooth and the blood flows easily. Plaque can build up on the inner walls of arteries, as in Figure 3.3.10. This build-up of plaque narrows the arteries and reduces blood flow to the heart muscles. Blood carries oxygen, so reduced blood flow means the oxygen supply is reduced too. A lack of oxygen to the heart muscle causes a condition called **angina**. A person suffering an angina attack experiences severe chest pain. If the arteries become completely blocked, then the part of the heart that the arteries normally supply with oxygen dies, and the person has a heart attack.

Plaque is made up of various substances that occur naturally in the blood. These substances include calcium, **cholesterol** and fibrin (a material involved in blood clotting). Some scientists believe that damage to the artery wall leads to inflammation. Cholesterol, along with the other substances, moves to the inflamed area to protect it. Research into the causes of the inflammation is continuing.

Other scientists believe that too much animal fat in the diet leads to a build-up of cholesterol in the blood, and that this excess cholesterol is the reason that plaque builds up.

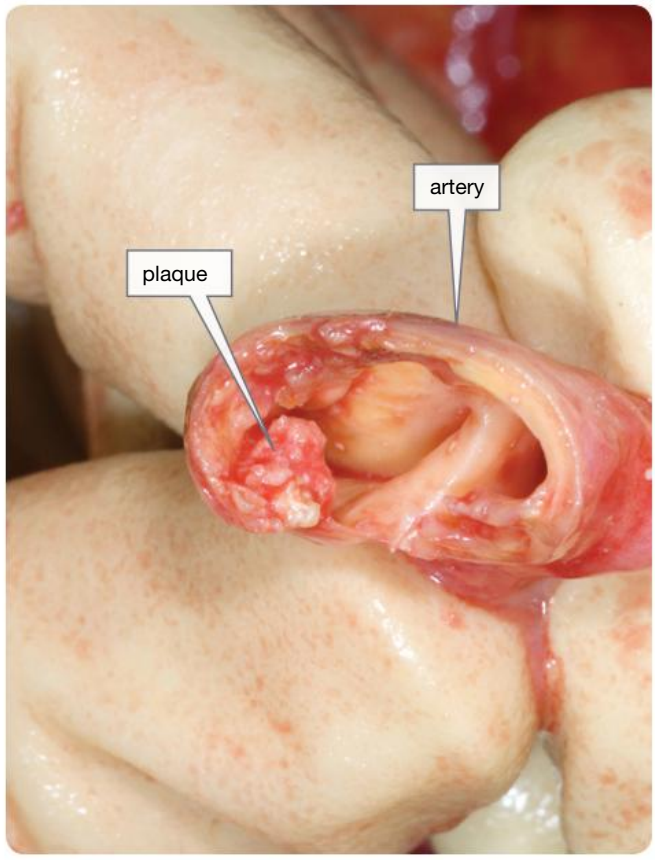


Figure 3.3.10 A surgeon's gloved hands hold an artery partly blocked by plaque.

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.

That's hot!
The human body generates enough heat in one day to boil 30 litres of water—this volume is equivalent to around 3½ buckets!

SciFile

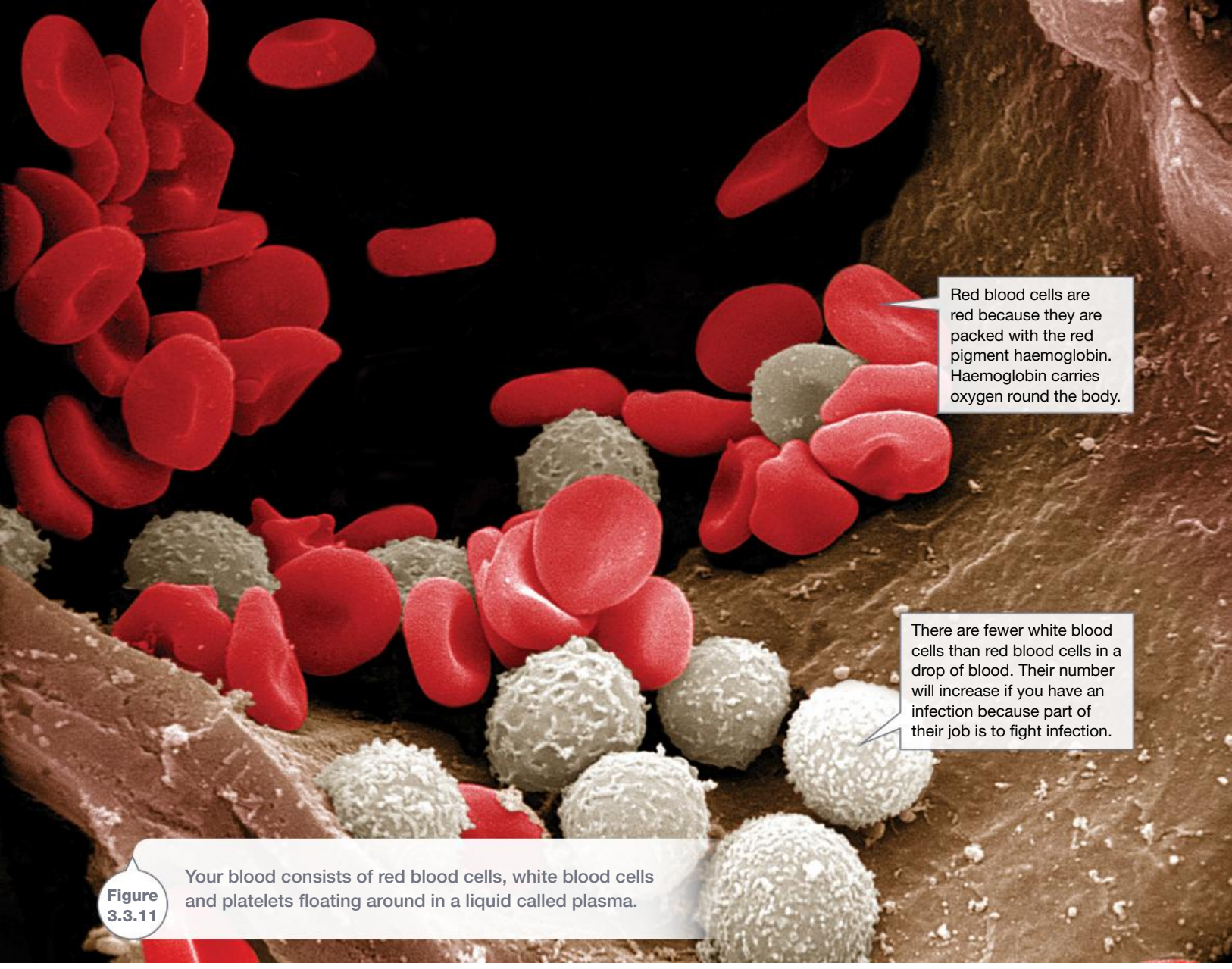


Figure 3.3.11 Your blood consists of red blood cells, white blood cells and platelets floating around in a liquid called plasma.

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 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.

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

Figure 3.3.12 This kidney has been cooled and the blood has been flushed from it to prepare it for transplant.

TRANSPLANTS

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

Some tissues and organs 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 a donor heart is stored correctly, it 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 pharmaceutical drugs to prevent rejection of the new organ by their body.

REVIEW

1. **Identify** the system of the body that causes rejection of transplanted organs.
2. **Identify** the technological development in the 1980s that led to more successful transplant operations.
3. **Explain** how it is possible for bone marrow or a kidney to be donated by a living person.
4. **Explain** why all the blood has to be flushed out of an organ that is to be transplanted.

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 **List** three things carried by the blood.

Understanding

4 **Describe** the characteristics of capillaries that suit them to their function.

5 **Explain** the importance of keeping oxygenated and deoxygenated blood separate in the heart.

6 **Describe** the double circulation system of the human body.

Applying

7 **Identify** the labelled parts of the heart in Figure 3.3.13.

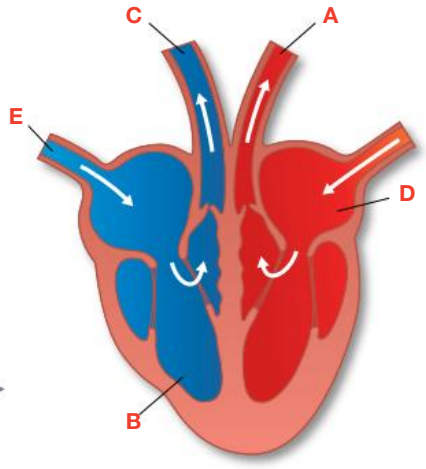


Figure 3.3.13

Analysing

8 a **Calculate** the pulse rate (in beats per minute) for the students listed in the table below. N

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.

9 **Compare** by listing their similarities and differences:

a an atrium with a ventricle

b a heart attack with a stroke

c oxygenated and deoxygenated blood.

Evaluating CCT

10 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.

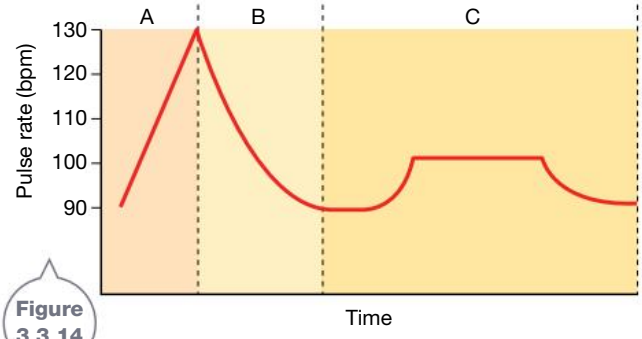


Figure 3.3.14

11 **Propose** what would happen to the blood in a person's leg if the valves in the veins:

a remained open

b were closed for a long period.

12 You can block the flow of blood through a vein in your wrist by putting pressure on it for a short time, like in the science4fun on page 107. **Propose** a reason why this doesn't cause any damage to your hand if done for a short time.

Inquiring

Research heart transplants and heart/lung transplants. Find:

- when the first transplants were performed in the world and in Australia
- how many of each type of transplant are performed each year (on average) in Australia
- the rules that govern which donor hearts and lungs can be used
- the technologies that allowed these transplants to be performed more successfully
- who Doctor Victor Chang was and why he was so important for transplants in Australia.

Present your research in digital form. ICT

3.3 Practical investigations

1 Heart dissection

Purpose

To investigate the structure of the heart.

Materials

- sheep or bullock heart

- scalpel
- tweezers
- blunt probe
- disposable gloves
- dissection board

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.

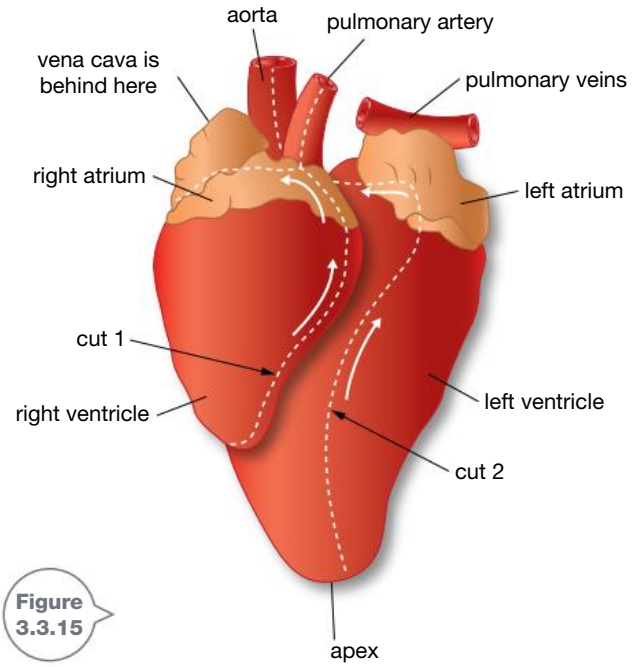


Figure 3.3.15

Practical review

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 valves 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.

N

For example, if you count 18 beats in the span of 15 seconds, then multiply 18 × 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.

3.3 Practical investigations

2 Heart rate and exercise

Purpose

To investigate the effect of exercise on heart rate.

Hypothesis

What do you think happens to your heart rate as you exercise? Before you go any further with this investigation,write a hypothesis in your workbook.

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. Copy the tables in the Results section into your workbook.
2. 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 113.
3. Repeat this step twice more and calculate an average by adding up the results and dividing by 3.
4. Run or jog on the spot for 3 minutes.
5. When you stop, immediately take your pulse rate again.
6. 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

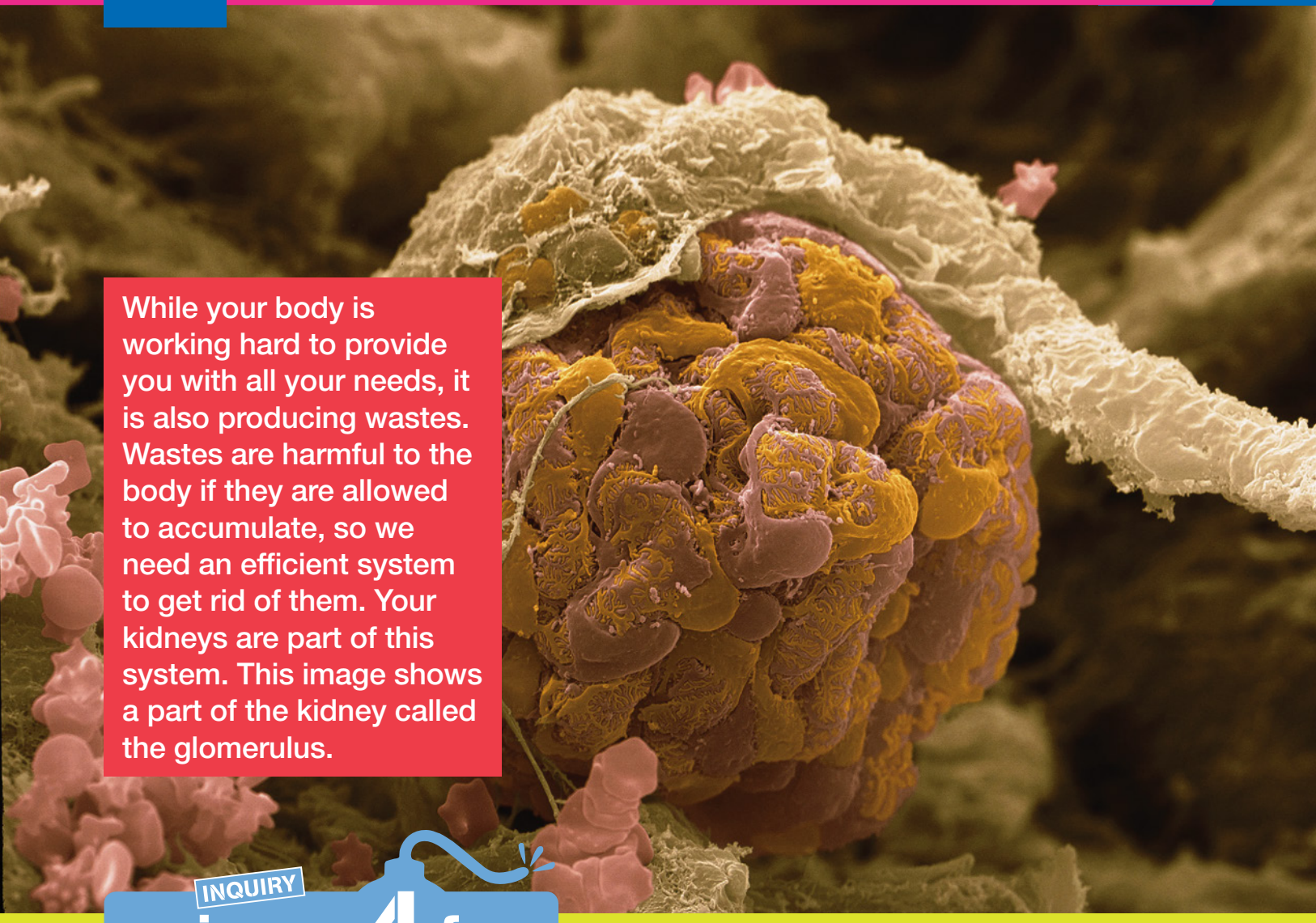
Time after end of jog (min)	Pulse rate (per minute)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

2. Construct a line graph from the results in the second table.

Practical review

1. a **State** what happened to your pulse rate when you started exercising.
   b **Propose** reasons for this change.
2. a **Describe** the change in your pulse rate after you stopped exercising.
   b **Propose** reasons for these changes.
3. a **Compare** your results with those from other members of the class.
   b **Account** for differences in the results.
4. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
5. **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 Waste disposal



While your body is working hard to provide you with all your needs, it is also 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 image shows a part of the kidney called the glomerulus.

INQUIRY

science 4 fun

It smells!

YES

Does what you eat affect the smell of your urine?

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, then 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 core body temperature at approximately 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 (Figure 3.4.1). Sweat also contains a very small amount of urea.

Figure 3.4.1 Your body gets rid of excess heat by sweating.

That's a lot of skin!

The whole of the human skin weighs twice as much as the brain.

SciFile

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 3.4.2 shows the position and relative size of the kidneys.

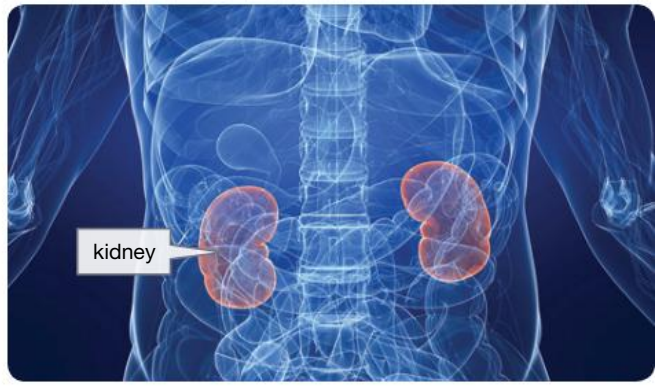


Figure 3.4.2 Although your kidneys are not large, they are very important. About 20% of the blood leaving your heart flows to the kidneys first before continuing its circulation of the body.

The kidneys excrete urea, which is a waste product when proteins are broken down. The kidneys also control the level of water in the body. When your body is well supplied with water, dilute urine is produced.

The urine is clear or pale yellow in colour. If your body has little water, then the kidneys take out only a small amount of water. This produces concentrated urine with a strong gold colour.

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 3.4.3 shows the structure of a kidney.

Urine

Urine is the waste material that has been filtered out of the blood by the kidneys. On average, 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 system is shown in Figure 3.4.4.

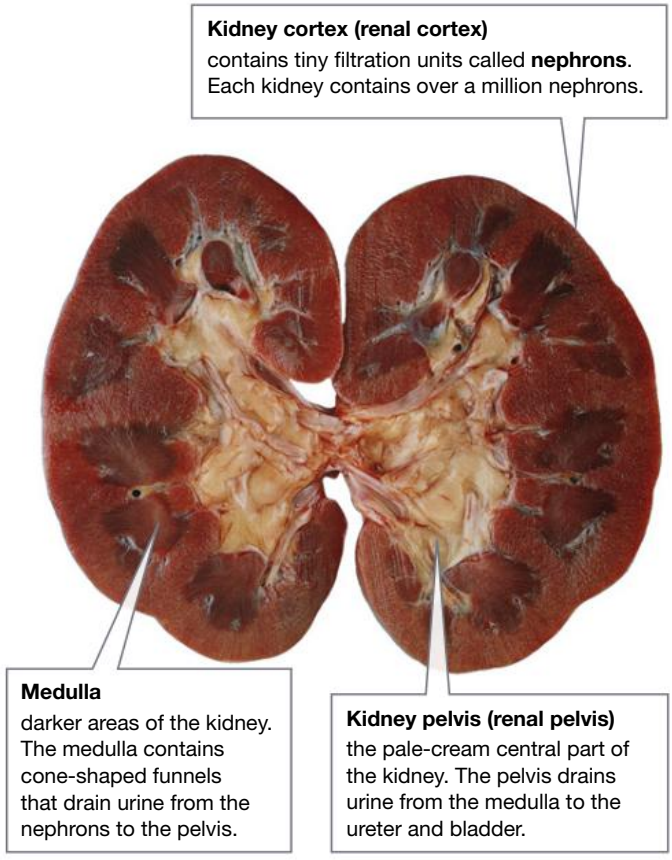


Figure 3.4.3 A dissected kidney. The image used in the introduction to this unit was of a glomerulus. Glomeruli are part of the nephrons in your kidneys.

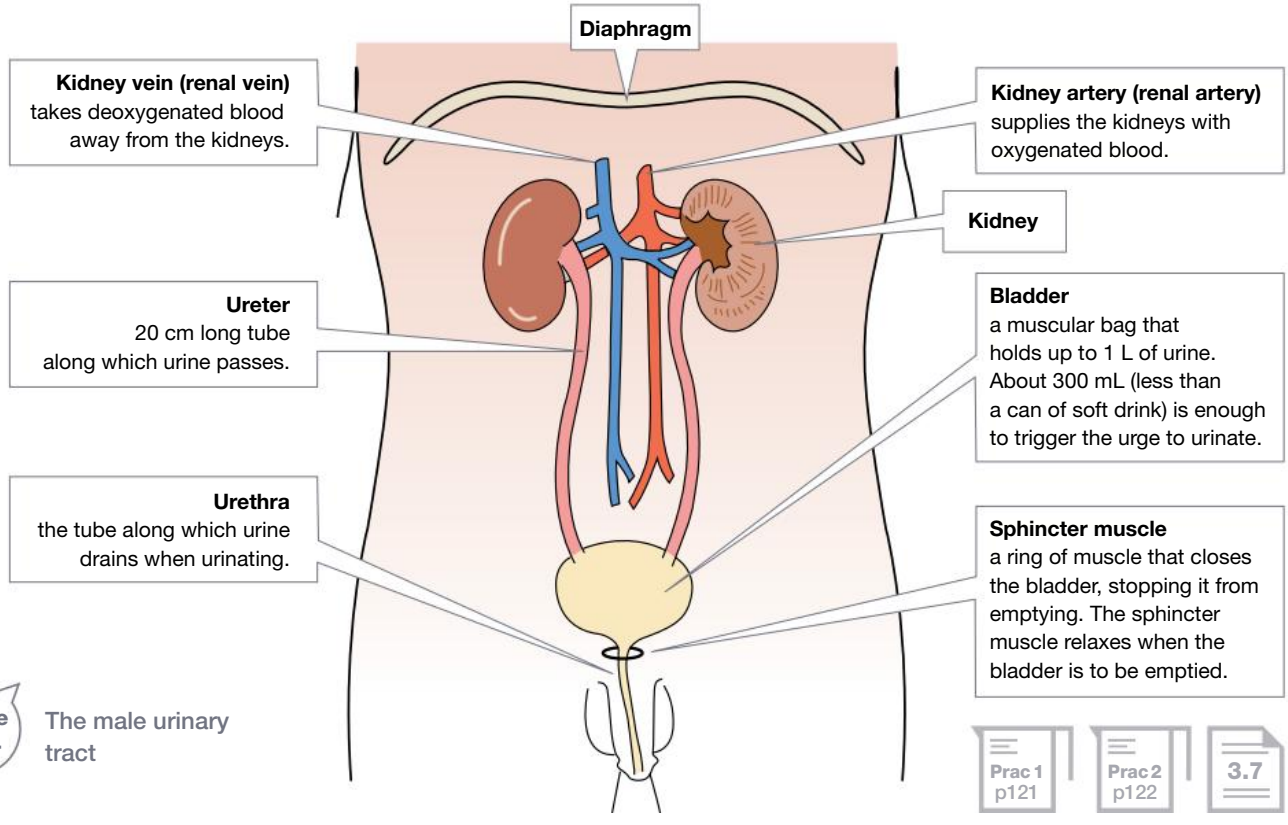


Figure 3.4.4 The male urinary tract

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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 3.4.5) 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.

Figure 3.4.5 The red dots in this X-ray are kidney stones.

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 3.4.6). You should drink enough to produce about 2 litres of urine in every 24-hour period.

Figure 3.4.6 Drinking plenty of water helps to keep the kidneys healthy.

Infections

The structure of the urinary tract prevents any backflow of urine from the bladder, and this reduces 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.

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

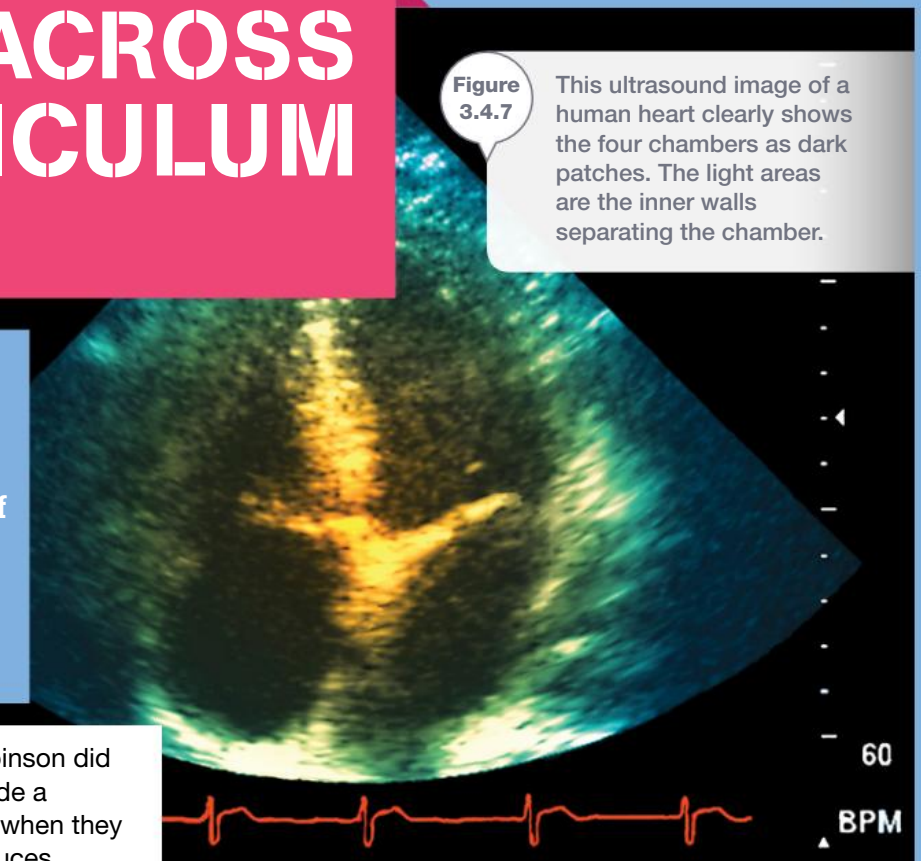


Figure 3.4.7 This ultrasound image of a human heart clearly shows the four chambers as dark patches. The light areas are the inner walls separating the chamber.

ULTRASOUND IMAGING

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 to create ultrasound images is due in part to the work of Australian scientists.

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 (Figure 3.4.8), it was easier to distinguish between liquid and solid tissues and to see the boundary between them.

Figure 3.4.8 A grey-scale ultrasound image of a baby at 12 weeks.

In 1970 Kossoff and Robinson published one of the earliest scientific papers relating to the diagnosis of developmental problems in fetuses, using ultrasound technology.

Grey-scale ultrasound imaging is used to find cancers in various parts of the body. It is also used to observe the direction and speed of blood flow, and to check 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, 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.

REVIEW

1. **Explain** why grey-scale images were a significant advance in ultrasound technology.
2. **Describe** the contributions that Australian scientists have made to ultrasound technology.
3. **List** three uses of ultrasound technology.
4. Continued research has improved ultrasound, ultrasound images and applications. **Propose** reasons why society should support continued research into medical technologies such as ultrasound.

3.4 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: N

- **a** 1 hour
- **b** 1 day.

10 Figure 3.4.9 is a diagram of the excretory system. **Identify** the parts labelled A–D.

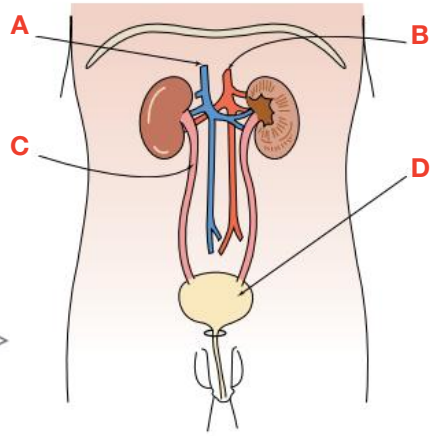


Figure 3.4.9

Analysing

11 The table below shows the composition of blood and urine. **Compare** the data for blood and urine and **identify** the substances that are: N

- **a** more concentrated in the urine
- **b** not excreted by the kidneys.

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

Evaluating CCT

12 **Propose** a reason for glucose not being excreted.

13 **Propose** why drinking water should reduce the chance of developing kidney stones.

14 **Propose** why urine could smell differently depending on what you have had to eat or drink.

Creating CCT

15 **Use** the following ten key terms to **construct** a concept map.

excretion
urea
kidneys
lungs
bladder
excretory system
urine
skin
ureter
urethra

Inquiring

Patients with kidney failure usually need to undergo regular dialysis. Find:

- what dialysis is and what it does
- why the person undergoes dialysis and not a kidney transplant
- how frequently and for how long they need to undergo dialysis per week
- the advantages and disadvantages of dialysis.

Present your findings in digital form. ICT

3.4 Practical investigations

1 Kidney dissection

Purpose

To dissect a kidney and look at its structure.

Materials

- sheep or bullock kidney

- dissecting board
- scalpel
- disposable gloves

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 3.4.10.

3 Identify the parts of the kidney as shown in Figure 3.4.3 on page 117.

Results

Draw a labelled diagram of the cut surface of the kidney.

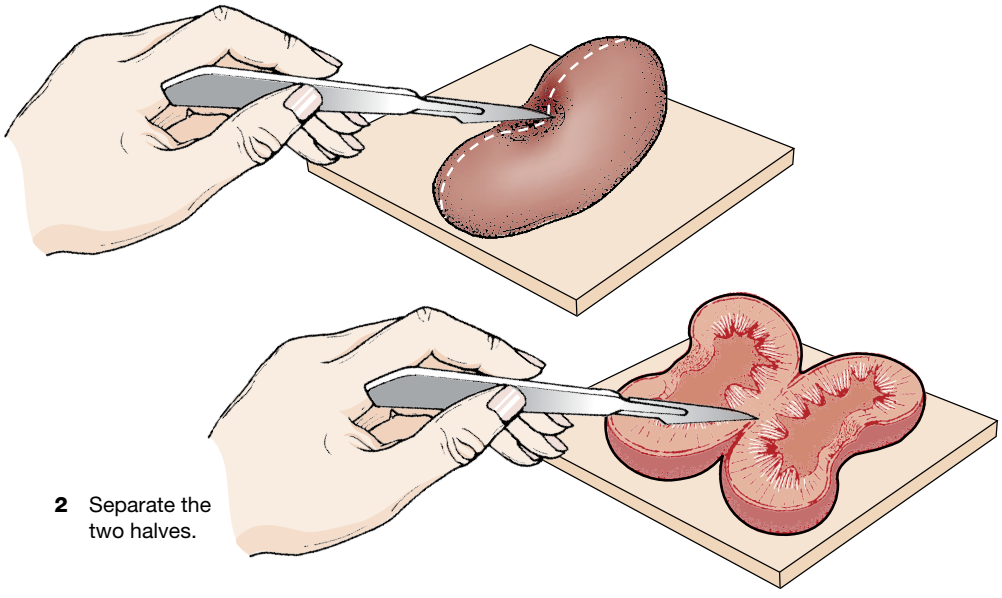
Practical review

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 3.4.3 on page 117. 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 3.4.10

2 Water and wee

Purpose

To gather information about the relationship between drinking and urinating.

Hypothesis

Do you think the amount you drink influences the amount of urine produced each time you urinate or just makes you urinate more frequently? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- liquids that are normally drunk in a day

- notebook and pencil
- graph paper

Procedure

1. Construct a table like the one in the Results section.
2. Use the table 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. Record your results in 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.

Practical review

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. N
2. **Calculate** the total amount of urine you produced in the 24-hour period. N
3. **Compare** the two amounts. Explain the difference.
4. a **Calculate** the length of time between drinking and urinating.
   b **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?
7. a **Construct** a conclusion for your investigation.
   b **Assess** whether or not your hypothesis was supported.

3.5 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—a system of bones known as your skeleton. Attached to this skeleton are your muscles. Together your bones and muscles form your skeletal/muscular system, which allows you to stand upright and to move about. This system also gives you shape and protects important organs such as your heart and brain.

Figure 3.5.1 A jellyfish has no skeleton and needs water to support it.

The skeleton

Your **skeleton** is your body's frame. It is made up of bones. The skeleton has three main functions:

- supporting your soft tissues. Without a skeleton, your skin and the organs inside your body would collapse to resemble a jellyfish stranded on the beach. You can see one in Figure 3.5.1. A jellyfish does not have a skeleton and is supported by the water in which it lives. You live on land and are surrounded by air. Air does not provide the same support as water and so you need a skeleton.

- protecting 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), vertebrae (which protect your spinal cord), and ribs and sternum or breastbone (which protect your lungs and heart).
- allowing movement. This is the main role of your **appendicular skeleton**, which is constructed from 126 bones. It includes your pelvis, shoulder blades and collarbones (clavicles), and the bones in your arms and legs.

Figure 3.5.2 shows your axial skeleton (shaded in yellow) and your appendicular skeleton (shaded in blue). Joints within the skeleton allow your body to move.

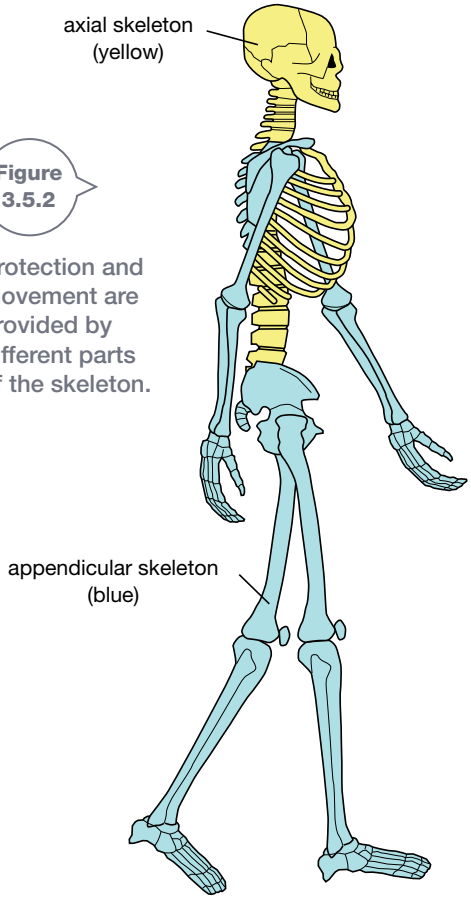


Figure 3.5.2

Protection and movement are provided by different parts of the skeleton.

Bones

The main bones of your body are shown in Figure 3.5.3. 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. The neck is usually under compression too, especially when carrying a load on the head, like the woman in Figure 3.5.4. Your arms experience tension forces whenever you carry shopping bags or when you hang off a bar like the gymnast in Figure 3.5.4.

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.

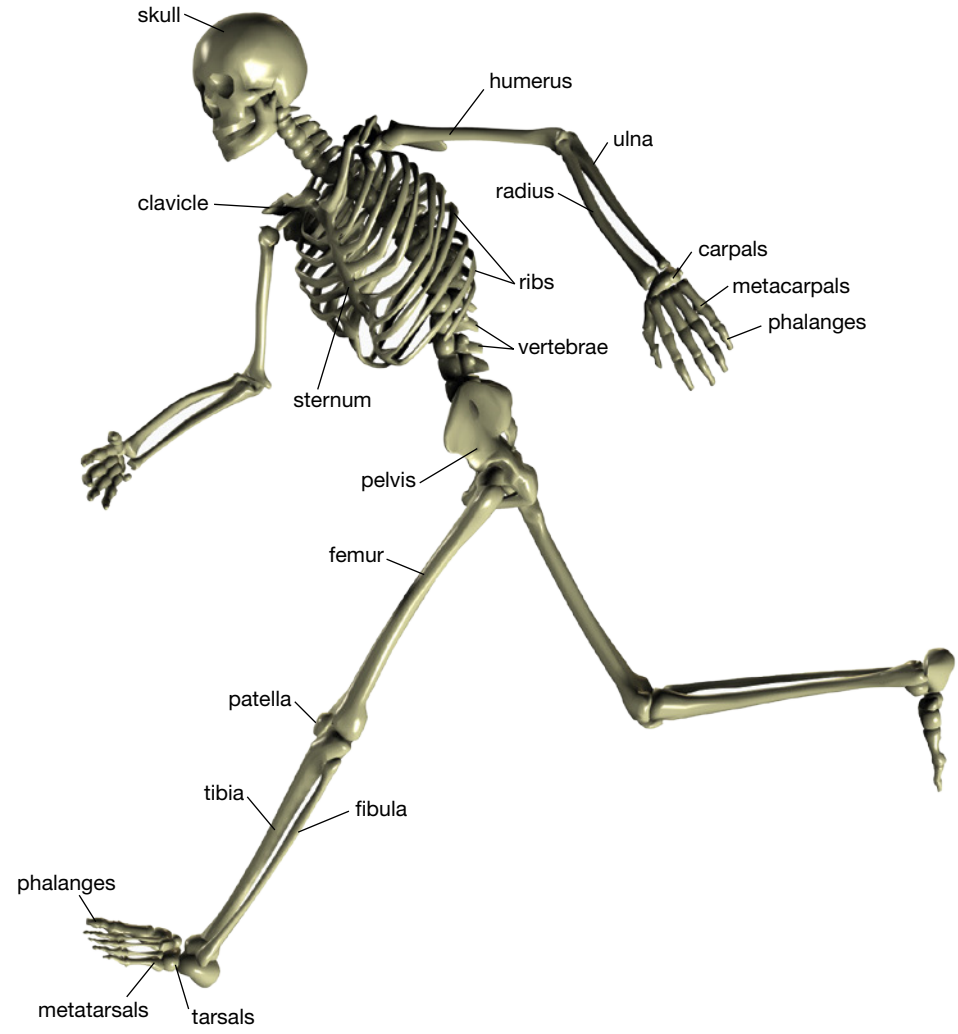


Figure 3.5.3 Your skeleton and its joints allow you to be active, relax and stand upright.

SciFile

Different bones

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.

3.8 3.9

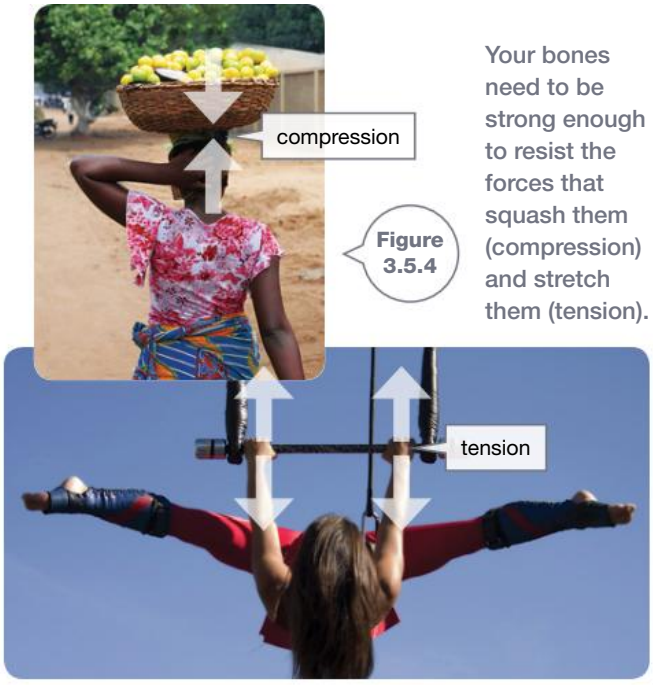


Figure 3.5.4 Your bones need to be strong enough to resist the forces that squash them (compression) and stretch them (tension).

Bones must also be light enough for your muscles to move. The strength and lightness of bones comes from their structure. The structure of a typical bone is shown in Figure 3.5.5. 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 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. Bones are living, and hence able to repair themselves and replace worn-out cells.

Prac 1 p129

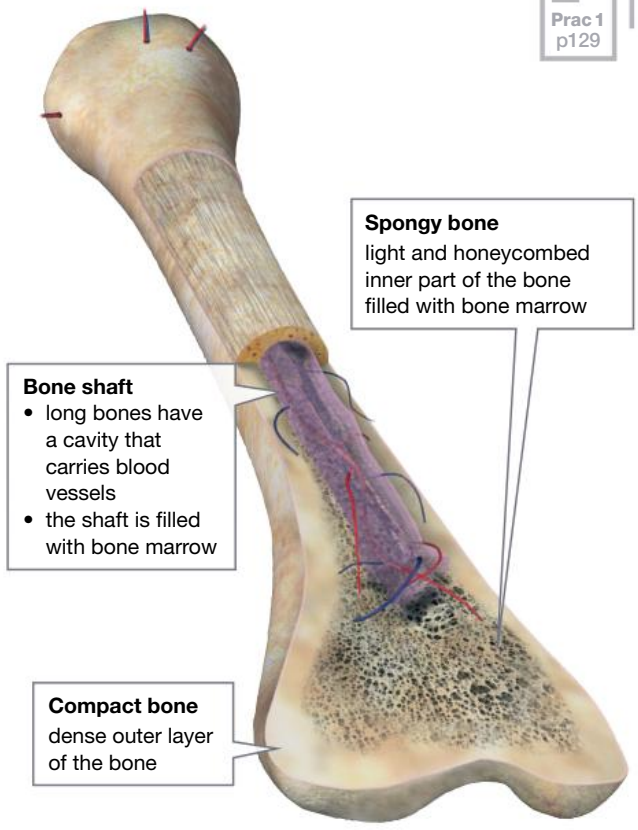


Figure 3.5.5 Bones are lightweight and living. This makes them easy enough for your muscles to move and allows them to renew and repair themselves.

INQUIRY science 4 fun

Broken bones

YES

Bones break in much the same way as spaghetti. Does spaghetti (or bones) snap into two pieces or more when broken?

Collect this ...

- strands of dry spaghetti
- tray to collect snapped spaghetti pieces

Do this ...

1 Over the tray, flex a strand of dry spaghetti until it snaps.
2 Count how many pieces it broke into.
3 Repeat until you see a pattern in the number of pieces you get.

Record this ...

Describe what happened.

Explain why you think this happened.

Figure 3.5.6 Both the bones in the lower leg shown here were broken in a ski accident.

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 3.5.7.

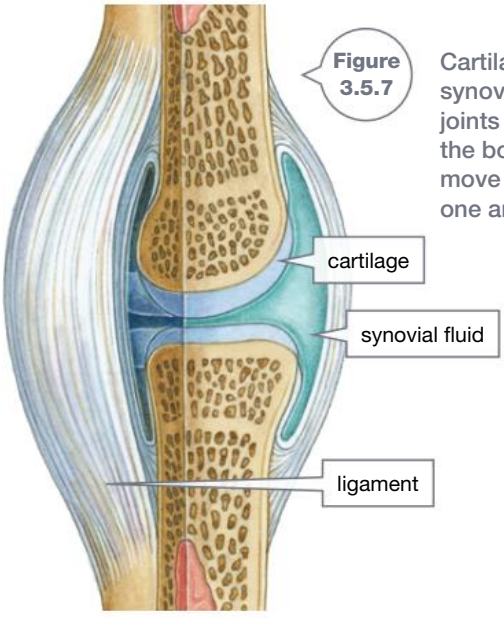
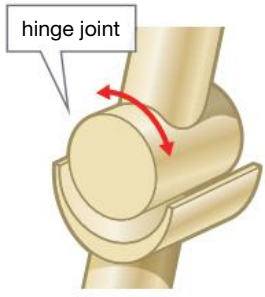


Figure 3.5.7 Cartilage and synovial fluid in joints ensure that the bones can move freely over one another.

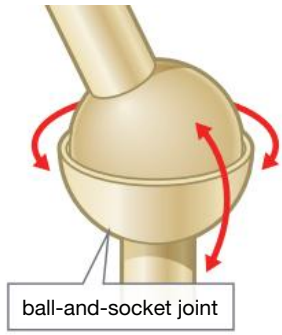
Types of joints

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 your hip and knee are different types of joints.



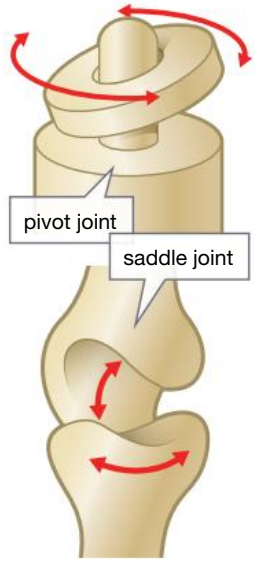
In a **hinge joint**, the ends of the bones are shaped so that movement is allowed in only one plane—backwards and forwards like the hinge of a door. There is a hinge joint between the bone of the upper arm (humerus) and the larger bone of the lower arm (ulna). Other examples are the knee joint and joints in your fingers.

In a **ball-and-socket joint,** one bone has a ball-shaped surface that fits into a cup-shaped socket in the other bone. The bone with the ball at its end is able to complete all types of movement. You have ball-and-socket joints in your hips and shoulders.



A **pivot joint** moves by a ring-shaped bone turning around another 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.

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.



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 3.5.8 shows the ligaments in the foot.

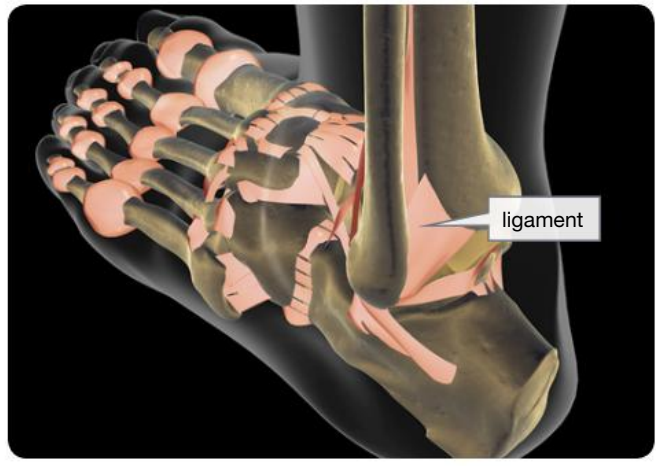


Figure 3.5.8 Ligaments hold all the bones of the foot together. Without them the foot would not be able to work as a single unit.

Muscles

It is your muscles that move bones. **Muscles** are tissues that are able to contract (shorten) 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 3.5.9. **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.

Prac 2 p130 Prac 3 p130 Prac 4 p131

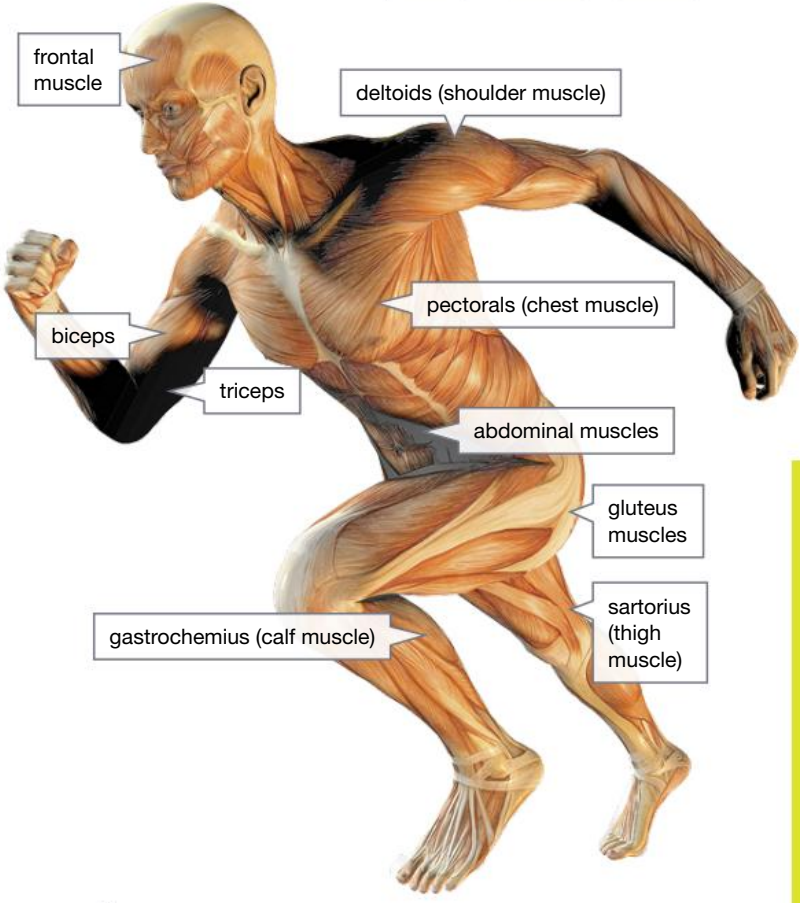


Figure 3.5.9 The human muscular system. The pale areas are tendons joining muscles to bones.

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**. Antagonistic means that they work in opposition to each other. The biceps and triceps are antagonistic muscles in your upper arm. The biceps contracts when activated, 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 3.5.10.

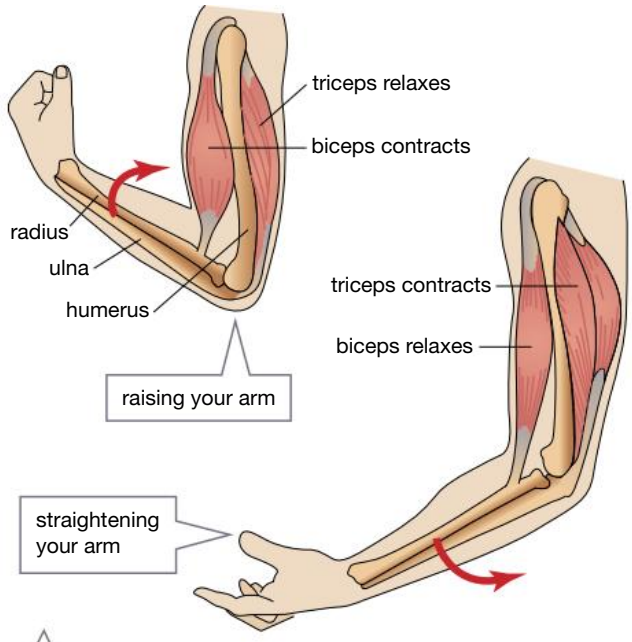


Figure 3.5.10 Muscles work in antagonistic pairs. The biceps flexes the arm; the triceps straightens it.

INQUIRY

science 4 fun

Flexing muscles

YES

Can you feel your muscles contract and relax?

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.

3.5 Unit review

Remembering

1 **List** the roles the skeletal/muscular system carries out in the human body

2 **State** how many bones there are in the adult human skeleton.

3 **List** the characteristics of bones.

4 **State** the number of muscles found in the human body.

Understanding

5 The bones in your arm need to perform well under the forces of 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 **Define** the term *antagonistic pair*. L

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 **Analyse** Figure 3.5.7 on page 126 and predict what would happen to the joint if:
- a cartilage wore away (osteoarthritis)
- b excess synovial fluid built up (rheumatoid arthritis).

12 **Contrast**:
- a the axial and appendicular skeleton
- b compact and spongy bone.

13 **Compare** the amount and direction of movement allowed by a hinge joint and a:
- a ball-and-socket joint
- b saddle joint.

Evaluating CCT

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.

16 Arthritis is pain in the joints. **Propose** what might cause this pain.

17 Babies have 100 more bones than adults. **Propose** what might happen to these 100 bones as a baby grows up.

18 Figure 3.5.6 on page 125 shows a broken tibia (the thicker bone) and broken fibula (the thinner bone).
- a **State** how many pieces each of these bones has broken into.
- b **Propose** reasons why the two bones broke in different ways.

Creating CCT

19 **Construct** a diagram showing the position of the muscles of the leg that cause the knee to bend and straighten.

Inquiring

1 Search the internet using the keyword EdHeads to find interactive activities that allow you to carry out virtual surgery on joints such as the knee and hip, replacing them with prosthetics. ICT

2 Rugby League player Jarryd Hayne injured his hamstring in 2012 (Figure 3.5.11). Find out what a hamstring is, how it is torn and ways of minimising the risk of such tears when playing sport.

Present your research as a pamphlet to be given out by coaches and sport physiotherapists.

Figure 3.5.11

3.5 Practical investigations

1 Hollow bones

Long bones are hollow along their centre and can be modelled using hollow paper cylinders.

Purpose

To test whether the strength of a bone depends on whether it is hollow or not.

Hypothesis

Which do you think will be stronger: thick, hollow bones or thin, solid bones? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- 9 sheets of recycled A4 paper
- 2 paper plates
- sticky tape
- 30 cm ruler
- assorted masses

SAFETY

Build your structure in a place that won't be damaged when it collapses.

Procedure

1. Copy the table from the Results section into your workbook.
2. Roll three A4 sheets into identical cylinders, forming hollow tubes. Attach a few pieces of tape to stop them unrolling.
3. Measure the outer diameters of the cylinders (in millimetres). Record them in your Results table.
4. Stick the cylinders on one of the paper plates to form a triangular base, as shown in Figure 3.5.12. Stick the other paper plate on top.
5. Add masses to the top paper plate and keep adding masses until the cylinders buckle and collapse. Record the total mass that just caused the cylinders to buckle.
6. Repeat the experiment, but this time roll the A4 sheets into tighter cylinders, with a smaller diameter and with less of a hollow tube along the centre.
7. Once again, repeat but with cylinders with very thin walls and a large hollow tube down their centre.

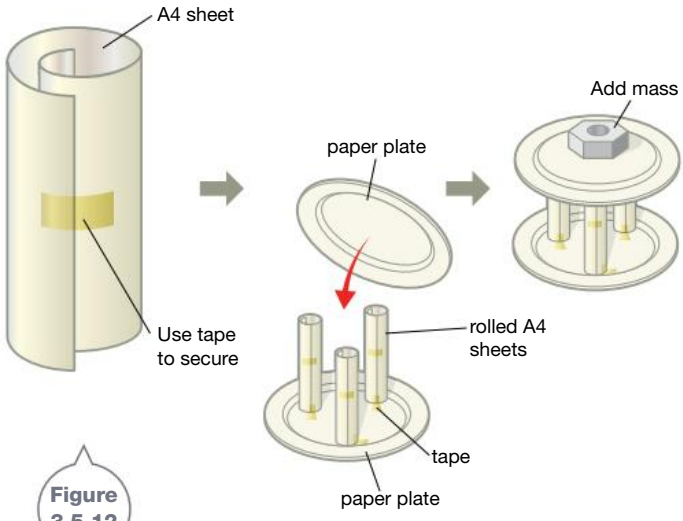


Figure 3.5.12

Results

Use the table below to record your measurements.

Trial	Outer diameter (mm)	Mass that caused buckling (g)
1		
2		
3		

Practical review

1. All the cylinders you made had exactly the same mass. **Explain** why.
2. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
3. **Propose** advantages of having hollow bones instead of solid ones.

3.5 Practical investigations

2 Investigating muscles and bones

Purpose

To investigate the structure of a chicken wing.

Materials

- uncooked chicken wing
- disinfectant

- dissecting kit (scalpel, scissors, tweezers/forceps)
- dissecting board
- newspaper
- 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.

Practical review

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.

STUDENT DESIGN

3 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 126 and decide which type of 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.

SAFETY

A risk assessment is required for this investigation.

Practical review

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.
3. **Evaluate** your model. Pick two other prac groups and **evaluate** their models too, identifying their strengths and weaknesses.

STUDENT DESIGN

4 Muscle fatigue

Purpose

To test how quickly your hand muscles fatigue (get tired).

Hypothesis

What do you think will happen as the muscles in your hand start to fatigue? Which do you think will fatigue more quickly—your right or left hand? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- springy test-tube clamp or similar
- stopwatch or access to clock or watch with second hand

SAFETY

A risk assessment is required for this investigation.

Procedure

1 Brainstorm in your group and come up with several different ways to investigate how quickly the muscles in your hands fatigue. Select the best procedure that:
   - a measures how many hand squeezes you (and your prac partner) can do every 30 seconds
   - b compares your right and left hands.

2 Write your procedure in your workbook.

3 Construct a suitable table to record your results. It could be similar to the table shown in the Results section.

4 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your results table, your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hints

1 Make sure each squeeze is exactly the same.

2 Stop the exercise if your muscles haven't fatigued after 2½ minutes.

Results

1 Record the results in the table in your workbook.

Time (s)	Number of squeezes completed by me		Number of squeezes completed by my partner	
	R	L	R	L
30				
60				
90				
120				
150				

2 Plot a line graph showing the number of squeezes completed against time for your right hand. Place the number of squeezes on the vertical axis and time on the horizontal axis.

On the same axes, plot another line for your left hand and for each hand of your prac partner.

Practical review

1 a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

2 **Propose** a meaning for the term *muscle fatigue*. L

3 **Propose** reasons why some people experience muscle fatigue more quickly than others.

4 **Evaluate** your procedure. Pick two other groups and **evaluate** their procedures as well, identifying their strengths and weaknesses.

Muscle facts

Muscles make up around half the weight of an adult male and about one-third the weight of an adult female. Your smallest muscle is the stapedius muscle in your middle ear—it is only 1 mm long!

SciFile

Figure 3.5.13 Smiling uses twelve facial muscles, while frowning uses eleven.

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 Your diaphragm contracts as you inhale.
- b You exhale because the air pressure in your 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 organs in the excretory system.

5 **Name** three things produced in the bone marrow.

6 **State** how many bones make up:
- a the axial skeleton
- b the appendicular skeleton.

Understanding

7 **Explain** why the lungs are included in both the respiratory system and the excretory system.

8 **Explain** why urine is a darker colour on a hot day.

9 **Describe** three situations in the body where a large surface area helps the functioning of a system.

10 Major arteries are a long way from the body surface. **Explain** why.

11 **Explain** the advantage of bone being a living tissue.

12 **Describe** the function of:
- a tendons
- b ligaments
- c joints.

Applying

13 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. N

14 **Identify** the organs labelled A–J in Figure 3.6.1.

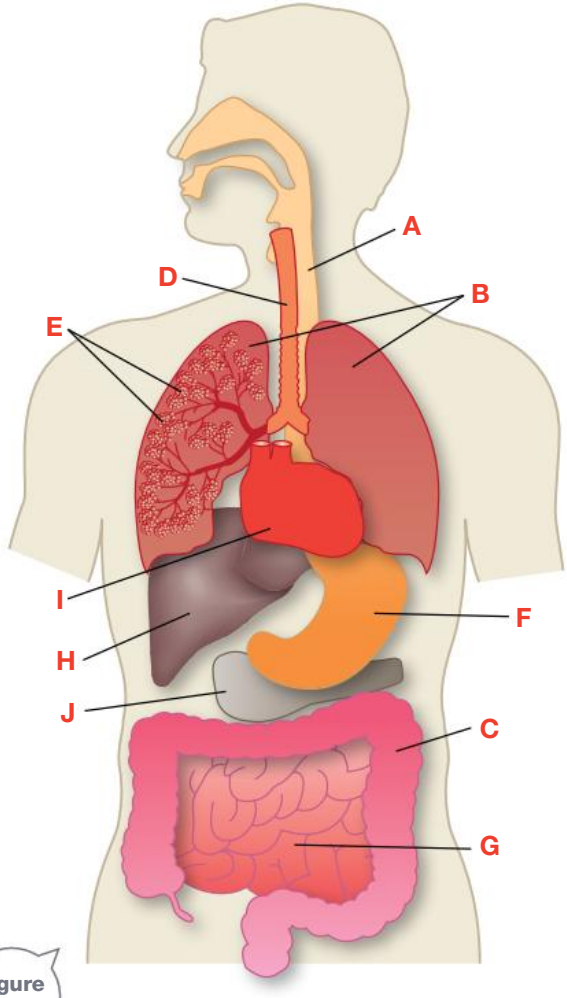


Figure 3.6.1

15 **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

16 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. Assume you breathe 12 times per minute, inhaling 500 mL of air with each breath. N

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

17 **Compare** the part of the lungs where gas exchange takes place with the lining of the small intestine.

Evaluating CCT

18 a **Analyse** Figure 3.6.2 and **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.

Figure 3.6.2

19 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.

20 Some athletes strap their wrists, ankles, knees and shoulders when playing sport. **Propose** reasons why.

21 Birds have hollow bones with very little compact bone. **Propose** an advantage of this characteristic.

22 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. N

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.

23 a **Determine** whether you can or cannot answer the questions on page 83 at the beginning of this chapter.

b **Assess** how well you understand the material presented in this chapter.

Creating CCT

24 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.

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

digestion
respiration
excretion
circulatory system
heart
diffusion
glucose
oxygen
breathing
kidneys

3.10

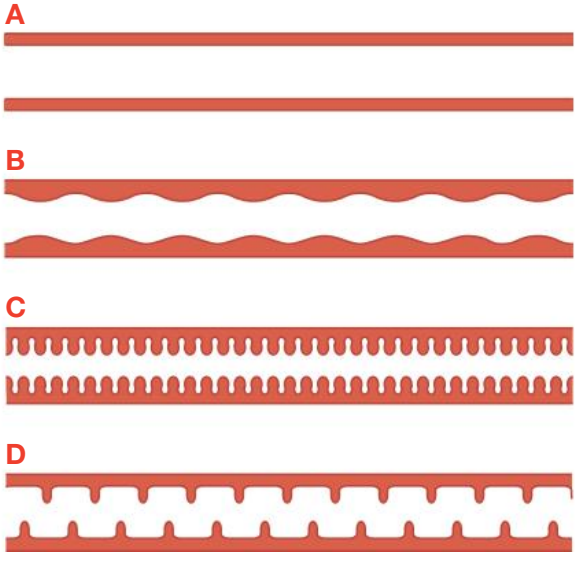
Thinking scientifically

Q1 Analyse the information in the table to decide which parts of the body had increased blood flow during exercise. CCT

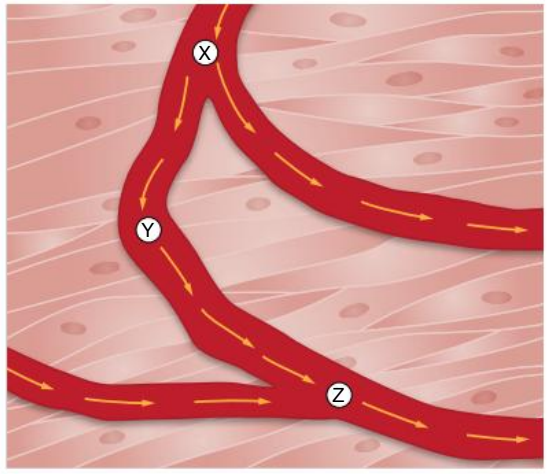
Part of body	Blood flow (L/min)		
	At rest	During light exercise	During medium exercise
Heart muscle	250	350	800
Leg muscle	1100	4600	13 000
Brain	750	750	750
Kidneys	1000	850	700
Digestive system	1300	1100	550
Skin	500	1500	1800

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. CCT



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. CCT



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. CCT

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 L

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

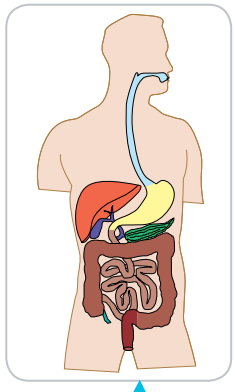
Duodenum: the first part of the small intestine

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

Ileum: the second part of the small intestine and the place where absorption of food takes place.

Large intestine: the final section of the digestive tract



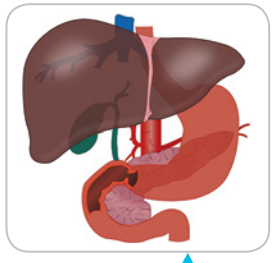
Digestive system

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

Pancreas: an organ associated with the digestive system that produces chemicals to help the digestion of carbohydrates, fats and proteins



Liver

Peristalsis: the process of pushing food through the digestive tract by alternating contraction and relaxation of muscles

Saliva: watery liquid containing a chemical that begins the digestion of starch

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 L

Alveoli: a cluster of sacs at the end of the bronchioles where gas exchange takes place; a single sac is called an alveolus

Bronchi: tubes formed by the division of the trachea

Bronchioles: small tubes formed by the division of the bronchi

Cilia: tiny hairs lining the nostrils

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 air into the body

Trachea: the tube that carries air from the nose and mouth into the chest cavity

Unit 3.3 L

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 type of blood vessel; capillaries reach 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

Deoxygenated blood: blood with carbon dioxide

Haemoglobin: the pigment that gives red blood cells their colour

Oxygenated blood: blood rich in oxygen

Pulse: the regular expansion and contraction of the arteries in response to the heartbeat.

Circulatory system

Vein: blood vessel that carries blood back to the heart

Glossary

Unit 3.4 L

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

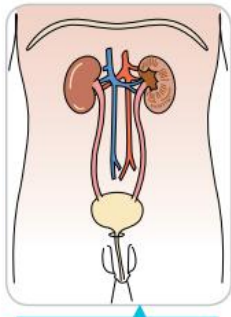
Excretory system: the system in the body that gets rid of the wastes that the body has produced

Urea: a waste product from the breakdown of proteins

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



Excretory system

Unit 3.5 L

Antagonistic pairs: pairs of muscles that work in opposition to each other

Appendicular skeleton: the bones whose main role is to allow the skeleton to move; includes the pelvis, bones of the limbs and shoulder blades

Axial skeleton: the bones whose main role is to protect the organs; includes the skull, vertebrae, sternum and ribs

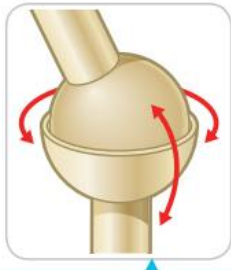
Ball-and-socket joint: a joint in which one bone has a ball- shaped surface that fits into a cup-shaped socket of another bone. The bone with the ball at its end is able to move in all directions

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



Ball-and-socket joint

Hinge joint: a joint that allows movement in only one plane.

Joint: the place where two bones meet

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.

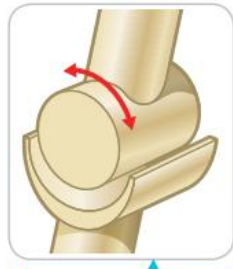
Saddle joint: a joint that allows movement in two directions

Skeleton: bony structure that holds the body upright, protects its organs and allows movement

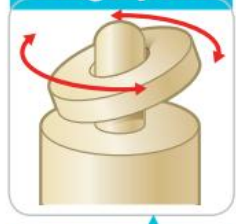
Spongy bone: honeycombed bone structure; makes up much of the inner structure of a bone

Synovial fluid: lubricating liquid in a joint

Tendons: elastic tissue that attaches the muscles to the bones



Hinge joint



Pivot joint

Saddle joint

4 Growth and reproduction

Have you ever wondered...

- why animals have different sexes?
- why males and females look different?
- why there are so many different types of flowers?
- how babies grow inside their mother?

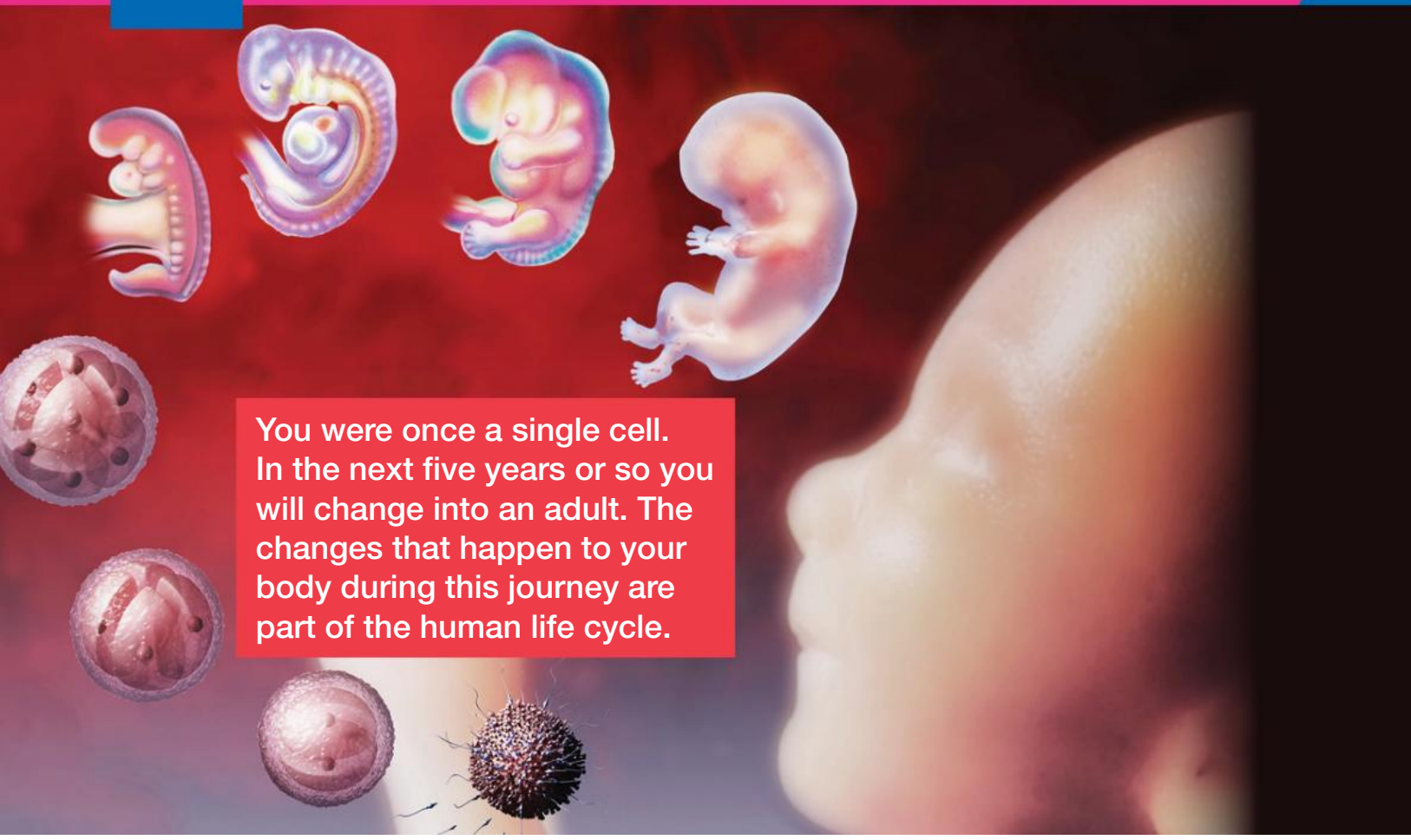
After completing this chapter students should be able to:

- identify that new cells are produced by cell division
- outline the role of cell division in growth, repair and reproduction in multicellular organisms
- describe the role of the flower in flowering plants L CCT
- outline the role of the reproductive system in humans
- research how changes in scientific knowledge have contributed to finding a solution to a human health issue CCT EU
- recall how scientific discovery has contributed to solving a real-world problem L PSC
- describe how developments in technology have contributed to finding solutions to a contemporary issue ICT L
- describe how people can hold different ideas about the application of a solution to a contemporary issue CCT DD PSC L

ADDITIONAL

- discuss how an understanding of the life cycles of native plants is used by Aboriginal and Torres Strait Islander peoples AHC
- propose reasons why society should support biological research. CCT PSC EU

4.1 Life cycles



You were once a single cell. In the next five years or so you will change into an adult. The changes that happen to your body during this journey are part of the human 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 in which parents produce new individuals, or offspring. For example, in humans, the **life cycle** goes through the stages of baby, toddler, child, adult and finally parent.

At each stage the organism might look different and have different roles. For example, a kitten is dependent on its mother. As a mature cat, it 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.

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. **Growth** is when an organism becomes larger, increasing its mass, length or volume. Development is about changes such as wings or legs forming. Usually as an organism grows, it also develops.

The life cycle of an insect

The life cycle of the wanderer butterfly is shown in Figure 4.1.1. It has four stages.

- 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, a life stage that 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 to form a butterfly.
- 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.

These four stages look very different—the wanderer butterfly has gone through dramatic changes known as metamorphosis. Most insects undergo metamorphosis during their life cycle, including moths, bees, wasps, flies, mosquitoes and beetles.

4.1 4.2

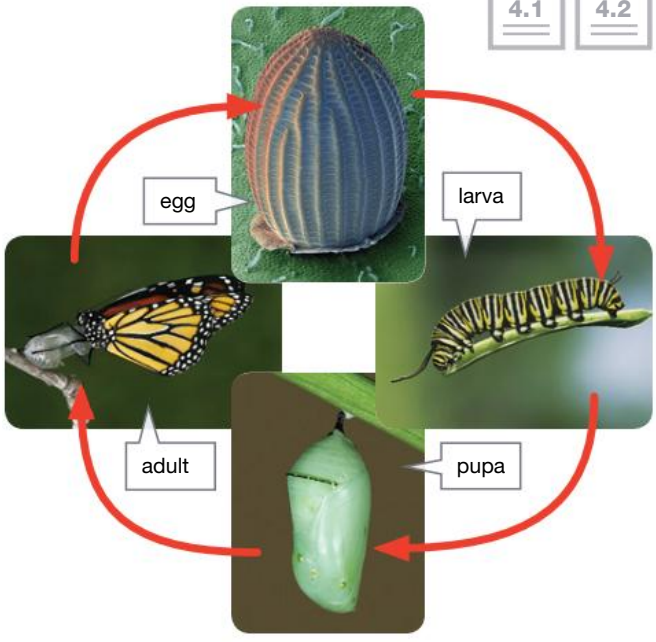


Figure 4.1.1 The life cycle of the wanderer butterfly shows four different life stages—egg, larva, pupa and adult.

The life cycle of a frog

As you can see in Figure 4.1.2, the life cycle of a frog has four stages: egg, tadpole, froglet and adult frog. The life cycle begins with two parents mating. During mating the male clings onto the female until she releases specialised cells called eggs into the water. Then the male spreads a fluid over the eggs that contains specialised cells called sperm. One sperm cell fertilises one egg cell. 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 froglet. The gills it used for breathing in water are gradually replaced by lungs for breathing air.

The froglet slowly absorbs its tail as its legs grow longer. Eventually it becomes an adult frog and can produce its own offspring.

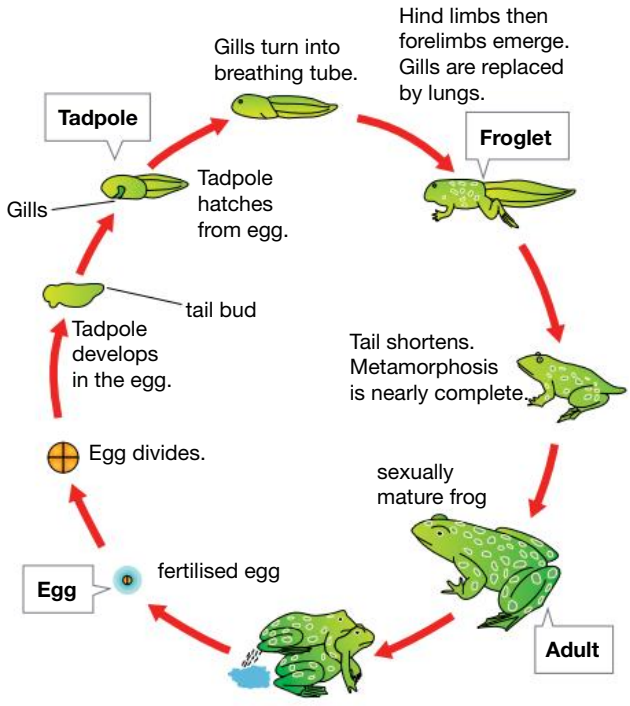


Figure 4.1.2 The life cycle of a frog, showing four main stages: adult, egg, tadpole and froglet

INQUIRY

science 4 fun

Life cycles in a garden

YES

Can you see a life cycle in the garden?

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.

Stomach breeders

SciFile

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 brooding frogs haven't been found in the wild for many years and may be extinct.

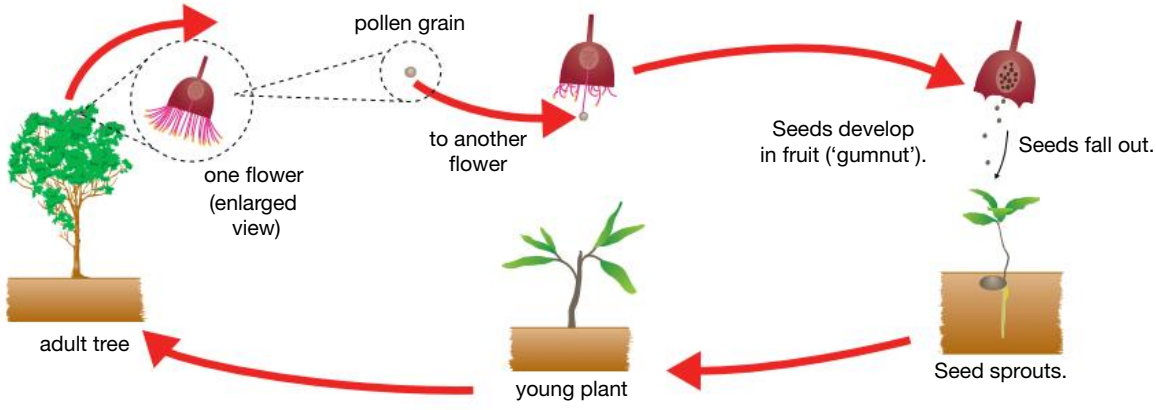
Figure 4.1.3 A gastric brooding frog giving birth to its young after they developed in its stomach. The paperclip shows how small this frog is.

Plant life cycles

Plants have many different types of life cycle. In Figure 4.1.4 you can see the life cycle of a eucalyptus tree (gum tree). The tree produces flowers, which are the organs that make its seeds. Flowers produce tiny particles called pollen, which contain sperm cells. This must join with the female egg in a different part of the flower. When these two reproductive cells join up, they develop to form seeds. The seeds will sprout (germinate) and grow into a new adult tree.

Prac 1 p144

Figure 4.1.4 The life cycle of a eucalyptus tree



Cell division, growth and repair

When multicellular organisms grow, they do so by making new cells. Each cell can divide into two new cells in a process called **cell division**. By repeated division, a few cells can produce the many cells that make up the tissues and organs that form the organism's body.

Cell division also allows multicellular organisms to repair themselves. **Repair** is the process of fixing damaged body tissues. Repair is necessary to rebuild:

- tissues that break or tear, such as your bones, muscles, tendons and ligaments
- tissues or organs that have been damaged by disease such as chickenpox, like that in Figure 4.1.5
- cells that break down or die as you get older
- tissues that are damaged by continual contact with materials from the environment. For example, your skin is constantly being worn away by the gases and dust of the air. The lining of your mouth is worn away by food and drinks that you consume.

Your body is continually repairing itself. Millions of your cells are dividing to form new cells right now! If it did not happen, your skin would wear away and so would the inside of your intestines. Cuts in your skin, torn muscles and broken bones would never heal. You would also run out of blood.

GO TO Unit 2.2

New blood

SciFile

Your body replaces almost 1% of its red blood cells every day. Each red blood cell only lives about 110 days, and so new blood cells constantly need to be formed through cell division in your bones and spleen.

Figure 4.1.5 The production of new cells in multicellular organisms enable tissues to grow and repair themselves. This child's skin will repair the damage caused by chickenpox.

Splitting the nucleus

When a cell splits into two, the most important part that must divide is its nucleus. The nucleus is the 'control centre' of a cell. It contains genetic information, which controls everything a cell does, such as making chemicals or repairing itself. **Mitosis** is the process in which a nucleus divides to form two cells with identical genetic information. You can see mitosis happening in Figure 4.1.6.

Mitosis gives each new cell its own nucleus—each nucleus is an exact copy of the nucleus from the original parent cell. In this way, each newly formed nucleus contains all the genetic information that the parent nucleus contained. In multicellular organisms like you, mitosis causes skin cells to form new identical skin cells. Likewise, muscle cells divide to form identical muscle cells and fat cells split to form identical fat cells.

If the nucleus is not copied correctly, then the new cells may be missing the genetic information needed to function properly. The new cells might even die.

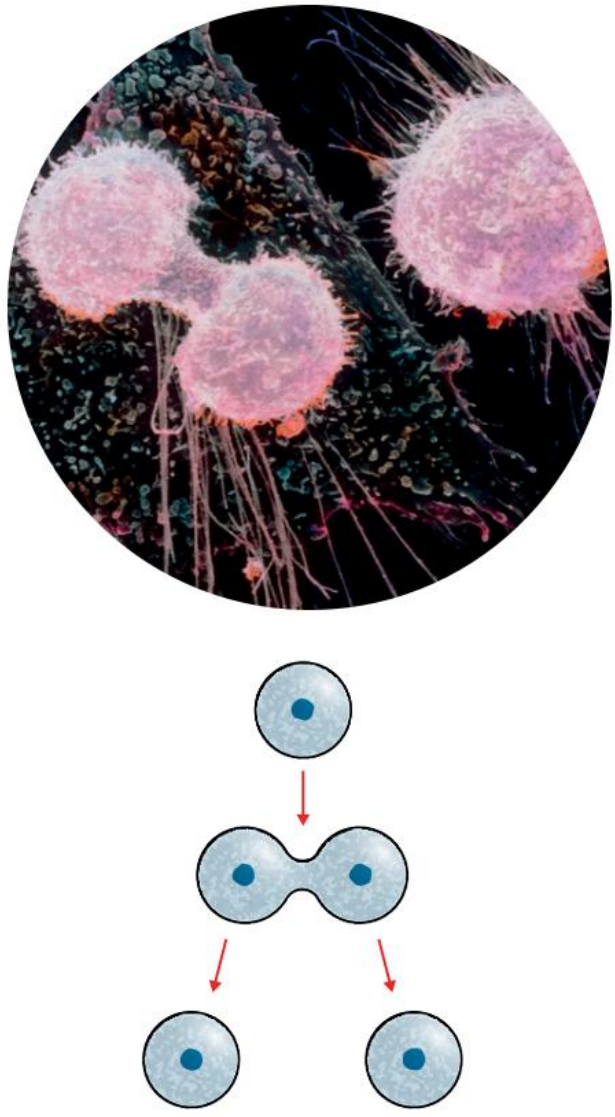


Figure 4.1.6 Mitosis produces two identical cells. Each new cell contains all the genetic information that the parent cell had.

When division goes wrong

Sometimes cell division goes wrong in multicellular organisms. The cells keep dividing out of control. Their genetic information can become changed by this continual division, resulting in new cells that are not able to perform their normal functions. The altered cells may also spread to other parts of the body and cause damage to other tissues. This is cancer.

SciFile

Prac 2 p144

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

IAN FRAZER AND THE HPV VACCINE

The human papilloma virus (HPV) causes painful and unsightly genital warts in males and females. Some types of HPV also cause some cancers, mainly in women. These cancers kill about 250 000 people worldwide each year.

In 2006, Australian scientist Professor Ian Frazer (Figure 4.1.7) developed a new vaccine called Gardasil®. Gardasil prevents about 75% of cancers of the cervix, 70% of cancers of the vagina and about 50% of cancers of the vulva. The vaccine also prevents most genital warts in males and females.

Vaccination (immunisation) is the process of injecting a chemical (called an antigen) into the body, which stimulates the body to defend itself against the chemical. The body produces several types of white blood cells that can destroy the foreign chemical. Some of these cells (called memory cells) then remain in the body. If the virus enters the body in future, the memory cells detect the chemical on the surface of the virus. The memory cells then stimulate the body to produce large numbers of white blood cells that can destroy the virus before it can multiply and damage the body. This is called the immune response.

Gardasil is now routinely used to vaccinate (immunise) males and females between 9 and 26 years of age (Figure 4.1.8). Vaccination makes it unlikely that they will develop cancer or genital warts in the future.

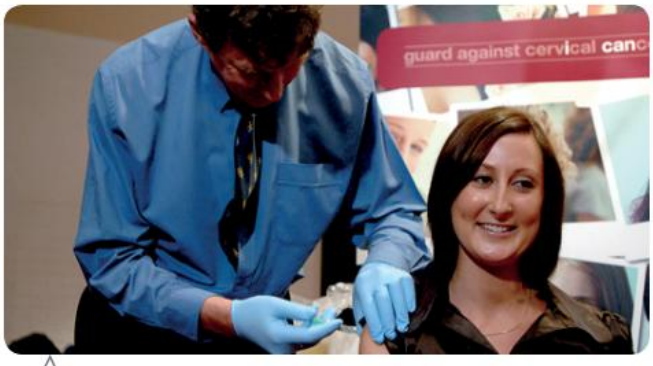


Figure 4.1.8 Professor Ian Frazer immunises a young woman with his Gardasil vaccine.

Figure 4.1.7 Ian Frazer developed a vaccine for HPV, a virus that can cause cervical cancer in women.

REVIEW

1 **Name** the diseases that Ian Frazer is helping to prevent.

2 **State** how many people die of the disease around the world each year.

3 **Describe** how the Gardasil vaccine causes the body to respond.

4 **Describe** how a person who has been immunised with Gardasil responds if they become infected by HPV.

ADDITIONAL

5 **Discuss** why society should support research in biological science, such as that of Professor Frazer.

ADDITIONAL

4.1 Unit review

Remembering

1 **Name** the process by which parents produce offspring.

2 **Name** the specialised:
- a male reproductive cell
- b female reproductive cell.

3 **List** the four stages in the life cycle of a butterfly.

4 **Recall** what happens inside a butterfly pupa.

5 **List** the evidence you might find in a garden that indicates that insects and plants have life cycles.

6 **List** four ways in which cell division is important in multicellular organisms.

Understanding

7 **Define** the following terms. L
- a reproduction
- b life cycle
- c mitosis

8 **Explain** why reproduction is a necessary part of a life cycle.

9 **Describe** some structural changes that occur when a tadpole becomes a frog.

10 **Explain** why the nucleus is the most important part of the cell.

11
- a **Explain** why the nucleus must be copied exactly during mitosis.
- b **List** what might happen if the nucleus is copied wrongly.

12
- a **List** three injuries and illnesses you have had.
- b **Explain** how cell division was important in helping you get better again.

Applying

13 A Year 8 boy fell off his skateboard and badly grazed his knee. A scab formed and remained there for several weeks. When the scab fell off, the skin below had healed. **Use** your understanding of cell division to **explain** what happened beneath the scab.

Analysing

14 **Use** the life cycle of the wanderer butterfly to help you **contrast** growth with development.

15
- a **List** some of the ways a person's body changes through life.
- b **Classify** each change as growth or development.
- c **Demonstrate** the importance of cell division in these changes.

16 **Compare** cancer with normal cell division.

Evaluating CCT

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 CCT

19 **Construct** a table listing five organs of the human body and the role that cell division plays in the function of each organ.

Inquiring

1 Research how changes in scientific knowledge have contributed to finding a treatment for a particular form of cancer. In particular:
- name the cancer you researched
- discuss recent advances in knowledge about the cancer
- discuss treatment methods that developed or are being developed from the new knowledge of the cancer.

Present your research in digital or written form. ICT EU

ADDITIONAL

2 Research how Aboriginal and Torres Strait Islander people benefited for thousands of years from their knowledge of the life cycles of the plants around them.

Present your findings in written or digital form. AHC ICT

ADDITIONAL

4.1 Practical investigations

1 Animal and plant life cycles

Purpose

To compare different animal and plant life cycles.

Materials

- specimens from the life cycle of animals such as fruit flies, mosquitoes, houseflies or silkworms
- specimens or images from the life cycle of plants such as flowering plants, mosses, ferns, conifers or cycads
- information sheets on each organism
- hand lenses or stereomicroscopes
- if using live animals, you will also need glass jars to hold them and appropriate food to keep them alive

Procedure

Move around the room from one specimen to another. Carefully observe the specimen and record as many observations about it as you can.

Results

1. Decide on the order in which the stages occur in the life cycle.
2. Construct a simple diagram that shows each stage for each specimen you investigate.
3. Annotate your diagram with the name of the animal or plant. Label each stage and connect the stages with arrows. Write down on your diagram any additional information that may be on an information sheet near the specimens.

Practical review

1. **Compare** the life cycles of the animals you observed.
2. **Compare** the life cycles of the plants you observed.

2 Observing cell division

Purpose

To observe cell division (mitosis) in plant roots.

Materials

- prepared slide of root tip (such as that from an onion)
- monocular microscope

Procedure

1. Use the low magnification lens on the microscope to focus on the root tip.
2. Search the few millimetres at the end of the root tip for nuclei that look like threads instead of dark circles. The cells with these nuclei are undergoing division.
3. Switch to high magnification and find a cell where the threads are clearly visible. Sketch this cell in your notebook.
4. Look for other cells that seem to be in different stages of dividing. For example, look for evidence of two newly formed cells.

Results

Draw and record the stages of division that you see.

Practical review

1. **Assess** whether all cells divide at the same time.
2. **Discuss** whether all the cells were dividing in the area of the root tip you looked at.

4.2 Methods of reproduction

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 would 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

NO

What is in a flower?

Collect this …

- 2 different garden flowers
- pair of tweezers
- knife or fine pair of scissors

SAFETY

Make sure you do not pick poisonous flowers such as oleander.

Take care with the knife and 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.

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 (most species having 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, known as **gametes**. The male gamete is sperm and the female gamete is the egg. Fertilisation results in a new cell called a **zygote**. The zygote 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 146 you can see many human sperm around a single egg.

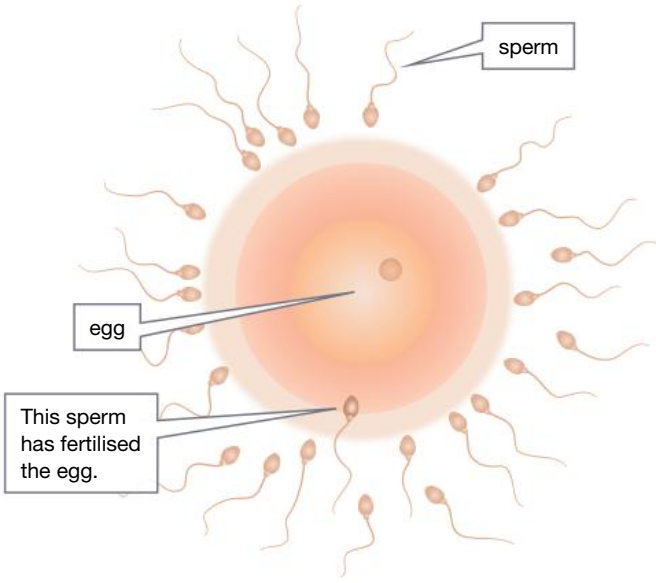


Figure 4.2.1 Human sperm and an egg. Sperm have a tail to help them swim. During fertilisation only one sperm enters the egg.

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**. For example, snails (like the ones shown in Figure 4.2.2), slugs and flatworms are hermaphrodites. The ovaries make the female gametes and the testes make the male gametes.

Figure 4.2.2 Snails are hermaphrodites, and have both male and female sex organs.

Sex-change fish

SciFile

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.

Cell division and gametes

Gametes are formed by a type of cell division that occurs only in the male and female reproductive organs. This process is called **meiosis**. The cell division that forms gametes is very different from the cell division that forms new body cells for growth and repair. In mitosis, a cell splits into two to form two identical cells, each containing all the genetic information the cell needs. However, in meiosis each cell splits into four. These four newly formed cells are different from each other.

In males, four sperm are formed from each parent cell. In females, four egg cells are formed. Each new gamete is different from the body cells, because it only has half the genetic information that a normal cell has.

To obtain the full amount of genetic information, a sperm cell needs to fertilise an egg cell. If this doesn't happen, then no new individual can form. The single fertilised cell that is formed (the zygote) has all the required genetic information that will allow it to grow into a new individual.

The zygote then divides repeatedly by cell division (mitosis). Every new cell in the individual comes from copying the original zygote cell formed at fertilisation. This is shown in Figure 4.2.3.

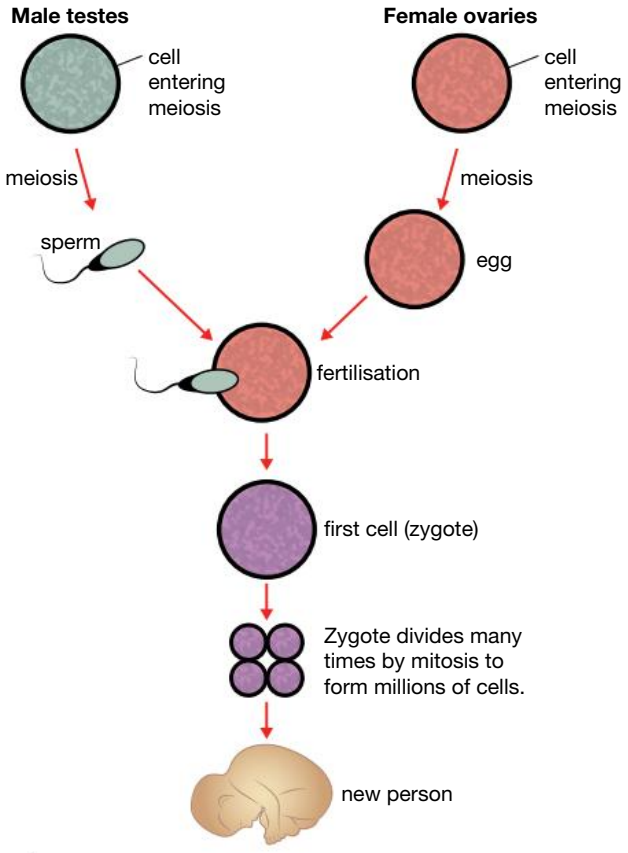


Figure 4.2.3 Meiosis forms gametes with only half the required genetic information. On fertilisation, the zygote cell has all the genetic information it requires and so a new individual is formed.

Sexual reproduction in animals

Depending on the animal involved, fertilisation takes place outside or inside the body.

External fertilisation happens outside the body. Figure 4.2.4 shows a male frog fertilising eggs laid by the female in water. Most fish reproduce externally, and so do sea urchins and jellyfish. The water stops the sperm from drying out, and the sperm can swim through it.

Internal fertilisation happens inside the body. All land animals use internal fertilisation, as do some water-based (aquatic) species. 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.

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. This is shown in Figure 4.2.5.

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.

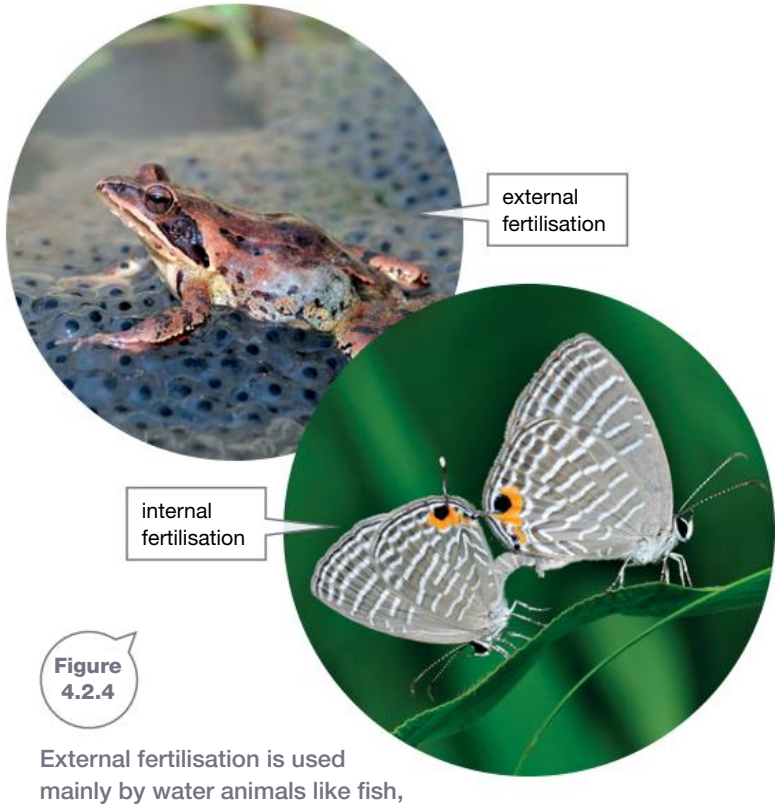


Figure 4.2.4 External fertilisation is used mainly by water animals like fish, and internal fertilisation is used mainly by land animals such as insects.

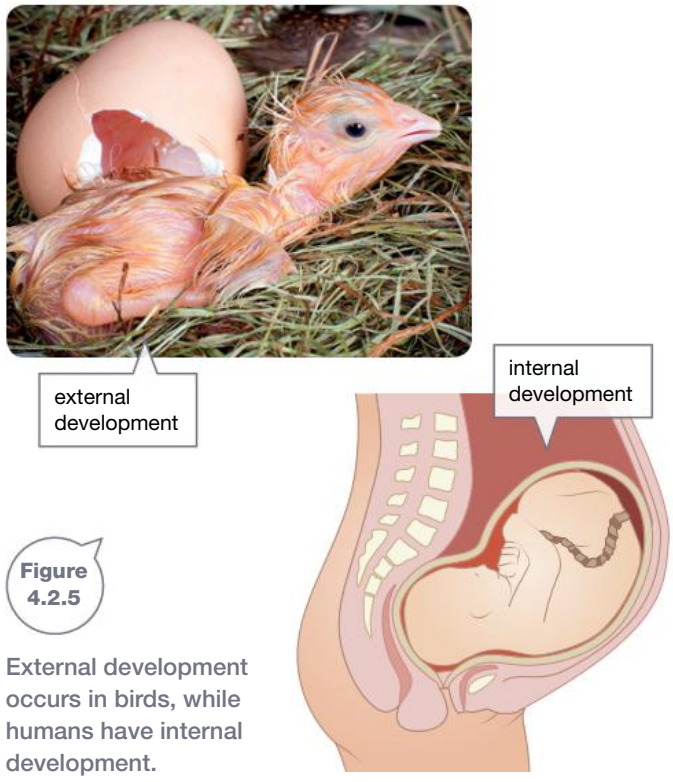


Figure 4.2.5 External development occurs in birds, while humans have internal development.

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. The structure of a typical flower is shown in Figure 4.2.6.

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. This tube grows down through the **style** 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.

Seeds develop in 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 4.2.7.

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 uses the stored food in the seed and begins to grow. The embryo then sprouts out of the seed in a process called **germination**. It will begin making its own food when it reaches the sunlight above the ground.

Prac 1 p153 Prac 2 p154 4.3

Figure 4.2.6 A flower is a reproductive structure.

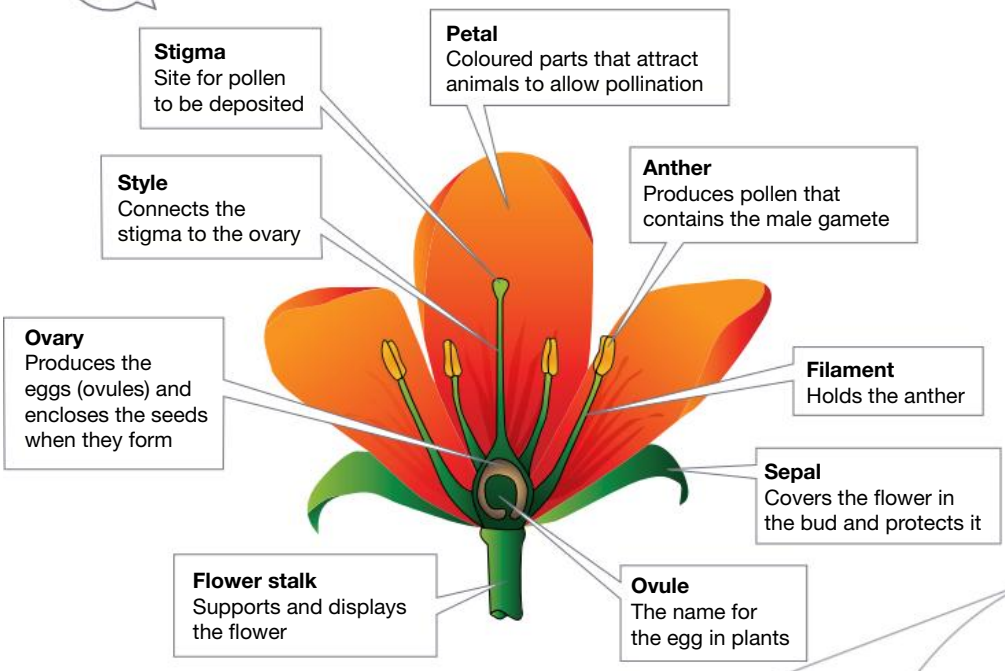
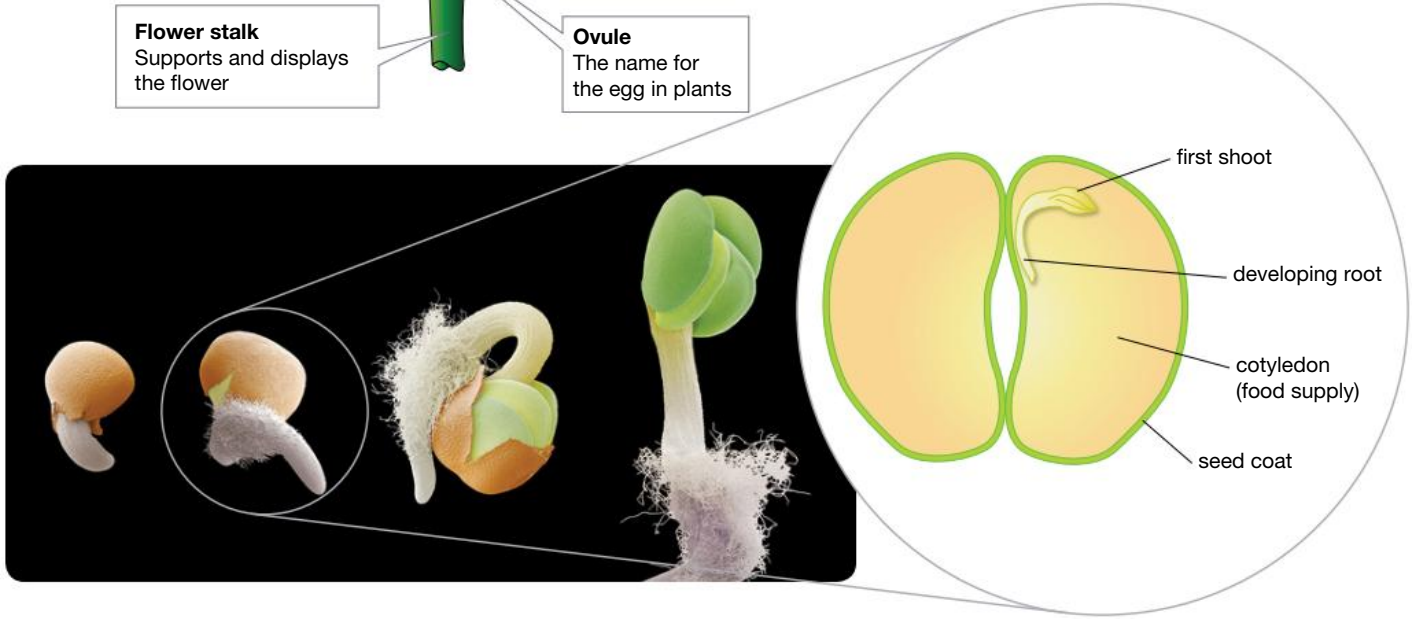


Figure 4.2.7 A seed is an embryo with a food supply. This seed has been split open.



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. Instead, the individual is produced by cell division using mitosis.

Asexual reproduction in animals

Few animals reproduce asexually. One that does is the freshwater animal called hydra. Hydra are relatives of jellyfish, and can reproduce both sexually and asexually. Figure 4.2.8 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.

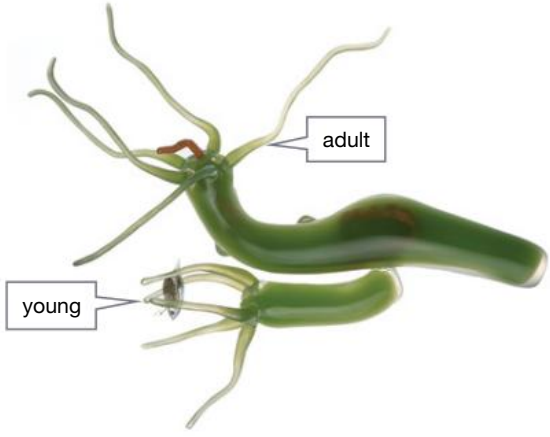


Figure 4.2.8 This adult hydra has a young hydra that was produced asexually still attached to it. The young one has caught a small water animal to eat.

Another type of asexual reproduction is called **parthenogenesis**, where offspring develop from eggs that have not been fertilised by a male. Parthenogenesis happens in water fleas, aphids (Figure 4.2.9), some bees, and a small number of reptiles and fish.

The weird world of rotifers

SciFile

Rotifers are animals about the same size as a single-celled protozoa. However, rotifers have about 1000 cells. Unlike other animals their cells do not seem to have cell membranes. Another strange thing about rotifers is that many species are only female, and all young are produced by parthenogenesis!

Figure 4.2.9 Aphids can reproduce asexually.

INQUIRY

science 4 fun

Asexual organisms

NO

Can you spot asexual reproduction?

Collect this …

- sample of pond water with organisms that reproduce asexually such as water fleas, rotifers, hydra, protozoa
- monocular microscope
- two cavity sides and coverslips

Do this …

1. If you have a hydra, place it on a cavity slide but do not add a coverslip (to prevent crushing the animal).
2. For the other organisms, place two drops of pond water on a cavity slide and add a coverslip.
3. Observe your hydra under low power. Use high power for the smaller organisms. Try to find water fleas, rotifers or other organisms that reproduce asexually.
4. Look for any evidence that the organisms may be reproducing at present.
5. Carefully return any hydra back to the container. Do this by dipping your slide into the container.

Record this …

Describe each organism that you saw. Did you observe any organisms reproducing asexually?

Explain what happens during asexual reproduction.

Asexual reproduction in plants

In plants, asexual reproduction can occur by different methods, as shown in Table 4.2.1.

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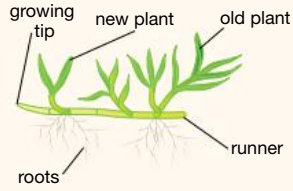
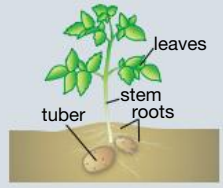
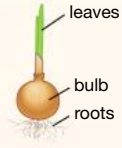
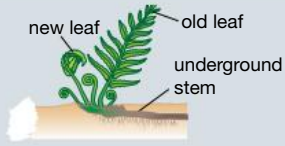
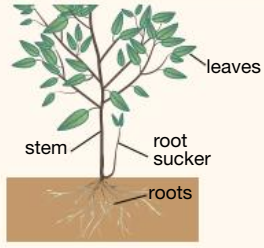
Table 4.2.1 Methods of asexual reproduction

Asexual 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.	

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.

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
- cannot move very far—they do not have to find a mate
- live in an environment that does not change much—the offspring will all be identical and therefore all will be suited to surviving in the environment.

In contrast, 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.

4.4

4.2 Unit review

Remembering

1 **Name** the two main types of reproduction.

2 a **List** three different ways that plants reproduce asexually.
   b For each way, **name** one plant that reproduces that way.

3 a **Name** two methods of asexual reproduction in animals.
   b For each method, **name** 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.

7 **List** three organisms that are hermaphrodites.

Understanding

8 Jo claims that an animal that was produced by sexual reproduction must have two parents. **Discuss** whether Jo is right or not.

9 a **Explain** what is meant by reproduction.
   b **Explain** why reproduction is necessary.

10 **Define** the following terms. L
   a fertilisation
   b copulation
   c embryo
   d internal fertilisation
   e external development
   f hermaphrodite

11 **Outline** some advantages of:
   a asexual reproduction
   b sexual reproduction

12 **Describe** what you might observe in the science4fun on page 149 to indicate that asexual reproduction is occurring in the pond water.

Analysing

13 **Contrast** sexual with asexual reproduction.

14 **Compare** the processes of copulation and fertilisation.

15 **Compare** the processes of internal and external development.

Evaluating CCT

16 Honeyeaters (like the one shown in Figure 4.2.10) 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 4.2.10 Honeyeaters have long thin beaks that allow them to get to the nectar inside flowers.

17 a **Propose** whether internal development is more likely to occur in animals that are internally fertilised or externally fertilised.
   b **Justify** your answer.

18 Whales are mammals. Their ancestors 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.

4.2 Unit review

19 Consider the following situations and **rank** 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

20 Self-fertilisation is when an individual fertilises itself.

- a **Propose** what the disadvantages of self-fertilisation are, for a species.
- b The male anthers and female stigma of geranium plants (like the one in Figure 4.2.11) mature at different times. **Explain** how this would stop the plant from self-fertilising.

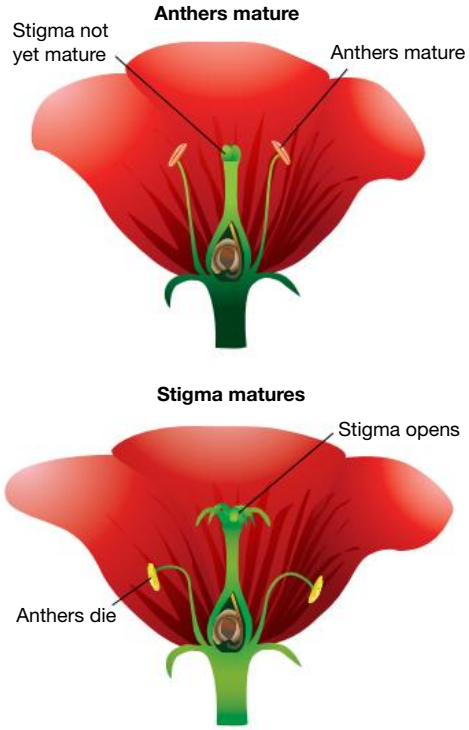


Figure 4.2.11 This geranium does not self-fertilise because the anthers and stigma mature at different times.

Creating CCT

21 **Construct** a table comparing the role of cell division in sexual and asexual reproduction.

Inquiring

1 Research three examples of animals that can change sex once they are born. In particular:

- find the term given to this change in sex
- state what change occurs in each species
- discuss how these changes benefit the species in your examples.

Present your findings as a poster to be displayed at the zoo.

Figure 4.2.12 All barramundi under 3–5 years old are male. They then all change sex to become females.

2 Research the growth and reproduction of rotifers. In particular, find:

- where rotifers live
- their general body parts
- their cell structure and how this affects their growth
- their methods of reproduction
- how their ability to withstand drying out helps them survive.

Present your research as a digital presentation. ICT

4.2 Practical investigations

1 Flower structure

Purpose

To compare the structure of different flowers.

Materials

- selection of flowers

- blade and forceps
- hand lens or stereomicroscope

SAFETY
Take care with sharp instruments.

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.

Practical review

1. **Use** the table below to **identify** the most likely method of pollination the flower may have.
2. **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, often red. Some have petals but many don't. Lots of nectar	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

4.2 Practical investigations

2 Germination

Purpose

To determine what affects the germination of seeds.

Hypothesis

Which variables do you think seeds need for them to germinate—water, light, oxygen or warmth? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- 1 mL (cool) boiled vegetable oil
- 10 mL (cool) boiled water

- 5 test-tubes
- 25 wheat seeds
- cotton wool
- labels or waterproof pens
- 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 4.2.13.

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.

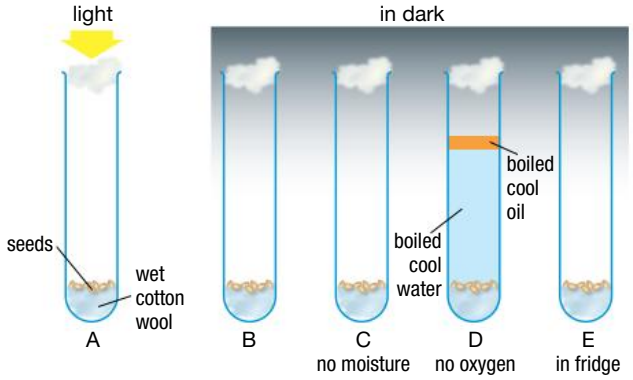


Figure 4.2.13

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.

Results

Describe the conditions in the test tubes in which seeds germinated.

Practical review

1 **Compare** your results with those of other teams.

2 a **Use** the class results to **construct** a conclusion for the investigation.

b **Assess** whether your hypothesis was supported or not.

3 **Propose** a reason why each variable affected germination.

4 **Evaluate** your experiment and **propose** ways to improve it, especially if the results were not clear.

3 Asexual reproduction

Purpose

To observe examples of asexual reproduction.

Materials

- selection of onion, potato, African violet, tree of life (*Bryophyllum*), clove of garlic, leaf of geranium, stem of bamboo or bracken
- soil

- glass jars
- 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 4.2.14 shows how to do this using an onion. Fill each jar with water.
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.
3. Place the leaf stalk of an African violet 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.

Results

1. Place each plant sample in a cupboard and check it regularly over the next few weeks.
2. Record your observations, perhaps using a camera or the camera on a mobile phone to record the changes.

Practical review

1. Each plant reproduced asexually. **Identify** the method of asexual reproduction each plant used.
2. **Evaluate** your investigation and **propose** reasons why some plants may not have reproduced.

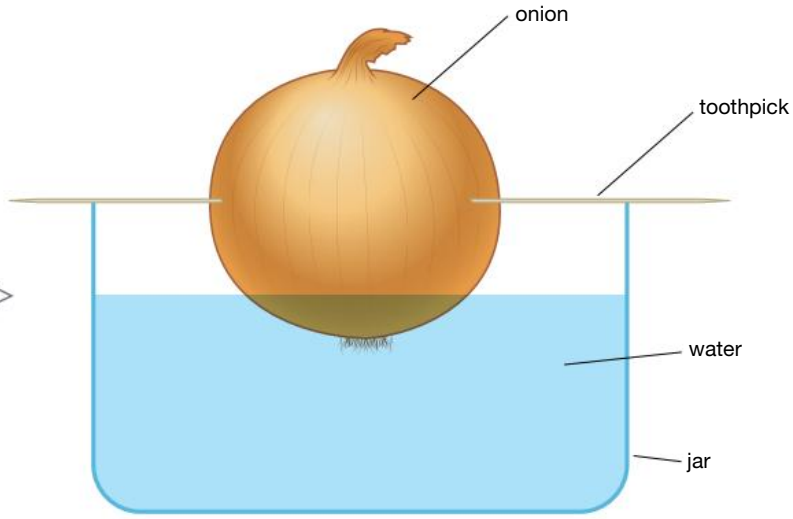
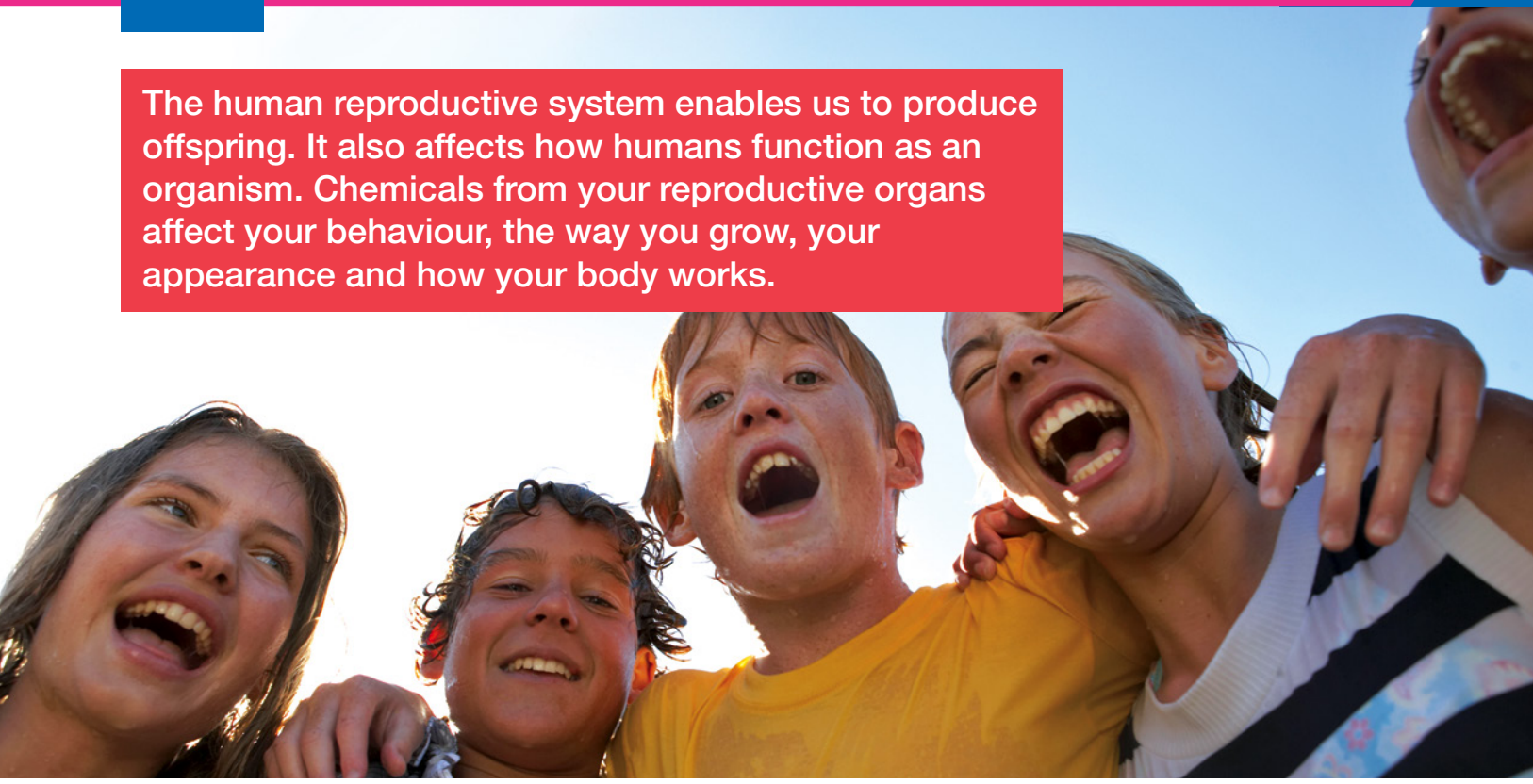


Figure 4.2.14

4.3 The human reproductive system

The human reproductive system enables us to produce offspring. 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. Its structure is shown in Figure 4.3.1.

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, then it is usually in this tube.

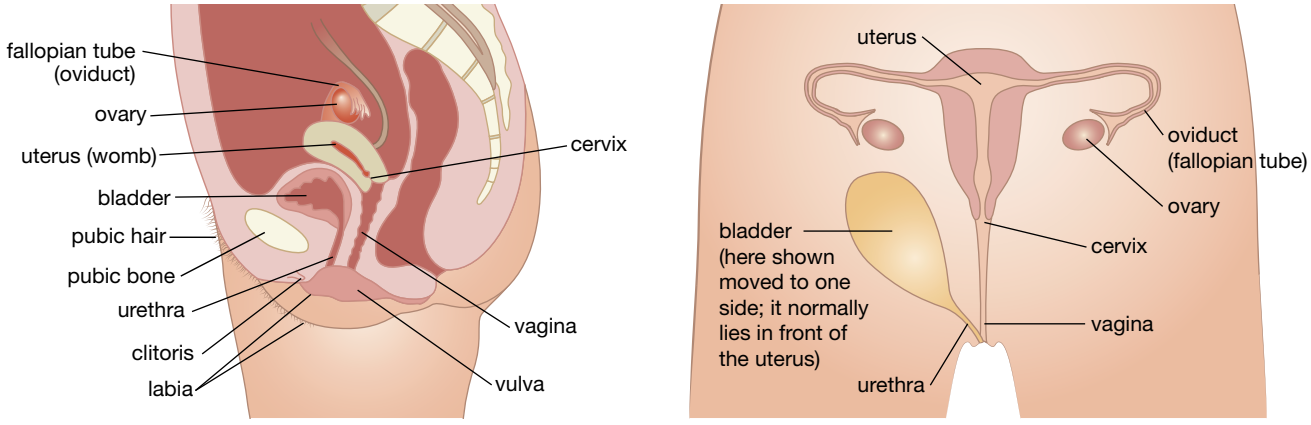


Figure 4.3.1 The human female reproductive system

The **uterus** (or **womb**) is a thick-walled muscular organ that is about 7 cm long and 5 cm wide. It has a lining that can change and become rich in blood vessels. A fertilised egg burrows into this lining. 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 **vagina** is where the male penis is 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 males and females is controlled by chemicals called **hormones** that are produced in the body and travel around in the bloodstream. One female hormone (known as FSH) causes the follicles to mature. A follicle is shown in Figure 4.3.2. Another hormone (known as LH) makes the egg burst out of the follicle. This is called **ovulation**.

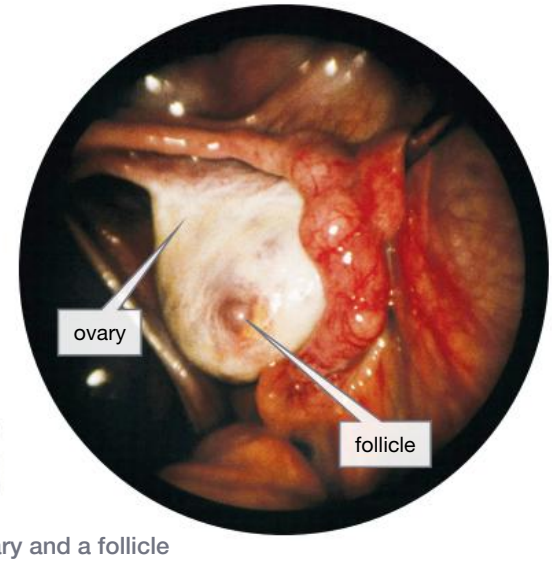


Figure 4.3.2 An ovary and a follicle starting to swell

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 4.3.3.

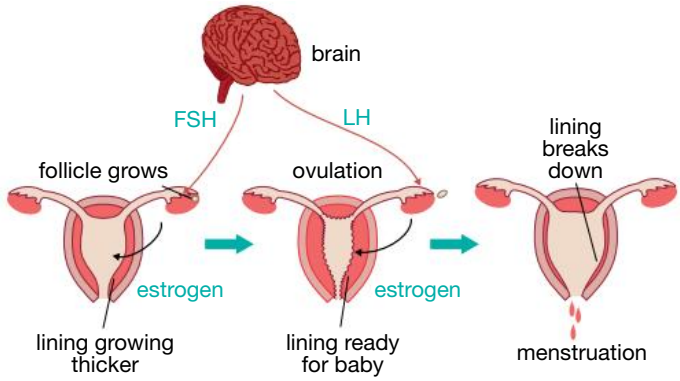


Figure 4.3.3 The menstrual cycle is controlled by hormones.

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 **menstruation**, commonly known as a **period**.

Menstrual cycles

Menstrual cycles can vary greatly in length, especially when they first begin. Once it becomes fairly regular, a typical menstrual cycle is about 28 days. In this 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 4.3.4. 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 usually stays the same is the time from ovulation to the start of menstruation. This is generally 14 days.

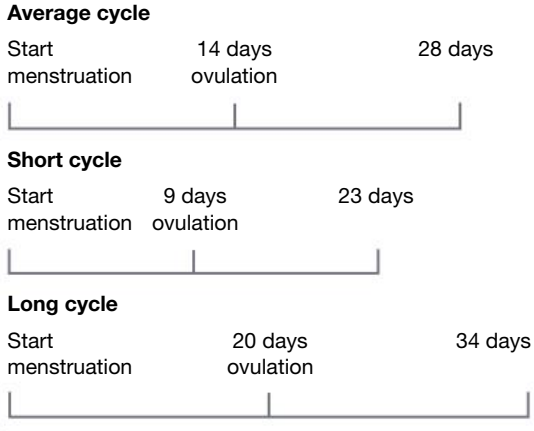


Figure 4.3.4 The menstrual cycle can vary in length.

WORKED EXAMPLE

Menstrual cycles

Problem

In a 25-day cycle, on what day would ovulation most likely occur?

Solution

Time from ovulation to menstruation is usually 14 days.

Therefore 25 – 14 = 11 days

So ovulation would have been on day 11 of the 25-day cycle.

Practice

N

Calculate the day on which ovulation would occur in a:

a 30-day cycle

b 24-day cycle.

The male reproductive system

The role of the male reproductive system is to produce and deliver sperm. Its structure is shown in Figure 4.3.5.

Sperm are produced in the **testes**. There are two testes, which are also known as testicles. A single testicle is called a testis. The testicles hang outside the body in a sac called the scrotum.

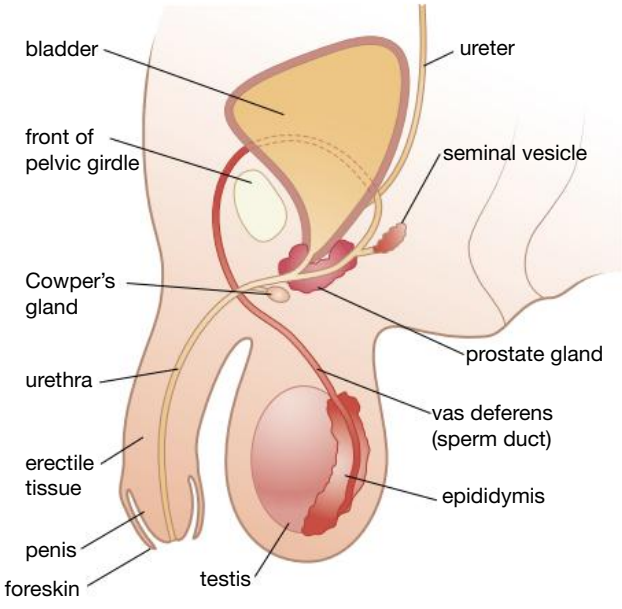


Figure 4.3.5 The human male reproductive system

Sperm are killed or deformed if they become too hot. It is cooler in the scrotum than inside the body, which helps to prevent the sperm being killed or deformed. Millions of sperm are produced in tubes inside the testes. Then they are squeezed into a coiled tube called the epididymis. There is one epididymis on the outside of each testis. Sperm mature inside the epididymis.

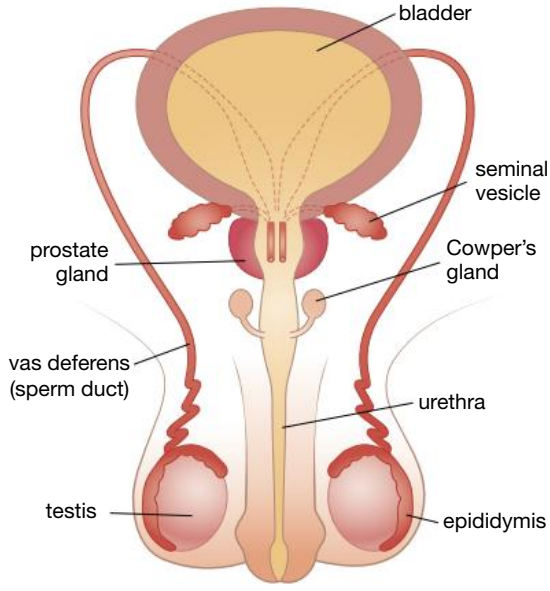
To get to the outside of the body, sperm are squeezed by muscles lining the epididymis. They are pushed into a hollow tube about 45 cm long called the **sperm duct**, or **vas deferens**. This tube has muscles in its walls that squeeze the sperm along. On the way, fluid is added to the sperm from glands 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. Urine cannot pass through at the same time as semen.

4.5

Acids, bases and reproduction

SciFile

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.



Puberty

Puberty is the time in a person's life when they become sexually mature and able to reproduce. 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 around 12 years of age on average, while boys are generally about 13. However, every person's body is different—you reach puberty when your 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 changes, 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.

These changes are shown in Figure 4.3.6.

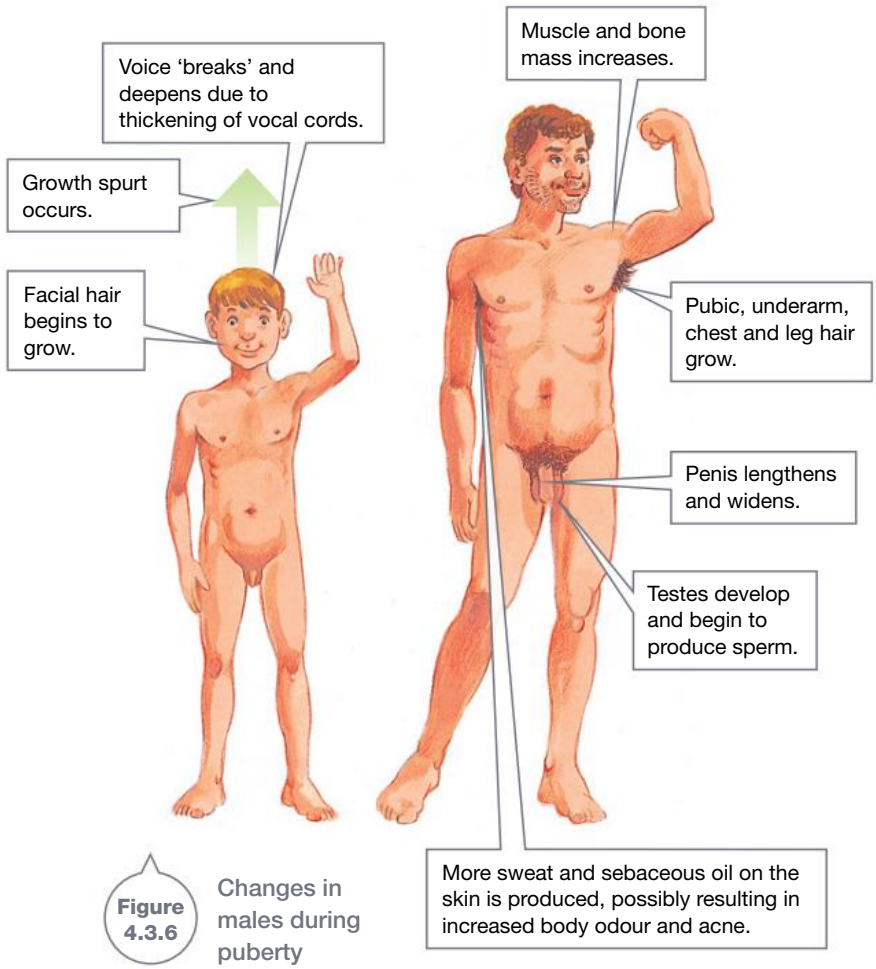


Figure 4.3.6 Changes in males during puberty

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 changes such as:

- the breasts begin to enlarge (generally the first sign of puberty)
- hair growth 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 4.3.7.

Prac 1 p161 Prac 2 p161 4.6

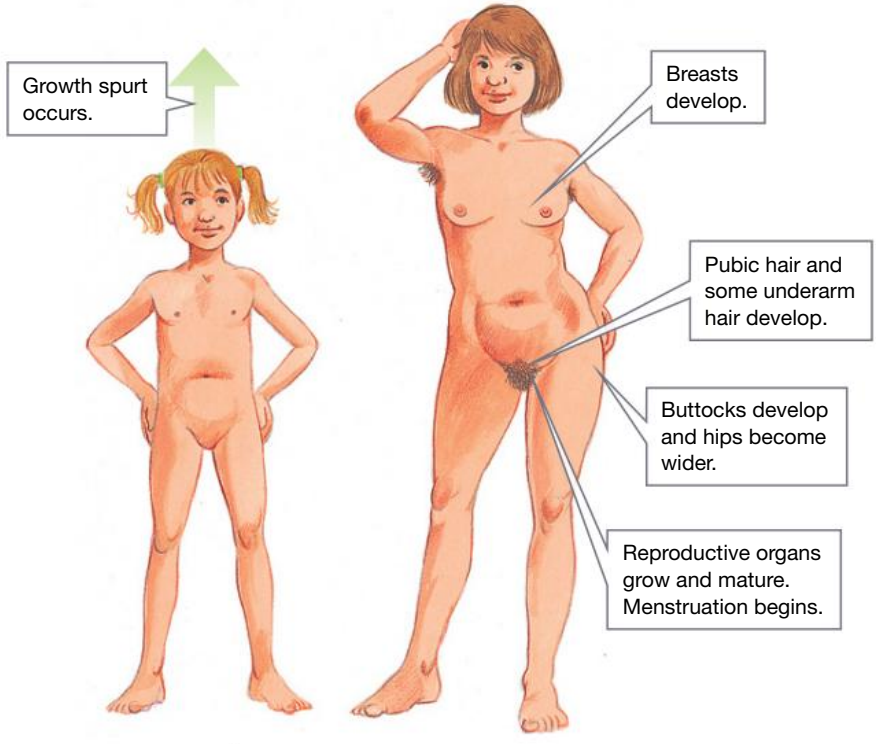


Figure 4.3.7 Changes in females during puberty

4.3 Unit review

Remembering

1 **Name** the part of the female reproductive system that:
   - a produces eggs
   - b keeps the uterus closed during pregnancy
   - c carries the egg to the uterus
   - d is where the baby grows and develops until birth
   - e is the site of fertilisation.

2 **Name** the part of the male reproductive system that:
   - a produces sperm
   - b carries sperm to the penis
   - c holds the testes
   - d places sperm in the vagina
   - e adds chemicals to the semen.

3 **List** the changes in males and females during puberty.

4 **State** on what day of a 28-day menstrual cycle a woman would ovulate.

Understanding

5 **Explain** what the menstrual cycle is.

6 **Explain** the role of hormones in the menstrual cycle.

7 **Define** the following terms. L
   - a ovulation
   - b period
   - c puberty

8 **Explain** why the testes are held in a sac outside the abdomen.

Applying

9 A particular woman reaches puberty at age 12 and produces one egg each month from puberty until she is 50. **Calculate** how many eggs she releases in her lifetime. N

10 **Calculate** when menstruation occurs if ovulation occurs at day 23. N

11 **Calculate** the time from menstruation to ovulation in a 36-day cycle. N

12 a **Identify** the male reproductive part that has functions in both the reproductive and excretory systems
   - b **Describe** its role in each.

13 Figure 4.3.8 shows how the proportions of a human body change as they grow. N
   - 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.

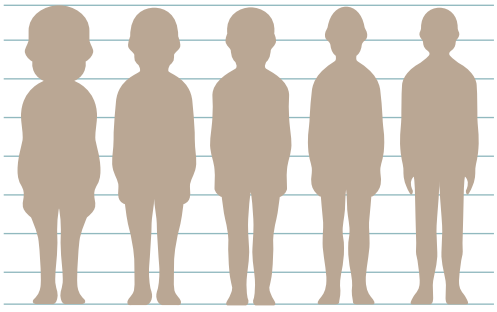


Figure 4.3.8

Analysing

14 **Compare** ova, ovulation and oviduct.

15 **Compare** ovaries and testes in:
   - a their position
   - b the number of gametes produced.

Evaluating CCT

16 Swelling of the prostate gland in a man often makes it difficult to urinate. **Propose** a reason why.

Creating CCT

17 **Construct** diagrams of the female and male reproductive systems from the front. Label each organ with its function.

Inquiring

Research how human twins are formed. Find:

- how fraternal twins differ from identical twins and conjoined twins
- how cell division influences the type of twins formed
- the percentages of fraternal twins, identical twins and conjoined twins born in Australia.

Present your research as a pamphlet to be distributed at family planning clinics.

4.3 Practical investigations

1 My changing body

Purpose

To identify the changes that occur during puberty.

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.
3. Describe the changes that occur to each body part as puberty proceeds.
4. At the bottom of your page, write down what causes these changes. Be as specific as possible, giving correct terms if possible.
5. 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.
6. When all the outlines in the class are up, wander around the gallery. Read all the posters and then place a sticky note on the one you think best represents all the changes that occur during puberty.
7. Tally the scores and identify which poster won.

Practical review

1. **Evaluate** the poster that won and **identify** what made it particularly good at explaining the changes that happen during puberty.
2. **Evaluate** your poster and suggest improvements you could make to it.
3. **Summarise** in 25 words what causes the changes during puberty.

STUDENT DESIGN

2 Reproduction models

Purpose

To construct models of the male and female reproductive systems.

Materials

- As chosen by students

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Construct a model of the male or female reproductive system. Your model should:
   - be 3D
   - have cutaway sections to show what the insides of different parts look like
   - clearly show its structure
   - be able to be suspended from string or cotton, or stood on a stand.
2. When all the models are complete, display them around the room.
3. Observe the other models and decide which ones you think are the best.

Practical review

1. **Explain** why you chose a particular model as the best.
2. **Evaluate** your model and suggest improvements.

4.4 Pregnancy

Before you were born, you spent almost 9 months in your mother's womb and were completely dependent on her for survival. In that time, all your organs such as heart, brain and lungs were formed, and eventually a whole new and unique individual was formed—you!

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. There are many different ways a sperm can be defective. Some are shown 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. You can see this happening in 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. The egg is now fertilised.

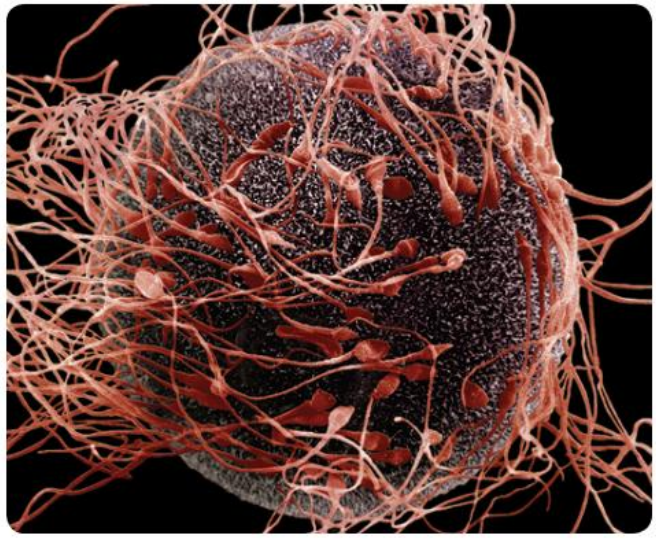


Figure 4.4.2 Sperm swarm around an egg, trying to penetrate its surface.

Implantation

The first cell of the new individual is called a zygote. The zygote begins to divide as it travels 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**. The woman is now pregnant.

Embryonic development

A baby takes about 38 weeks to develop from fertilisation to birth. For the first 8 weeks 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. This is because any chemical that can affect cells could damage the embryo. So, too, do some illnesses, such as rubella. These can cause deformities such as missing limbs and can also cause brain damage. In Figure 4.4.4 you can see an embryo.

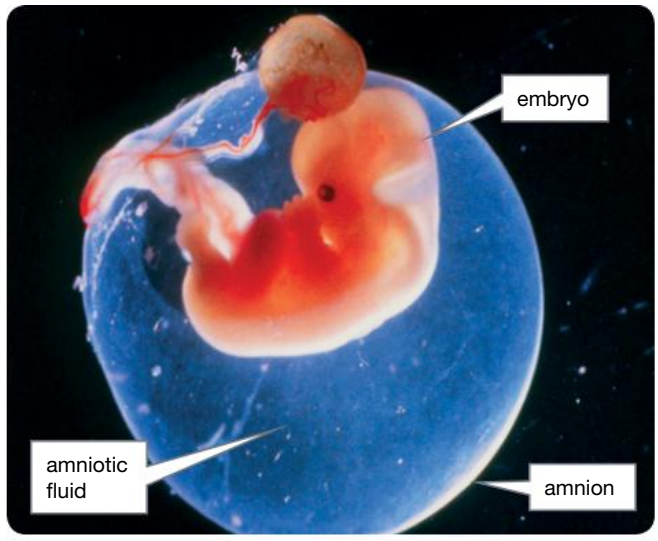


Figure 4.4.4 Major tissues, organs and systems form during the early development of the embryo. This image shows an embryo floating in its protective amniotic fluid.

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.

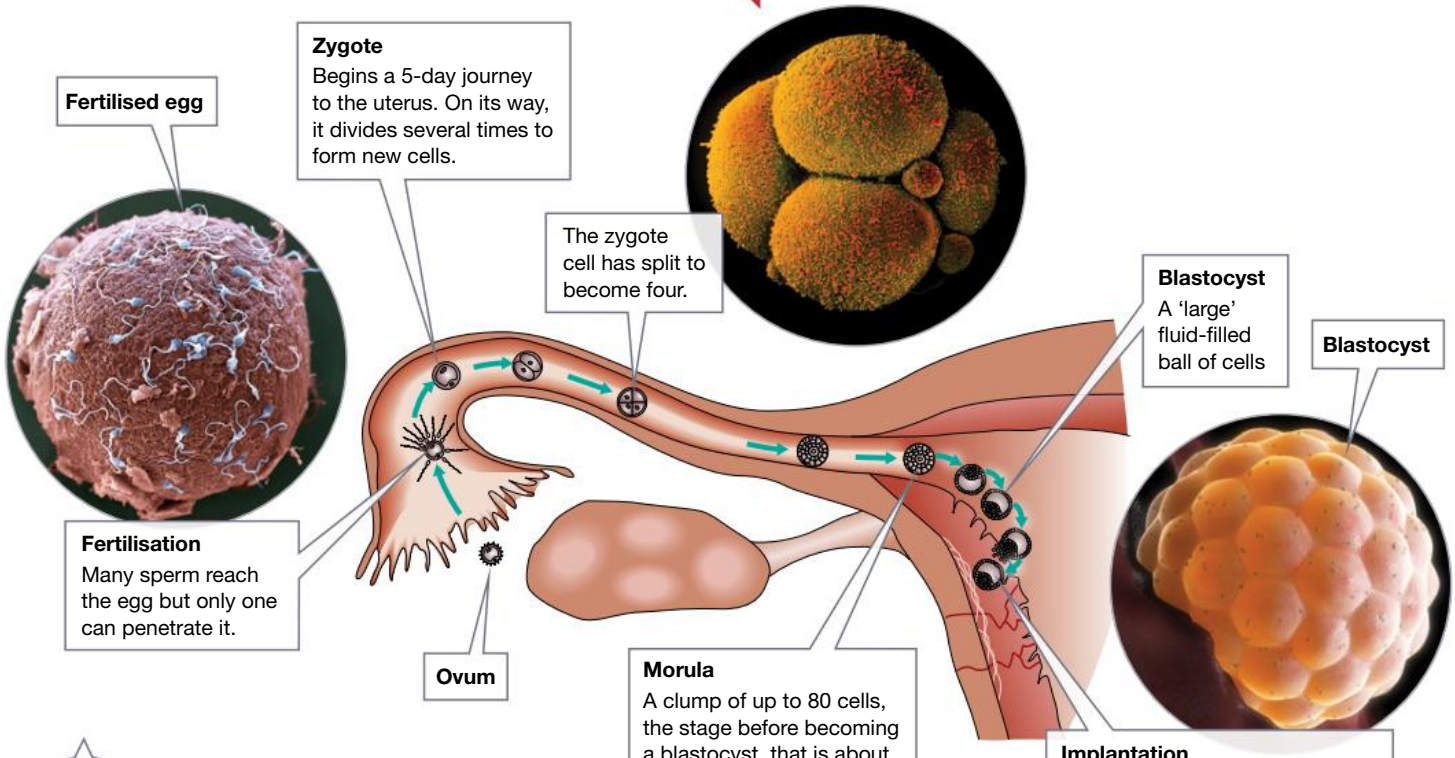


Figure 4.4.3 The sequence of steps from ovulation to implantation takes about 5 days.

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, 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.

Belly buttons

SciFile

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.

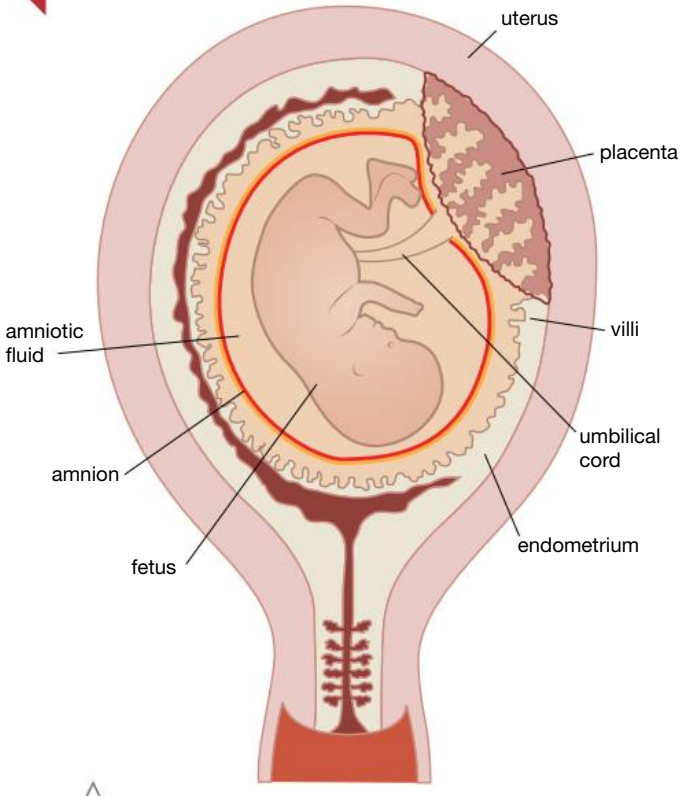


Figure 4.4.5 The umbilical cord connects the baby to the placenta.

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.

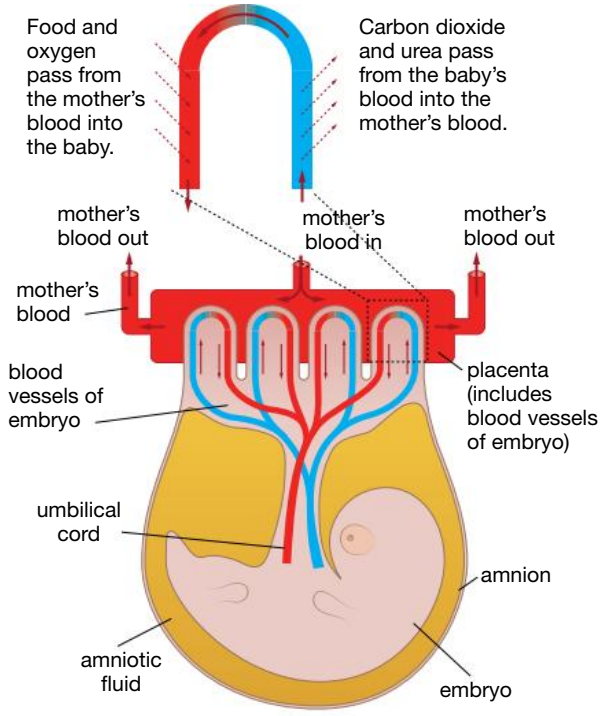


Figure 4.4.6 The placenta allows exchange of materials between the mother and the developing baby.

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, because menstrual cycles vary in length, doctors can't be sure when ovulation actually occurred. So, they usually talk about 'weeks pregnant'. These are counted from the start of the last menstrual cycle. Since this is 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 referring to the weeks since the last menstrual period.

4.7

Fetal development

Most of the major organs and systems have been formed when the embryo is about 9 weeks old. Its external appearance looks more human-like. It increases in size and the organs mature so they can function at birth. The developing baby is now classified as a **fetus** (also spelled foetus.)

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**.

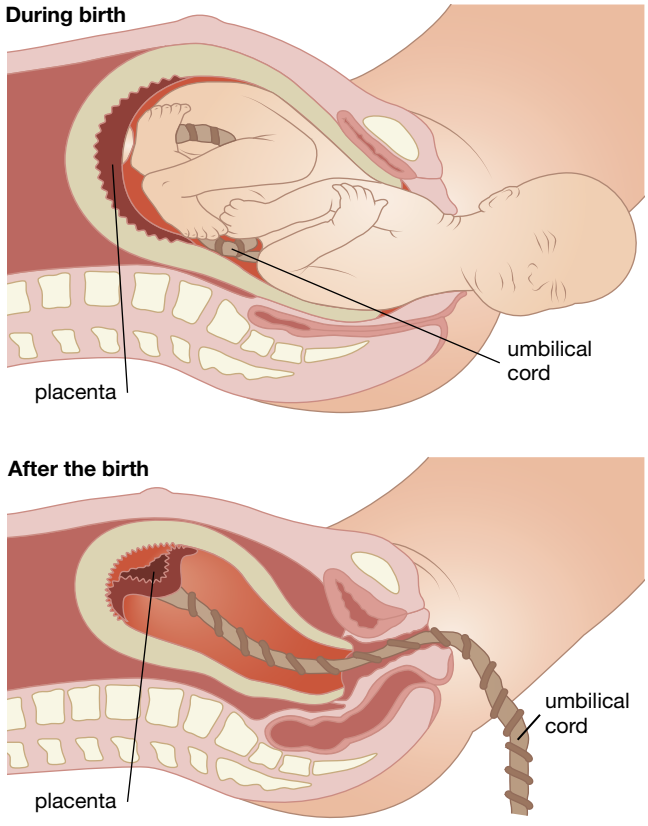


Figure 4.4.7 Labour involves birth of the baby and expulsion of the afterbirth.

4.8

Pregnancy tests

SciFile

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.

Big baby

SciFile

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.

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

DRUGS AND PREGNANCY

Research over the past fifty years has shown that some drugs and chemicals can damage the developing baby during pregnancy.

Figure 4.4.8 Alcohol and smoking can do great harm to a developing fetus.

THALIDOMIDE

In the 1960s Australian scientist Dr William McBride noticed that a large number of children were being born with birth defects such as missing or shortened limbs, like those of the girl shown in Figure 4.4.9. When Dr McBride investigated the medical histories of the mothers, he found that they had been taking a pharmaceutical drug called thalidomide. The drug was prescribed by doctors to help relieve nausea and vomiting during pregnancy, symptoms called morning sickness. Further research by Dr McBride showed that thalidomide crossed the placenta and entered the embryo as it developed. It affected cell division, resulting in missing or deformed limbs. Thalidomide was then banned for use by pregnant mothers.

Under certain circumstances, thalidomide is still an effective drug. It has been shown to:

- slow cell division in cancer cells, preventing their spread
- help cure multiple myeloma, a cancer of the white blood cells
- ease the pain and halt the progression of leprosy, a bacterial disease that damages nerves, causing weakness and inability to use arms and legs.

Figure 4.4.9 Deformed and shortened arms and legs are typical symptoms of thalidomide taken by the mother during pregnancy.

In most of these cases, thalidomide is prescribed by specialist doctors to ensure that it is not taken by pregnant women.

Despite this, it is estimated that there have been over 7000 cases of thalidomide-affected babies born in Brazil in the past twenty years. Some of these cases are because doctors have prescribed thalidomide to pregnant women who have leprosy. Brazil is the world's largest user of thalidomide, with over 300 000 leprosy patients in that country.

ALCOHOL

Drinking while pregnant can have consequences for the baby. Research has shown that alcohol crosses the placenta and that high alcohol intake can cause a condition known as fetal alcohol syndrome (FAS). Babies born with FAS can have low birth weight, a smaller head, small eyes, flattened face and nose, and heart defects.

Children with FAS are affected for life and cannot be cured. FAS can result in serious problems such as:

- low intelligence, poor memory and learning difficulties (due to damage to the growing brain)
- behavioural problems such as attention deficit hyperactivity disorder (ADHD). However, not all ADHD is due to FAS
- increased risk of mental illness.

SMOKING

Research has shown that smoking damages both the mother and her unborn baby, because many chemicals from cigarettes can cross the placenta. Smoking can cause:

- death of the fetus in the womb
- miscarriage (expulsion of the fetus from the womb)
- premature birth
- slower growth and development
- increased risk of cleft lip and cleft palate
- lower birth weight
- twice the risk of sudden infant death syndrome (SIDS).

OTHER DRUGS

Many other legal and illegal drugs and chemicals have been shown to damage an unborn baby. These include:

- cocaine
- high doses of vitamin A
- some antibiotics.

Legal drugs such as antibiotics have warnings printed on their labels indicating whether there is a risk of damage to the unborn child if taken during pregnancy (Figure 4.4.10).

REVIEW

1 **Explain** how thalidomide causes birth defects.

2 **Propose** why a specialist doctor might give a patient thalidomide.

3 **Explain** how a fetus could be affected when a pregnant woman drinks a lot of alcohol.

4 **List** four permanent effects of fetal alcohol syndrome on children.

5 **Recommend** to pregnant women the approach they should take to smoking, alcohol and other drugs.

6 **Use** the information presented here to **demonstrate** how people can have different opinions on using a particular treatment to solve a health problem. CCT DD PSC EU

Prac 1 p169

Figure 4.4.10 An ultrasound allows doctors to check for any physical deformities or threats to the health of the fetus.

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. L
   - 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. N

10 If a zygote was definitely formed on 1 January, **calculate** the date when the baby should be born. N

Analysing

11 **Compare** the major features of an embryo and a fetus.

12 **Distinguish** between the placenta and the umbilical cord.

13 **Compare** the meaning of labour and birth.

14 **Distinguish** between fertilisation, implantation and pregnancy.

Evaluating CCT

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 CCT

18 **Construct** a diagram of a developing fetus and the uterus. Label each part on the diagram with its function in reproduction.

Inquiring

1 Research how new biological knowledge and new technology have helped improve the health of pregnant mothers and babies. In particular, find the:
   - benefits of ultrasound and amniocentesis
   - use of fetal transfusions
   - problems that high blood pressure during pregnancy can bring
   - methods used to control high blood pressure during pregnancy
   - effect of nicotine in pregnant mothers and development of asthma in their children.

   Present your findings as a digital slide show to run on the TV in a doctor's waiting room. ICT EU

2 Research warning labels for pregnant women on any five common drugs (pharmaceuticals) that may be in your medicine cabinet at home. Some typical drugs are aspirin, Panadeine®, Panadol®, ibuprofen (Nurofen®), Zyrtec® (or other allergy relievers). In particular:
   - take digital photos of the warnings (if you have a digital camera)
   - research the internet to find out why each warning is on the packet
   - explain why pregnant women should always read warning labels on packets.

   Present your research in digital form. ICT

4.4 Practical investigations

STUDENT DESIGN

1 Interview a mother

Purpose

To interview a mother about her experiences of pregnancy and the advice she received.

Materials

- paper and pen or recording device such as the video function on a mobile phone

Procedure

1. Design an interview with a woman who has been a mother—either your own mother, or someone you know. Scientists must always be ethical and so it is important that the woman agrees to participate freely. You need to find out what advice they received about pregnancy and birth before they occurred, and what they think of their experiences.
2. After compiling your list of questions, discuss them with another student to get their opinion on them. Check with your teacher that your questions are good ones.
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 your teacher. It would be best if you could actually talk to her and write out or record 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.

Hints

The first step is to think about the questions you should ask them, and write these down. Some examples are:

- 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?

Practical review

Assess what you have learnt in this activity, including any lessons that could help if you become a parent in the future.

4 Chapter review

Remembering

1 **Name** the following.
   - a the process of producing new cells during growth
   - 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

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 **Explain** the important role of the lining of the uterus in human reproduction.

6 a **Define** the term *repair*. L
   b **Explain** how it relates to body tissues.

7 **Outline** the role of cell division in growth and repair.

8 **Outline** the role of cell division in sexual and asexual reproduction.

Applying

9 **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

10 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

11 **Compare** the processes of sexual reproduction in plants and animals.

12 **Compare** the structures involved in sexual reproduction in plants and animals.

13 **Contrast** sexual and asexual reproduction.

14 **Compare** the roles of the male and female reproductive systems in humans.

15 **Compare** the changes in male and female bodies during puberty.

16 **Compare** cell division in sexual and asexual reproduction.

Evaluating CCT

17 **Justify** the argument that illegal drugs should not be taken during pregnancy.

18 a **Determine** whether you can or cannot answer the questions on page 137 at the start of this chapter.
   b **Assess** how well you understand the material presented in this chapter.

Creating CCT

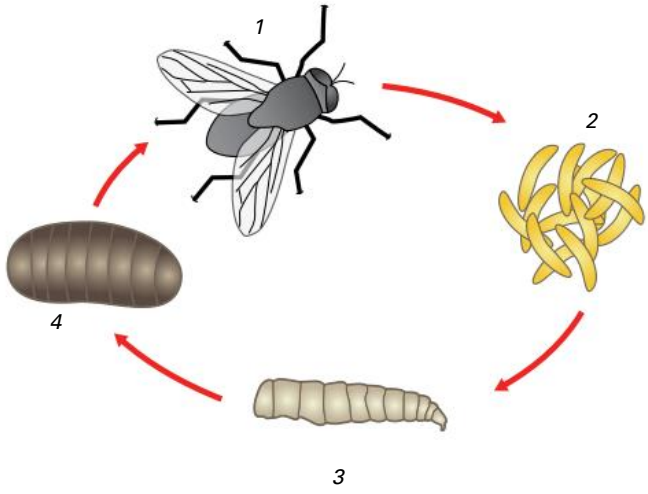
19 **Construct** flash cards about the male and female reproductive systems. Each card can be either a word or a diagram. Do some as words and some as diagrams. Write the answer on the back without your partner seeing it. Use the flash cards to test a partner. If you flash a word, they must tell you the function or meaning. If you flash a diagram, they must tell you the name. Take turns testing each other with your flash cards.

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

life cycle	growth
sexual reproduction	asexual reproduction
flower	cell division
reproductive system	repair
fertilisation	placenta
pregnancy	

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? CCT

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)? CCT

A 1 and 2 **B** 2 and 3
C 3 and 4 **D** 4 and 1

Q3 Bats are like humans in that they are placental mammals. Which of the following should occur in the life cycle of a bat? CCT

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? CCT

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? CCT

A pair 1 **B** pair 3
C pair 4 **D** pair 5

Q6 The tables below show the names of four processes (numbered 1 to 4) that occur in humans, and a description of events (numbered i to iv). CCT

Process number	Name of process
1	Growth
2	Reproduction
3	Repair
4	Fertilisation

Event	Description of event
i	Sex cells join
ii	New cells form
iii	New individul forms
iv	New cells replace those that die

Identify which of the following correctly matches the name of a process with the event it describes.

A 1 – i **B** 2 – iv
C 3 – iii **D** 4 – i

Glossary

Unit 4.1 L

Cell division: process of a cell dividing to form new cells

Development: changes in body form and shape in an organism's life

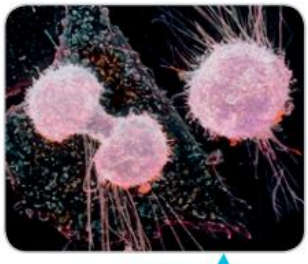
Growth: an increase in body size

Life cycle: the changes that happen to an individual from its formation until it has produced offspring

Mitosis: the process of the cell nucleus dividing into two new nuclei

Repair: the process of fixing damaged body tissues

Reproduction: the process of parents producing new individuals, or offspring



Mitosis

Unit 4.2 L

Anther: the part of the flower that produces pollen

Asexual reproduction: reproduction that requires only one parent; does not involve sperm and eggs

Copulation: two individuals joining to allow gametes to become fertilised

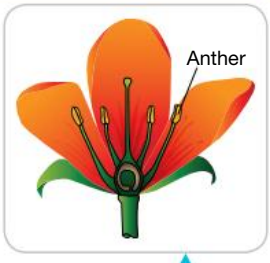
Development: the process by which the cell formed by fertilisation divides and develops to begin to look like an adult

Embryo: a developing offspring at a very early stage of development

Fertilisation: the joining of gametes

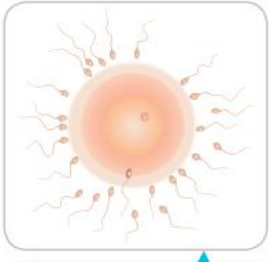
Flower: the reproductive structure in plants that makes male sex cells and female sex cells

Fruit: the structure that the ovary of a flowering plant turns into as the seeds ripen



Anther

Asexual reproduction



Fertilisation

Gametes: reproductive cells; sperm in males and eggs in females

Germination: when the young growing plant sprouts out of the seed

Hermaphrodite: an individual with both male and female sex organs

Meiosis: process that forms sex cells by division of a cell nucleus into four nuclei

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

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

Unit 4.3 L

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

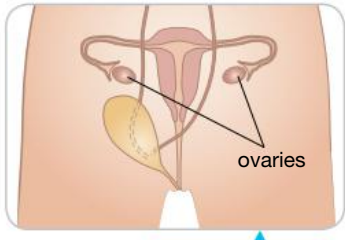
Hormones: chemicals made in the body to control reproduction and physical characteristics

Menstrual cycle: regular monthly changes in the hormones and reproductive organs of adult females

Ovaries: organs that produce the eggs or ova

Ovulation: the egg bursting out of the follicle

Period (menstruation): 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

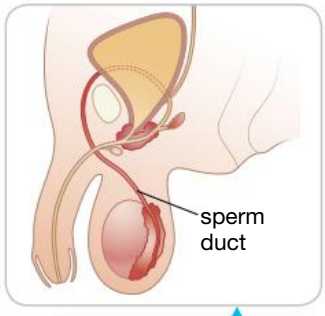
Semen: a mixture of sperm and other fluid released from the penis

Sperm duct (vas deferens): tube carrying sperm from the testes to the urethra

Testes: male organs that produce 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; also acts as the birth canal down which the baby passes



Sperm duct

Unit 4.4 L

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

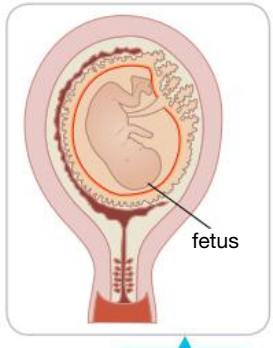
Copulation: two individuals joining together for sexual reproduction

Ejaculation: process of sperm being squeezed out of the penis

Embryo: early stages of development before the major organ systems are formed

Fetus: stage of development when most of the major organs and systems are present

Blastocyst



Fetus

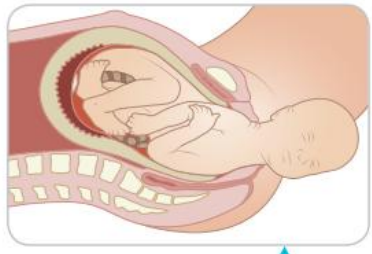
Gestation: the time period from fertilisation to birth

Implantation: process of the blastocyst burrowing into the lining of the uterus

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


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 in my own 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 Energy

Have you ever wondered...

- why the buckle on a seatbelt can feel hotter than the belt?
- why car engines get hot?
- what the energy stars on a new refrigerator mean?
- what insulation does in a house?
- why electricity needs a circuit to flow around?

After completing this chapter students should be able to:

- identify objects that possess kinetic energy and potential energy
- describe the transfer of heat energy by conduction, convection and radiation
- investigate everyday situations that involve energy transformation
- identify that most energy conversions are inefficient, leading to the production of heat CCT
- research ways in which the efficiency of devices has been increased CCT S
- discuss the implications of the development of devices that have better efficiency and release less heat CCT EU
- explain electricity as energy transferring around a simple circuit
- construct and draw simple circuits

ADDITIONAL

- outline the history of the development of technologies such as circuitry to microcircuitry
- investigate simple machines such as levers, pulleys, gears or inclined planes
- describe the scientific principles used in traditional technologies of Aboriginal and Torres Strait Islander peoples. AHC

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

YES

Can you release energy by mixing two substances together?

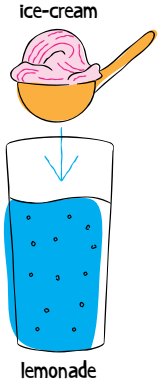
SAFETY!
Do not eat food prepared in the science laboratory.

Collect this …

- lemonade
- ice-cream
- spoon

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 noise or light, or to change an object's shape. Energy makes things happen.

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.

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

WORKED EXAMPLE
Measuring 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

Practice

N

1 **Calculate** how many joules of energy are contained in:
   a 6 kJ
   b 1.8 MJ

2 **Calculate** how many kilojoules of energy are contained in:
   a 4000 J
   b 16 400 J

Forms of energy

As Figure 5.1.1 shows, there are many different forms of energy.

- **Kinetic energy** is the energy of movement. Anything that moves has kinetic energy. The faster an object moves, the more kinetic energy it has.
- **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** is produced by power stations, solar cells, batteries and lightning. Electrical energy powers your TV, computer, microwave and toaster.

Figure 5.1.1 All these common forms of energy make things happen.

INQUIRY

science 4 fun

Creepy crawly

YES

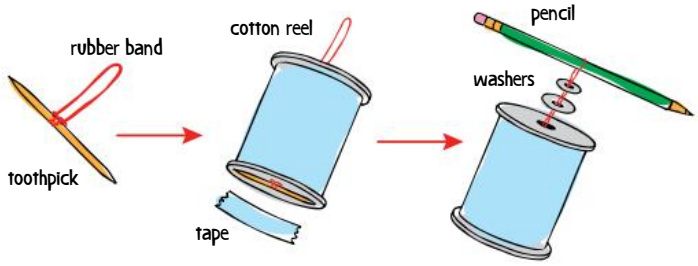
What happens when you twist a rubber band?

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 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 tiny atoms that make up all matter. Nuclear energy is released in a nuclear power plant, when a nuclear bomb explodes, and inside the Sun. Nuclear reactions produce heat and light.

Prac 1 p185 5.1

Figure 5.1.3 Objects that store potential energy may release the energy in different forms at a later time. When stored energy is released, things happen.

INQUIRY science 4 fun

Making a spinning snake

Can you see the effect of heat transfer?

NO

Collect this ...

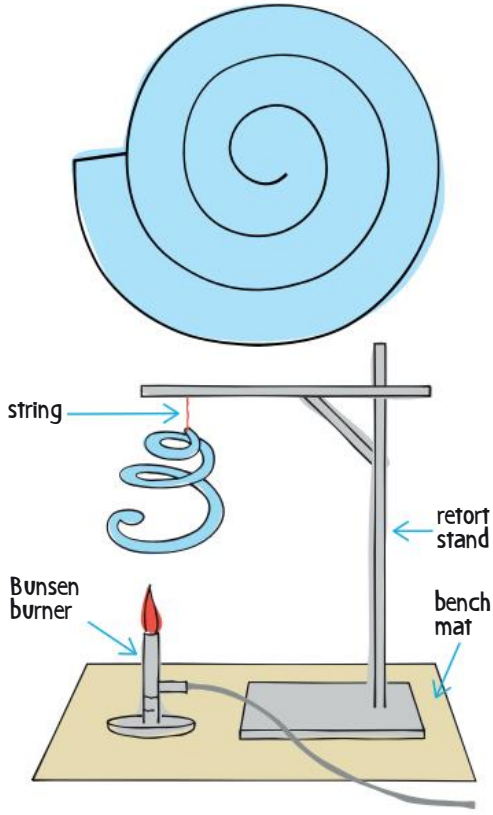
- aluminium pie dish
- retort stand and clamp
- Bunsen burner and bench mat
- 15 cm of string

SAFETY

Be careful not to touch the spiral just after it has been heated.

Do this ...

1. Carefully cut a spiral shape from an aluminium pie dish
2. Make a small hole in the tip of the spiral and tie some string from this to a clamp
3. Position the Bunsen below the spiral and light it, and adjust to get the blue flame.



Record this ...

Describe what happened to the spiral.

Explain why you think this happened.

Energy transfer

Energy can be passed from one object to another. This is known as **energy transfer**. For example, when you kick a ball, kinetic energy from your foot is transferred to the ball, causing the ball to move. You can see this in Figure 5.1.4.

Figure 5.1.4 Kinetic energy is transferred here from the person's foot to the ball.

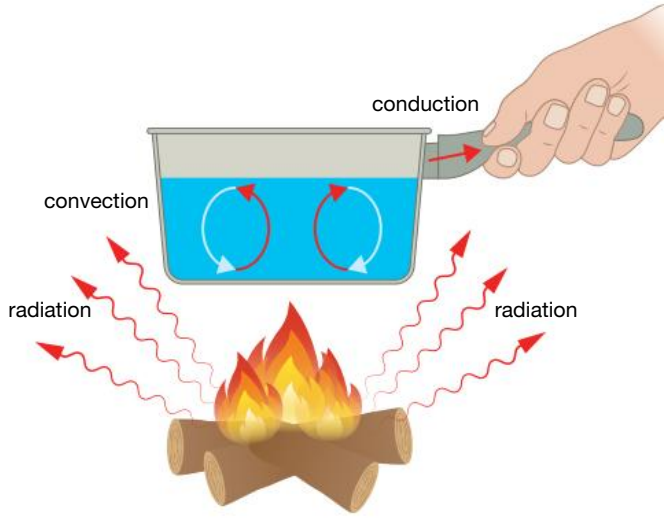


Figure 5.1.5 Radiant heat is released in waves from the fire. The liquid in the saucepan is heated by convection currents. Heat from the saucepan handle is transferred by conduction to the person holding it.

Heat transfer

Kinetic energy is not the only type of energy that can be transferred. When you stand in front of a heater, heat energy is transferred from the heater to you, warming you up. Heat energy can be transferred in three ways:

- conduction
- convection
- radiation.

Often heat is transferred using a combination of these methods. Figure 5.1.5 shows an example.

Conduction

When you consume hot soup, you feel the heat of the soup as it warms your mouth and passes down your throat. Heat has been transferred from the soup to you. This type of heat transfer is called conduction. **Conduction** happens between two objects that are in contact. Heat transfers from the hotter object into the cooler one, until they are both the same temperature. Conduction explains why you get burnt if you touch a hot tripod or stovetop. Conduction also explains why a can of lemonade feels cold. The can feels cold because heat transfers away from your warm hand into the metal of the can and the cold drink inside. In this way, conduction makes your hand get colder and the can and lemonade warmer.

Prac 2 p186

Convection

You don't need to touch a heater in a room to feel heat transfer. This is because heat can flow through liquids and gases. This process is called **convection**. It is convection that causes heat to rise, making it hotter near the ceiling than down on the floor, and it is convection that spreads heat from ducted heating vents through rooms of a house. Convection also spreads heat through soup being heated in a saucepan.

Radiation

Heat radiates (spreads outwards) from any hot object. This type of heat transfer is called **radiation**. Radiant heat is transferred as a wave that can travel even through the vacuum of space. This explains why you feel the heat of the Sun when you are outside. However, radiation is easily blocked. If you stand in the shadow of a tree it feels much cooler, because the radiant heat of the Sun cannot get to you.

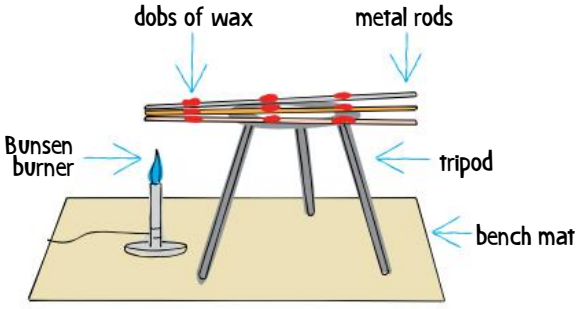
When you are warmed by a camp fire, you feel the fire's radiant heat. The air around the fire also warms up due to convection. If you placed a marshmallow in the flames it would burn as the result of heat conduction.

INQUIRY

science 4 fun

Heat transfer

How is heat energy transferred?



Collect this …

- three rods of different metals (e.g. iron, copper and steel)
- Bunsen burner, tripod and bench mat
- candle
- timer
- matches

SAFETY

The metal rods will stay hot for a long time, so do not touch them until well after the Bunsen burner has been turned off.

Do this …

1. Set up the equipment shown, using a lit candle to drip 3 dobs of wax on each rod.
2. 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.
3. From your observations, identify the rod that was best at transferring heat.

Record this …

Describe what happened.

Explain why you think this happened.

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 5.1.6 shows some energy transformations using an **energy flow diagram**.

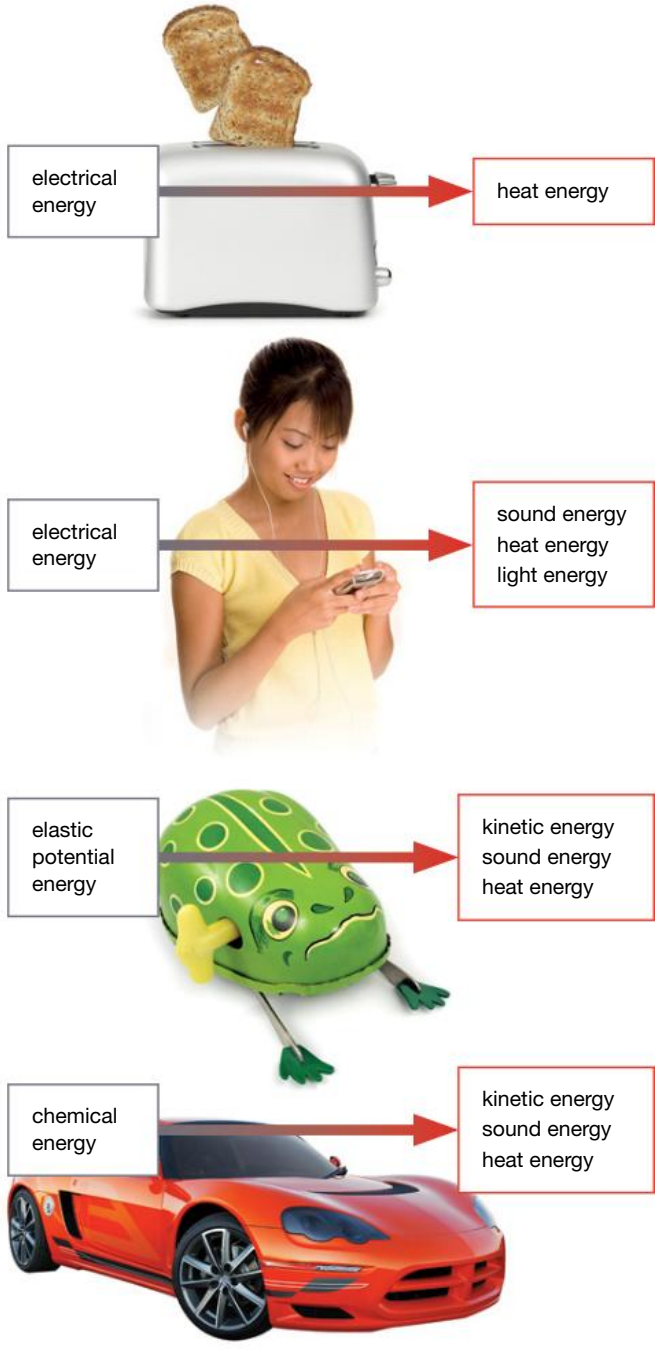


Figure 5.1.6 Energy transformations are shown using an arrow. Here are some typical energy transformations.

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 heat energy and the sound of glass smashing.

A solar cell converts light energy into electrical energy. This energy can then be converted into many different types of energy. Figure 5.1.7 shows an energy flow diagram for the energy changes involved in using a solar-powered electric 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. The ball's kinetic energy has instead 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.

Prac 3 p187 Prac 4 p188 5.2

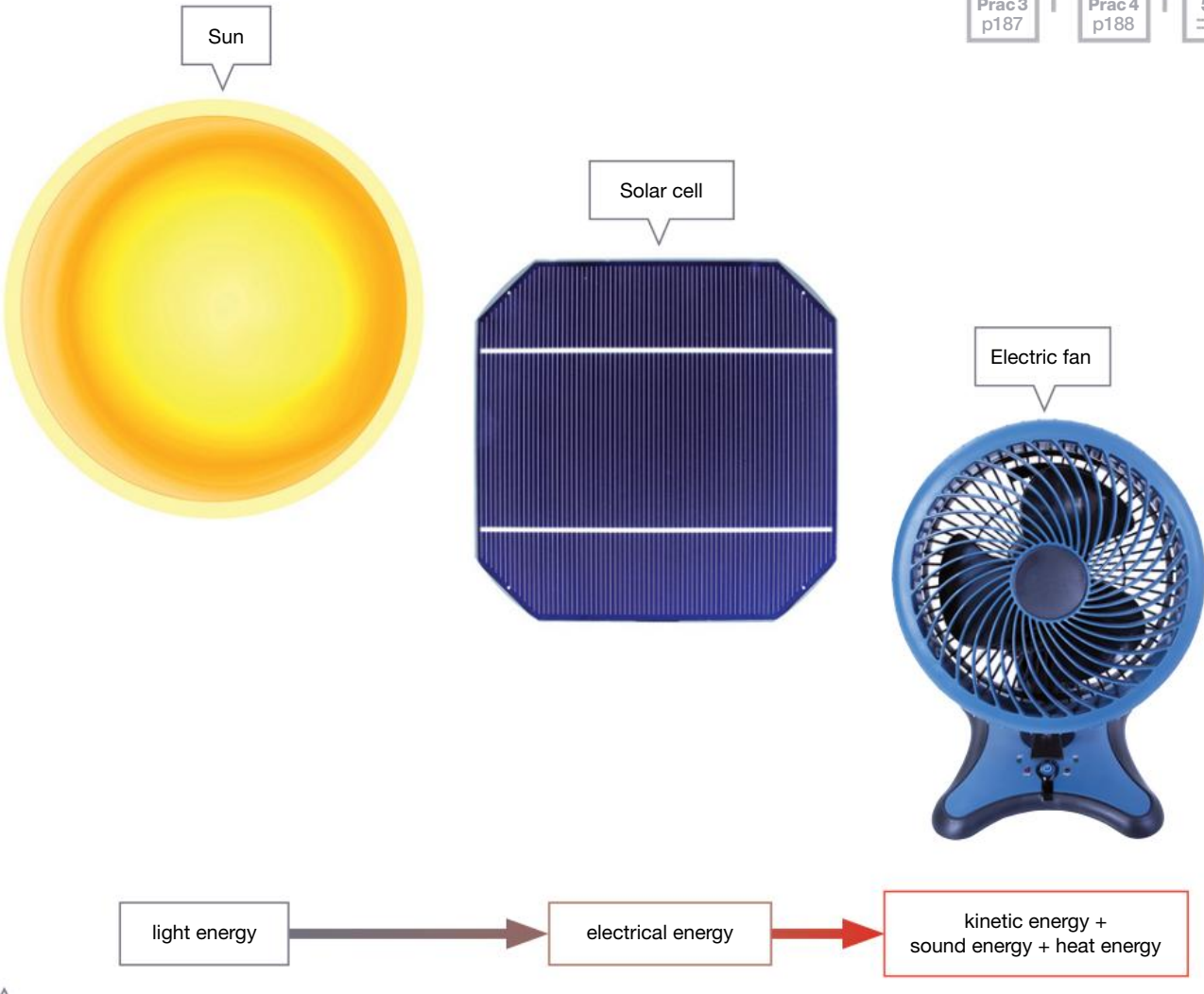


Figure 5.1.7 A solar cell converts light energy from the Sun directly into electrical energy. This electrical energy is converted into the kinetic energy of the blades, as well as sound and heat energy produced by the solar fan.

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

4 **List** the three ways that heat can be transferred.

Understanding

5 **Explain** why the energy in food is usually stated in kilojoules rather than joules.

6 a **State** the law of conservation of energy.
b **Explain** what this law means, using an example.

7 Petrol, kerosene and oil are all types of fuel. **Clarify** which type of energy these fuels possess.

Applying

8 **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.

9 **Identify** the *major* method of heat transfer in each of the following situations.

a Taylah boils a kettle of water to make a cup of tea.
b Mein sits on a deckchair by a pool and feels the Sun's heat.
c Emmaline opens the metal gate at the front of her house and feels that the gate is hot.

10 **Calculate** how many joules of energy are in: N

a 3 MJ
b 7500 kJ

11 **Calculate** how many megajoules would be in these quantities: N

a 2 500 000 J
b 5000 kJ

12 **Identify** the types of energy that caused the changes in the:

a 'Making spiders' science4fun on page 176.
b 'Creepy crawly' science4fun on page 178.

13 Your body needs a source of energy. **Use** Figure 5.1.8 to **list** four different ways that the chemical energy in food can be used by your body.

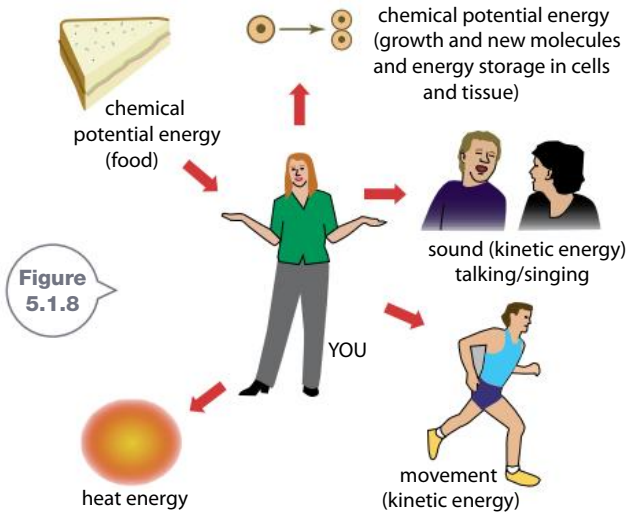


Figure 5.1.8

14 **Use** your knowledge of energy transformations to match the situations a–d below with the appropriate energy transformations i–iv.

a A girl toboggans down a slope.
b You ride a bike.
c A wind-up toy car travels across the floor.
d 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

5.1 Unit review

Analysing

15 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

16 a **Identify** which type of heat transfer is occurring in the science4fun activities 'Making a spinning snake' on page 179 and 'Heat transfer' on page 181.

b **Compare** these two types of heat transfer.

Evaluating CCT

17 For each pair of objects shown in Figure 5.1.9:

- **i** **identify** which type of energy they possess
- **ii** **identify** which (A or B) has more energy
- **iii** **justify** your response.

a

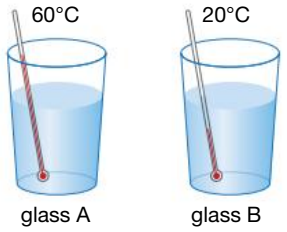
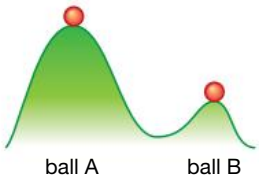
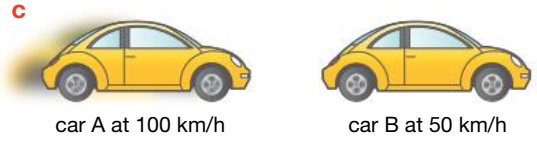


Figure 5.1.9

b



c



Inquiring

1 Research the approximate number of joules of energy contained in a:

- litre of full-cream milk
- litre of petrol
- litre of oil
- kilogram of coal
- kilogram of wood.

Present your findings as a column graph that shows the energy content of these substances.

2 Find the website of one of your favourite fast food chains on the internet.

- Select a typical meal and drink that you may eat at this restaurant.
- State the energy content of each of the foods you have listed.
- Add these together to produce a total kilojoule count for this meal.
- Name a sport or leisure activity that you enjoy.
- Search the internet to find an estimate of the number of kilojoules per hour your body burns up while conducting this exercise.
- Use this figure to estimate how many hours of this exercise it would take to burn off the kilojoules in the meal that you have selected.
- Suggest a reason why fast food is recommended to be an occasional treat in a balanced diet.

Present your findings as a set of answers to the above tasks.

3 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.

Present your findings in digital form. ICT

5.1 Practical investigations

1 Energy makes things happen

Purpose

To observe how different types of energy can cause a change.

Materials

- sparkler
- beaker half-filled with soil
- matches
- torch
- tennis ball
- rubber popping ball
- 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.

Stand clear of the popping ball before it releases.

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. Turn a rubber popping ball inside out and place it on a bench. Observe.
6. Peg a damp piece of cloth to a coat hanger. Blow warm air from a hair dryer over the cloth.

Results

Record all observations in your Results table.

Situation	Type of energy that caused the change	Changes you observed
A sparkler burns.		
A torch is turned on.		
A tennis ball falls.		
A popping ball pops.		
Warm air is blown over a damp cloth.		

Practical review

1 a The sparkler, the torch, the tennis ball and the popping ball 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.

3 **Construct** a conclusion for your investigation.

2 Investigating heat

Some materials are better conductors of heat than others. To keep a hot drink warm, you would try to choose a cup made from a material that is a poor conductor of heat. In this way, your drink will lose minimal heat. A poor conductor is a good insulator. It insulates the drink, stopping its heat from transferring to its surroundings.

Purpose

To compare how effectively different substances conduct heat.

Hypothesis

Which material do you think will be the poorest conductor of heat and so the best insulator—metal, polystyrene or ceramic? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- supply of hot water
- polystyrene cup
- metallic mug
- ceramic coffee mug
- thermometer or temperature probe and data logger

SAFETY

A risk assessment is required for this investigation. Be careful when handling hot liquids.

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

1 Plot a line graph showing the temperature of the water in the cup over 10 minutes.

2 On the same set of axes, use different colours to plot line graphs for each mug you tested.

Practical review

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 **Use** your results to **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.

4 a **Construct** a conclusion for your investigation
b **Assess** whether or not your hypothesis was supported.

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			

3 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.

Do not touch the steel wool until it has cooled completely.

In part E, do not flick polystyrene balls near people.

Procedure

1 Copy the Results table on page 188 into your workbook. As you complete each task, fill in your observations in this table.

Part A

2 Use two alligator clips to connect a light globe to a battery or power pack as shown in Figure 5.1.10.

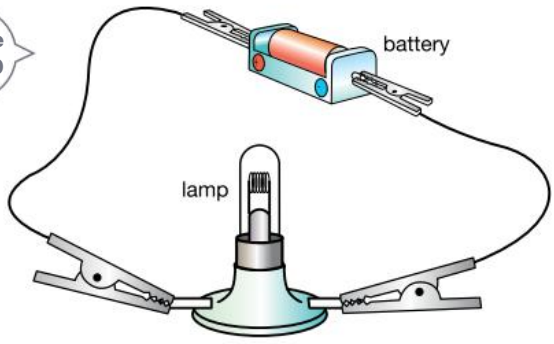


Figure 5.1.10

Part B

3 Place the steel wool on a bench mat. Tease the steel wool to thin out its strands. Use alligator clips to connect these to a battery and a switch as shown in Figure 5.1.11. Close the switch for a few seconds and watch the steel wool.

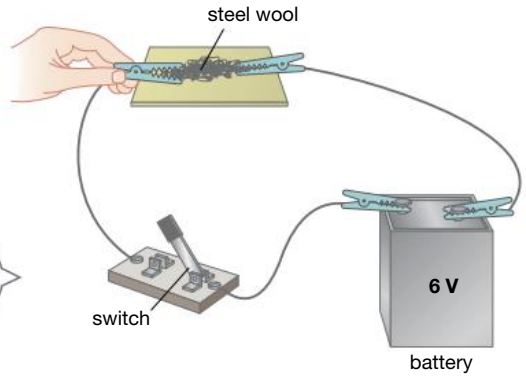


Figure 5.1.11

Part C

4 Strike a tuning fork on a rubber stopper. Put the ends of the tuning fork into a beaker of water.

Part D

5 Drop the 200 g mass onto a lump of modelling clay from a height of about 30 cm.

Part E

6 Place the polystyrene ball on the bench. See if you can make the ball roll along the bench using a stretched rubber band. Figure 5.1.12 shows the method.

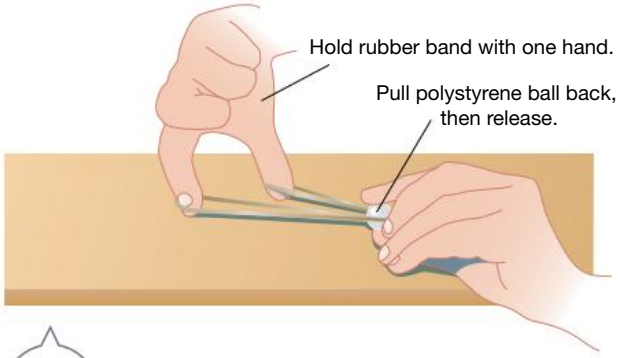


Figure 5.1.12

Energy changes continued on next page

Energy changes continued

Results

1 Record all observations in your Results table.

2 Next to the observations recorded in your results, list the source of energy in each case, and any forms of energy produced.

Practical review

1 **Discuss** whether there were any situations in which energy was transferred but not transformed into a different form.

2 **Name** two household 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			

STUDENT DESIGN

4 Bouncing balls

Purpose

To investigate whether a warmer ball will bounce higher than a cooler ball.

Hypothesis

Which do you think will bounce higher—a ball that is cool or the same ball when hotter? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

A risk assessment is required for this investigation.

Materials

As selected by students.

Procedure

1 Design an experiment that will test whether a ball bounces higher if the ball is warmer.

2 Brainstorm in your group and come up with several different ways you could investigate the problem. Select the best procedure and write it in your workbook.

3 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Results

Record your observations in writing or in a table, or capture the motion using a camera.

Practical review

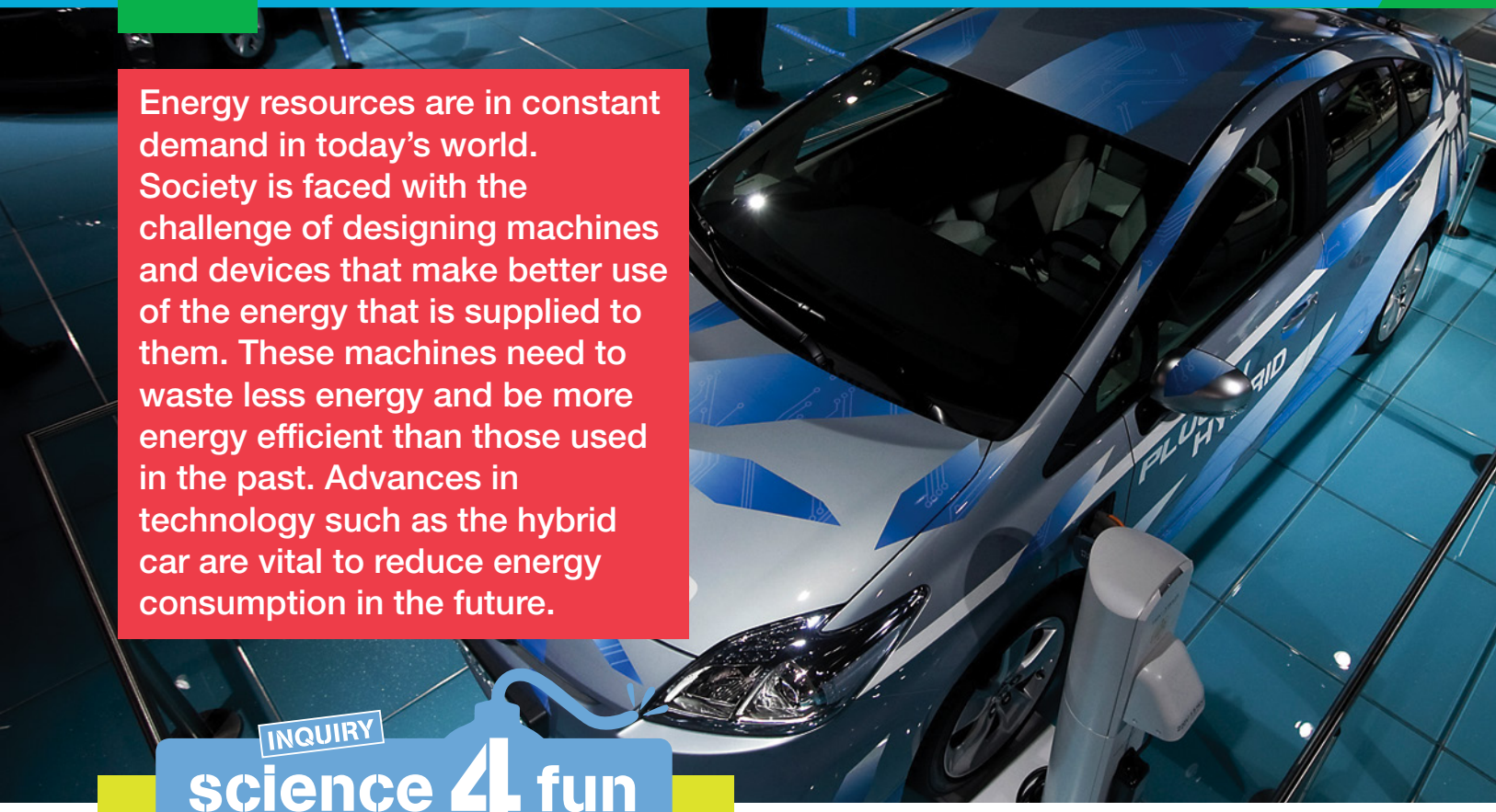
1 For this investigation, **identify** the:
- a independent variable (the variable you changed)
- b dependent variable (the variable that changed as you changed the independent variable)
- c controlled variables (the variables you kept the same throughout the investigation).

2 a **Construct** a conclusion for your investigation.
- b **Assess** whether your hypothesis was supported or not.

3 **Identify** any sources of error in your investigation.

4 **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

5.2 Energy efficiency



Energy resources are in constant demand in today's world. Society is faced with the challenge of designing machines and devices that make better use of the energy that is supplied to them. These machines need to waste less energy and be more energy efficient than those used in the past. Advances in technology such as the hybrid car are vital to reduce energy consumption in the future.

INQUIRY

science 4 fun

Hot stuff!

YES

Does friction produce heat?

Collect this ...

- bike tyre or inflatable ball
- hose or needle attachment that fits the bike tyre or ball
- pump

SAFETY

Do not over-inflate balls or tyres, or they could explode.

Do this ...

1. Fit the hose to the bike tyre or the needle into the ball.
2. Pump up the tyre or ball.
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.

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.

Likewise, a light globe like the one in Figure 5.2.1 quickly gets hot, releasing heat energy. This is wasted energy because you don't use a light globe for its heat. Instead, you want the light energy it produces.

Figure 5.2.1

The useful energy you want from a light globe is light energy. The heat released is wasted energy.

Most energy conversions waste some energy. This 'wasted' energy is usually released 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	Chemical energy from batteries	Light 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. Unfortunately, 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 100% 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 5.2.2 compares the efficiency of a car with that of a bike. Cars are inefficient because only about a quarter of the chemical energy supplied by petrol goes into making the car move. Bikes are much more efficient—around 95% of the energy from your muscles is converted into the kinetic energy of movement.

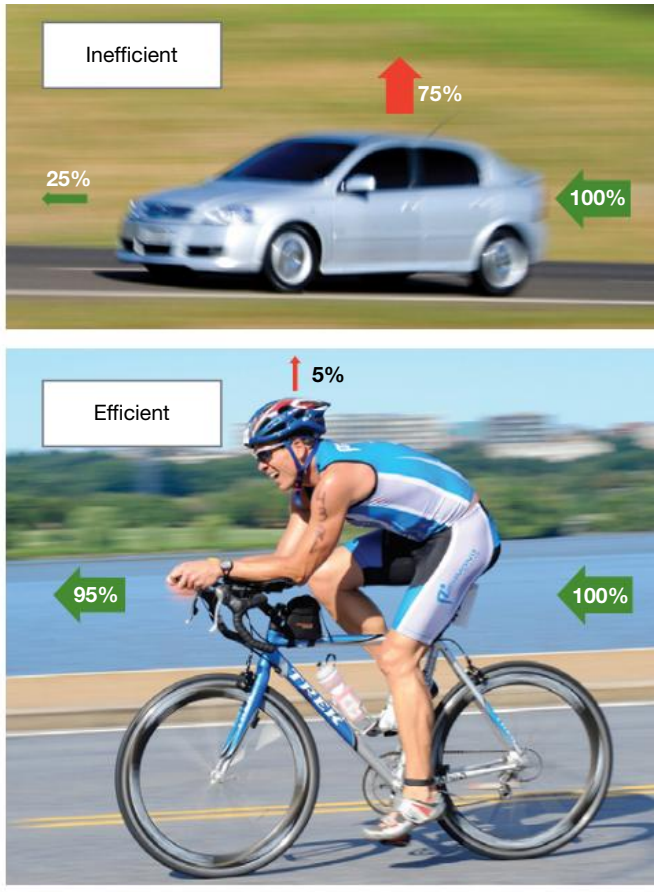


Figure 5.2.2 For every 100 J of chemical energy supplied to a car, only 25 J of kinetic energy is produced. In contrast, when riding a bike, up to 95 J out of every 100 J of energy that your muscles supply is converted into the kinetic energy of the bike.

Table 5.2.2 compares the typical percentage energy efficiencies of some energy converters.

Table 5.2.2 Sample energy efficiencies

Energy converter	Efficiency (%)
Incandescent light globe	5
Electric motor	80
Steam engine	40
Power station	30
Human	25

Idle energy

Auxillary power units (APUs) are portable units that allow a truck driver to turn off the engine without turning off the truck's heating or cooling units. Auxillary power units save billions of litres of fuel that would be used to keep the engine running during driver rest breaks.

SciFile

Calculating efficiency

Efficiency measures how much energy is converted into useful forms in a device. Efficiency is expressed as a percentage. The higher the percentage, the higher the efficiency. A device that is 100% efficient converts all its energy into useful forms and wastes no energy. If a device is 60% efficient, then 60% of its energy is converted into useful forms, with 40% of its energy being wasted.

$$\text{energy efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

Prac 1 p199

5.3

Renewable and non-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.

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. Over 10 million tonnes of coal is burned each year to meet the electrical energy demand across New South Wales. Figure 5.2.3 on page 192 shows that heat is lost at each step of generating and delivering electricity. The whole process is inefficient because 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.

WORKED EXAMPLE
Calculating 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.

Practice

N

1 A device uses 200 J but only 120 J is converted into useful forms. **Calculate** the efficiency of the device.

2 Jim mows a section of grass. In two minutes, the lawnmower used 3200 kJ of chemical energy from the petrol in its engine. Of this chemical energy the lawnmower converted 800 kJ into kinetic energy, 1200 kJ into heat energy and 1200 kJ into sound energy.

a **Identify** the useful and wasted forms of energy the mower produced.

b **Calculate** the percentage efficiency of the lawnmower.

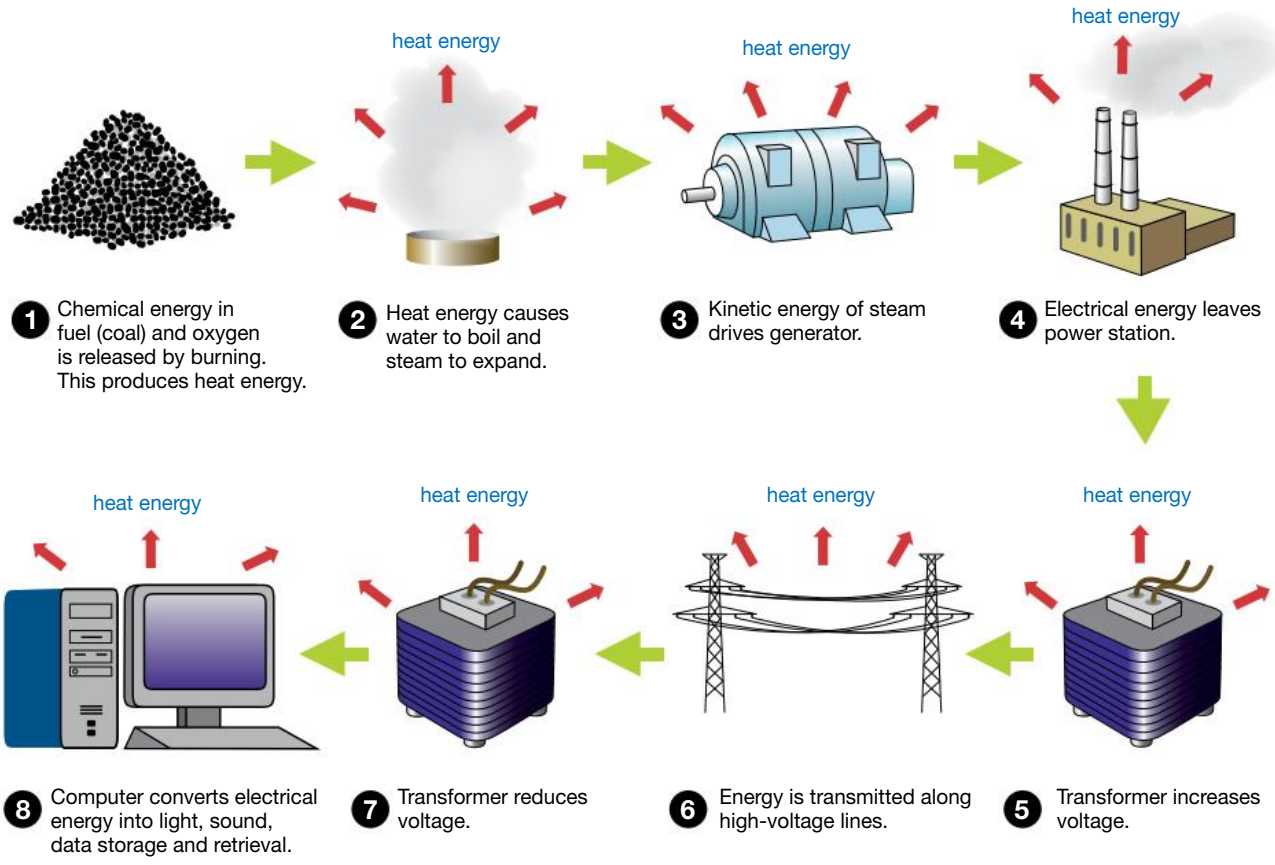


Figure 5.2.3 It is estimated that 65–70% of the energy produced when coal is burned is transformed into heat. Heat is lost in every part of the process of generating, transmitting and distributing electrical energy.

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.

See the light!

SciFile

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.

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
- raise sea levels, putting some coastal areas, towns and suburbs at risk of flooding.

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 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 5.2.3 compares the efficiencies of incandescent and fluorescent globes.

5.4

Table 5.2.3 Comparison of incandescent and compact fluorescent globes

Power	Approximate balloons of greenhouse gas produced over its lifespan
75 watt incandescent	3600
15 watt (75 watt equivalent) fluorescent	730

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. Look around shops selling electrical appliances and you will see that most large appliances carry a red and yellow **energy rating label**. A sample label is shown in Figure 5.2.4.

Prac 2 p200

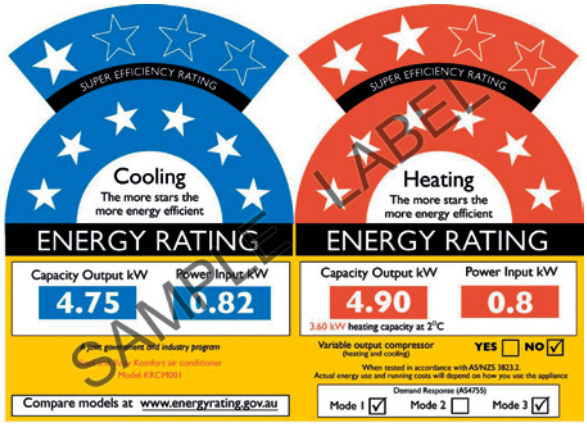


Figure 5.2.4 Appliances are tested under Australian standards to produce an energy rating label. Appliances labelled up to 6 stars are said to be 'efficient'. Those with more than 6 stars are 'super-efficient'.

Energy efficiency is shown by the number of stars on the label. The more stars (usually from 1 to 10) 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.

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!

SciFile

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.

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 (kWh). One kilowatt hour is equal to 3 600 000 joules of energy. This can also be written as 3.6 megajoules (MJ).

SciFile

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 5.2.5 shows design features that make a house more energy efficient.

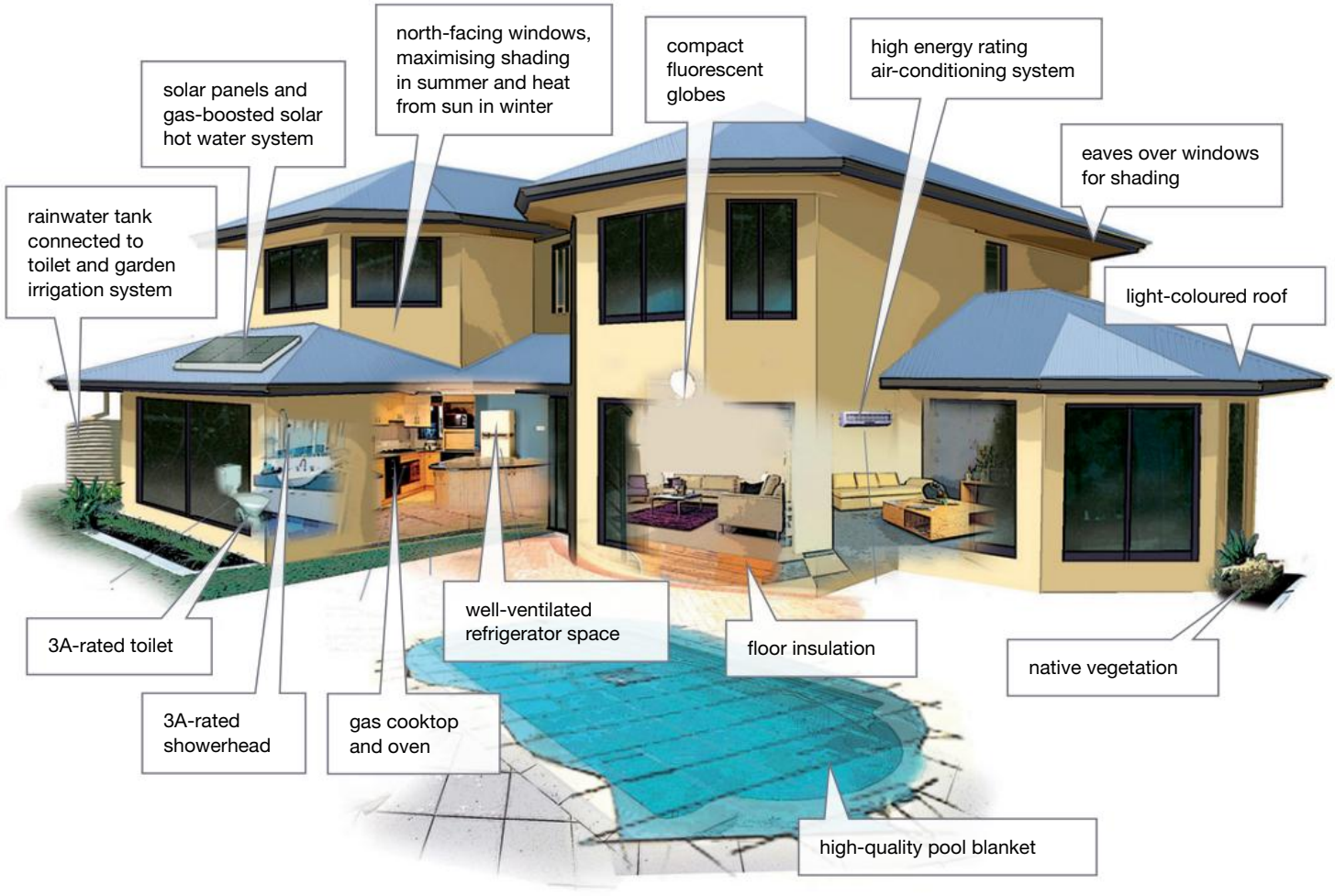


Figure 5.2.5 The design features of this home allow its occupants to be comfortable while reducing energy consumption. They also include water-saving features.

Prac 3 p201 5.5 5.6

INQUIRY

science 4 fun

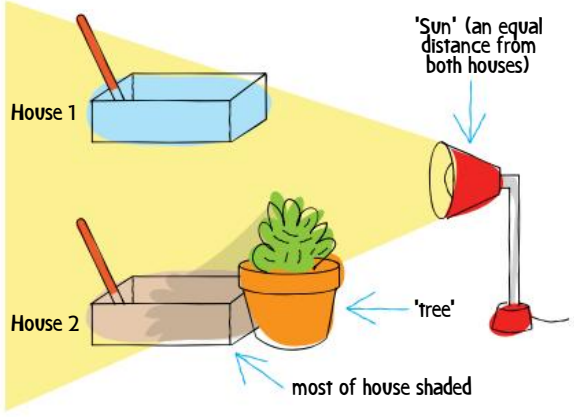
Shading a house

What 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.

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 machines.

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.

If you have ever looked at a car engine then you have probably noticed belts used to transfer energy to the alternator and to the air-conditioner. Sometimes a fan belt is used to turn a fan that cools the engine. However, most new cars now rely upon an electric motor instead of belts to turn the fan. A beltless engine reduces car maintenance, engine noise and heat loss due to friction. Lighter cars are also being built through the use of materials such as carbon fibre, plastics and aluminium. All these changes improve the efficiency of the vehicle. Figure 5.2.6 shows an example.

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 5.2.6 New technology has made this car 109 kg lighter than the previous model. Although the new model is larger, energy-efficient design features enable it to use 23% less fuel.

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.

LEDs (light-emitting diodes) produce very little heat and are extremely energy efficient. They are used in traffic lights, torches and many lighting units. LED televisions use LEDs to backlight an LCD screen. The high efficiency of LEDs has improved the energy efficiency of these televisions. Figure 5.2.7 shows the spectacular use of coloured LEDs to light a building.

Organic photovoltaics are a new generation of flexible and cheap solar cells that are made from carbon-based materials. Researchers are trying to increase the efficiency of these solar cells from their current 5% to the 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 5.2.8.

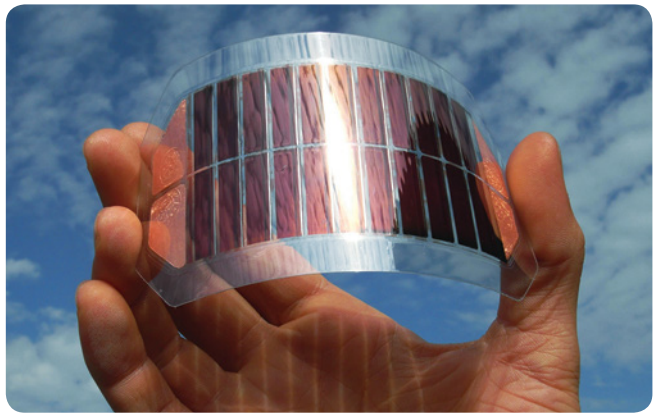


Figure 5.2.8 Lightweight, flexible and cheap organic solar cells could be attached to bus stops, buildings and even clothing to generate electricity.

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!

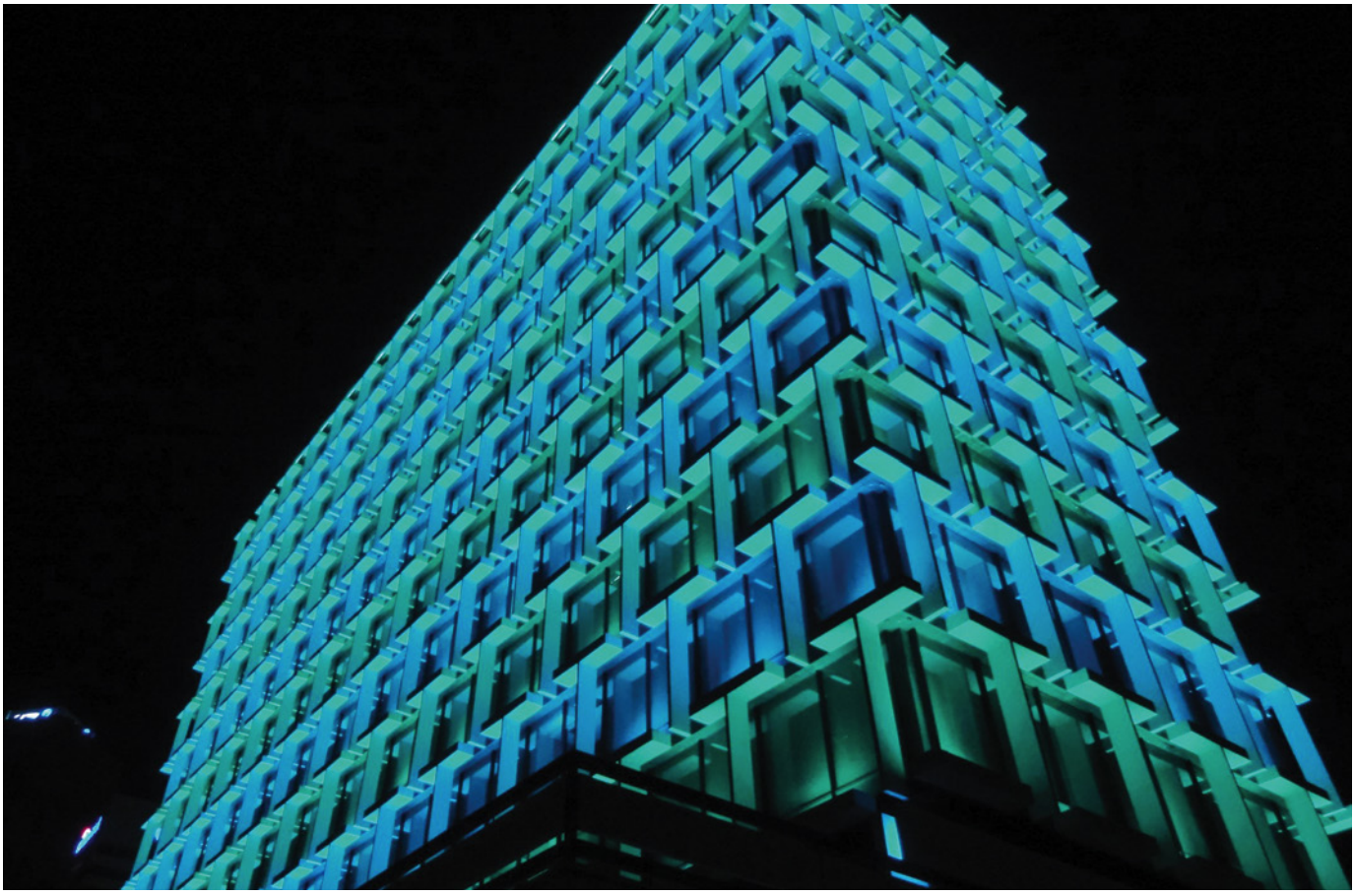


Figure 5.2.7 Over 20 000 LEDs were installed on Council House in the city of Perth. This energy-efficient lighting display is controlled by computer.

5.2 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 Refer to Table 5.2.1 on page 190 and **list** the wasted forms of energy that occur when you:
- a listen to an MP3 player
- b play cricket.

4 **Name** the type of energy possessed by fossil fuels.

Understanding

5 **Define** the term *energy efficiency*. L

6 **Describe** how heat losses reduce the efficiency of a device.

7 **Outline** why the process of converting the chemical energy of coal into electrical energy is very inefficient.

8 **Explain** why incandescent light globes have now almost completely been replaced by compact florescent globes.

9 **Explain** what the star rating in Figure 5.2.4 on page 193 tells a consumer about the energy efficiency of this appliance.

10 **Describe** three ways in which the house shown in Figure 5.2.5 on page 194 reduces household energy consumption.

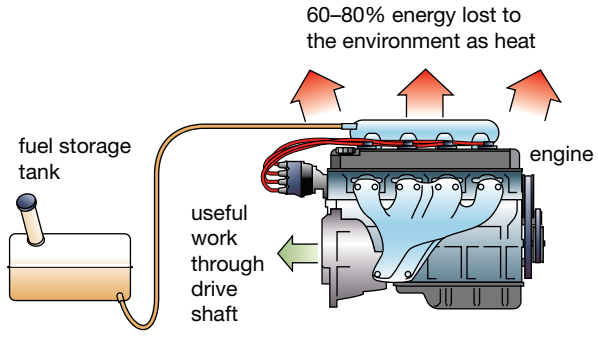
11 **Explain** how adding insulation to a house and sealing gaps can reduce the energy costs of heating and cooling the house.

12 **Explain** how regenerative braking makes a car more energy efficient.

13 **Explain how** a dry washing machine could save energy compared to a regular washing machine.

Applying

14 a **Use** the information in Figure 5.2.9 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.



Efficiency:

petrol engine	25%
diesel engine	35%
jet turbine	30%
steam engine	40%

Figure 5.2.9

Analysing

15 **Classify** the method of heat transfer that is blocked by the 'tree' in the science4fun on page 195—is it conduction, convection or radiation?

16 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. N

17 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: N
- a number of joules of sound energy produced
- b percentage efficiency of the device for converting electrical energy into sound energy.

5.2 Unit review

18 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.

19 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.

Evaluating CCT

20 **Predict** what a car would be like if it was 100% efficient.

21 The hose and needle of a bike pump get hot when used to pump up a tyre. **Propose** a reason why.

Creating CCT

22 **Construct** a flow diagram to show the energy changes that happen when you:
- a ring a doorbell
- b light a match
- c fall over.

23 **Use** Figure 5.2.10 to **construct** a flow diagram to show the energy changes that occur when you vacuum the floor using electricity from a wind generator.

24 **Construct** an advertisement for a new energy-efficient appliance. **Outline** how your appliance will save energy and why people should buy it.

Inquiring

1 Find a website that compares the energy rating labels found on household appliances.
- Select one type of appliance such as an air conditioner, television or refrigerator.
- Choose three models of the appliance you are investigating that are similar in retail price.
- Compare the energy rating labels of the three models.
- Propose which appliance you would purchase if given the choice of these three models.

Present your research as an article for a consumer website.

ADDITIONAL

2 Research one form of transportation such as the bike, car, train or aircraft.
- Find three images of this type of transportation from about 100 years ago.
- Find three images of this type of transportation from now.
- Compare differences in the shape and design of vehicles from each age.
- Describe the typical materials used to construct these vehicles from today and 100 years ago.
- Suggest whether today's materials offer benefits over those used in the past.
- State whether you think today's vehicles are more energy efficient than previous models.
- Discuss why it is important that vehicle designs are continually reviewed to lead to greater efficiency.

Present your research in any way that completes all of the above tasks.

ADDITIONAL

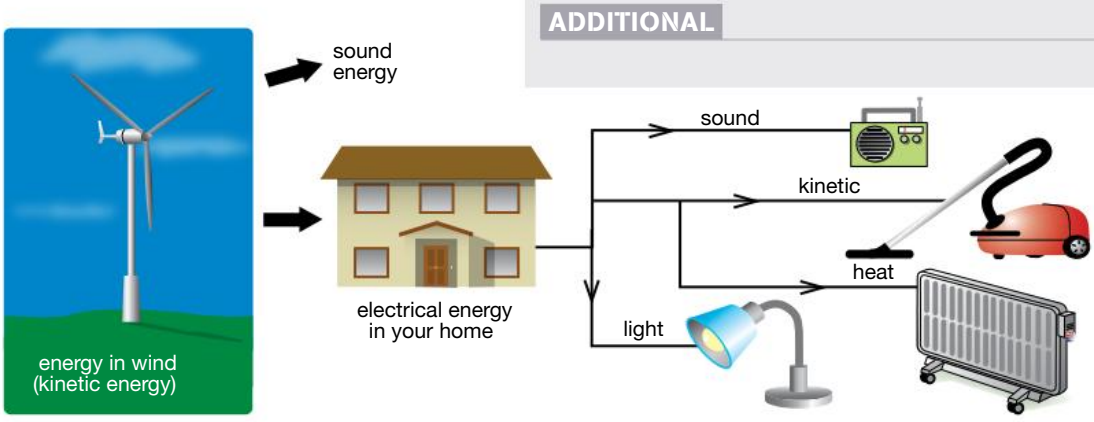


Figure 5.2.10

5.2 Practical investigations

STUDENT DESIGN

1 Investigating the efficiency of bouncing balls

When a ball is dropped from a height, its gravitational potential energy is converted to kinetic energy and heat. As the ball bounces (rebounds) from the floor, some of the ball's kinetic energy is converted back into gravitational potential energy. This process continues until all 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:

$$\text{Efficiency} = \frac{\text{rebound height of first bounce}}{\text{initial height above ground}} \times 100\%$$

Purpose

To calculate and compare the efficiency of bouncing balls.

Hypothesis

Which type of ball do you think will be the most efficient and will rebound to greater heights when dropped—a table tennis ball, a squash ball, a hi-bounce ball or some other type? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

As chosen by students but likely to include:

- a range of balls of different types, such as table tennis, squash, tennis, hi-bounce
- equipment to measure the height of a bounce, such as video equipment, motion sensors or metre rulers.

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment to measure the rebound height of a range of different types of balls.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of how you intend to run your experiment.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Results

1. Construct a table to display your results.
2. Use your drop height and measured rebound heights to calculate the efficiency of each ball.

Practical review

1. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
2. **Identify** sources of error in your investigation.
3. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.
4. **Propose** how your investigation could have been improved.
5. Squash balls get very hot after a short time in play. **Use** your results from this investigation to **explain** why.
6. **List** the balls in order from the one you **predict** will be the hottest after a bounce to the one that will be coolest.

2 Building a kettle

Purpose

To build a model kettle or jug and study its energy transformations.

Materials

- 40 cm nichrome wire
- pencil
- 150 mL beaker
- connecting wires with alligator clips stripped of plastic covering
- 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.

Do not let the alligator clips touch each other, as this could cause a short circuit.

Plastic can melt, so ensure the alligator clips do not have plastic covering the metal clip.

Procedure

1 Copy the results table into your workbook.

2 Make a heating element as shown in Figure 5.2.11 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.

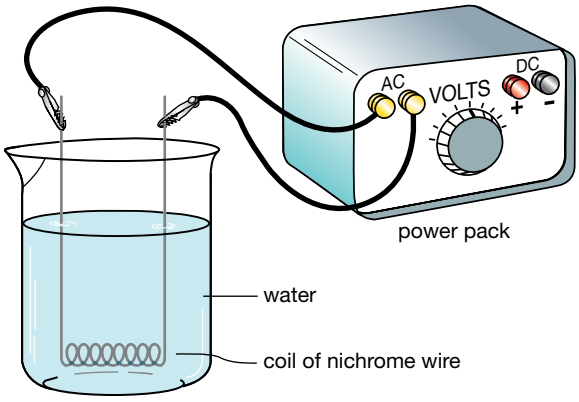


Figure 5.2.11

3 Add about 70 mL of water to the beaker.

4 Place the heating element in the beaker, making sure it is completely covered by water.

5 Connect the element to the power supply using the connecting wires.

6 Set the power pack to 4 volts and switch the power supply on.

7 Record the temperature of the water every minute for 10 minutes in your table.

Results

1 Record all temperatures in your Results table.

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.

Practical review

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 the kettle's design to make it more energy efficient.

3 Effect of double-glazing on heat loss

Purpose

To investigate the effect of double-glazing in preventing heat loss.

Materials

- hot water
- 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)

Procedure

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 5.2.12.

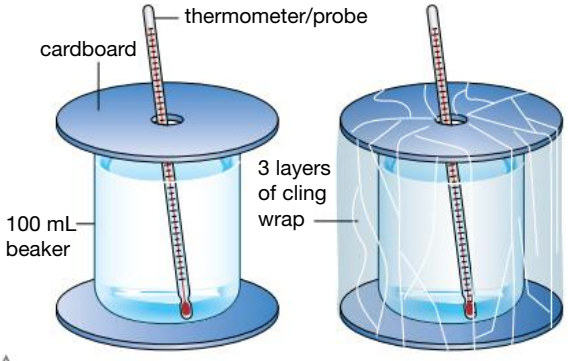


Figure 5.2.12

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

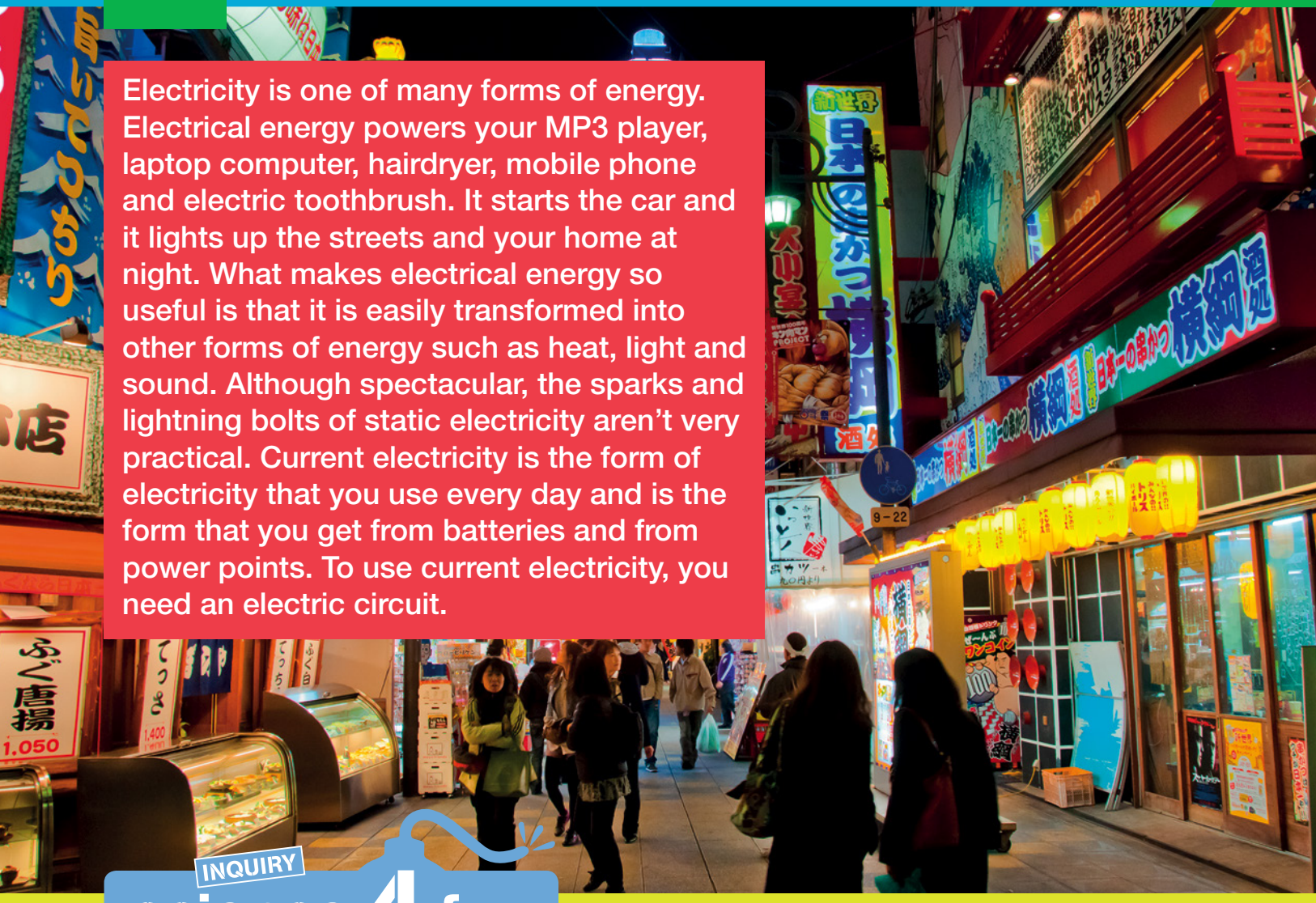
Record all temperatures in your Results table.

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		

Practical review

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.

5.3 Electrical energy



Electricity is one of many forms of energy. Electrical energy powers your MP3 player, laptop computer, hairdryer, mobile phone and electric toothbrush. It starts the car and it lights up the streets and your home at night. What makes electrical energy so useful is that it is easily transformed into other forms of energy such as heat, light and sound. Although spectacular, the sparks and lightning bolts of static electricity aren't very practical. Current electricity is the form of electricity that you use every day and is the form that you get from batteries and from power points. To use current electricity, you need an electric circuit.

INQUIRY

science 4 fun

Sparks on opening!

YES

In a solid, forces bond the particles together and energy is needed to break those bonds. Can you see the energy released when the bonds break?

Collect this ...

- self-stick envelope
- sugar cubes
- pliers or multi-grips

Do this ...

1 Do this activity at night or in a very dark room. Allow your eyes time to get used to the dark before you start.

2 Seal a self-stick envelope. While in the dark, open the seal as quickly as you can (don't tear the envelope, just open its seal).

3 If you're unsure what happened, then seal the envelope and repeat.

4 While still in the dark, crush a sugar cube with pliers or multi-grips.

Record this ...

Describe what happened.

Explain why you think this happened.

Electric charge

Everything is made of atoms, which are themselves made of **protons**, **neutrons** and **electrons**. As Figure 5.3.1 shows, protons and neutrons are located in a small and dense core called the **nucleus**. Around the nucleus spin tiny electrons. Protons and electrons are electrically charged. Protons carry a positive charge (+) and electrons carry a negative charge (–). Neutrons carry no charge and are said to be **neutral**. Overall, the atom is neutral, because the numbers of protons and electrons are always equal. Their opposite charges balance each other out and so the atom has no *overall* charge.

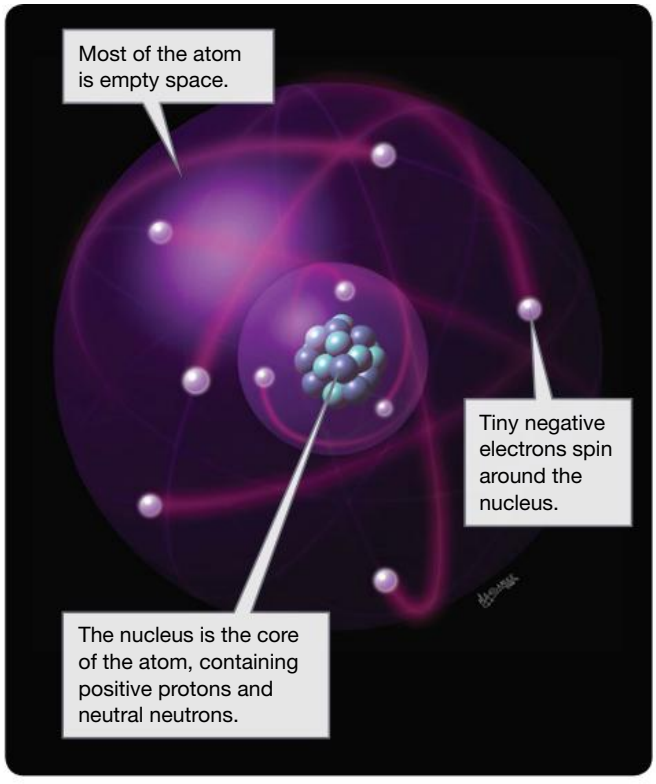


Figure 5.3.1 Atoms are neutral but contain charged particles. Charges form when there are unequal numbers of protons and electrons.

Electrons sometimes get knocked, rubbed or pulled off an atom. This leaves the atom with more protons than electrons, giving the atom an overall positive charge. This 'charged atom' is known scientifically as an **ion**. In this case, it's a positive ion. The electrons that have been removed then attach themselves to another atom nearby. The atom to which they attach themselves will then have more electrons than protons and so will have a negative charge. A negative ion is formed.

Static electricity

Static electricity is the build-up of electric charge on a surface. This build-up of charge most commonly occurs because the surface has been rubbed against another surface. Electrons have been rubbed off one surface (charging it positive) and have transferred to the other surface (charging it negative).

Static charge usually leaks away after some time into its surroundings, including the air around it. This returns the materials to their original neutral state. However, if the build-up of charge continues, the electrons may jump across a gap from the negatively charged surface back to the positively charged surface. As they jump back, the electrons release all their energy in one go. This converts the energy into the heat, light, sound and motion (kinetic energy) that you observe as a spark or lightning bolt. This is what is happening in Figure 5.3.2.

Figure 5.3.2 A lightning bolt happens when static charge builds up within the atmosphere and then jumps to Earth, a building or another cloud.

Strike me lucky!

SciFile

A bolt of lightning:

- is about 5 cm wide
- has a temperature of around 30 000°C (hotter than the surface of the Sun)
- is the main source on Earth of plasma, the fourth state of matter
- could power a 25 watt light globe for a year!

Prac 1 p208

Pearson science NSW 7 Unit 7.4

Current electricity

The electricity you get from a battery or a power point is not static electricity. It is made up of electrons moving along a wire, like those in Figure 5.3.3. This movement of charge is called an electric **current**. These moving electrons have energy that is transformed into other forms of energy as the electrons pass through things like light globes (transforming electrical energy into light), heating elements (into heat) and motors (into movement).

If the electrons don't move, then no energy is received by the light globe, heater or motor and so nothing happens. It remains 'off'.

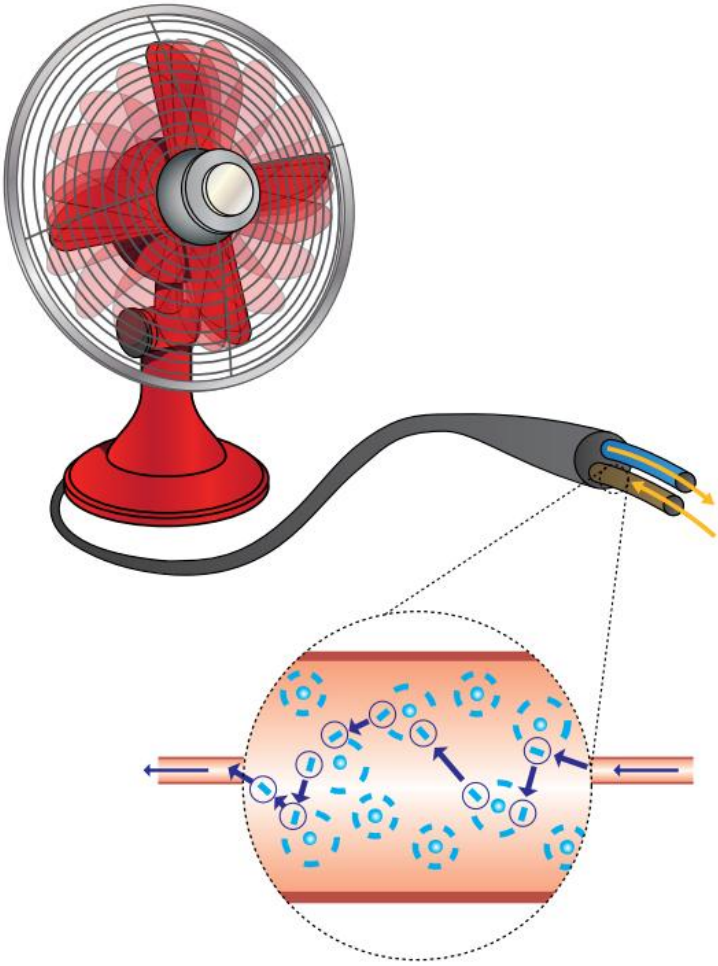


Figure 5.3.3 Electrical appliances work because electrons flow through their circuits. The energy the electrons carry is then transformed into heat, light or motion.

Simple electric circuits

Electrons need a path to travel around so that they can deliver their energy. This path is called an **electric circuit**. As Figure 5.3.4 shows, an electric circuit needs:

- an energy source, such as a battery, a power point or a generator like the dynamo on a bike. This supplies the electrons in the wire with the energy they require to get them moving around the circuit
- an energy user, such as a light globe, heating element or motor. These devices convert the energy that electrons are delivering to them
- wires to connect everything, making the circuit complete.

Any break in an electric circuit stops the flow of electrons and stops them from delivering their energy. Most electric circuits have switches that deliberately break the circuit, turning it on and off.

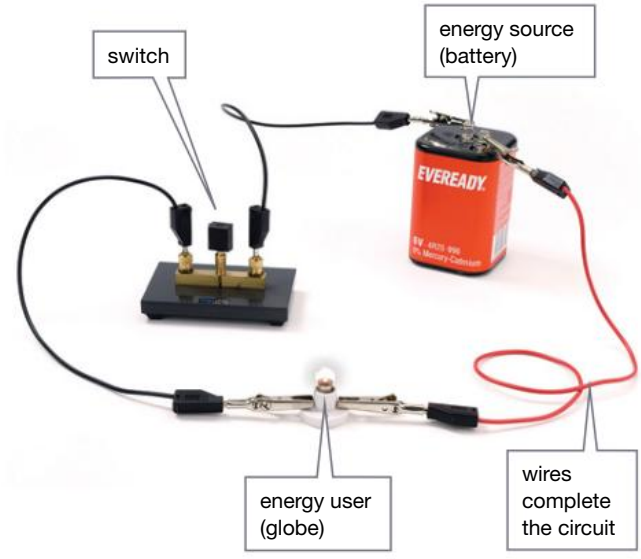


Figure 5.3.4 A circuit needs an energy source, an energy user and wires to connect them all. The circuit usually has a switch too.

Bright spark!

Electrons from a 240 V power point have insufficient energy to jump the gap in a switch. However, extreme voltages cause air in the gap to break down, allowing a spark to jump across it! A 1 cm gap requires about 3000 V for it to 'spark'.

SciFile

Circuit components

The different parts of a circuit are known as its **components**. Each component is given a different symbol. This makes diagrams of circuits easier to construct and easier to understand. Some of these components are shown in Figure 5.3.5.

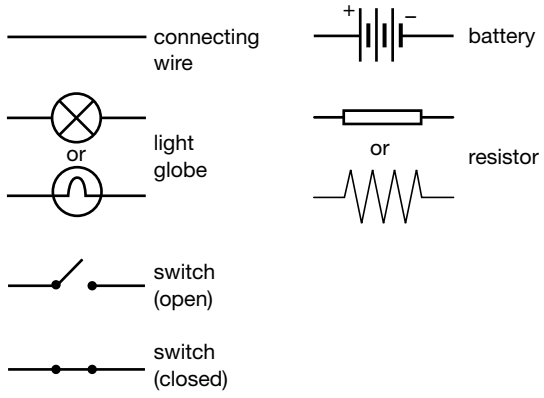


Figure 5.3.5 These symbols are used to show the different components that are connected up to make a circuit.

5.7

Circuit diagrams

A **circuit diagram** is a simplified and shorthand version of a real circuit. It shows how all the components in the circuit are connected.

A torch is an example of a very simple circuit. Its energy source is a battery and its globe transforms electrical energy into light. The circuit diagram for a torch is shown in Figure 5.3.6. The battery supplies the electrons with energy. As the electrons flow through the globe, they lose almost all their energy, which is transformed into light energy and some heat energy. The electrons then travel back to the battery, where their energy is replenished.

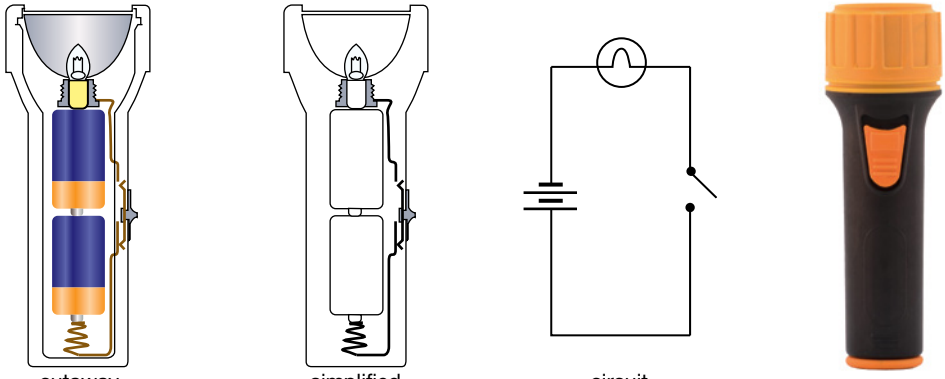


Figure 5.3.6 A torch has a battery, a globe, wires and a switch.

INQUIRY science 4 fun

Pull apart a torch

What's inside a torch?

YES

Collect this ...

- battery-powered torch

Do this ...

1. Pull apart a torch.
2. Follow its circuit from battery to globe and back again. Note that the torch might not use wires but might use the torch body, strips of metal or springs instead.

Record this ...

Describe the circuit by constructing a simple circuit diagram for it.

Explain how the electrons moved from the negative terminal of the battery around the circuit back to the positive terminal.

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5.3 Unit review

Remembering

1 **State** whether the charges of the following are positive, negative or neutral.
- a an atom
- b a proton
- c a neutron
- d an electron

2 **Recall** charges by copying the following statements and completing them. To complete each statement, insert the sign = or > (is greater than) or < (is less than).
- a In an atom, the number of protons ___ the number of electrons.
- b In a positive ion, the number of protons ___ the number of electrons.
- c In a negative ion, the number of protons ___ the number of electrons.

3 **List** the forms of energy released when a spark jumps across a gap.

4 **Name** the charged particles that carry an electric current through a circuit.

5 **List** what an electric circuit needs.

6 **List** three examples of each of the following components of an electrical circuit.
- a an energy supplier
- b components that use electrical energy

7 **Recall** the symbols for the following electric components by sketching them.
- a globe
- b battery
- c switch

Understanding

8 **Define** the following terms. L
- a nucleus
- b neutral
- c component

9 a **Draw** a simple circuit diagram that shows how a torch works.
- b **Explain** how energy transfers around the circuit of the torch.

10 **Calculate** whether the particles in Figure 5.3.7 would be neutral, positively charged or negatively charged. N

a b c

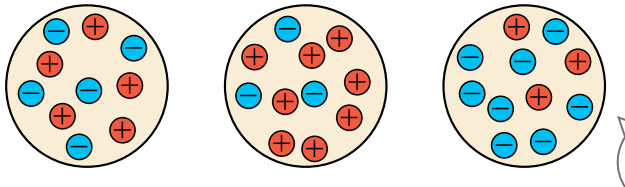


Figure 5.3.7

Applying

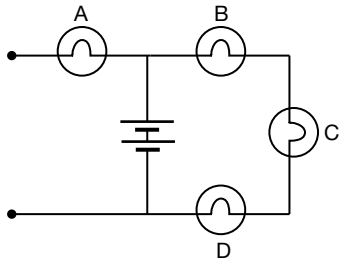
11 **Identify** whether the following are displays of static electricity or current electricity in action.
- a the spinning motor of a hairdryer
- b lightning
- c a spark felt when you touch a doorknob after walking across carpet
- d the TV when it is on

Analysing

12 **Contrast** static electricity with current electricity.

13 **Analyse** the circuits shown in Figure 5.3.8 and **identify** which globe(s) would never light up.

a



b

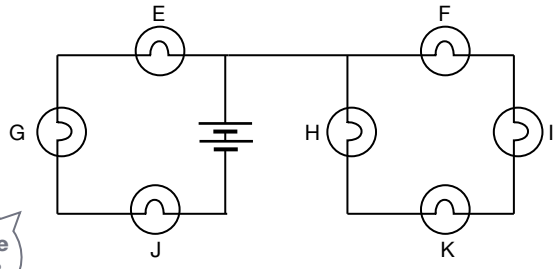


Figure 5.3.8

Evaluating CCT

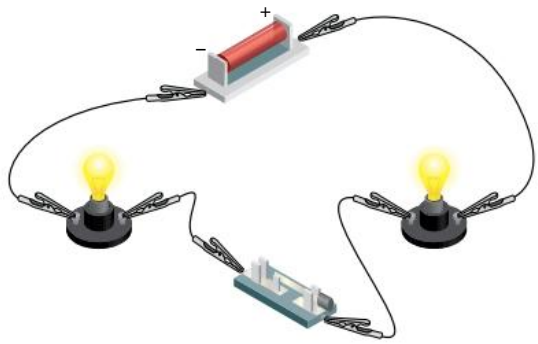
14 It is difficult to get all the grains of rice out of the plastic bags they come in, because some always stick to the sides. **Propose** an explanation for this observation.

15 When you rip open a self-stick envelope or crush a sugar cube with pliers while in the dark, you should see small flashes of light as the bonds break. **Propose** a reason why this happens and how it is related to static electricity.

Creating CCT

16 **Construct** circuit diagrams for the circuits shown in Figure 5.3.9.

a



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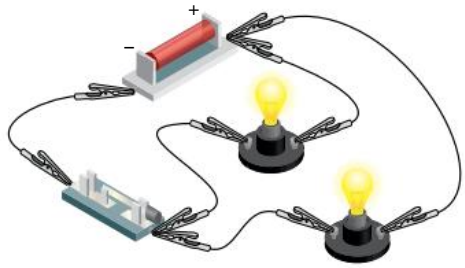


c

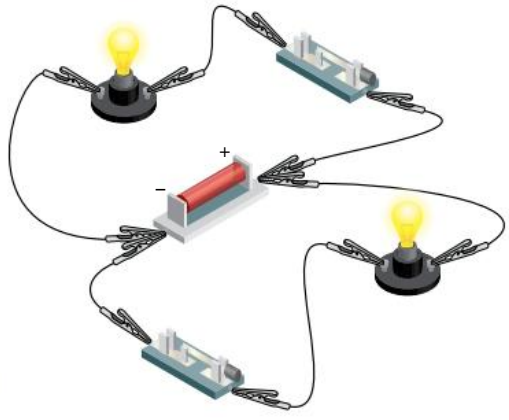


Figure 5.3.9

Inquiring

1 Find video clips showing amazing lightning strikes and static electricity displays. ICT

2 Research lightning. Find out:

- how it is generated
- how it discharges (releases)
- its voltage
- what it is most likely to strike
- whether it can strike the same place twice
- what you should do if you are outside when lightning is around.

Present your research in digital form. ICT

3 Investigate animals that detect their prey by using the electrical signals that come from the movement of the prey's muscles. You might investigate the platypus, sharks or manta rays.

Present your findings as text for a poster at the zoo or aquarium to be placed next to the enclosure or tank holding your animal.

ADDITIONAL

4 Electric circuits were once large and used devices such as valves. This meant the devices containing these circuits were huge and heavy. However, modern circuits now use tiny electronic components such as diodes and transistors. This has allowed circuits to become miniaturised, allowing the development of small, light, portable devices like smartphones, tablets, laptops and MP3 players. Research how components and circuits have changed over time, particularly how these changes influenced the development of the radio. As part of your research, find:

- who first transmitted audio signals via radio and when it happened
- what a valve was and what it was used for
- images of early radios that used valves
- what a transistor is, what it is used for and details about its invention
- why transistors eventually replaced valves in radios
- images of early transistor radios
- the difference between FM and AM signals
- the advantages that digital radios have over FM and AM radios.

Present your research in digital form. ICT

ADDITIONAL

5.3 Practical investigations

1 Electroscopes

An electroscope detects whether an object is charged, and indicates whether it is positive or negative.

Purpose

To construct an electroscope and use it to test the charge on different objects.

Materials

- 3M Scotch Magic Tape® or similar
- small plastic cup such as the top from a soft drink bottle
- play dough or plasticine
- 2 plastic straws with an end that can be bent
- marking pen
- plastic comb
- various electrostatic rods (Perspex, ebonite) and cloths (wool, cotton)

Procedure

Part A: Testing the tape

1 Cut two strips of sticky tape (each about 10 cm long). Record what happens when you hold the two strips of tape close to each other:
   - with their sticky sides facing each other
   - with the sticky side of one tape facing the non-sticky side of the other.

Part B: Constructing your electroscope

2 Make a base by adding play dough or plasticine to the small plastic cup. Then stick the straws in the base and bend the other end so that your set-up looks like Figure 5.3.10.

3 Cut two 10 cm lengths of tape. Stick one on your bench, leaving a little overhanging that can be used as a 'handle'. Stick the other tape on top of the first tape, once again leaving a little 'handle'. Label the tape on top with 'TOP'.

4 Rip the top tape off and stick it to the arm of one straw. Rip the bottom tape off the bench and stick it to the other straw.

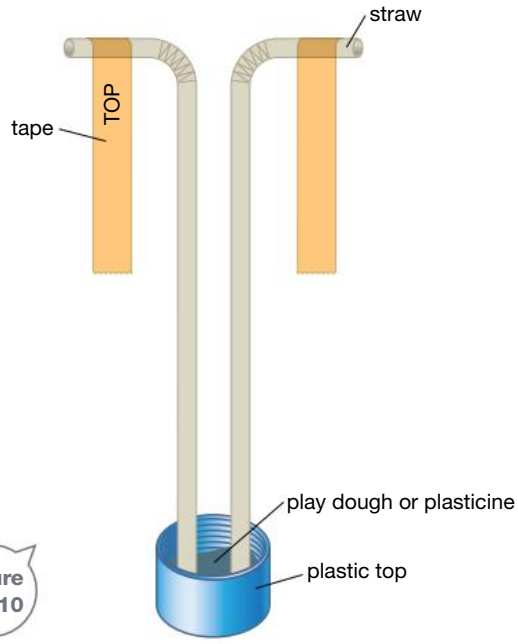


Figure 5.3.10

Part C: Using your electroscope

5 In your workbook, construct a table like the one shown on page 209.

6 Rub the plastic comb on your hair. Place the comb near (don't touch) the tapes and record your observations in the table.

7 Repeat step 6 with a balloon and different rods rubbed against different materials.

8 Finally, point your finger (don't touch) at each of the tapes.

Results

1 Record what you saw when you brought the following sides of the tapes to face each other:
   - a sticky facing sticky
   - b sticky facing non-sticky.

2 Record your results to Part C in your table.

3 The charge on the comb is negative when rubbed against your hair. Use the results obtained for the comb to predict the charges of the other objects based on what they do to the electroscope.

Object	Rubbed against	Top tape	Unmarked (bottom) tape	Object's charge (+, – or neutral)
Comb	Hair	Attracts	Repels	–
Balloon	Hair			
Perspex				
Ebonite				

Practical review

1 **State** which arrangement of tapes (sticky side facing sticky or sticky side facing non-sticky):
   a attracted b repelled.

2 **Use** the idea of static electricity to **explain** your results in the previous question.

3 **Propose** reasons why the tapes were charged after being ripped off:
   a the roll b each other.

4 **Explain** why charged objects repel or attract the tapes.

2 How steady are you?

Purpose

To construct a simple, fun electrical circuit.

Materials

- 1 wire coat hanger
- wooden board
- 2 screws
- 1 empty plastic pen casing
- sticky tape
- electrical leads
- alligator clip
- globe
- switch
- battery
- access to pliers or multi-grips
- access to screwdriver

Procedure

1 Cut a length of coat hanger wire and bend it into a twisted shape. Use screws to secure it to the wood so that the wire stands upright.

2 Cut another length of coat hanger wire and bend one end into a loop around the twisted wire. Insert the other end into the plastic body of a used pen. Secure both ends with tape.

3 Connect up the circuit as shown in Figure 5.3.11.

4 Test how steady your hand is by trying to pass the loop along the twisty wire without making the globe light up.

Practical review

1 **Explain** why the globe only lights up when you touch the twisty wire with the loop.

2 Electrical current can pass along a coat hanger wire. **Justify** this claim.

3 Imagine you touched the loop half way along the twisty wire. **Contrast** what is happening to the electrons in each half of the twisty wire when this happens.

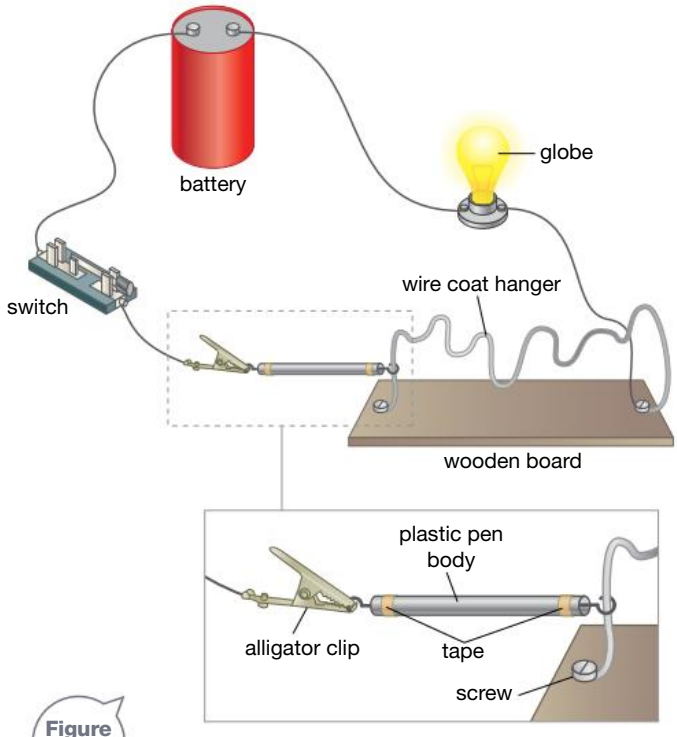


Figure 5.3.11

5.3 Practical investigations

STUDENT DESIGN

3 Super-sparker

SAFETY

A risk assessment is required for this investigation.

Be aware that this device produces sparks.

Purpose

To construct a super-sparker.

Materials

As selected by students

Procedure

1 Search the internet ICT for instructions on how to construct a super-sparker. Copy, print or save the instructions.

2 Before you start any practical work, assess how you are going to build and test your super-sparker. List any risks that it might involve and what you might do to minimise those risks. Show your teacher your planned design, testing procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Results

Record your observations.

Practical review

1 To charge your super-sparker and produce sparks, you needed to rub something against something else. **Identify** the two materials that rubbed against each other in this case.

2 The super-sparker didn't spark immediately. It only sparked when you did something to it. **Describe** what you needed to do.

3 For your super-sparker to discharge and produce a spark, it needs to be earthed. This means that a current needs to be able to travel from it to the Earth. **Explain** how this happened in your design .

STUDENT DESIGN

4 Sticky rice

Dry rice grains or hundreds and thousands tend to stick to the inside of a plastic container or plastic bag that has been holding them. This makes it extremely difficult to get them all out.

Purpose

To determine what factors make rice grains or hundreds and thousands stick to the inside of their container.

Hypothesis

What do you think will cause rice grains or hundreds and thousands to stick to their container—is it the container size or material, the number of grains or the time they were stored? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

As selected by students.

SAFETY

A risk assessment is required for this investigation.

Procedure

Select a factor and design an investigation that tests how it influences the number of rice grains or hundreds and thousands that stick inside their container.

Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hint

Only change one factor at a time.

Results

Record your observations. If you take measurements then record them in a table.

Practical review

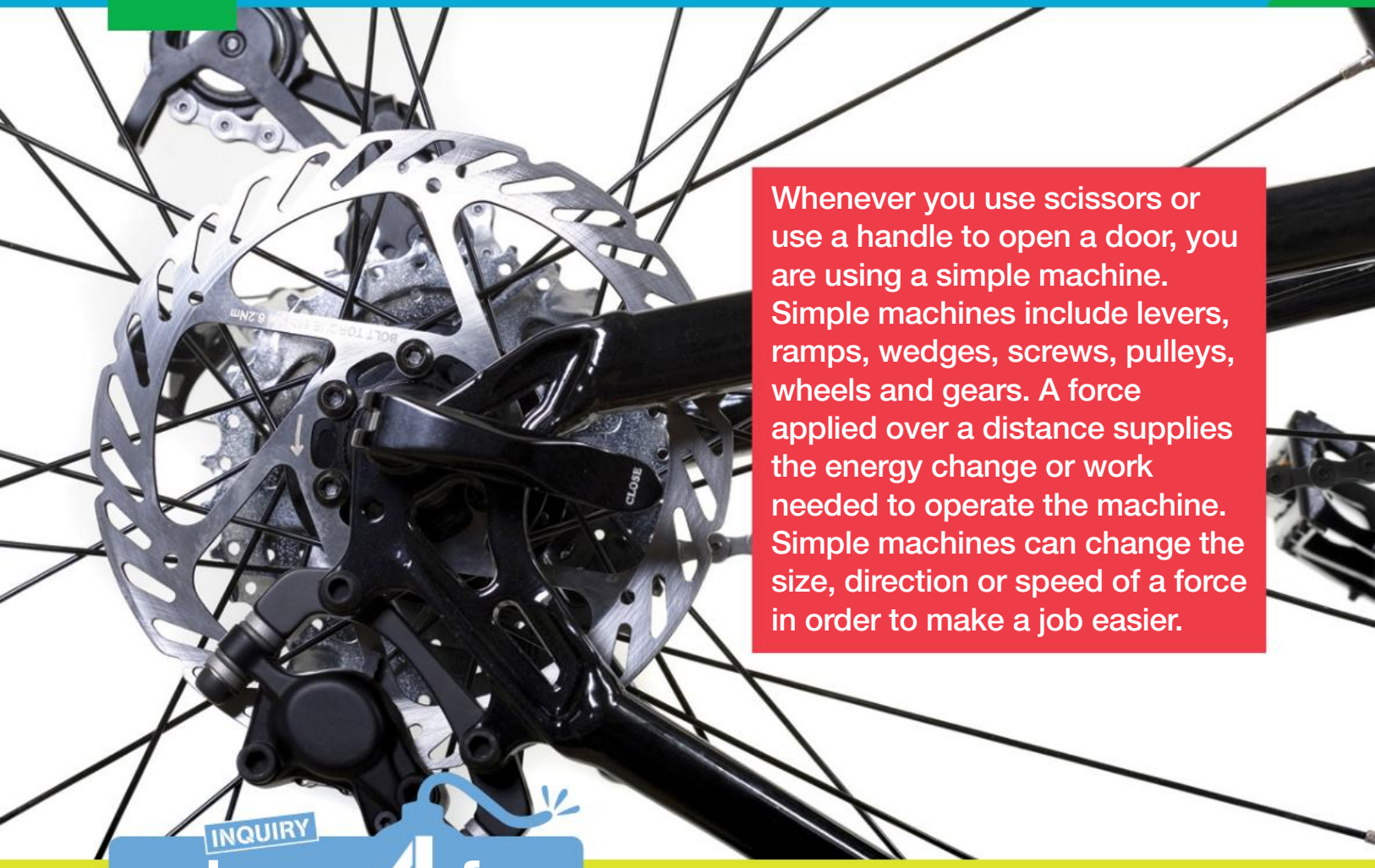
1 The grains got stuck because of static electricity.
   a **Identify** which substance rubbed against which other substance to cause the static electricity.
   b **Explain** how static electricity can cause something like rice grains to cling to their container.

2 **Describe** another situation in which static electricity causes a substance to cling to something.

3 a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

ADDITIONAL

5.4 Simple machines



Whenever you use scissors or use a handle to open a door, you are using a simple machine. Simple machines include levers, ramps, wedges, screws, pulleys, wheels and gears. A force applied over a distance supplies the energy change or work needed to operate the machine. Simple machines can change the size, direction or speed of a force in order to make a job easier.

INQUIRY

science 4 fun

Turning on a tap

YES

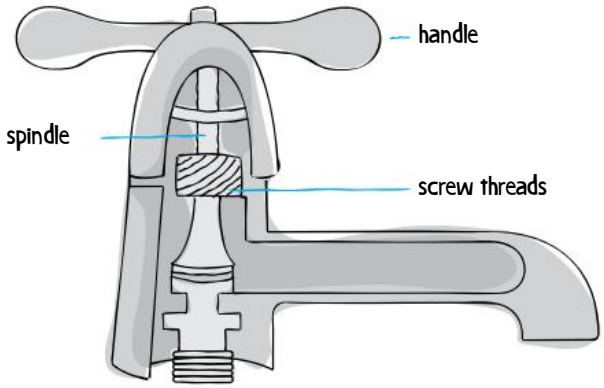
Can you turn on a tap without its handle?

Collect this …

- a tap that has a handle that can be unscrewed

Do this …

1. Place a plug in the sink to avoid losing any parts down the drain.
2. Carefully unscrew a tap.
3. Place the screw, handle and cap on the basin.
4. The tap should now just be a spindle, or an axle.
5. Try to turn on the tap using just your hands.
6. Offer a challenge to your friends and family. Can it be done?



Record this …

Describe what happened.

Explain why you think this happened.

Machines, energy and force

The amount of energy required to do a job depends on the job, not how you do it. For example, if you need to move sound equipment into a van, then the energy you need to put into the job depends on the gravitational potential energy you need to give it. This depends on how heavy the equipment is and how high you have to lift it.

A simple machine is a device that makes a job easier to do. A ramp is a simple machine that would help you lift the equipment into the back of the van (Figure 5.4.1). These simple machines don't save you any energy, but they make the job a little easier by reducing the force you need to apply. The force you need to apply to get a job done is called effort.

The **load** is the force actually required to do the job. Simple machines work in three different ways. They can:

- change the size of a force
- make things speed up
- change the direction of a force.

Figure 5.4.1 Loading and unloading heavy sound equipment such as this would be almost impossible without the use of a ramp.

Force multipliers

Lifting a car to change a tyre would require a huge effort. For most of us, this task would be impossible despite it being a small distance. However, a jack makes the task easier and the effort required smaller. You apply a small force to the handle of the jack, but wind it over a very long distance. This is shown in Figure 5.4.2. In the same way, a crowbar can be used to shift a rock that would otherwise be too heavy to move. Machines used in this way magnify the force you apply to do a job. These machines are known as **force multipliers**.

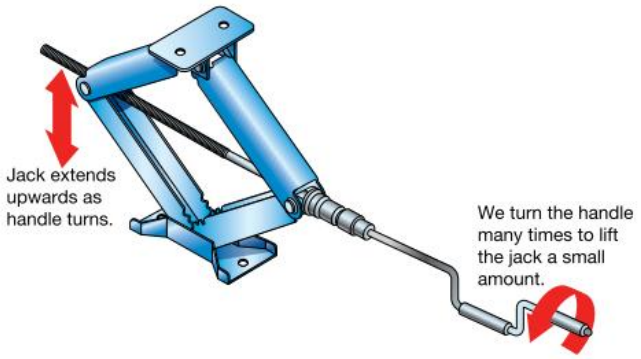


Figure 5.4.2 You use a small force to turn the handle of a jack through a very large distance, in order to lift a car.

Levers

A **lever** is a simple machine that is made of a long, rigid object (such as a stick or metal rod) and a pivot or **fulcrum** about which it rotates. Most levers, like the crowbar shown in Figure 5.4.3, are force multipliers.

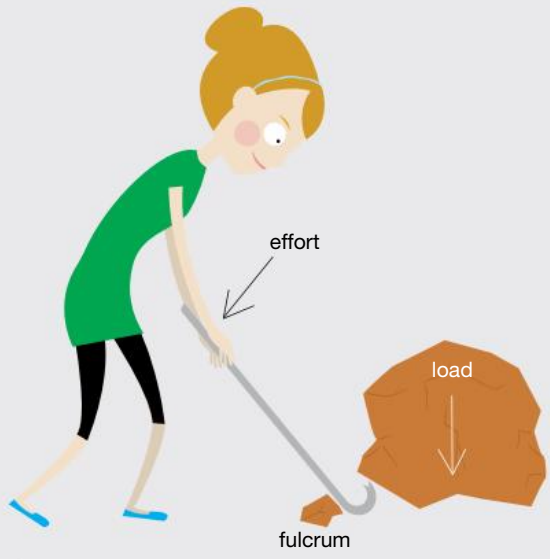


Figure 5.4.3 A crowbar or long stick used like this acts as a lever. The lever increases the force that you can supply.

Figure 5.4.4 shows how the claw of a hammer can be used as a lever to pull a nail (the load) out of a piece of wood. If you used just your fingers, then the effort required would be so high that the task is nearly impossible. Using a teaspoon to remove the lid of a coffee tin multiplies force in the same way. This is shown in Figure 5.4.5.

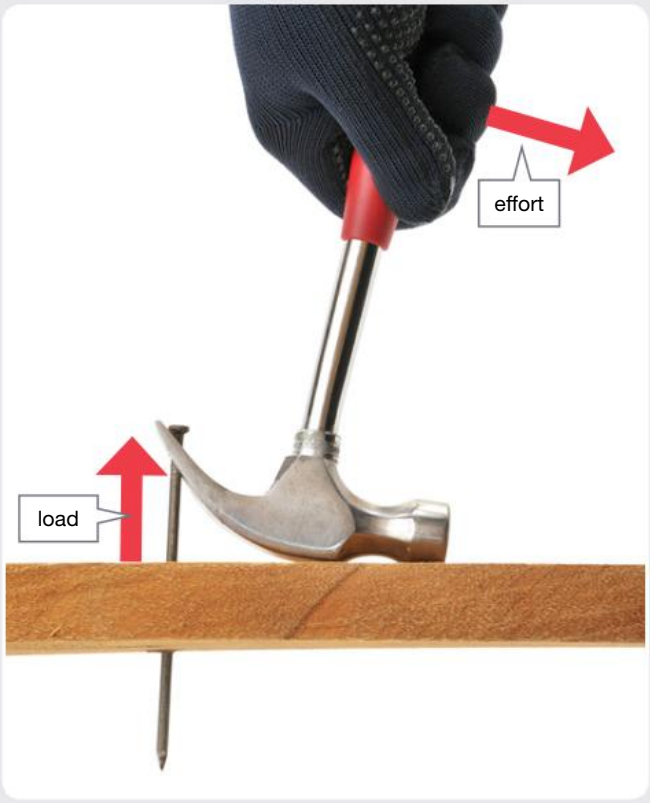


Figure 5.4.4 Using a hammer as a lever reduces the effort needed to pull a nail from a piece of wood. This makes the task much easier.

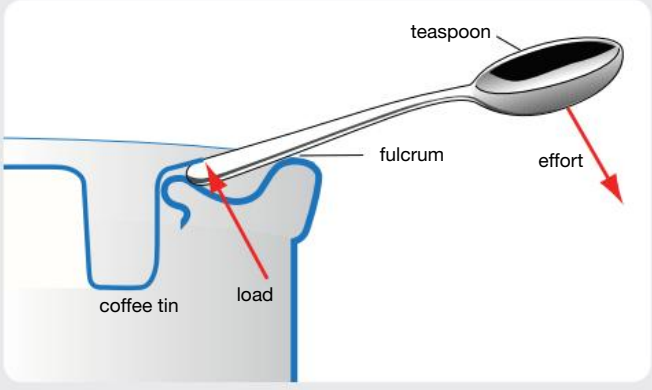


Figure 5.4.5 The load being shifted here is the lid. The edge of the tin is the fulcrum. The teaspoon is a lever that multiplies the force, making it easier to remove the lid off the tin.

When you use a lever as a crowbar, or use a teaspoon to lift a lid from a tin, you are using a **first-class lever**. Some first-class levers are shown in Figure 5.4.6. First-class levers have the fulcrum positioned between the effort and load forces. When you use a first-class lever, the lever moves through a larger distance than the load. In doing so, the force applied is increased. Other first-class levers are pliers, tin snips, hedge-cutters and scissors.

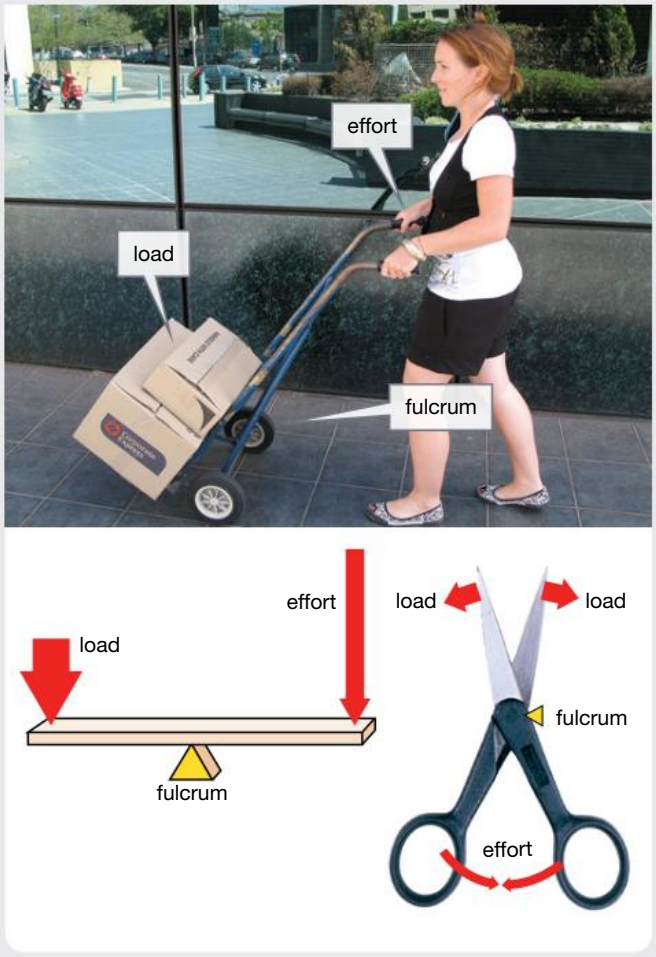


Figure 5.4.6 A first-class lever has its fulcrum positioned between the effort and the load. These levers act as force multipliers.

If the load is positioned between the fulcrum and the effort, then the lever is called a **second-class lever**. This also acts as a force multiplier. A wheelbarrow is an example of such a lever. By lifting the handles a greater distance than the load, the force applied is increased. This is shown in Figure 5.4.7 on page 214. Other second-class levers include bottle openers, paper guillotines and nutcrackers.

Prac 1 p220

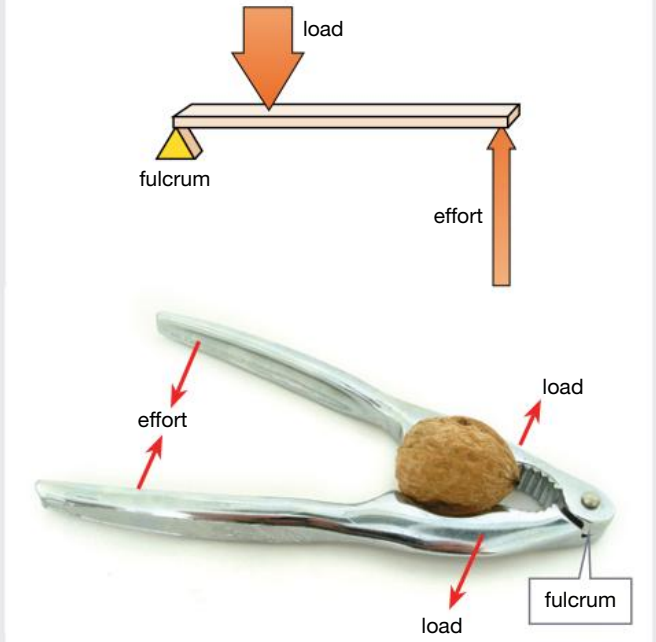


Figure 5.4.7 A second-class lever has its fulcrum positioned at one end of the system and the effort at the other. These levers also act as force multipliers.

Wheels

The centre of a **wheel** is called its **axle** and the outside of a wheel is its **rim**. This is shown in Figure 5.4.8. A wheel on an axle is a special type of lever. Each spoke of the wheel is a lever, the axle is the fulcrum and the wheel rim is the outer end of the lever. Figure 5.4.9 shows how a wheel can act as a force-multiplier. When you apply a force to turn on a tap, the handle acts as a wheel. It increases the force you apply at its centre, allowing the axle to turn.

Prac 2 p221

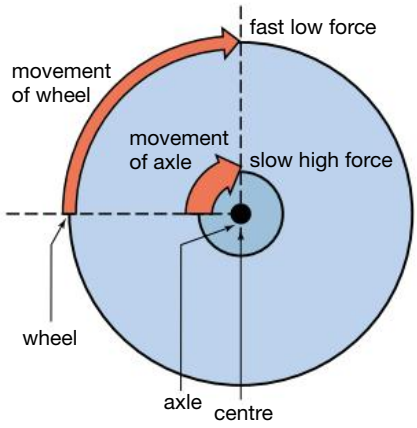
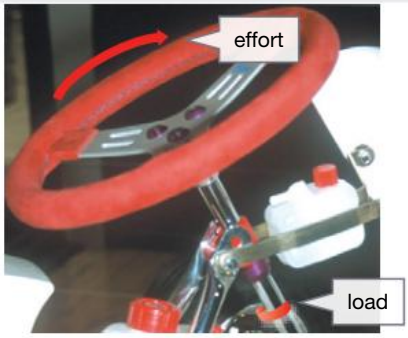


Figure 5.4.8 The rim of the wheel rotates with greater speed than the axle in its centre. As the wheel turns, the force at its centre is larger than the force at its rim.



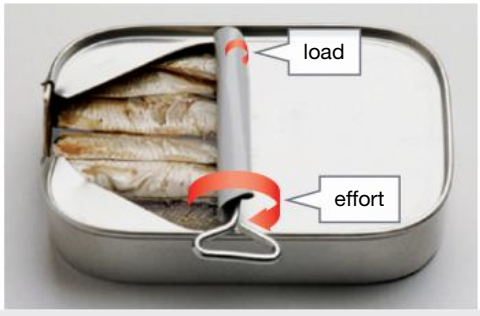


Figure 5.4.9 In each of these situations, a wheel is used to produce a force advantage.The force applied to the wheel rim is increased at the axle of each wheel. The larger the steering wheel, the easier the axle is to turn.

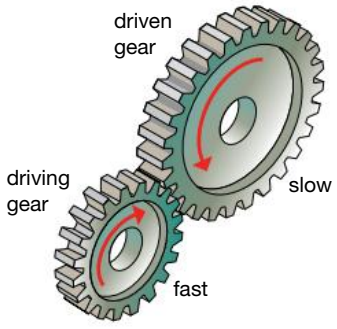
Gears

Gears are wheels that have teeth around their rim. Gears can mesh directly together, or be joined by a chain, such as on a bicycle or in the overhead cam shaft in some car engines. A set of gears that are connected is called a **gear train**. When one gear turns, the gear it interlocks with also turns, but in the opposite direction. The gear that supplies the force is called the **driving gear**. The gear that is connected to this gear is called the **driven gear**.

If the driving gear is smaller than the driven gear, then the combination acts as a force multiplier. The larger cog will rotate more slowly, but the force it delivers is much larger. This gear combination is called gearing down and is useful when you need a large force. For example, it would help a car get up a hill or help in using a winch. This is shown in Figure 5.4.10.

Figure 5.4.10

In this gear combination, the driven gear rotates more slowly than the driving gear, but with greater force.



Gearing down

Inclined planes

While levers, wheels and gears can multiply a force to make it larger, **ramps** or **inclined planes** are force multipliers that *reduce* the effort force needed to do a job. Ramps make it easier to shift heavy sound equipment into vans. They also make it easier to climb a mountain. This is why roads wind up mountains. Ramps reduce the effort force required, by making you travel further. The longer the ramp, the less steep it will be. It will be easier to climb but you need to go further.

Prac 3 p222

Screws

A screw has a double inclined plane winding around it. This spiral is called the thread. A screw is easy to screw into wood but you need to turn it many times with your screwdriver. This can be seen in Figure 5.4.11.

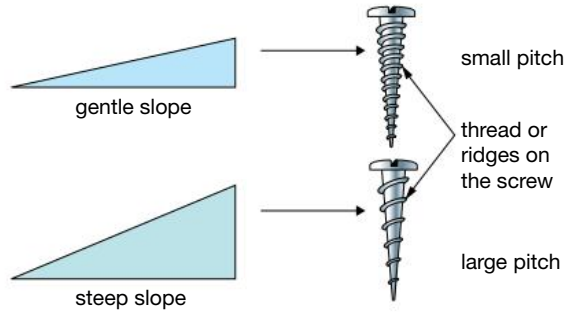


Figure 5.4.11

The screw with the small pitch has a longer spiral inclined plane than the screw with the large pitch. This means less force is required to screw a small-pitch screw into wood.

Speed multipliers

A machine can also make something move faster than otherwise possible. You need to apply greater force to these types of machines but the machines speed things up. For this reason, they are known as **speed multipliers**. An example is the egg beater shown in Figure 5.4.12.

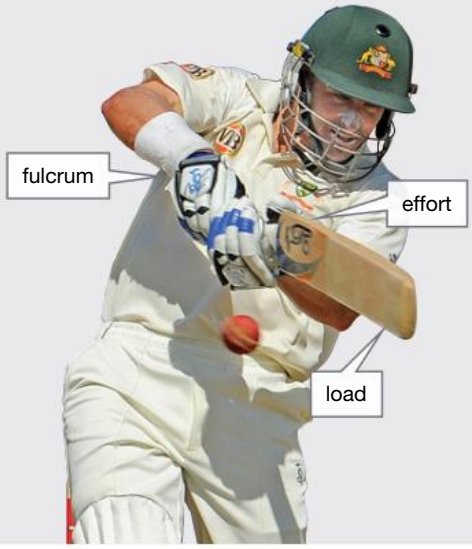
Figure 5.4.12

A machine can increase the speed of moving parts.

Tennis racquets, cricket bats and golf clubs are levers that are used as speed multipliers so that they hit balls at high speed. They are examples of **third-class levers**, with the effort positioned between the fulcrum and the load. This is shown in Figure 5.4.13 on page 216.

When using a broom, you apply a large effort force to the handle. The handle moves though a much shorter distance than the end of the broom, which moves much faster, but with less force. The broom acts as a third-class lever. It has traded an increase in force for an increase in speed.

Gears can also act as speed multipliers. If the driving gear is larger than the driven gear then the combination acts as a



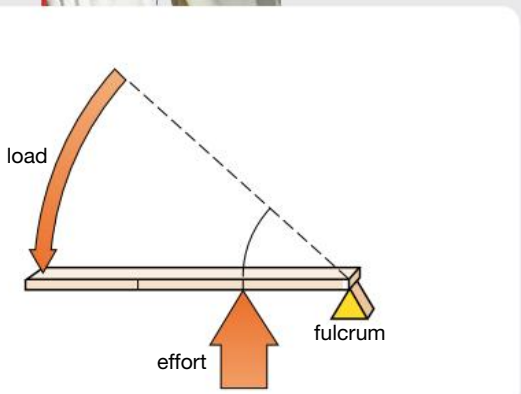
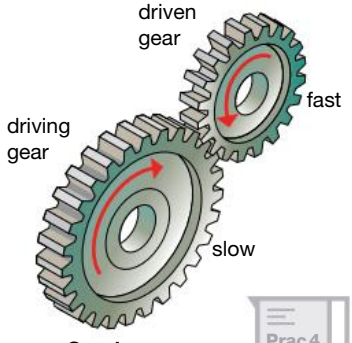


Figure 5.4.13 Cricket bats are third-class levers. They are speed multipliers.

5.9

speed multiplier. This happens because one turn of the large cog makes the smaller cog spin a number of times. This gear combination is called gearing up. It is useful when using an eggbeater, where you require the beaters to spin faster than the handle turns. This is shown in Figure 5.4.14.

Figure 5.4.14 Gearing up makes the driven gear spin faster but with less force.



Gearing up

Prac 4 p223

Changing the direction

A machine can also change the direction in which a force acts.

Wedges

Imagine trying to bite into an apple without your front teeth. Your front teeth, called *incisors*, cut like a knife. These are simple machines called **wedges**. A wedge is a double inclined plane that moves through another object. Wedges are used to split objects because they change the direction of a force by 90° and increase its size. When an axe is pushed downwards, the wedge of the axe head pushes the wood apart, as shown in Figure 5.4.15. Pins, needles, nails and doorstops are all examples of wedges.

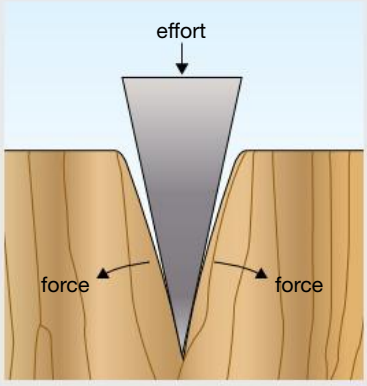
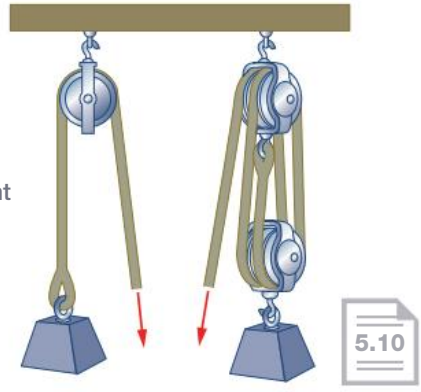


Figure 5.4.15 A wedge changes the direction of a force, enabling an object to be split. The longer the inclined edge of this wedge and the sharper the axe, the easier the wood is to split.

Pulleys

Sometimes it is necessary to change the direction of a force. To lift a set of Venetian or Roman blinds, it is much easier to apply a downwards force on a cable than to try to lift it upwards from a height. A simple way of doing this is to use a **pulley**. A pulley is a wheel with a groove around it into which a rope or chain can move. Pulleys can also be used as force multipliers if more than a single pulley is used. The single pulley shown in Figure 5.4.16 changes the direction, but not the size of the effort force required to lift a load. Using two pulleys halves the size of the effort force required. In this case, the force is applied over a greater distance.

Figure 5.4.16 The arrangement shown on the right provides four times the force of the single pulley on the left.



5.10

LEARNING ACROSS THE CURRICULUM

ABORIGINAL & TORRES STRAIT ISLANDER HISTORIES AND CULTURES

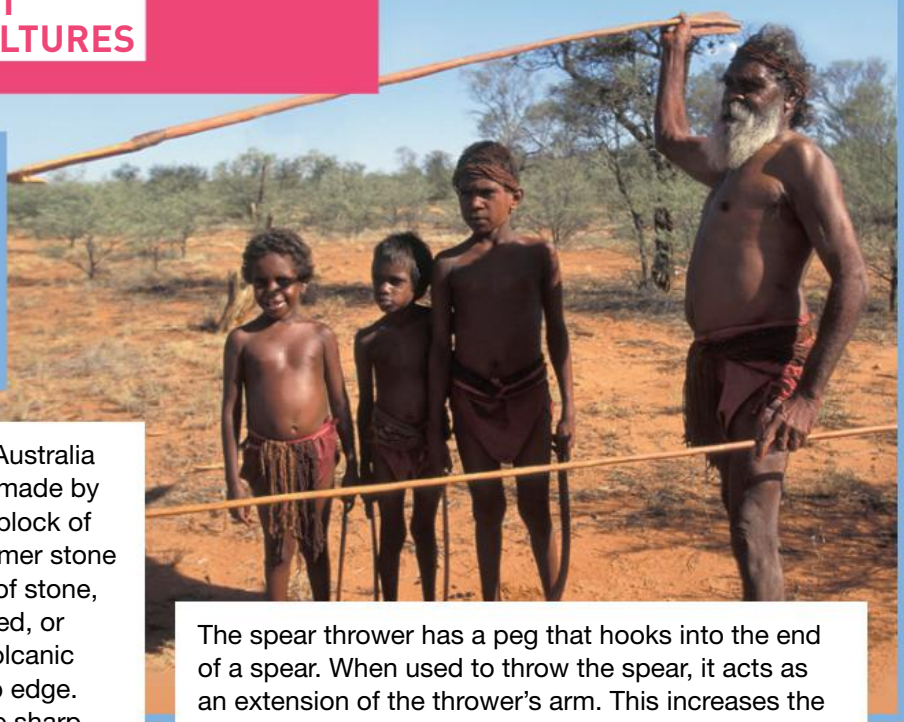


Figure 5.4.17 A spear thrower is a machine that allows people to hunt better.

INDIGENOUS TOOLS AND WEAPONS

Indigenous Australians developed and used a range of tools that were designed to perform specific tasks.

Stone tools recently discovered in Western Australia are over 35 000 years old. Stone tools were made by grinding or flaking. In the flaking process, a block of stone (called a core), was struck with a hammer stone (usually a pebble), to chip off a sharp piece of stone, called a flake. These flakes were further flaked, or 'retouched' to be reshaped. Often a hard, volcanic piece of rock was also used to grind a sharp edge. Using these techniques, people could create sharp points of spears, chisels, axes, saws or knives (Figure 5.4.18). The types of stone that were best suited to producing flakes were those rich in silica, such as quartz, quartzite, chert and flint. These stones are hard but brittle. These sharp stone tools could cut more cleanly than a steel blade. Resins were used to attach a cutting stone to a piece of wood as a handle.

Figure 5.4.18 These stone flakes have been chipped off a core rock. They can be reshaped or resharpened as required.

Indigenous Australians developed a number of unique weapons. Spears were used with a various shaped tips. The tip of a spear itself is a simple machine, being a double inclined plane. Different designs of spear throwers were used throughout Australia. The device shown in Figure 5.4.19 is called a woomera (wumara) in parts of New South Wales. It was made from a dense wood, such as wattle.

The spear thrower has a peg that hooks into the end of a spear. When used to throw the spear, it acts as an extension of the thrower's arm. This increases the length of time the force is applied to the spear and multiplies the speed with which it is launched. This device makes the mechanics of throwing a spear far more efficient and as a result, the spear travels much further than would otherwise be possible.

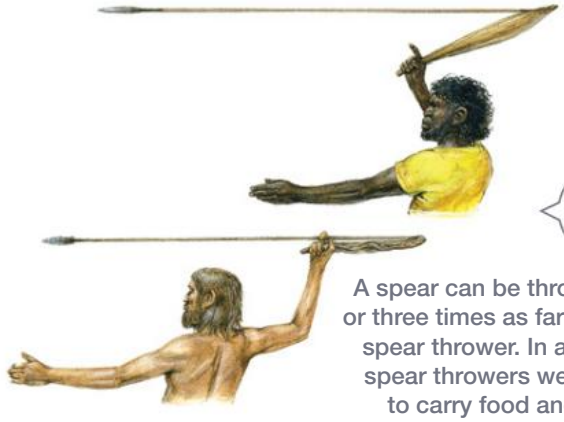


Figure 5.4.19 A spear can be thrown two or three times as far using a spear thrower. In addition, spear throwers were used to carry food and water.

REVIEW

1. **Describe** how a stone is flaked.
2. **Recall** five devices that can be produced by flaking.
3. **Explain** why stone rich in silica is suitable to use in creating stone tools.
4. **Explain** how a spear thrower allows a spear to be thrown much further than otherwise possible.

5.4 Unit review

Remembering

1 **List** three ways a machine can make a task easier.

2 **State** whether each statement below is true or false.
- a A lever is a simple machine that can increase the effort supplied to get a job done.
- b If using a crowbar to lift a tree stump, then the tree stump is called the effort.
- c A crowbar used as a lever rotates about a point called the fulcrum.
- d When using the claw of a hammer to pull a nail out of a piece of wood, the hammer acts as a force multiplier.

3 **Recall** which class of lever multiplies speed.

4 **State** which simple machine could be called a:
- a double inclined plane
- b spiral inclined plane.

5 **List** two examples where a wheel is used as a force multiplier.

6 **List** two examples where a wheel is used as a speed multiplier.

Understanding

7 Most levers used in ball sports are third-class levers. **Explain** why.

8 A tennis player serving a ball will toss it into the air and reach upwards to hit the ball. **Explain** how this increases the speed of their serve.

Applying

9 **Identify** whether each of the following machines makes a task easier by increasing the size of a force, speeding something up, or changing the direction of a force.
- a axe
- b crowbar
- c hand drill

10 Ping uses a chisel to lift the lid from a paint tin. **Identify** what acts as the:
- a load
- b effort
- c fulcrum.

11 **Identify** the following as first-, second- or third-class levers.
- a Load positioned between the fulcrum and the effort
- b Effort positioned between the fulcrum and the load
- c Fulcrum positioned between the effort and the load

12 **Identify** which type of simple machine (inclined plane, wedge or screw) is described by these devices.
- a corkscrew
- b axe
- c electric fan
- d car park ramp
- e chisel
- f escalator

Analysing

13 **Classify** the objects shown in Figure 5.4.20 as first-, second- or third-class levers.

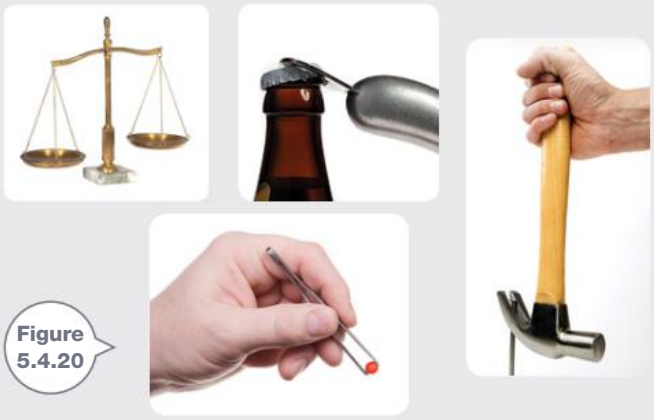


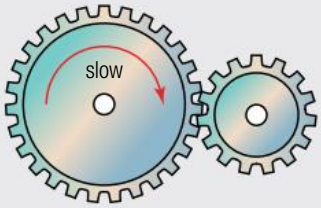
Figure 5.4.20

14 a Copy each diagram in Figure 5.4.21. **Analyse** how each object operates and label the position of the fulcrum (F), load (L) and effort (E) on each diagram.
- b **Identify** which class of lever is shown in each diagram.
- c **State** whether each is a force multiplier or a speed multiplier.

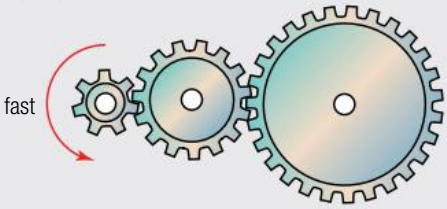
Figure 5.4.21

15 Copy the three gear trains from Figure 5.4.22. **Analyse** the direction of rotation and speed of each gear and show these on your diagram.

a



b



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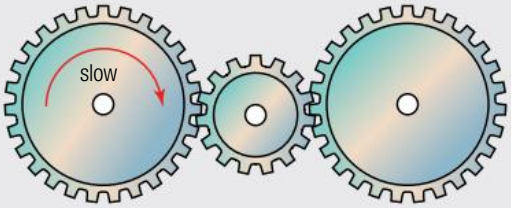


Figure 5.4.22

16 The photo in Figure 5.4.23 shows Korean acrobats using a see-saw. **Classify** the see-saw by grouping it into the correct class of lever.

Figure 5.4.23

Evaluating CCT

17 **Propose** a reason why a tap without its handle is nearly impossible to turn on or off.

18 The person shown in Figure 5.4.24 needs to get to the top of this dam wall. There are two options: climb straight up or use the stairs on the right.

a **Identify** which will be the easiest way to the top.

b **Justify** your choice.

Figure 5.4.24

Inquiring

The Archimedes screw is an invention designed by the famous Greek physicist and mathematician Archimedes. Research to describe:

- what its design looks like
- what it was designed to do
- how it works
- where it is used today.

Present your findings in digital form. ICT

5.4 Practical investigations

1 Modelling a see-saw

Purpose

To investigate how the effort force required to balance a load on a see-saw is affected as it is moved closer to the fulcrum.

Materials

- metre ruler
- stiff cardboard square
- 2 plastic cups
- slotted masses
- masking tape
- scissors

Procedure

1. Copy the table below into your workbook.
2. Use the scissors and ruler to score two lines so that the square is divided into thirds. Bend the cardboard to make a triangular prism to use as a fulcrum, as shown in Figure 5.4.25.

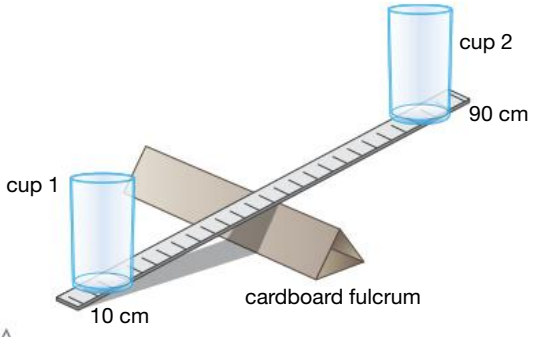


Figure 5.4.25

3. Position the ruler so that the fulcrum is halfway along its length.
4. Tape one of the plastic cups at one end of the ruler, so that its centre sits at the 10 cm mark, and a second cup at the 90 cm mark.
5. Copy the results table below.
6. Put 100 g of masses in the first cup and measure how much mass needs to be added to the second cup to balance this.
7. Repeat this process with the centre of the second cup positioned above the 85, 80, 75, 70, 65 and 60 cm marks along the ruler.

Results

Record all measurements in your Results table.

Practical review

1. **Describe** whether more or less mass was required to balance the load as the effort force moved closer to the fulcrum of the see-saw.
2. **Discuss** whether you have experienced this yourself on a see-saw.
3. **Calculate** the columns in your table:

   Mass in cup 1 × D_1
   and
   Mass in cup 2 × D_2
4. **State** whether the values calculated above are similar. **Explain** your result.

Mass in cup 1 (g)	D_1 (distance of cup 1 from fulcrum) (cm)	Mass in cup 1 × D_1	Mass in cup 2 (g)	D_2 (distance of cup 2 from fulcrum) (cm)	Mass in cup 2 × D_2
100	40			40	
100	40			35	
100	40			30	
100	40			25	
100	40			20	
100	40			15	
100	40			10	

2 Using a wheel and an axle

Purpose

To build a simple machine consisting of a wheel and an axle.

Materials

- 250 mL beaker or tin can
- 2 paperclips
- length of stiff wire
- sticky tape
- 100 g mass
- string

Procedure

1. Set up the equipment as shown in Figure 5.4.26a. Tape the two paperclips to hold the wire axle in position.
2. Try to lift the 100 g mass by twisting the wire around using your thumb and index finger.
3. Remove the paperclips and remove the wire. Bend the end without the masses to form a handle, as shown in Figure 5.4.26b.
4. Reassemble the equipment and try to lift the masses by turning the handle.

Practical review

1. **Describe** the difficulty of using the equipment with the straight axle to lift the masses using the straight piece of wire.
2. **Explain** any differences in doing this when using the bent handle.
3. **Propose** a reason this change makes the task easier.
4. This handle is acting as a lever. **Identify** why turning the handle provides the force advantage needed to lift the mass.
5. **Identify** three places you have seen systems similar to this being used to provide a force advantage.

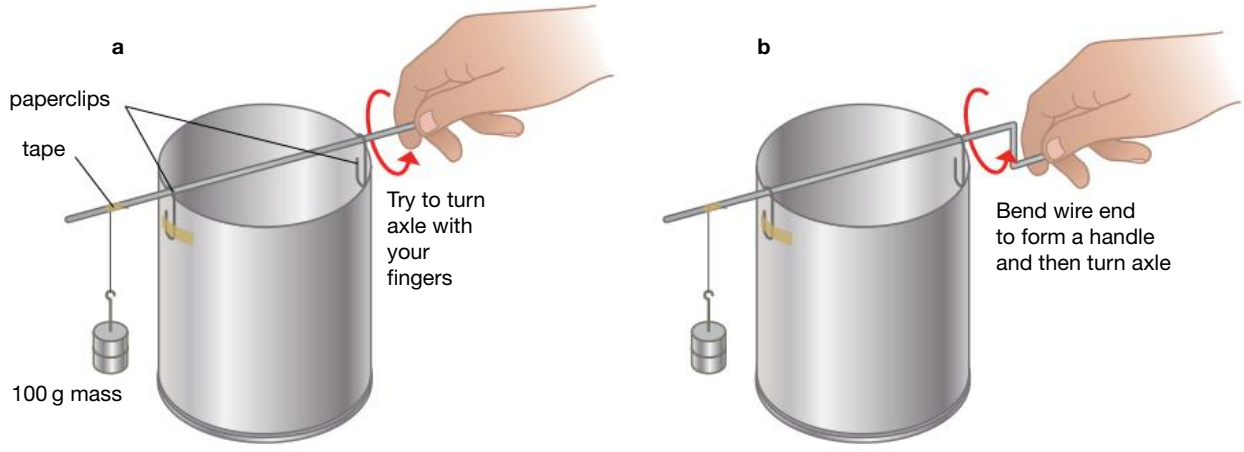


Figure 5.4.26

5.4 Practical investigations

3 Using ramps

Purpose

To measure the force required to lift a cart vertically and to lift it using ramps of differing slope.

Materials

- trolley
- spring balance (or force sensor)
- a number of books or a couple of blocks or bricks to elevate ramp
- wooden ramp
- spring balance
- protractor

Procedure

1. In your workbook, copy the table shown in the Results section.
2. Position a plank of wood on a pile of books (or a brick and some books) to make a ramp that is about 10 cm high, as shown in Figure 5.4.27.

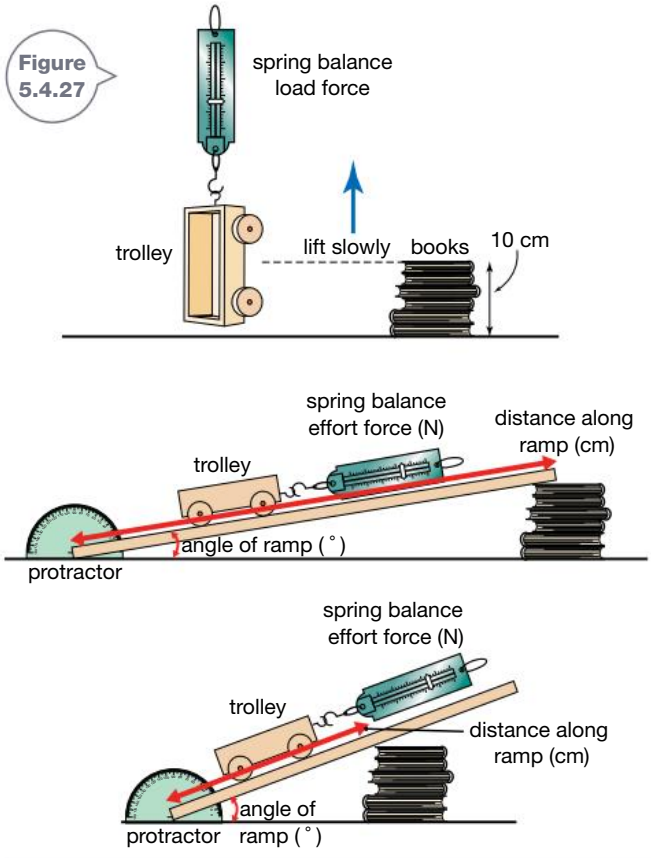


Figure 5.4.27

3. Attach the trolley to a spring balance (or force sensor). Carefully lift it vertically until its rear is level with the height of your ramp. Record this weight as the load force.
4. Measure the angle of elevation of the ramp and its distance from the base to the pile of books. Record these values in the table.
5. Slowly drag the trolley up the ramp to the pile of books. Record the effort force required.
6. Repeat steps 4 and 5 for four different angles of the ramp. Measure the new ramp length and effort force each time.

Results

Record all measurements in your Results table.

Angle of ramp (°)	Distance along ramp (cm)	Effort to pull trolley up ramp (N)

Practical review

1. **State** whether having a large or a smaller angle of ramp increased the effort force required to pull the trolley up the ramp.
2. **Explain** why this occurred, considering how the effective distance of the ramp varied with the changing angle.
3. **List** three situations in which using a ramp at a shopping centre is useful.

4 Investigating bicycles

Purpose

To examine the gearing combinations of a bicycle.

Materials

- geared bicycle
- broom handle
- piece of chalk

Procedure

1. Copy the table from the Results section.
2. Lift the rear of the bicycle off the ground and support it against two stools or benches, as shown in Figure 5.4.28.

Figure 5.4.28

3. Select the first gear, so that the chain wheel is on the smallest sprocket and the rear sprocket is on the largest.
4. Make a mark with chalk on the rear tyre. Slowly turn the pedals one revolution and count how many revolutions the rear wheel makes in this time.
5. Record this data in the first row of your table.
6. Count the number of teeth on the front and rear sprockets and enter this data.
7. Repeat steps 3–6 for another four gear combinations.

Results

Complete the table.

Combination number	Number of turns of rear wheel for one turn of pedals	Number of teeth on chain wheel sprocket (N_1)	Number of teeth on rear wheel sprocket (N_2)	Gear ratio $\frac{N_1}{N_2}$
1				
2				
3				
4				
5				

Practical review

1. **Identify** which gear combination is best suited to riding uphill. **Justify** your choice.
2. **Identify** which gear combination is best suited to riding along a flat, easy road. **Justify** your choice.

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.

5 **Name** the components shown in Figure 5.5.1.

a b c

Figure 5.5.1

Understanding

6 **Describe** three examples of an object with kinetic energy.

7 **Describe** two examples in which heat is transferred by conduction.

8 **Explain** how energy rating labels help consumers who are purchasing new electrical appliances.

Applying

9 **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	

10 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. N

11 a **Identify** the particles that transfer energy around an electric circuit from a battery to a light globe.

b **Identify** the energy transformations that occur within the:

i battery

ii light globe.

Analysing

12 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 CCT

13 A Washwell washing machine has 5 stars and a SudZ washing machine has 7½ 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.

14 a **Determine** whether you can or cannot answer the questions on page 175 at the start of this chapter.

b **Assess** how well you understand the material presented in this chapter.

Creating CCT

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

kinetic energy
sound energy
electrical energy
heat energy
potential energy
gravitational potential energy
chemical energy
energy efficiency
light energy
elastic potential energy

5.11

Thinking scientifically

Q1 Lucy accidentally drops a chocolate cake on the floor. Select the most likely sequence of energy transformations that occur. CCT

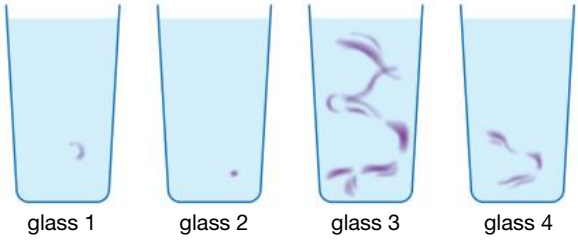
A heat energy → gravitational potential energy → kinetic energy → sound energy

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. CCT

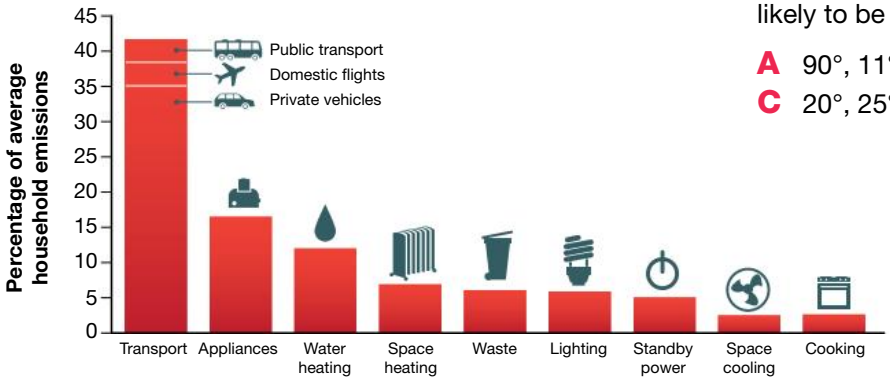


Which of the following correctly ranks the water in the glasses in order of increasing temperature?

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 This graph is from the Australian Government website *Working together for a clean energy future*. CCT



Use the graph to select the correct statement.

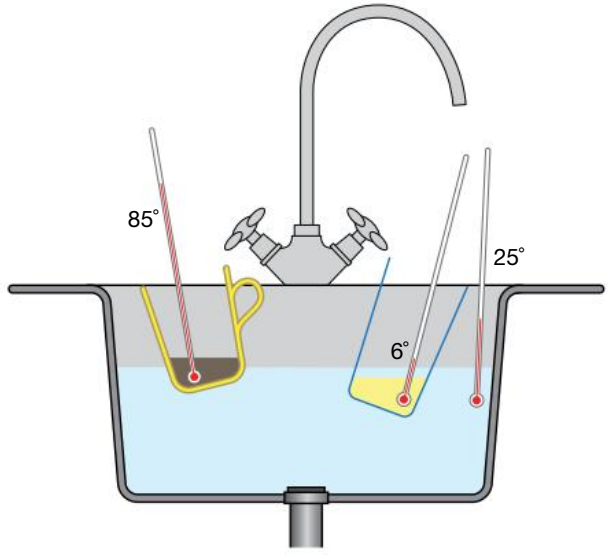
A The average percentage household emissions are greater for waste disposal than those associated with space heating.

B The use of public transport generates a greater percentage of emissions than the use of a private vehicle.

C Emissions due to standby power are greater than emissions produced from cooking.

D Lighting produces more emissions than water heating.

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. CCT



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 L

Chemical energy: energy stored within a substance such as fuel or food that may be released when the substance is burnt or digested

Conduction: heat transfer between two objects in contact

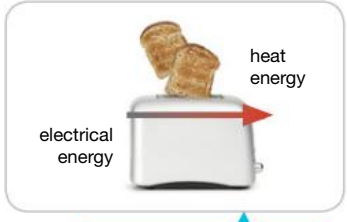
Convection: the transfer of heat in a liquid or gas

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

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

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

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.

Light energy: form of energy that is visible, such as that produced by the Sun

Light energy

Nuclear energy: energy stored inside an atom

Photosynthesis: process in which green plants convert light energy into chemical energy

Potential energy: stored energy possessed by an object, such as elastic potential energy of a squashed spring

Potential energy

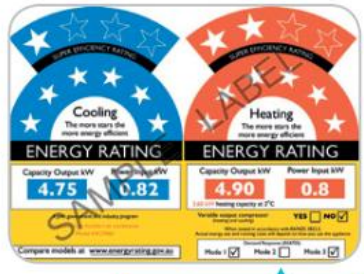
Radiation: heat transfer as a wave, which can even travel through the vacuum of space

Sound energy: energy that travels as vibrating waves and can be heard by our ears as sound

Unit 5.2 L

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 rating label: a label showing a number of stars (usually from 1 to 10), 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

Unit 5.3 L

Circuit diagram: a simplified and shorthand version of a circuit; shows how all components in the circuit are connected

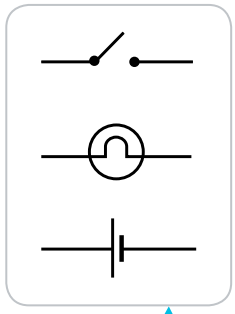
Components: the parts of a circuit (light globes, switches, resistors, wires, globes and batteries)

Current: the flow of charge

Electric circuit: the path down which charge flows

Electrons: tiny negative (–) particles spinning around the nucleus of an atom

Ion: a charged 'atom' created when electrons are gained or lost



Components

Neutral: having no charge

Neutrons: neutral particles found in the nuclei of most atoms

Nucleus: the core of an atom; it contains protons and neutrons

Protons: positive (+) particles found in the nuclei of all atoms

Static electricity: the build-up of electric charge on a surface

Unit 5.4 L

Axle: shaft on which a wheel rotates

Driven gear: the gear that receives force from a driving gear

Driving gear: the gear that supplies force to another gear

First-class lever: lever with effort and loads located at each end, and fulcrum in the centre

Force multiplier: machine that increases the force applied for a task, such as a first-class lever

Fulcrum: point about which a lever pivots

Gears: a wheel with teeth used to turn another gear wheel

First-class lever

Gear train: a system of interconnected gears

Inclined plane (ramp): a simple machine that reduces the effort needed to lift a load by increasing the distance it acts

Lever: simple machine consisting of a rigid rod that pivots about a point

Load: force that a lever is used to overcome

Pulley: a wheel with a groove over which a rope or cable can slide, used to change the direction of a force

Ramp: an inclined plane used to help lift an object

Rim: outer edge of a wheel

Second-class lever: lever with the fulcrum located at one end, the effort at the other and load in the centre

Second-class lever

Simple machine: a device that makes work easier by changing the size or direction of a force

Speed multiplier: machine that requires a small movement of an effort to produce a large movement of a load, such as a third-class lever

Third-class lever: lever with the fulcrum located at one end, with the load at the other and effort in the centre

Third-class lever

Wedge: a double inclined plane that moves through another object, changing the direction of force

Wheel: a type of lever with an axle acting as its fulcrum

6 Elements, compounds and mixtures

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 is written as H_2O?

After completing this chapter students should be able to:

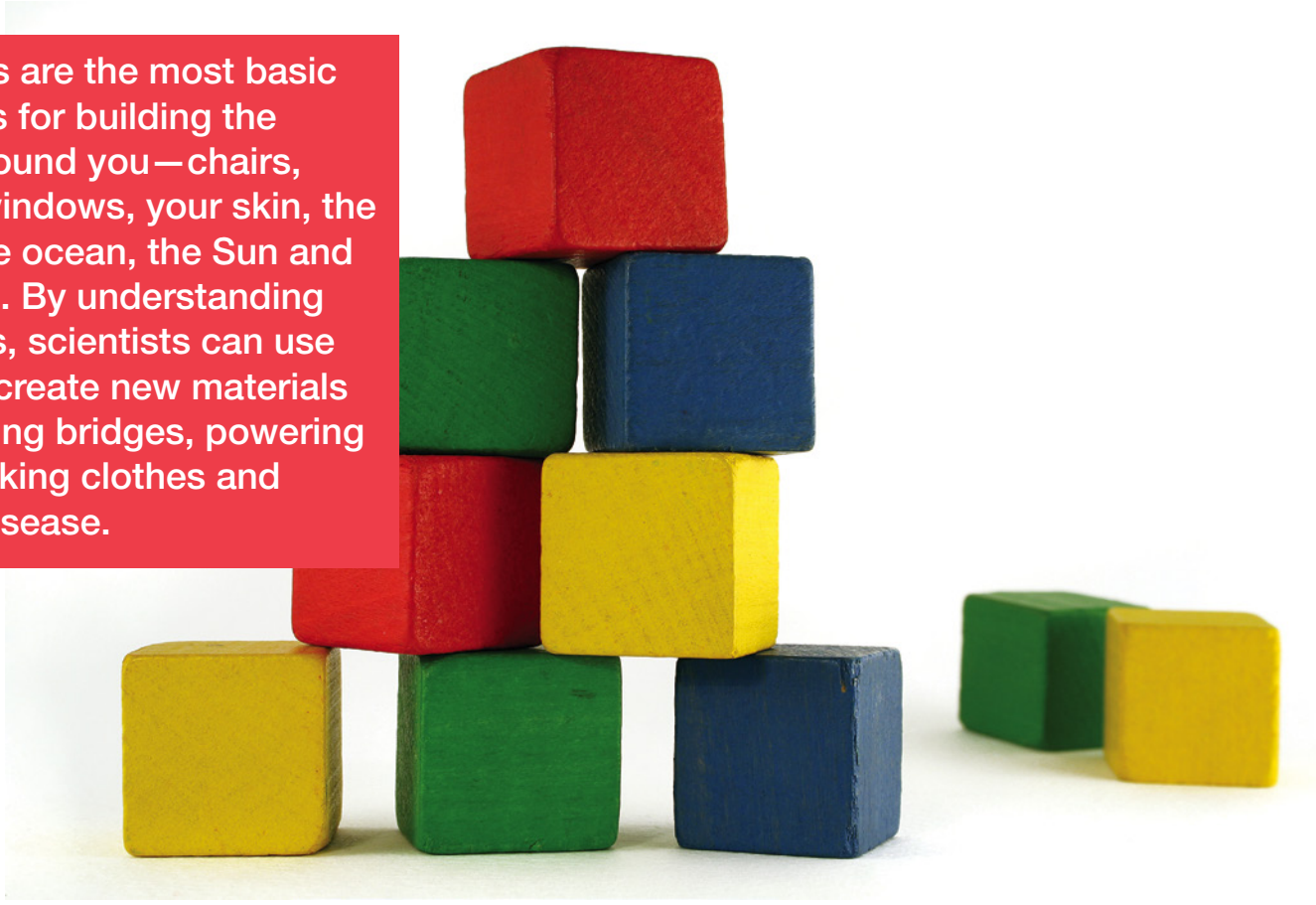
- describe the properties and uses of some common elements, including metals and non-metals
- explain why symbols are used for elements
- identify examples of common compounds
- use the type and arrangement of particles to contrast elements, compounds and mixtures
- describe how new technologies have changed our understanding of elements
- investigate how different cultures have applied their knowledge of elements and compounds to their use in everyday life L IU A
- propose reasons why society should support scientific research into new materials such as pharmaceuticals and polymers EU CCT PSC S
- describe how science is used to produce new substances CCT

ADDITIONAL

- discuss the cost and benefits to society of the development of new materials
- investigate how the chemical properties of a substance affect its use.

6.1 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. With just these three types you can construct many different Lego combinations. Figure 6.1.1 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 6.1.2 on page 230.

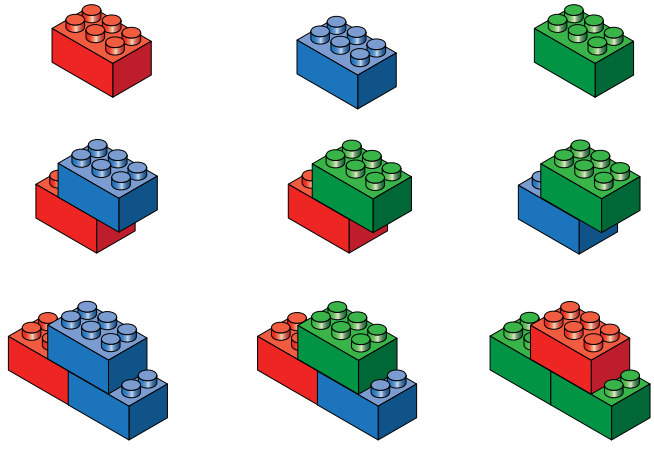


Figure 6.1.1 With just a few types of Lego, you can create many different combinations. Similarly, it takes just 100 or so different types of atoms to make up every substance in the universe.

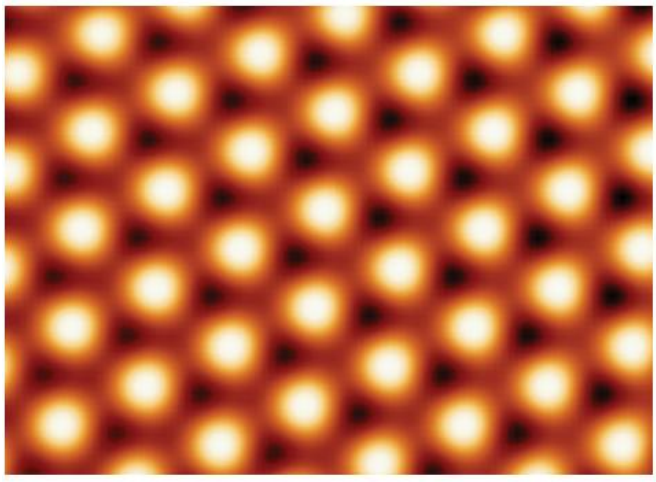


Figure 6.1.2 An STM is the only type of microscope powerful enough to get an image of these copper atoms.

Elements

Elements are substances that are made up of just one type of atom. The air you breathe is not pure but is a mixture, mostly made up of two elements—the gases oxygen and nitrogen. Billions of invisible oxygen and nitrogen atoms surround you. They are what you feel hitting your skin when a breeze blows. In addition to oxygen and nitrogen, there are many other elements that are useful in your everyday life.

Each element has a unique set of characteristics that scientists refer to as its **properties**. These properties determine whether an element is classified as metallic or non-metallic.

Metallic elements

Aluminium, iron, mercury, gold and silver are all examples of metallic elements that are used every day in construction, electronics and jewellery. Your body needs metals too—iron, calcium, sodium and potassium are all needed for it to function properly. Metallic elements (such as the ones shown in Figure 6.1.3) all share some characteristic properties. **Metals**:

- tend to be shiny (or can be polished to make them shiny). This is referred to as being **lustrous**
- 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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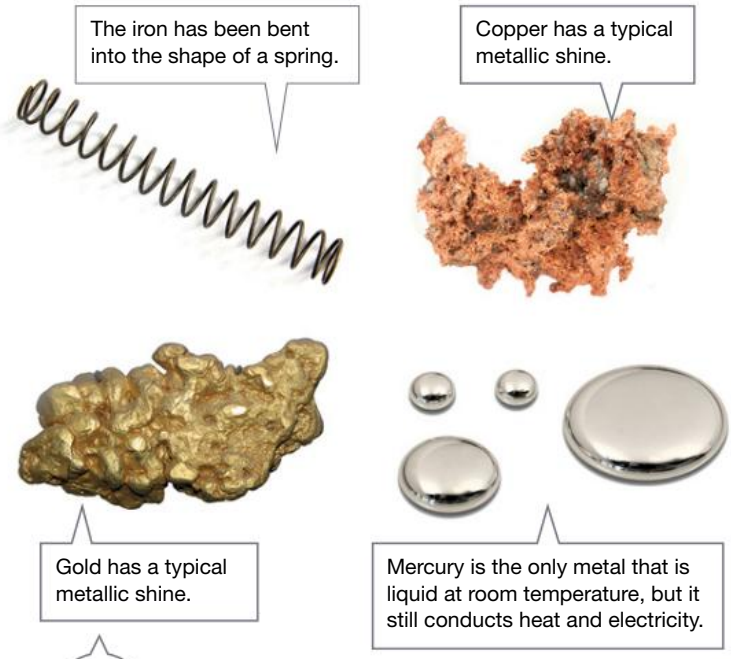


Figure 6.1.3 Common metallic elements

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®
- water
- potato masher
- long pencil
- mixing bowl
- magnet
- sticky tape

Do this …

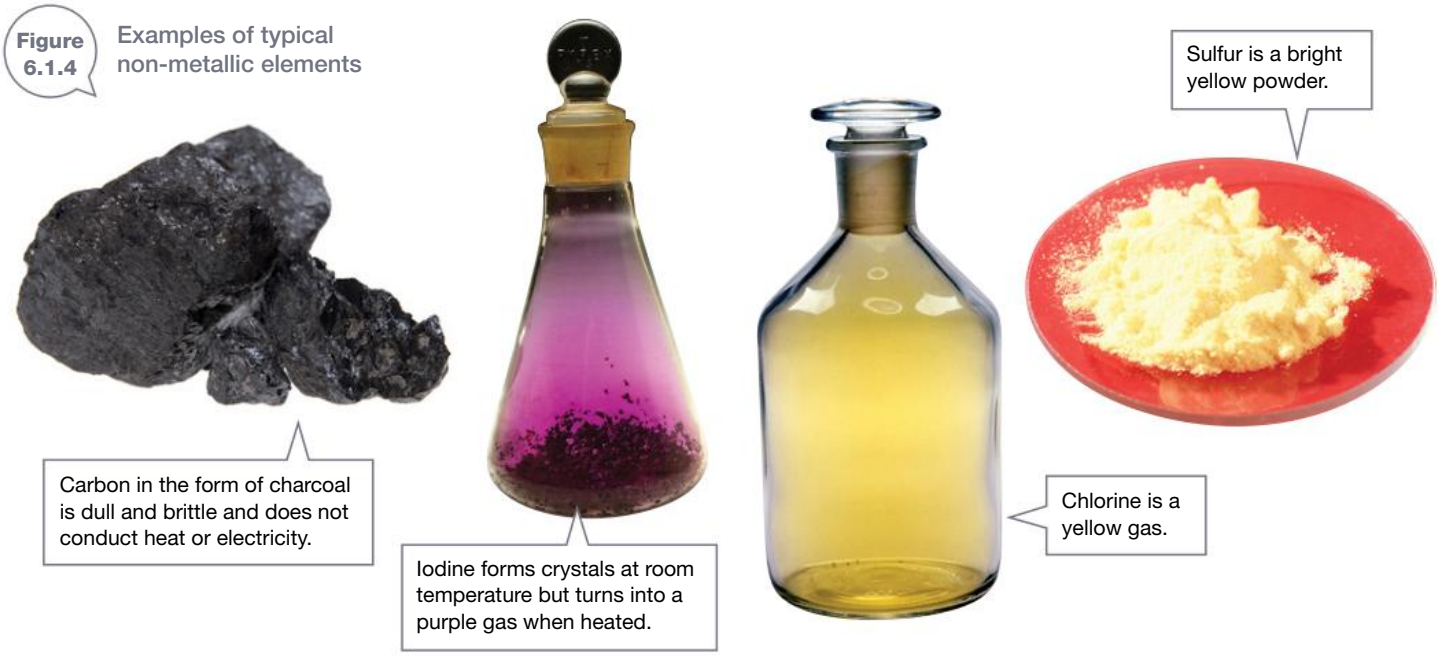
1. Pour 2–3 cups of iron-rich cereal into the mixing bowl.
2. Use the potato masher to crush the cereal to pinhead-sized pieces.
3. Add enough water to just cover the cereal and continue to mix with the potato masher for 10 minutes or until it looks like soup.
4. Use the sticky tape to attach the magnet 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 6.1.4 Examples of typical non-metallic elements



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 6.1.4. **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 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.

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The periodic table

There are 118 known **elements** but only 98 of these occur naturally—the rest are synthetic and must be made in a laboratory. Each element has a name and a chemical symbol.

The same set of chemical symbols is used by scientists all around the world. This makes communicating new scientific research between scientists much clearer and more accurate.

Scientists display all the known elements and their symbols in a table called the **periodic table**, shown in Figure 6.1.6 on page 232. The periodic table lists the elements from lightest to heaviest and helps scientists to understand some of their physical and chemical properties.

SciFile

The elements of war

The non-metallic element chlorine was used in World War I (1914–1918) 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 6.1.5).

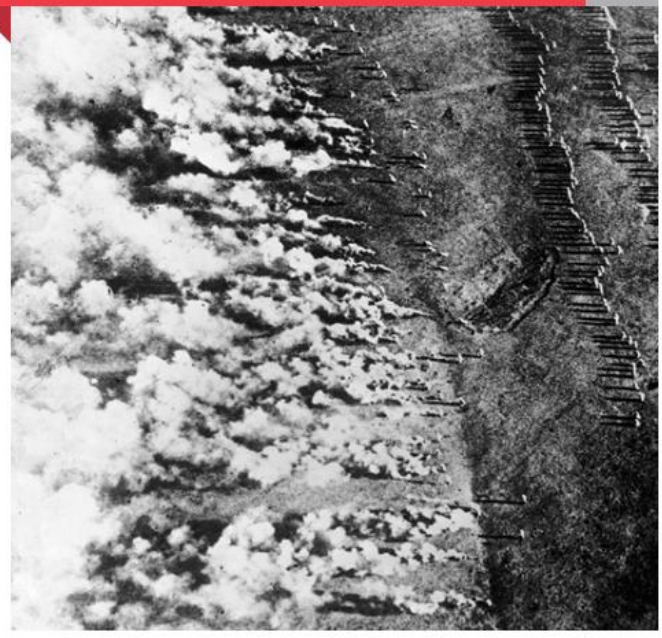

Figure 6.1.5 Chlorine gas floating over the trenches in France during World War I

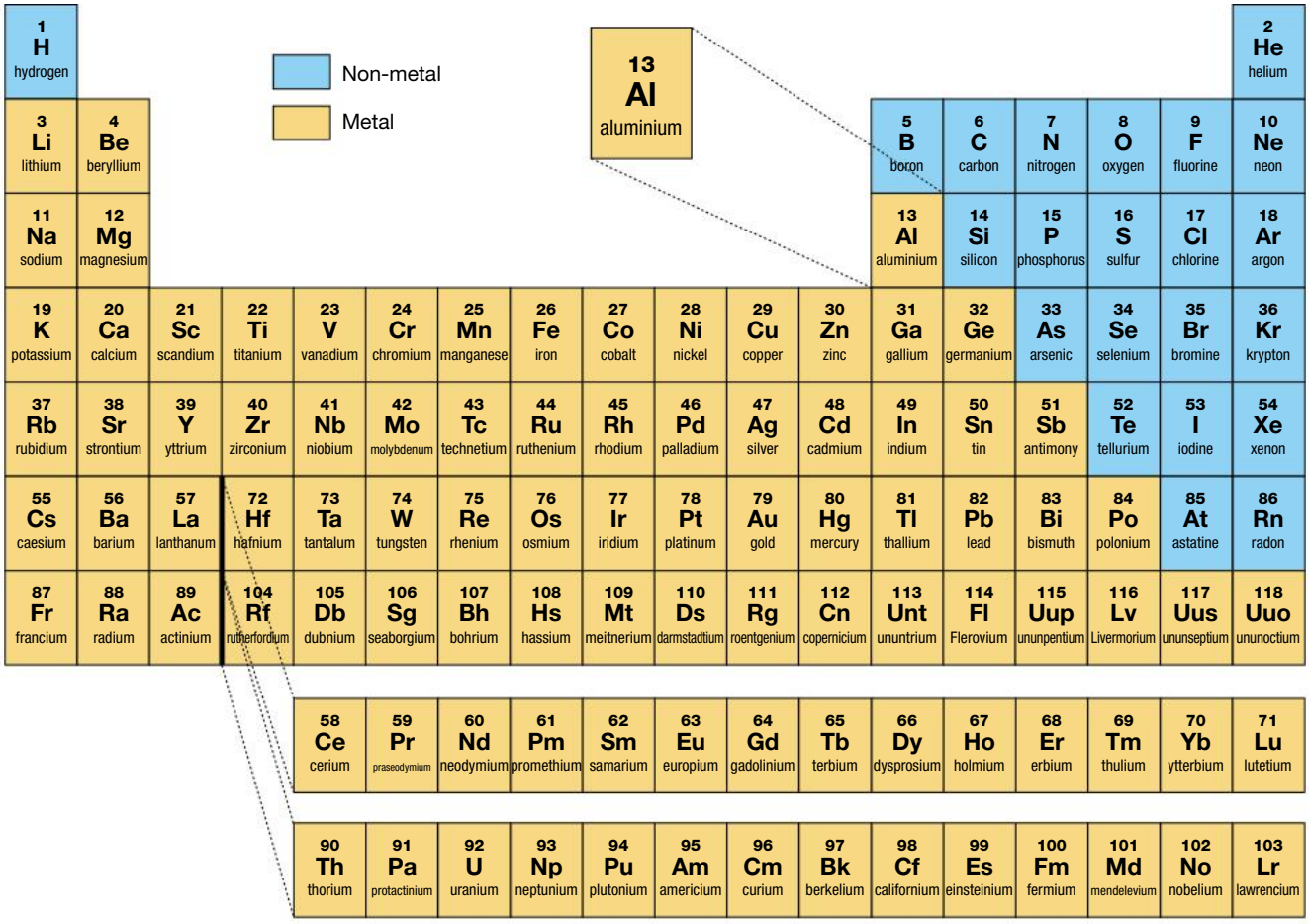

Figure 6.1.6 The periodic table is a list of the known elements from the lightest to the heaviest.

Chemical symbols

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 names for the elements in other languages. These names may be different from those used in English. For example, the Latin name for potassium is *kalium,* while sodium is *natrium*—knowing this, their symbols K and Na make sense.

Writing chemical symbols

The chemical symbol of an element is usually made of one or two letters.

- The first letter is always in upper case.
- The second letter is always in lower case.

So the chemical symbol for chlorine is always written as Cl and never CL or cl. Likewise, sodium is Na and not NA or na.

The last six elements of the periodic table are so radioactive that they have not yet been absolutely proved to exist. Until their existence is confirmed, these elements are given temporary symbols of three letters. An example is Uup. When confirmed, it will be given a 'normal' chemical symbol of one or two letters.

6.1 6.2 6.3

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.

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 bends or breaks when a force is applied.

Monatomic elements

An element that consists of just single atoms is known as **monatomic**. Monatomic elements are rare, with only six of the 98 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 6.1.7.

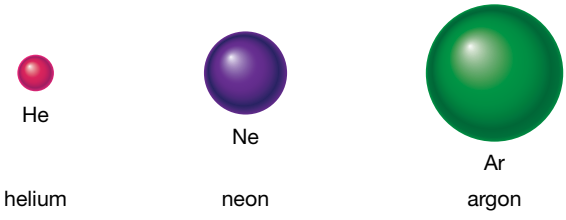

Figure 6.1.7 Helium, neon and argon are monatomic and do not combine with other elements.

The monatomic element helium (He) is used in party balloons because it is less dense (lighter) than air and so the balloons float (Figure 6.1.8).

Figure 6.1.8 A helium-filled weather balloon collects data on the atmosphere.

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.

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 6.1.9.

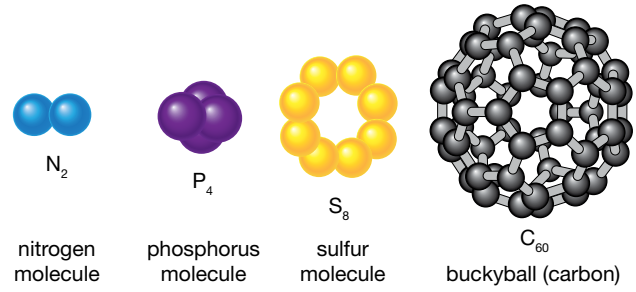

Figure 6.1.9 Non-metallic elements tend to form molecules like these where every molecule contains just one type of atom.

The oxygen you're breathing 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. The molecular formula shows 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}.

Elements in lattices

Crystal **lattices** are large grid-like structures that repeat the same arrangement of atoms over and over. All metallic elements form crystal lattices. Only a few non-metallic elements form crystal lattices.

Metallic lattices

Eighty per cent of the known elements are metals. The atoms in metals form lattices, rather than molecules. An example is shown in Figure 6.1.10. The lattice structure makes metals dense, strong and solid at room temperature. The only exception is mercury, which is a liquid at room temperature. As a result, metals are important materials for the construction and manufacture of a large variety of objects—from buildings and bridges through to trains, planes, cars, tools and jewellery.

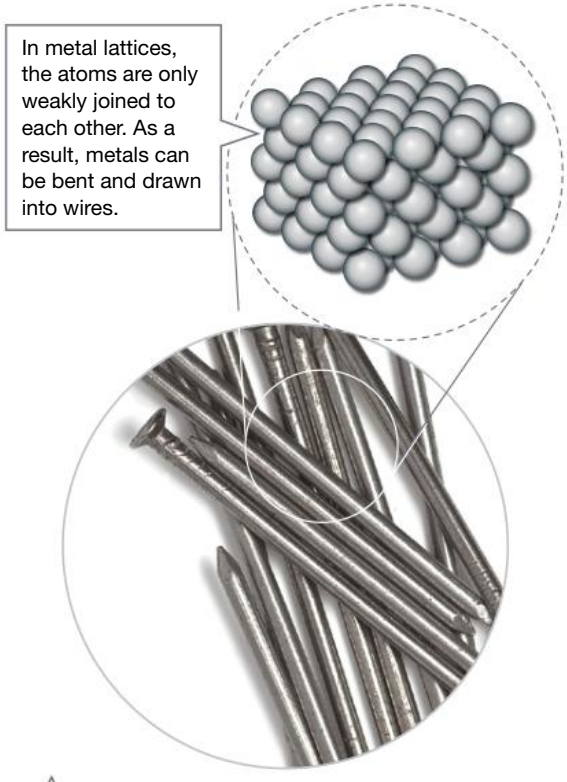

Figure 6.1.10 The atoms in metal lattices can move across one another, allowing metals to bend, be drawn into wires and be hammered into thin sheets.

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The atoms in metallic lattices can slide and move over each other without breaking the lattice. This means that metals can be bent, drawn into thin wires or hammered into thin sheets. Metal sheets can be thick, like the ones used to build a corrugated iron shed. Or the sheets can be very thin, like aluminium foil. In addition, metals are very good at conducting heat and electricity, making them perfect for pots, pans, heating elements and electrical wiring.

Non-metallic lattices

Only a few non-metallic elements form lattices. An example is silicon. You can see its lattice in Figure 6.1.11. Another example is carbon, which forms crystal lattices to make graphite and diamond.

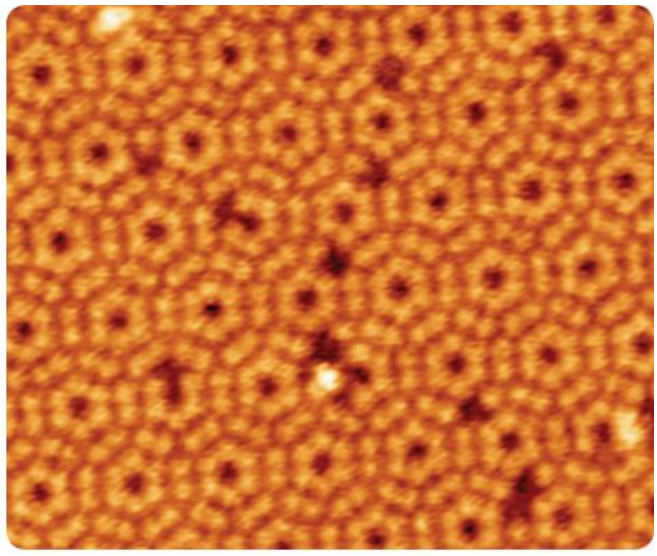


Figure 6.1.11 An image of a lattice of silicon atoms taken with a powerful microscope known as a scanning tunnelling microscope (STM)

In graphite, the carbon atoms form sheets that are stacked on top of each other as shown in Figure 6.1.12. 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, and so it can be used to replace electrical wiring in very hot situations such as industrial kilns for firing clay tiles.

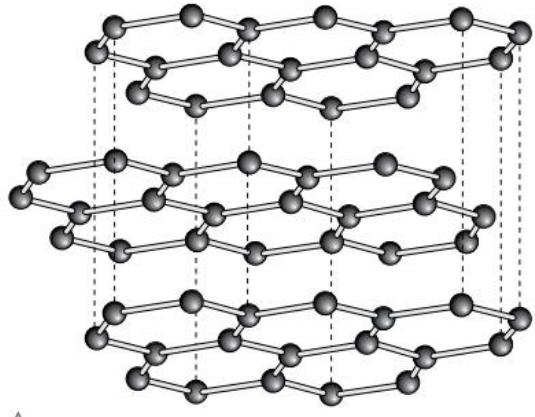


Figure 6.1.12 The carbon atoms in graphite form layers. The layers are difficult to break but can slide over each other easily. This makes graphite an excellent lubricant.

Prac 4 p239 6.4 6.5

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

Figure 6.1.13 Conflict diamonds are diamonds that are exported from a country to finance civil wars and rebellion.

CONFLICT DIAMONDS

For a long time, diamonds have been symbols of wealth, power, elegance and romance. However, the recent history of some diamonds is not so glamorous.

Chemically, diamonds are just carbon, one of the most common elements on Earth. However, in diamonds, the carbon atoms have been forced into a rigid crystal lattice by extreme temperatures and pressures deep beneath the Earth's surface. The crystal lattice is so strong that diamonds are Earth's hardest natural material. As a result, 80% of diamonds mined today are used mainly for industrial purposes such as cutting and polishing tools.

Diamonds have another property that makes them highly desired gemstones. Light that enters a diamond can be reflected (bounced) around many times inside it before being reflected out again. This property gives diamonds a dazzling sparkle when cut and polished, like the one in Figure 6.1.14. It is both the beauty and the rarity of diamonds that makes them so desirable and expensive.

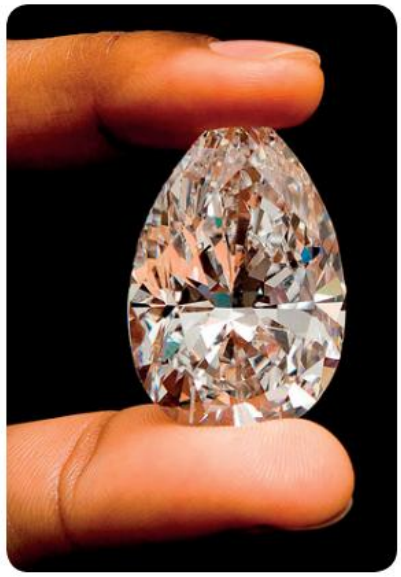


Figure 6.1.14 When diamonds are cut and polished, they sparkle with a brilliance unlike most other stones.

DIAMONDS AND CIVIL WAR

Despite their beauty, some diamonds have a dark history. The high price of diamonds and their relative abundance in Africa led to some diamonds being used to illegally fund civil wars in countries such as Angola and Sierra Leone from the late 1970s to the early 2000s. Rebel groups and even some governments threatened people, forcing them to work in their diamond mines in poor conditions. They then sold the diamonds in exchange for weapons, resulting in wars and millions of lives lost. In 2006, President Charles G. Taylor of Liberia was charged with crimes against humanity because of his role in funding the conflict in Sierra Leone with conflict diamonds. He was found guilty in 2012 and sentenced to 50 years in prison.

Figure 6.1.15 Angola and Sierra Leone were two African countries where civil war was funded by conflict diamonds.

KIMBERLEY PROCESS CERTIFICATION SCHEME

It wasn't until 1998 that the world officially became aware of the link between diamonds and the conflicts in Africa. The United Nations acted quickly and in 1998 banned the purchase of conflict diamonds from Angola. In 2000, government and diamond industry groups began working together to find a solution to the conflict diamond problem. In 2003, the Kimberley Process Certification Scheme was established. This scheme aimed to keep track of where diamonds came from. This would make it harder for criminals to export their diamonds and fund wars.

In recent years there has been a lot of criticism of the Kimberley Process. Some have claimed that it has failed to fully halt the trade of conflict diamonds. Nevertheless, the number of conflict diamonds on the world market is now estimated to be less than 1% of the total diamond market. This is down from the estimated 20% in the 1980s.

Figure 6.1.16 Keeping track of the origin of diamonds is one of the best ways of stopping the flow of conflict diamonds. However, keeping track on a global scale is not an easy task.

REVIEW

1 **Explain** how the arrangement of carbon atoms in diamonds makes diamonds useful for cutting and polishing tools.

2 **Explain** what a conflict diamond is.

3 **Outline** what the Kimberley Process is and what it aims to do.

4 a **Evaluate** whether or not you would be happy to wear a diamond that was mined in the 1980s.

b **Assess** whether your attitude would change if the diamond was mined today.

c **Justify** your responses.

6.1 Unit review

Remembering

1 **Name** the particles that make up all matter.

2 **List** four properties of metallic elements.

3 **Name** three monatomic elements and give their chemical symbols.

4 **State** which of the following is the correct way to write the chemical symbol for iron.

A Ir B FE
C Fe D fe

5 **Recall** the chemical symbols of the following elements:

a hydrogen
b helium
c carbon
d oxygen
e nitrogen.

Understanding

6 **Define** the following terms. L

a ductile
b malleable
c brittle

7 **Explain** why metallic elements bend, while solid and non-metallic elements break or crumble.

8 **Explain** why graphite might be used instead of gold or copper wires to conduct electricity in very hot situations such as an industrial kiln.

Applying

9 **Use** the periodic table to **identify** an example of a metal and a non-metal.

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 An allotrope is a different form of the same element. **Analyse** the molecular formulas given on page 233 and **identify** three allotropes. .

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, neon, iron, nitrogen, argon, gold.

Evaluating CCT

15 a Imagine you have four Lego blocks. One is red, one blue, one green and one yellow. **Determine** how many different combinations of blocks you can construct from these four blocks.

b **Assess** how the Lego blocks in part a help you understand how millions of different compounds can be constructed from just 118 elements.

16 Iron and calcium are metallic elements that are important in anyone's diet. Both are sometimes added to breakfast cereals.

a Iron helps with the transport of oxygen in the blood. **Propose** a reason why people with anaemia (a lack of iron) are often pale and have little energy.

b **Propose** what calcium is used for in the body.

Creating CCT

17 **Use** the periodic table to **construct** a table of elements with chemical symbols that do not match their name in English.

Inquiring

Research one element in detail. Find:

- when the element was discovered
- who discovered the element
- whether it is a metal or a non-metal
- some of its properties
- some of its uses.

Present your research as a poster or digital slide show. ICT

6.1 Practical investigations

1 Obtaining copper, a metallic element

Purpose

To form crystals of metallic copper.

Materials

- zinc metal strip
- 0.1 M copper sulfate solution

- beaker
- filter paper
- magnifying glass or microscope

SAFETY

Copper sulfate is toxic, so wear gloves and safety glasses and avoid contact with eyes, skin and mouth.

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.

Practical review

1. **Use** the periodic table to **state** the following information for copper:
   - a chemical symbol
   - b atomic number
   - c whether it is a metal or a non-metal.
2. a **State** whether copper would exist in a monatomic form, as a lattice or as molecules.
   b **Justify** your answer.

2 Obtaining hydrogen, a non-metallic element

Purpose

To form the element hydrogen.

Materials

- 2 M hydrochloric acid
- magnesium metal strip

- test-tube
- scissors
- eye-dropper

SAFETY

Hydrochloric acid is very corrosive. Take care to ensure none touches your skin or clothing. Be aware of first aid procedures. Report any spills to your teacher immediately.

Procedure

1. Use scissors to cut the magnesium ribbon into small pieces (2 cm) and place them into the test-tube.
2. Using the eye-dropper, add enough hydrochloric acid to cover the pieces of magnesium metal.
3. Watch what happens.

Results

Record your observations.

Practical review

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 **state** the following information for hydrogen:
   - a chemical symbol
   - b atomic number
   - c whether it is a metal or a non-metal.
4. a **State** whether hydrogen would exist in a monatomic form, as a lattice or as molecules.
   b **Justify** your answer.

3 Measuring density, a physical property

Density measures the amount of matter packed into a certain volume. It is calculated using the formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Density is commonly measured using the unit g/cm^3.

Purpose

To measure the density of metals.

Materials

- cubes of metallic elements such as iron, copper and aluminium

---

- access to electronic balance
- ruler
- calculator

Procedure

1. In your workbook, construct a table like the one below.
2. Use the electronic balance to measure the mass of each metallic cube and record your measurements in the table.
3. Use the ruler to measure the length, width and height of the cubes. Once again, record your measurements.

Results

1. Enter all the masses and sizes you measured in the table.
2. Calculate the volume of each cube by multiplying length × width × height. Enter these values in the table. N
3. Calculate the density of each cube by dividing the mass by the volume. Enter these in the table. N

Practical review

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 your calculated densities with these values.
3. **Propose** reasons why the values above might be a little different from the ones you calculated.

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						

STUDENT DESIGN

4 Making models

Purpose

To construct models of molecules and lattices.

Materials

- to be selected by students
- camera, mobile phone or tablet with camera function

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Construct a model of one of the molecules or lattices found throughout this unit.
2. Take a photo of your model, then pull it apart and make a different one.

Results

Print out your photos and paste into your workbook.

Practical review

Use your photos to **contrast** molecules with crystal lattices.

6.2 Compounds and mixtures

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 characteristic properties. 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 6.2.1.

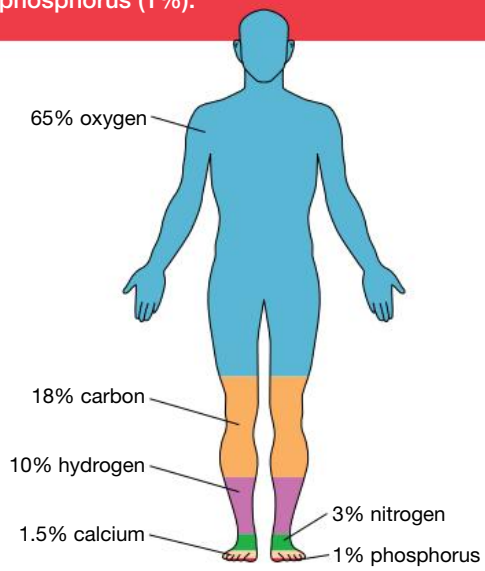
Some compounds are made up of molecules—such as water, wax and vegetable oil. In these compounds, each molecule contains two or more types of atoms. Other compounds form crystal lattices. For example, table salt is made of a lattice of sodium and chlorine atoms, while beach sand is a lattice of silicon and oxygen.

Figure 6.2.1 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?

SciFile

The human body is made up of just 16 elements arranged into a huge variety of compounds. 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%).



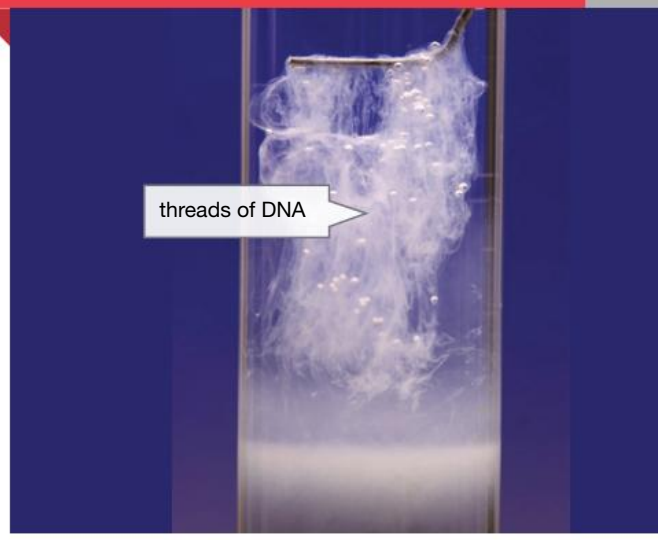
Scientists represent the molecules of compounds in a similar way to the molecules of elements. The chemical formula they write is also known as a molecular formula because it describes what makes up the molecules of the compound. For example, water is a molecular compound with the molecular formula H_2O. This molecular 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).

Prac 1 p246

DNA

SciFile

The DNA in each of your body cells is an extremely long molecule. The fine threads of DNA shown below would each be 2–3 metres long if stretched to their full length.



Molecular compounds

All the molecules in a compound are identical in size, shape and number of atoms. Many molecules are small and contain just a few atoms. For example, a molecule of carbon monoxide (formula CO) has just one carbon (C) atom and one oxygen (O) atom. The molecules in other compounds, such as some plastics, contain thousands of atoms. Figure 6.2.2 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.

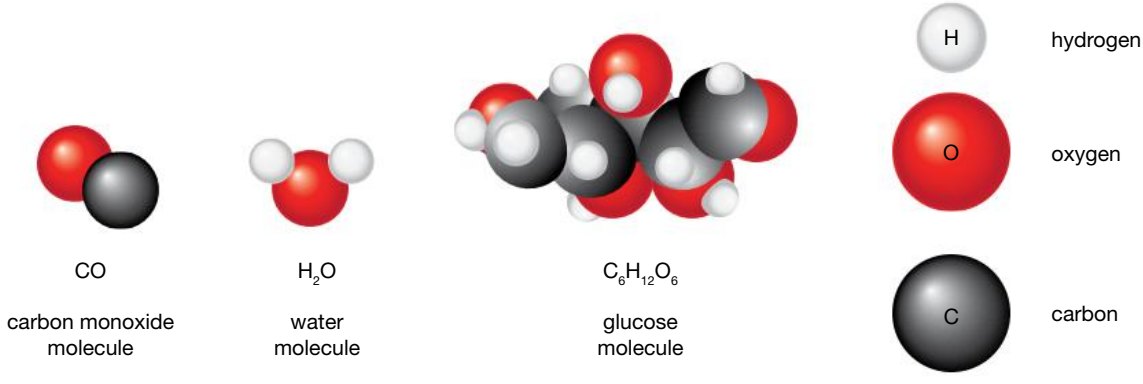


Figure 6.2.2 Molecules of three common compounds. All of these compounds are made from just three elements—oxygen, hydrogen and carbon.

Making sense of molecular formulas

The molecular formula of a compound indicates exactly what is in the compound's molecules.

- The chemical symbols tells you the types of atoms in each molecule.
- Subscripts tell you the numbers of each type of atom in the molecule. A subscript is a small number set slightly below each chemical symbol in the molecular formula. If there is no subscript, then there is only one of that type of atom in the molecule.
- Sometimes an element's chemical symbol may appear more than once in a molecular formula. In these cases, add the numbers for the repeated elements together. This will tell you how many of that type of atom are present.

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 6.2.5. 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 NaCl does not contain molecules. Instead the formula tells you that in the crystal lattice there is one sodium for every chlorine.

WORKED EXAMPLE
Making sense of molecular formulas

Problem 1

Identify the types and numbers of atoms in a molecule of nitric acid, HNO_3.

Solution

H and N have no subscripts, so there is one H atom and one N atom in each molecule.

O has 3 as its subscript, so there are three O atoms in each molecule.

Problem 2

Identify the types and numbers of atoms in a molecule of ethanol, C_2H_5OH.

Solution

C has the subscript 2, so there are two carbon atoms.

O has no subscript, so there is one O atom.

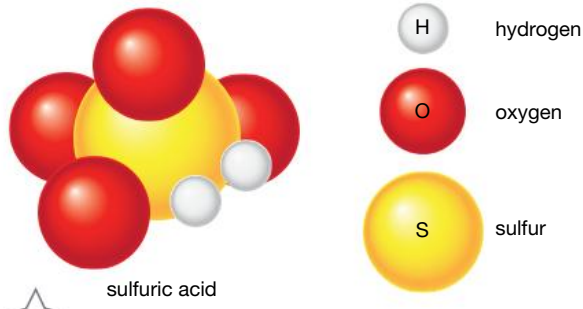
H appears twice, so add the subscripts together:
5 + 1 = 6. So there are six H atoms in each molecule.

Problem 3

Construct a molecular formula for the sulfuric acid molecule shown in Figure 6.2.3.

Solution

There are two H atoms (white balls), one S atom (yellow) and four O atoms (red), so the subscripts are 2, 1 and 4. So the molecular formula for sulfuric acid is H_2SO_4.



sulfuric acid

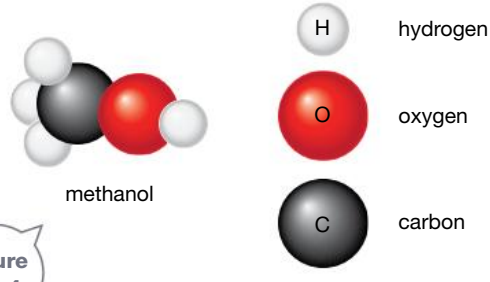
Figure 6.2.3

Practice

N

1 **Identify** the types and numbers of atoms in molecules of:
   - a benzene C_6H_6
   - b acetone CH_3COCH_3

2 **Construct** a molecular formula for the methanol molecule shown in Figure 6.2.4.



methanol

Figure 6.2.4

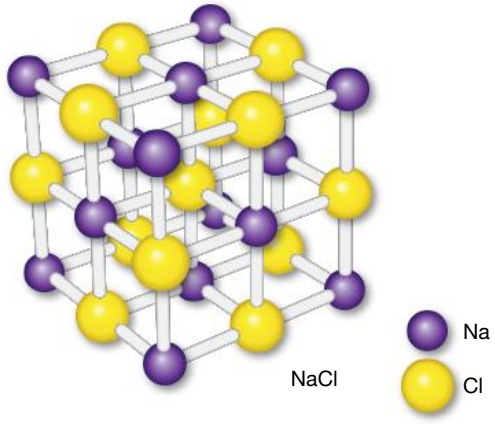


Figure 6.2.5 In a lattice of sodium chloride, sodium and chlorine atoms form a grid-like structure with one sodium atom for every chlorine atom.

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.

You can see the structure of silicon dioxide in Figure 6.2.6. Silicon dioxide also makes up minerals like quartz, amethyst and opal. It is the main ingredient in glass, and so it is used in optical fibres to carry information such as cable TV and broadband internet.

Prac 2 p246 Prac 3 p247 6.6

Mixtures

Many of the substances used every day are not simply elements or compounds but are **mixtures** of elements and compounds. For example, air 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 carbon monoxide (CO). Likewise, water from the tap is not pure but a mixture of water molecules (H_2O) and elements 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 6.2.7 shows the ingredients of a typical mixture.

Unlike elements and compounds, you cannot write chemical formulas for mixtures. This is because mixtures are made up of a variety of molecules and crystal lattices. In contrast, elements and compounds contain only one type of molecule or crystal lattice.

GO TO Pearson science NSW 7 Unit 4.1

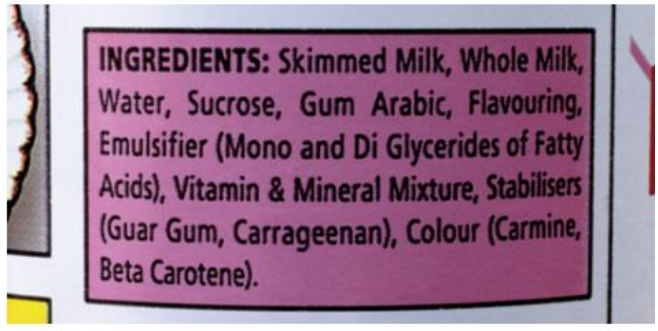


Figure 6.2.7 Any substance made up of two or more ingredients is a mixture.

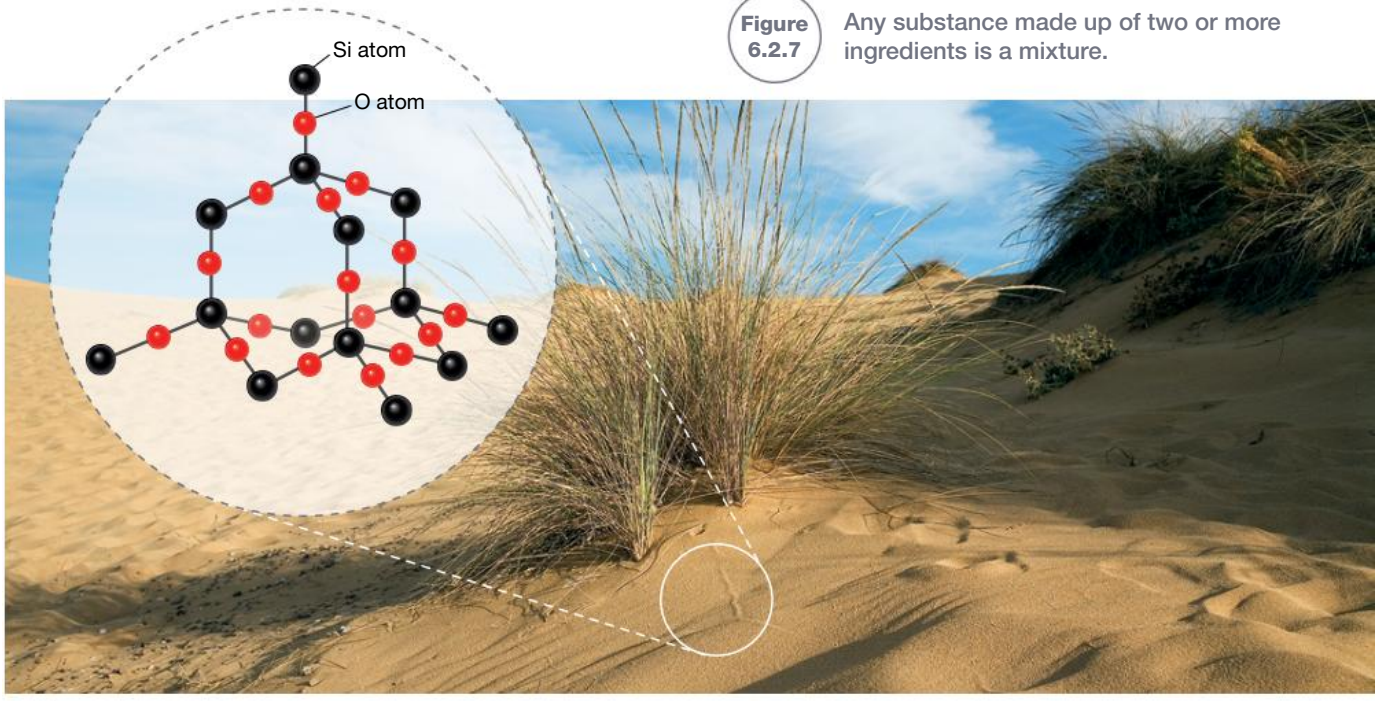


Figure 6.2.6 Silicon dioxide is a compound lattice. Its formula indicates that there are two oxygen atoms for every silicon atom in the lattice.

Everyday mixtures

There are many different types of mixtures that you use every day. One common type of mixture is a **solution**. A solution is formed when a solid dissolves in a liquid. In a solution:

- the dissolving solid is known as the **solute**
- the liquid in which the solute dissolves is known as the **solvent**.

Many common solutions have water as their solvent. These water-based mixtures are referred to as **aqueous solutions**. For example, sugar dissolves in water to form an aqueous sugar solution—sugar is the solute and water is the solvent.

If the solid is insoluble (doesn't dissolve) then the mixture formed is either a colloid or a suspension. In a colloid, the solid particles are so small that they never settle to the bottom of the liquid. Blood and milk are examples of colloids. In a suspension, the solid particles are larger and heavier, and so they will eventually settle at the bottom. A mixture of sand and water is an example of a suspension.

Some liquids can also dissolve to form solutions. Liquids that dissolve in another liquid are said to be **miscible**. For example, detergent is miscible in water and will dissolve to form a detergent solution. However, not all liquids are able to dissolve in one another. An example is oil and water. These liquids are said to be **immiscible**. Gases too can form solutions. For example, oxygen gas dissolves in water. This dissolved oxygen is what fish require to live.

There are many other types of mixtures that you will probably be familiar with. For example, a foam is a mixture of gas bubbles in a liquid. Examples are beaten egg whites used in cooking and the shaving cream in Figure 6.2.8. A mist or fog is a mixture of tiny water droplets suspended in a gas. Smoke is a mixture of solid particles suspended in a gas.

6.7

Figure 6.2.8 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 the alloy 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 6.2.9.

Figure 6.2.9 Different mixtures of metals make different alloys with very different properties and a wide range of uses.

6.2 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 **Recall** the chemical formulas for the following compounds.
- a carbon monoxide
- b glucose
- c water
- d silica (silicon dioxide)

4 **List** the elements and compounds that make up air.

Understanding

5 **Explain** what the chemical formula tells you about:
- a a molecular compound
- b a crystal lattice compound.

6 **Explain** why a chemical formula cannot be written for a mixture.

7 **Explain** why iron is rarely used in its pure form.

Applying

8 **Identify** the number and type of atoms in each of the following molecules.
- a carbon dioxide, CO_2
- b nitrous oxide, N_2O
- c sucrose (sugar), $C_{12}H_{22}O_{11}$
- d trinitrotoluene (TNT), $C_7H_5N_3O_6$
- e acetic acid (vinegar), CH_3COOH
- f urea, NH_2CONH_2

Analysing

9 **Contrast** elements and compounds.

10 **Contrast** mixtures and compounds.

11 **Classify** the following as element, compound or mixture.
- a pool water
- b helium
- c air
- d nitrogen
- e gold
- f sugar
- g cordial
- h carbon dioxide.

12 **Classify** the following compounds as either molecular or lattice.
- a water
- b carbon monoxide
- c silicon dioxide
- d carbon dioxide.

13 **Determine** the chemical formula for the molecule of methane shown in Figure 6.2.10.

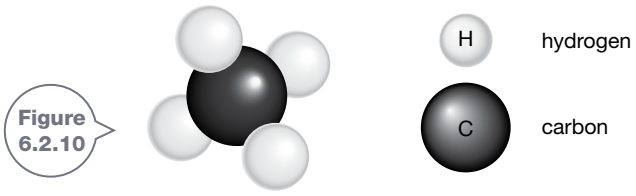


Figure 6.2.10

14 **Compare** the molecular compounds glucose (a type of sugar, $C_6H_{12}O_6$), ethanol (a type of alcohol, C_2H_5OH) and acetone (nail-polish remover, C_3H_6O).

Evaluating CCT

15 a **State** the chemical name for salt.
- b **Recall** its chemical formula.
- c **State** whether salt is an example of a molecule or a crystal lattice.
- d **Classify** salt as an element or a compound.
- e **Justify** your classification.

Inquiring

1 Research an alloy to find:
- what elements the alloy is a mixture of
- the alloy's properties
- how those properties contrast with the properties of the elements that make up the alloy
- where and how the alloy is used.

Present your findings as a poster.

2 Research how table salt is harvested at the Dampier salt mines in Western Australia.

Present your findings as a flow chart or annotated diagram.

6.2 Practical investigations

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, so wear safety glasses at all times.

Procedure

1. Use the spatula to deposit a small amount of sodium carbonate in the test-tube.
2. Use the dropper to add enough hydrochloric acid to the sodium carbonate to cover it.
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.

Practical review

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

- alum
- water

- 250 mL beaker
- glass rod
- measuring cylinder
- string
- filter paper
- spatula
- electronic scales
- hotplate or Bunsen burner, bench mat, tripod and gauze mat
- thermometer
- camera, mobile phone or tablet with camera function (optional)

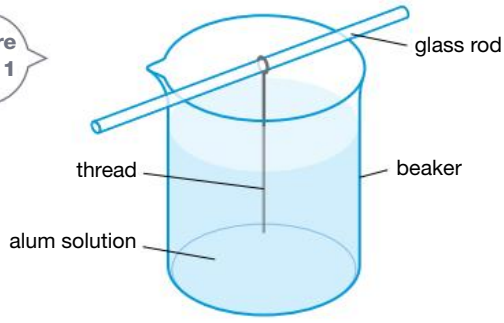
SAFETY

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 6.2.11.

Figure 6.2.11



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 photos to record your observations every day.

Practical review

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.

5 The diagram in Figure 6.2.13 is a 3D diagram of the experimental setup. **Construct** a 2D scientific diagram of the apparatus.

3 Making models

Purpose

To construct models of different compounds.

Materials

- different-coloured sticks of modelling clay

Procedure

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			

Practical review

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.

6.3 Ten substances that changed the world

Every substance is unique in some way, regardless of whether it is an element, a compound or a mixture. The unique properties of substances allow them to be used for different purposes. Some substances have revolutionised the way humans live. They have changed our health, our technology, how we can communicate and how war is conducted.

Five elements that changed the world

Some elements such as oxygen are essential for life. As you breathe in, you take in oxygen and the more plentiful but less useful element nitrogen. Both elements are in the mixture of gases that we call air. Carbon was an element known to every prehistoric human because it was in the charcoal and ashes of the fires they used to cook and keep warm. Gold was perhaps the earliest metallic element used by humans. With the discovery of every new element, people understood more about the elements, their properties and potential uses. Using these most basic building blocks of matter, human civilisation has taken huge leaps, developing new technologies that have dramatically changed our lives.

Copper

Copper was the first metallic element to be extracted from rock. Some types of rock contain minerals rich in copper. These minerals are known as copper **ores**. As early as 9000 BCE, humans heated copper ores with carbon to extract pure copper metal. Being metallic, copper is shiny and malleable (it can be hammered into sheets). This made copper perfect for making decorative plates, jewellery and utensils.

However, a truly revolutionary step in human civilisation came when it was realised that copper could be mixed with the element tin to form the alloy **bronze**. Bronze was much stronger and harder than copper, and so it could be used to produce better tools. Examples of some of these tools are shown in Figure 6.3.1. This discovery took human civilisation out of the Stone Age and into the **Bronze Age** (approximately 3300 BCE to 1200 BCE). Bronze could also be used to make much better weapons and armour. This meant that civilisations that had mastered the technology of creating bronze had a huge advantage over their rivals.

Figure 6.3.1 Tools from the Bronze Age

Today, copper is still a very important element because it is an excellent conductor of electricity and is cheaper than other good conductors like gold and silver. As a result, copper is used extensively for electrical wiring and is currently used for much of Australia's telephone network.

Prac 1 p256

GO TO Unit 8.5

Iron

Iron is much more difficult to extract and work with than copper because iron requires much higher temperatures. For this reason, the technology for extracting iron from its ore did not appear until about 3000 BCE. An illustration of how prehistoric humans may have extracted iron is shown in Figure 6.3.2. Pure iron is not particularly useful because it is relatively soft and rusts easily. However, when iron is mixed with small amounts of carbon it forms **steel** alloys that are harder, stronger and less likely to rust.

Steel changed many aspects of human civilisation. Because steel is strong, it was used to make better utensils, tools, weapons and armour. This made domestic life, agriculture and warfare easier. The use of steel tools defined the **Iron Age**, which went from approximately 1200 BCE to 500 CE.

GO TO Unit 8.5

6.8

Today, iron and its steel alloys are still extremely important metals because of their strength and because they are relatively cheap. Steel is used extensively in the construction of cars, ships, buildings and bridges, as well as the manufacture of household objects such as cutlery, nails, staples and pins.

Figure 6.3.2 The extraction of iron from its ores was a significant technological challenge for early humans as it required much higher temperatures than those needed to extract copper.

SciFile

The Iron Age of data storage

Recently, scientists demonstrated that they could store one piece of data on just 12 iron atoms. Normal data storage devices like hard disks and USB drives require about a million atoms to store one piece of data. Using the new technology, an MP3 player could store around 4 million songs!

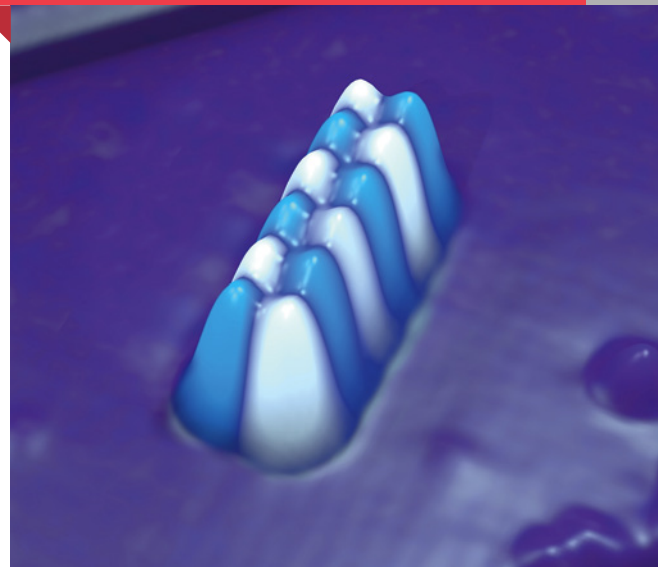


Figure 6.3.3 These 12 iron atoms were used to store one piece of data. This image was obtained with a scanning tunnelling microscope (STM).

Oxygen

All living things depend on oxygen to survive, making this element possibly the most important of all. However, the discovery of oxygen also led to a revolution in our understanding of how things burn.

Being a colourless, odourless gas, oxygen was much harder to identify than most solid elements. For this reason, oxygen gas wasn't discovered until 1772. This is when Swedish chemist Carl Wilhelm Scheele (1742–1786) formed pure oxygen by heating mercury oxide with other compounds. Oxygen may also have been discovered at around the same time by British scientist Joseph Priestley (1733–1804) and French chemist Antoine Laurent Lavoisier (1743–1794).

However, it was Lavoisier's experiments with oxygen that turned the scientific world upside down (Figure 6.3.4). Lavoisier showed that when metals burned in oxygen, the ashes weighed more than the original metal. Until this discovery, it was believed that burning released a substance known as phlogiston. Releasing phlogiston should have decreased the weight. In contrast, Lavoisier's experiments showed that burning *combined* substances with oxygen. This proved that the widely accepted phlogiston theory was wrong.

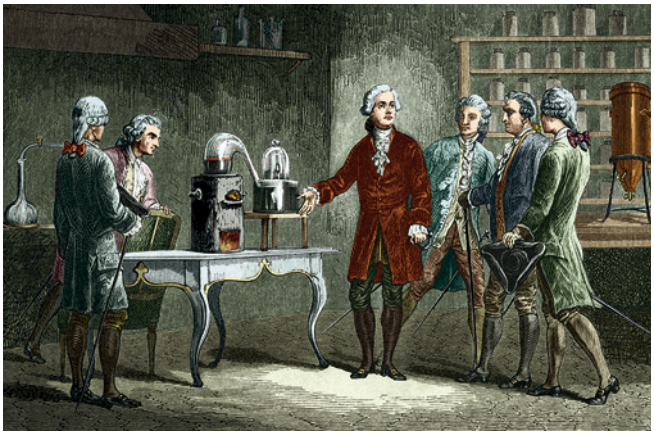


Figure 6.3.4 Lavoisier shows his experiments using oxygen to other members of the scientific community.

Uranium

The element uranium was first extracted in 1789 by German chemist Martin Heinrich Klaproth (1743–1817). However, until the early 1930s, uranium was considered a fairly useless material. It was then discovered that uranium could be used to create nuclear explosions. The extreme power of uranium was demonstrated with devastating effect in World War II. On 6 August 1945, the first uranium-fuelled atomic bomb was detonated over Hiroshima, Japan. The bomb was codenamed *Little Boy*. You can see the mushroom-shaped cloud from this explosion in Figure 6.3.5. Three days later, a plutonium atomic bomb codenamed *Fat Man* was detonated over Nagasaki, Japan. These two atomic bombs killed more than 200 000 people, and marked the beginning of the end of World War II. Since then the world has never been the same. The atomic bomb started an arms race between the USA and the USSR (Russia) and the development of even more powerful nuclear weapons, such as the hydrogen bomb (which uses the element hydrogen as its fuel). Many countries around the world have now developed nuclear weapons, and this has prompted the need for international treaties (agreements) to prevent the use of such weapons.

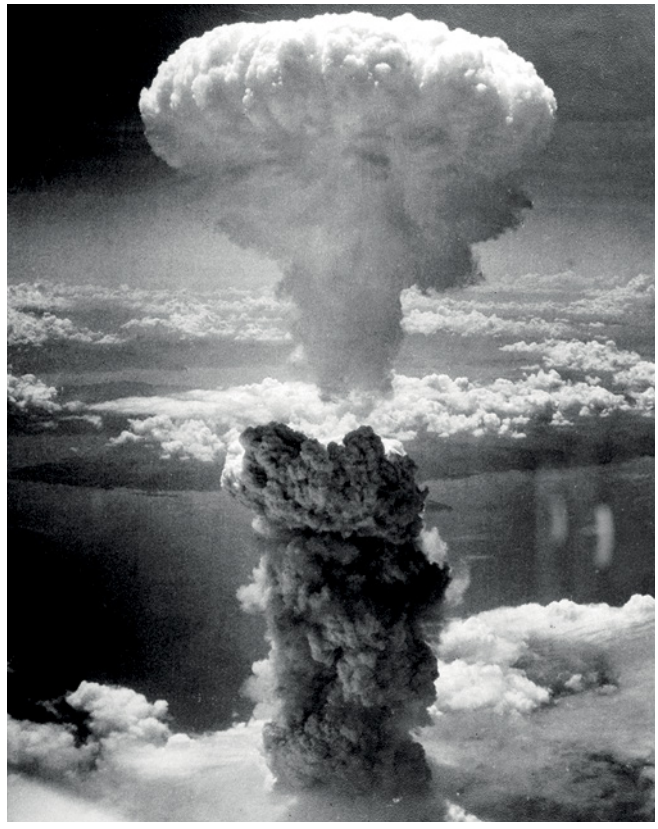


Figure 6.3.5 Hiroshima was extensively damaged when the uranium-fuelled atomic bomb *Little Boy* exploded above it.

The huge amount of energy stored in nuclear materials like uranium has also been used to help society. For example, it can be used to generate electricity in nuclear power plants. Nuclear power plants release much less carbon dioxide than traditional coal-fired power plants and now supply almost 15% of the world's electricity. However, nuclear power plants produce dangerous nuclear waste, and the mining of uranium is damaging to the environment.

Silicon

Silicon was discovered in 1824 by Jons Jacob Berzelius (1779–1848). However, it was another 100 years before the true usefulness of silicon was discovered. Today, silicon forms the basis of a multibillion-dollar industry that drives computing and electronics.

Silicon is unusual in that it is a semiconductor. This means that it can be made to conduct electricity like a metal, or insulate like a non-metal. In 1954, scientists discovered how to use this property to make a **transistor**—an early version of the silicon microchip. Before transistors, computers used vacuum tubes. The vacuum tubes were very large and very slow. This meant that computers processed information slowly, and they were so big that they would fill an entire room. You can see an early computer in Figure 6.3.6. The invention of the silicon transistor meant computers could process information much more quickly and could be made much smaller. This led to the invention of desktop computers, laptops, tablets and smart phones.

Computers were people!

SciFile

The workers who processed information on these early large machines were known as computers. Eventually, the machines took over their name!

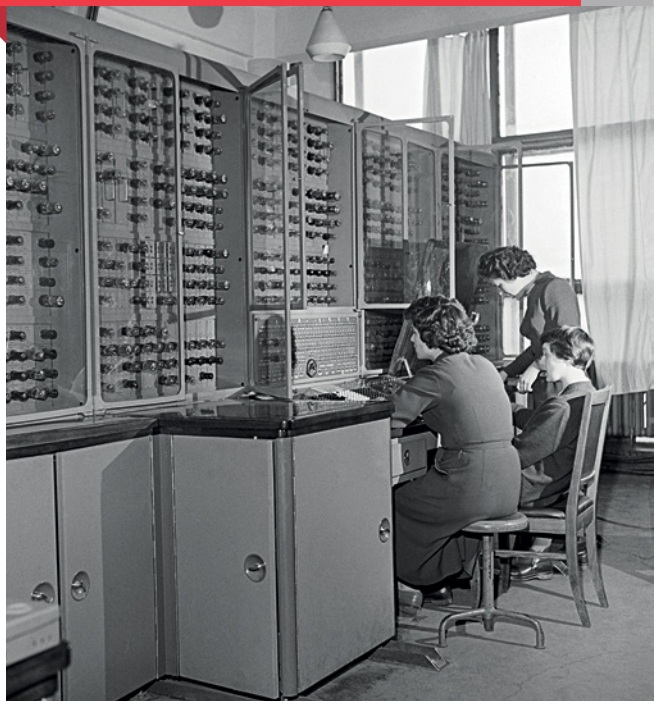


Figure 6.3.6 Before transistors, computers used vacuum tubes, which meant one computer would take up an entire room.

Five compounds that changed the world

Most of the materials that you use in your everyday life are made of compounds. By understanding more about what makes each compound unique, chemists have created new materials, technologies and medicines to help improve the quality of our lives.

Salt

Common table salt (sodium chloride, NaCl) was once a highly valued substance that influenced the rise and fall of civilisations. Salt could determine who won wars, and it was even used for payment instead of money. All this occurred because in ancient times, salt was the best way to preserve food, especially meat.

The ability to preserve food was a major advance because it enabled human settlements to survive cold winters or dry summers. As a result, these settlements could grow into cities and even empires. Preserving food also meant that it could be transported over longer distances. This allowed humans to travel further and trade goods between distant cities.

Initially, salt was obtained from mines in mineral form, and was called rock salt. Cities around the world were founded near rock salt mines. In the 1500s, Poland controlled a large kingdom because of its salt mine. However, the kingdom fell when Germany began to collect salt from sea water using salt pans similar to the ones shown in Figure 6.3.7. The invention of saltpans meant that almost any country that bordered the ocean could obtain an unlimited supply of salt and did not need to rely on countries with salt mines.

Figure 6.3.7 Saltpans like these use heat from the Sun to evaporate water from pools of seawater, leaving salt behind. Salt from salt pans was once considered to be of much better quality than rock salt.

GO TO Pearson science NSW 7 Unit 4.3

Saltpetre

Saltpetre is the common name for the compound potassium nitrate (KNO_3). Saltpetre is a white crystalline compound used in fertiliser and food additives. It has one very important chemical property: when mixed with the elements carbon and sulfur it produces **gunpowder**, the world's first chemical explosive.

It is thought that gunpowder was first discovered in China around 800 CE, although no written records exist until 1044 CE (Figure 6.3.8). The exact recipe for combining potassium nitrate, carbon and sulfur to make gunpowder required much trial and error. However, by 1100 CE the Chinese had developed an explosive that could be put in iron metal containers, forming a weapon similar to a grenade.

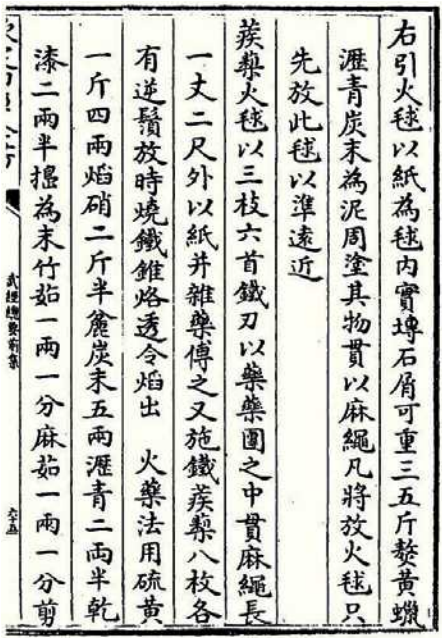


Figure 6.3.8 This is the first description of gunpowder. It was recorded in China in 1044.

Between 1200 and 1300 CE, knowledge of gunpowder was carried across Asia, the Middle East and Europe by the invading Mongols as they spread from northern Asia. The Mongols conquered China and then used Chinese gunpowder technology to help them in their conquests. However, it wasn't until the 1400s that gunpowder was used to produce effective, long-range weapons like cannons. After 1600, firearms such as early guns started to dominate warfare.

6.9

Silica

Silica (silicon dioxide, SiO_2) is a compound made of a lattice of silicon and oxygen atoms. It is one of the most common substances on Earth, making up sand and the rock called quartz. The silica in sand is one of the major components of glass and so it is found in everything from windows to drinking glasses.Because silica can bend and reflect light, it is also suitable for making **optical fibre**.

Optical fibres are made of a long cable with a silica core. Light that enters one end of the cable reflects (bounces) along the edges of the silica core until it comes out the other end. In this way, optical fibres can be used to guide light signals along almost any path. The light signal travels very fast through the optical fibre and doesn't get weaker, even over very large distances. This allows huge amounts of data to be sent very quickly and over very long distances. You can see some examples of optical fibres in Figure 6.3.9.

Optical fibres have enabled the development of very high-speed Internet technology. Optical fibre technology is also used in medical applications. For example, it is commonly used to shine light inside the body during surgery.

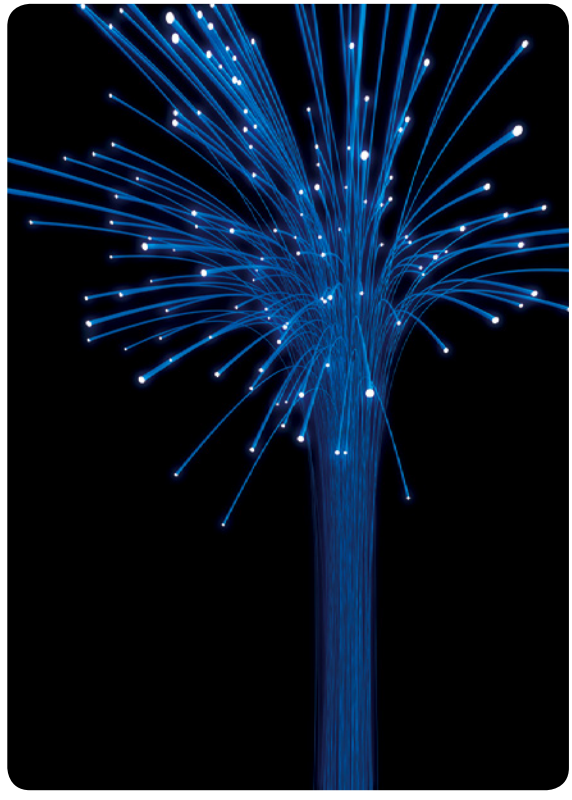


Figure 6.3.9 Optical fibres can carry light signals along curved or twisted paths and over very long distances.

Figure 6.3.10 Plastic is made from polymer. It can be made in almost any colour and moulded into almost any shape.

INQUIRY

science 4 fun

Milk putty

YES

Can you create putty using just milk and vinegar?

SAFETY

Be careful with hot milk. It can cause serious burns if it comes in contact with your skin.

Collect this …

- 1 mug of milk
- white vinegar
- teaspoon
- sieve
- access to a microwave oven

Do this …

1. Warm the mug of milk in the microwave so that it is hot but does not boil (about 60–90 seconds in most microwaves).
2. Carefully remove the mug of milk from the microwave and then add about 1 tablespoon of white vinegar to the mug.
3. Stir quickly with a teaspoon.
4. Pour the contents of the mug into the sieve over a sink and let it strain and cool for 2 minutes.
5. When it is dry and cool enough to touch, take out the solid from the sieve and mould it with your hands into putty.

Record this …

Describe your observations.

Explain what happened.

Polymers

The term **polymer** does not refer to just one compound. It includes a wide range of compounds that make up important materials such as rubber, plastic, glue, putty and synthetic fibres like polyester and nylon. Figure 6.3.10 shows an example of plastics made from polymers. Polymers are the source of many of the materials that you use in your everyday life. All polymers are made of very long chains of smaller molecules. This is shown in Figure 6.3.11.

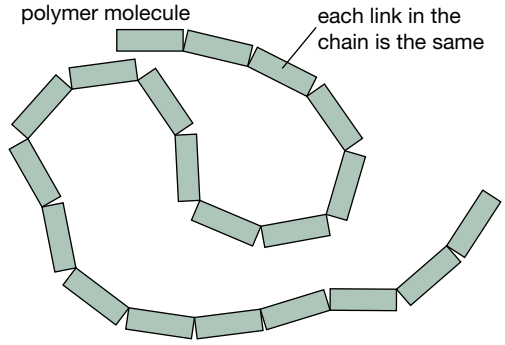


Figure 6.3.11 Polymers contain very long molecules that are made up of a chain of smaller molecules. Every link in the chain is the same.

There are many naturally occurring polymers such as wool, silk and natural rubber. In 1909, chemist Leo Baekeland (1863–1944) produced the first synthetic polymer. This was a form of plastic known as Bakelite. It was termed 'the material of 1000 uses' but polymers have had many more uses than that. By understanding how to create new polymers, scientists have been able to manufacture a huge range of artificial materials with useful properties. These include hard plastics for pipes and construction, thin plastic films for cling wrap and plastic bags, flexible rubber, extremely strong glues, light polystyrene foams, synthetic fibres like rayon and nylon, and non-stick surfaces like Teflon®.

One of the benefits of plastics and other polymers is that they tend to be extremely weather resistant and are unaffected by things like bacteria and mould. However, these properties have also led to environmental issues. Most plastics are not biodegradable, so they don't rot when discarded into landfill. Instead, they will remain for centuries. Scientists are continuing research into polymers to find solutions to these environmental problems. One solution has been to create recyclable plastics and biodegradable plastic for use in packaging and shopping bags.

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DNA

DNA (deoxyribonucleic acid) is a molecule found in the nuclei of your cells. DNA contains all the genetic information that makes you who you are. Although DNA has existed as long as organisms have on Earth, its existence and structure have only been known since the mid-twentieth century.

DNA is not a typical compound. Normally, the molecules that make up a compound are identical throughout the world and even the universe. For example, methane is made up of CH_4 molecules regardless of whether it is found on Earth or Jupiter. However, DNA molecules can be different. For example, your DNA molecules are different from your friend's DNA molecules. The only time DNA is the same is in identical twins and clones. Also, the DNA that makes up a human is different from the DNA that makes up a dog, a rat or an insect.

The structure of the DNA molecule is also unique. Each DNA molecule is extremely long and can stretch 2 to 3 metres. The molecule is made up of two strands twisted together in a spiral known as a **double helix**. This is shown in Figure 6.3.12. Using a technique called X-ray diffraction, Rosalind Franklin, James D Watson, Francis Crick and Maurice Wilkins discovered the highly unusual structure of DNA. Watson, Crick and Wilkins were awarded the Nobel Prize in Medicine in 1962 for their work.

The long, twisted strands that make up DNA contain thousands of smaller molecules. The order in which these small molecules are arranged gives your body all the information it needs to make you who you are. This includes things like your height, skin colour and blood type through to whether or not you are more likely to develop some diseases.

In 1990, scientists around the world worked together to map all the information contained in human DNA. This was known as the Human Genome Project. The project was completed in 2003 but so much data was collected that the research will continue for many more years.

By understanding the DNA molecule, scientists have opened up a whole new world of medicine that can predict, prevent or treat some previously incurable diseases.

No prize for you!

Rosalind Franklin and Maurice Wilkins created the X-ray diffraction images from which Watson and Crick worked out the structure of DNA. Despite her contribution, Franklin is rarely given any credit for being part of the discovery. Franklin did not receive the 1962 Nobel Prize because the prize is only given to those still living and she had died four years before. The cause of her death? Cancer, possibly triggered by prolonged exposure to all those X-rays!

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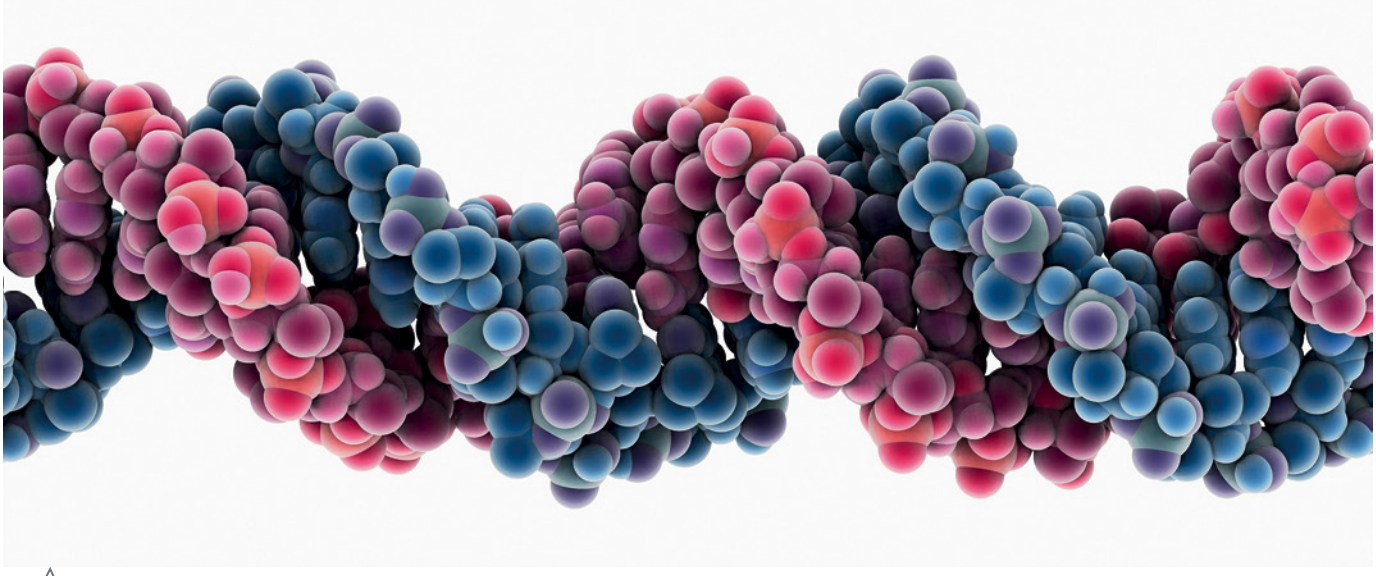


Figure 6.3.12 The DNA molecule is made up of two strands twisted together to form a double-spiral structure, as shown here. This structure is known as a double helix.

6.3 Unit review

Remembering

1 **State** what copper is commonly used for today.

2 **Name** the elements that were mixed with the following metals to make them into more useful alloys.
- a copper
- b iron

3 a **Name** the alloy that marked the end of the Stone Age.
- b **List** the advantages that this alloy brought.

4 **Name** the atomic bomb that was dropped on Hiroshima.

5 **State** the full scientific name for:
- a table salt
- b silica
- c DNA.

6 **Recall** the term used to describe the structure of the DNA molecule.

Understanding

7 a **State** the years in which it is thought copper and iron were first extracted.
- b **Calculate** how many years were between these events. N

8 **Explain** why the Iron Age came after the Bronze Age

9 a **Explain** what phlogiston was thought to be.
- b **Outline** the scientific evidence that proved that the phlogiston theory was wrong.

10 **Explain** how the development of silicon transistors made computers faster and smaller.

11 **Define** the term *polymer*. L

12 **Explain** why most plastics are a problem for the environment.

13 **Describe** how the structure of DNA is different to that of most other compounds.

14 **Outline** what the Human Genome Project is.

Applying

15 **Identify** the elements and compounds in this unit that:
- a changed warfare
- b changed how data is processed and communicated
- c changed the way useful materials are produced.

Evaluating CCT

16 a **Assess** whether or not modern-day society could have existed without salt.
- b **Justify** your answer.

17 **Propose** how the development of uranium-fuelled nuclear weapons in the twentieth century could be considered similar to the development of gunpowder in the Middle Ages.

18 The milk putty made in the science4fun on page 253 has many of the properties of the putty that builders use to repair cracks in a house. **Propose** a list of properties that milk putty would probably have.

19 **Propose** a list of potential advantages of having a detailed knowledge of your DNA.

Creating CCT

20 **Construct** a timeline of the important technological discoveries mentioned in this unit.

Inquiring

1 The Australian telephone network is largely based on copper wires, which makes our internet slower than many other Western countries around the world. Research how the Australian government plans to improve Australia's internet speeds. Find:
- how it will work
- how much it is expected to cost
- how long it will take to complete
- how it will compare to our current network
- what some of the benefits to society will be.

Present your findings as a magazine or television advertisement either for or against the plan.

ADDITIONAL

2 Investigate another element or compound that you think has changed the world. Find:
- when it was discovered and by whom
- the chemical properties that make the substance special
- how and when it changed the world
- how it is used today.

Present your research as a short essay or presentation to the class. In it discuss the costs and benefits of your chosen material for society.

ADDITIONAL

6.3 Practical investigations

1 Extracting copper from copper oxide

Purpose

To model the process of extracting copper from its ore by extracting copper from copper oxide.

Materials

- copper oxide powder
- carbon powder

- large spatula
- medium-sized test-tube
- wooden test-tube holder
- Bunsen burner and bench mat
- large filter paper or petri dish

SAFETY

Your test-tube might roll off the bench, so make sure it is always in the test-tube holder.

Material may spit out of the test-tube, so point its opening away from everyone, including you. Wear safety glasses at all times.

When not using your Bunsen burner, turn it off or to a yellow flame.

Procedure

1. Use the spatula to fill 1 cm of the test-tube with equal parts of copper oxide powder and carbon powder.
2. Mix the powders thoroughly.
3. Light the Bunsen burner and use the wooden test-tube holder to heat the test-tube containing the copper oxide and carbon mixture (Figure 6.3.13).
4. Heat the test-tube, moving it in and out of the flame to heat it evenly. Heat until you can clearly see a red-brown solid at the bottom of the test-tube.
5. Pour the solid from the test-tube onto a filter paper or petri dish, and record your observations.

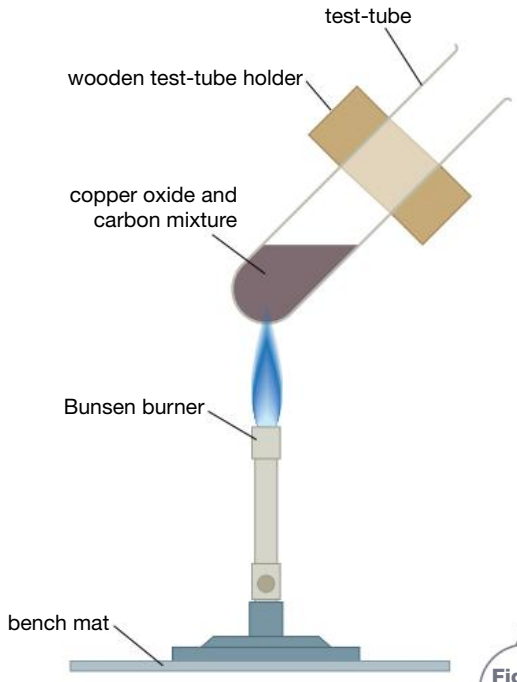


Figure 6.3.13

Practical review

1. **Name** the substance that is acting as the copper ore in this process.
2. **Describe** a source of carbon that would have been readily available to prehistoric humans.
3. **Propose** how prehistoric humans may have discovered this technique for extracting copper from its ore.

2 Making casein plastic

Casein was an early plastic that is still used for buttons and some wood glues. In industry, casein is hardened using a chemical called formalin.

Purpose

To make casein.

Materials

- 100 mL low fat milk
- 10 mL vinegar

- Bunsen burner, bench mat, tripod and gauze mat
- 100 mL measuring cylinder
- 2 × 250 mL beakers
- thermometer
- stirring rod
- elastic band
- coarse cloth for straining, paper towel/filter paper
- assorted moulds (such as bottle caps, moulded chocolate trays)
- fine sandpaper
- tongs

SAFETY

Do not drink or taste any of the materials.

Once you have started heating, do not touch the beaker with your bare hands.

When not using your Bunsen burner, turn it off or to a yellow flame.

Allow everything to cool before packing away.

Procedure

1. Set up the Bunsen burner.
2. Place 100 mL of milk in one of the 250 mL beakers. Warm gently until it reaches 50°C. Do not overheat.
3. Add 10 mL vinegar and stir with the glass stirring rod.
4. The milk should curdle to form white lumps of curds (casein) and yellowish liquid called whey.
5. Secure the piece of cloth tightly over the other 250 mL beaker and strain the curds and whey.
6. Carefully remove the cloth and squeeze to remove as much liquid as you can.
7. Empty onto the paper towel/filter paper. Pat dry, then press firmly into moulds. Leave the casein to dry in the sun.
8. After a couple of days, remove the mould and polish with the sandpaper.
9. Use tongs to hold a small amount of the dry casein in a Bunsen flame. Does it melt, burn or char?

Results

Stick a small piece of dry casein into your workbook, along with a piece of casein that you placed into the flame. Label each sample and write your observations beneath each sample.

Practical review

1. Polymers and plastics can be classified as thermoplastic (these melt when heated) or thermosetting (these burn or char when heated). **Use** this information to **classify** casein as thermoplastic or thermosetting.
2. **State** what casein is currently used for.
3. **Name** the chemical used by industry to harden casein.

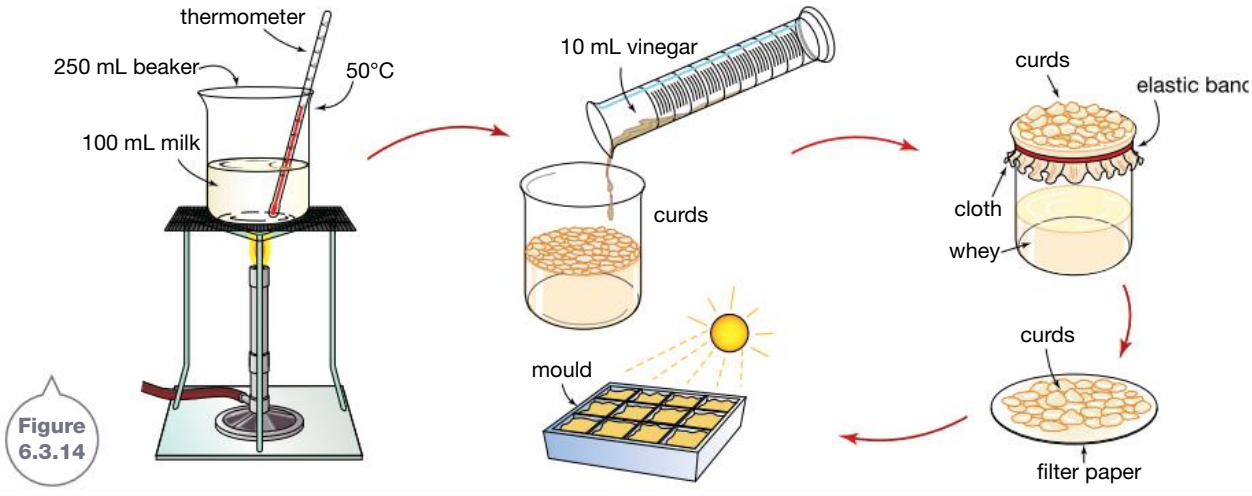


Figure 6.3.14

6.3 Practical investigations

STUDENT DESIGN

3 Preserving fruit

Purpose

To compare the ability of salt water to prevent fruit from browning with other household liquids.

Materials

- 1 red apple or potato
- salt
- water
- selection of lemon juice, soft drink, sugar, vinegar, honey

---

- knife

SAFETY

A risk assessment is required for this investigation.

Take care with the knife.

Procedure

1. Some fruits and vegetables such as red apples and potatoes turn brown when exposed to air. Design an investigation that will:
   - determine whether salt water helps to preserve these foods by preventing browning
   - compare the preserving ability of salt water with other household liquids such as lemon juice, soft drink, sugar water, vinegar or a mixture of water and honey.
2. Brainstorm in your group and come up with several different ways to investigate the problems. Select the best procedure and write it in your workbook.
3. Before you start any practical work, assess your procedure. List any risks that the procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risk. If your teacher approves, then collect all the required materials and begin your investigation.

Hints

Make sure that you only change one variable at a time. Keep everything else exactly the same.

You need a 'control' in this investigation. This shows what would have happened if the flesh of the apple had *nothing* put on it.

Practical review

1. **State** which variables you tried to keep constant for each test.
2. **Explain** why a control is important in this investigation.
3. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.
4. **Determine** which substances had antibacterial properties and **rank** them from best to worst.
5. **Evaluate** whether any substances other than salt could have been used by humans to preserve their food.
6. **Propose** reasons why salt was the most widely used substance for preserving food. Also consider other factors such as taste, availability and transport.

6 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 **Name** the following substances.
- a O_2
- b CO
- c P_4
- d $C_6H_{12}O_6$
- e S_6
- f NaCl
- g SiO_2

Understanding

5 **Define** the following terms. L
- a malleable
- b ductile
- c miscible
- d monatomic
- e molecule

6 **Describe** the scientific evidence that originally showed that oxygen was needed whenever something was burnt.

7 **Explain** why salt was so important for human civilisation.

8 **Explain** what an alloy is and why alloys are useful.

9 **Describe** the positive and negative effects that resulted from the discovery of uranium.

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, $C_{45}H_{73}NO_{15}$

Analysing

11 **Compare** elements, compounds and mixtures by listing their similarities and differences.

12 **Classify** the following as elements, compounds or mixtures.
- a lemonade
- b carbon (C)
- c zinc (Zn)
- d bronze
- e air
- f tap water
- g pure water (H_2O)
- h carbon dioxide (CO_2)
- i chlorine gas (Cl_2)
- j sodium chloride (NaCl)
- k shampoo
- l iron (Fe).

13 **Classify** the following as monatomic, molecular or crystal lattice.
- a gold
- b helium
- c pure water
- d sodium chloride
- e carbon dioxide
- f copper
- g neon
- h nitrogen

Evaluating CCT

14 a **Evaluate** whether or not it would be possible to have a monatomic compound.
- b **Justify** your answer.

15 **Propose** reasons why it is important to continue research into elements and compounds, such as polymers and pharmaceuticals.

16 a **Determine** whether you can or cannot answer the questions on page 228 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

Creating CCT

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

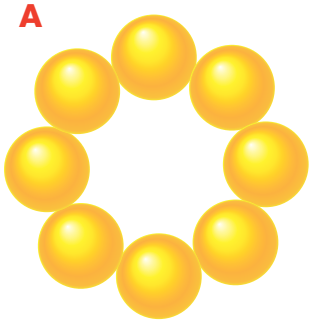
atom	molecule
crystal lattice	element
compound	mixture
metal	non-metal
brittle	malleable

6.10

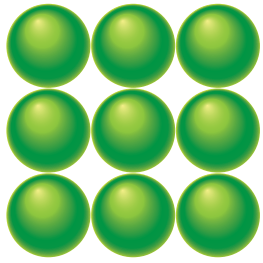
Thinking scientifically

Q1 Elements are substances made up of only one type of atom. Which one of the following does *not* represent an element? CCT

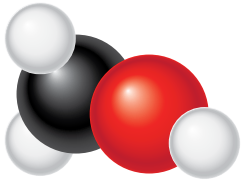
A



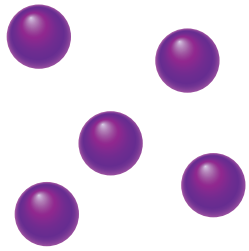
B



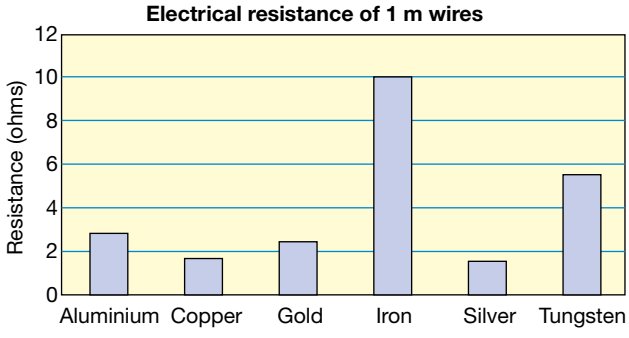
C



D



Q2 Alberto measures the electrical resistance of 1-metre wires made from different metals and plots the resistances in the graph below. CCT



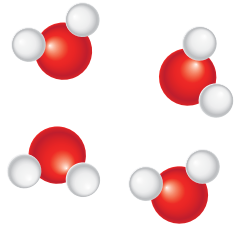
The three wires with the highest resistance in order from highest to lowest resistance are:

A silver, copper, gold
B iron, tungsten, aluminium
C iron, tungsten, gold
D aluminium, tungsten, iron.

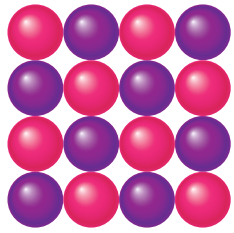
Q3 Compounds are substances that are made up of more than one type of atom. Which one of the following diagrams does *not* represent a compound? CCT

A

B



C



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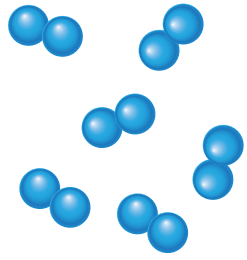
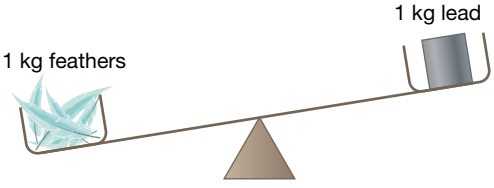
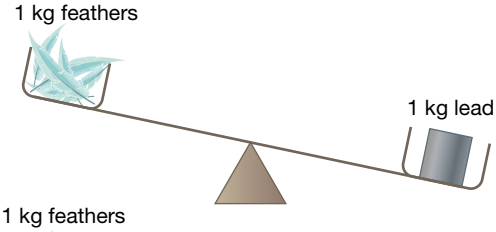


Q4 1 kilogram of feathers and 1 kilogram of lead were placed on a balance. Which of the following diagrams shows what would happen? CCT

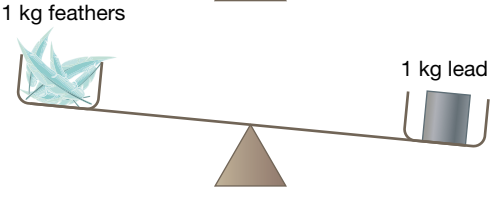
A



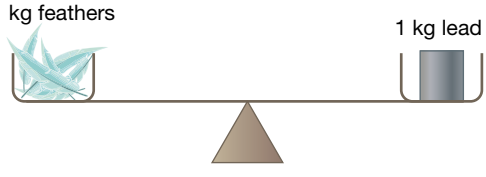
B



C



D



Glossary

Unit 6.1 L

Atoms: the smallest building blocks of matter

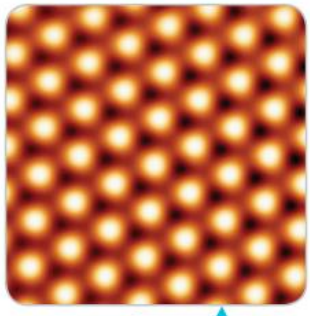
Brittle: easily crumbled or shattered

Ductile: able to be stretched to form a wire

Elements: substances made up of only one type of atom

Lattices: grid-like structures of atoms

Lustrous: shiny



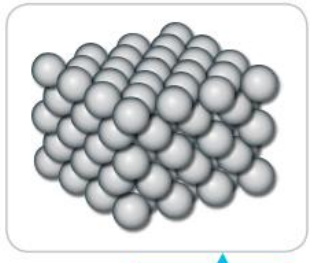
Atoms

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

Molecules: clusters of atoms

Monatomic: describes elements that consist of single atoms



Metal

Non-metals: substances that are usually dull (not shiny), do not conduct heat and electricity, and break or crumble

Periodic table: a table that shows all the known elements

Properties: the characteristics of a substance

Non-metal

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 6.2 L

Alloy: mixture of a metal with other metals or non-metals

Aqueous solution: a solution in which a substance is dissolved in water

Alloy

Compounds: substances made of lattices or identical molecules with two or more types of atoms

Immiscible: describes liquids that do not mix

Miscible: describes liquids that can be mixed

Mixtures: any combination of two or more elements and compounds

Solute: a substance being dissolved

Solution: a mixture in which one substance is dissolved in another

Solvent: a substance that dissolves another substance

Mixture

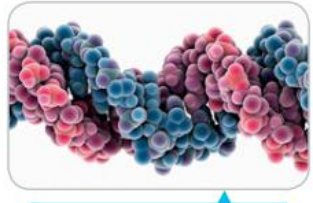
Unit 6.3 L

Bronze: an alloy of copper and tin that is much harder than pure copper

Bronze Age: a period in human civilisation between approximately 3300 BCE and 1200 BCE in which humans used copper and bronze to create useful utensils, tools, weapons and armour.

Double helix: the term used to describe the structure of the DNA molecule; consists of two strands twisted into a double spiral

Gunpowder: the first chemical explosive; made up of a mixture of saltpetre, sulfur and carbon



Double helix

Iron Age: a period in human civilisation between approximately 1200 BCE and 500 CE during which humans used steel to create useful utensils, tools, weapons and armour.

Optical fibres: long cables with a silica core that can be used to guide light signals from one end of the cable to the other

Ores: minerals rich in metals such as copper and iron; the pure metal can be extracted from the ore

Polymer: a substance made up of long chains of smaller units that are repeated along the chain

Steel: an alloy of iron and carbon that is much harder than iron and less likely to rust

Transistor: an electrical switch used in computers to process data quickly

SCIENCE TAKES YOU PLACES

Look who is using science

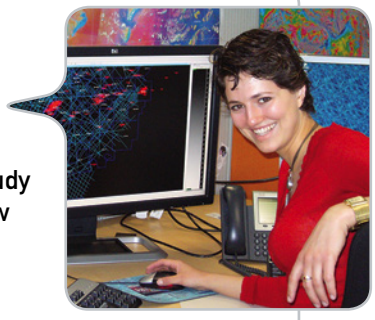
FOOD TECHNOLOGIST

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!

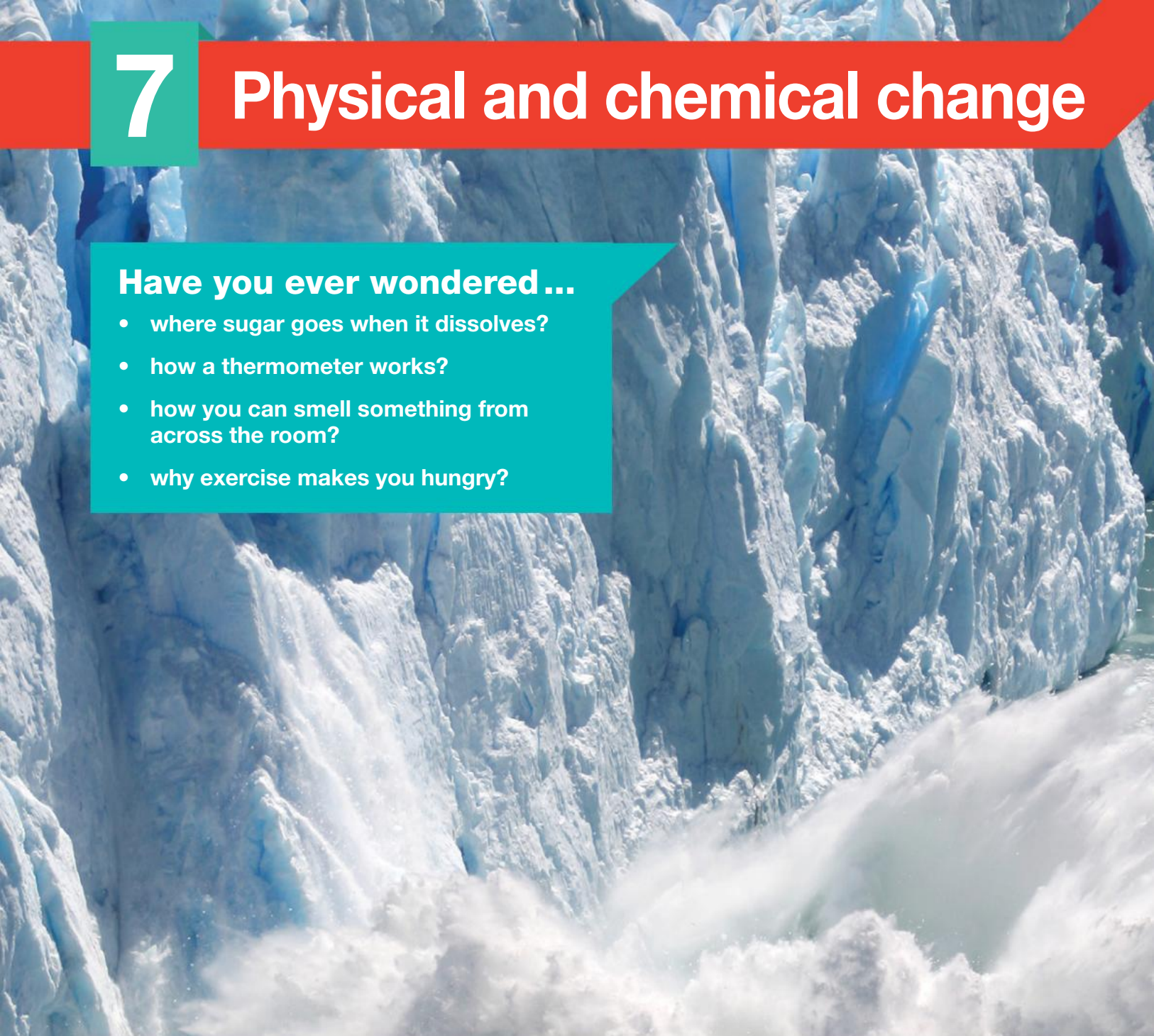
CHEMICAL ENGINEER

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.

7 Physical and chemical change



Have you ever wondered...

- where sugar goes when it dissolves?
- how a thermometer works?
- how you can smell something from across the room?
- why exercise makes you hungry?

After completing this chapter students should be able to:

- describe matter in terms of particles that are continuously moving and interacting
- outline how particle movement is related to energy
- use the particle model to predict what happens when different states of matter are heated or cooled
- explain how the physical properties of matter change during changes of state
- identify when a chemical change is taking place by observing a change in temperature, the appearance of new substances or the disappearance of an original substance
- demonstrate that a chemical change involves substances reacting to form new substances
- investigate examples of chemical changes including photosynthesis, respiration and chemical weathering
- compare physical and chemical changes in terms of the arrangement of particles and reversibility of the process

ADDITIONAL

- explain how gas pressure is related to the frequency of particle collisions
- investigate how the chemical properties of a substance affect its use.

7.1 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 can be classified as physical or chemical changes depending on whether any new substances are produced.

INQUIRY
science 4 fun

Invisible ink

YES

Can you use a chemical change to write a secret message?

Collect this…

- lemon juice
- paper
- fine paintbrush
- warm light globe or hairdryer

Do this…

1. Use the paintbrush 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.

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. Figure 7.1.1 shows some examples. The physical properties of the substance may change but the substance before and after the change is exactly the same. For this reason, physical changes can often be easily reversed.

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 the can is still made of aluminium. Similarly, if you crush an aspirin tablet into a powder, it is still aspirin but in a different form. These changes can be reversed relatively easily.

Figure 7.1.1 During these physical changes, no new substances are produced.

If you bend a metal rod in one direction then you can easily bend the rod back to its original shape. Even the crushed aspirin powder can be compacted back into the form of an aspirin tablet.

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. The reverse of expansion is **contraction**. When a solid, liquid or gas is cooled, it contracts—the volume of the substance 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.

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Hot-air balloons use the expansion of heated air to lift off the ground. Figure 7.1.2 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 7.1.2 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**). These changes are easily reversed. When 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

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. Likewise, 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, but they are both made from the same substance. Therefore melting is a physical change.

Freezing

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. Freezing can also be seen when drops of liquid candle wax cool and become solid again.

Evaporation

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 on a hot day. 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.

Condensation

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 7.1.3. 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.

GO TO Pearson science NSW 7 Unit 2.3

Figure 7.1.3
Water vapour in the air condenses as liquid water on the outside of a can taken straight from the fridge.

SciFile

High and dry

Australia 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 7.1.4 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 7.1.4
The balls do not change or form new colours despite being spread evenly through this mixture.

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.

Liquids and gases can also be dissolved. For example, Figure 7.1.5 shows liquid food colouring dissolving in water.

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 can join together again to form crystals. This process is known as **crystallisation**.

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 the dissolving process is reversed and sugar is left behind.

Figure 7.1.5 When two substances mix, one substance is spread evenly through the other but no new substances are formed.

GO TO Pearson science NSW 7 Unit 4.1
GO TO Pearson science NSW 7 Unit 4.3

Identifying chemical change

To distinguish between a **chemical change** and a physical change, you need to determine if a new substance has formed as a result. 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 the presence of a new substance 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
- seeing light or feeling a change in temperature.

These indications of chemical changes are shown in Figure 7.1.6. However, these are just guidelines. Identifying chemical change also requires a good understanding of physical changes because there can be exceptions to these rules. Also, sometimes both types of change can happen at roughly the same time. For example, toasting bread starts as a physical change—heat evaporates water from the bread, drying it out. The drying bread then starts to burn, changing colour to brown then black. This is a chemical change.

Figure 7.1.6 Some indications of a chemical change

Permanent colour change

If you see something changing colour, then it is very likely that a chemical change has occurred. This happens because the new substance produced by the chemical change has a different colour to what you started with. Burning a match, paper or wood produces a black powder, which is carbon. When iron is left in the rain, 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, a bruised leg turning purple, bleaching or dyeing clothes or hair (as shown in Figure 7.1.7).

Figure 7.1.7 Dyeing hair is an example of a permanent colour change caused by a chemical reaction.

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 (chemical formula H_2O).

Mixing paint is another example of a physical change that causes a colour change. Figure 7.1.8 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 7.1.8 Despite changing colour, mixing paint is still a physical change because no new substance has been formed.

A gas is given off

The production of a gas usually 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 antacid tablets are dissolved in water.

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 the smell. This is because burning causes a chemical change that 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.

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.

A precipitate forms

Occasionally, a new solid is produced when two solutions are mixed. This indicates 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 7.1.9. 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.

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Figure 7.1.9 Scale or lime can precipitate from water, causing blockages in pipes.

Light or a change in temperature

Energy plays an important role in chemical changes. Some chemical changes release energy in the form of heat, light or both. As a result, a change in temperature or a flash or glow of light can be a sign that a chemical change has occurred. Some chemical changes release huge amounts of energy. For example, the explosion in Figure 7.1.10 released so much energy as light, heat and sound that it would have been felt, seen and heard from far away. Likewise, the light, heat and sound from bushfires, fireworks and sparklers are easily seen, felt and heard. In contrast, some chemical changes give out light but with little or no heat. Examples are the chemical changes that happen in glow sticks and glow worms.

Figure 7.1.10 Fires and explosions are examples of extreme exothermic reactions—they release large amounts of heat and light energy.

Other chemical changes absorb heat, causing their surroundings to cool. For example, the chemical ice pack shown in Figure 7.1.11 uses a chemical change that absorbs a lot of heat energy and so feels icy cold. Photosynthesis in plant leaves is another example of a chemical change that absorbs energy, this time from sunlight.

However, some physical changes can also cause a change in temperature. When you sweat, you feel cooler because the moisture evaporates and absorbs some heat from your skin. On the other hand, steam can cause serious burns as it condenses on your skin and releases its heat energy.

7.1

Figure 7.1.11 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 endothermic change.

LEARNING ACROSS THE CURRICULUM

SUSTAINABILITY

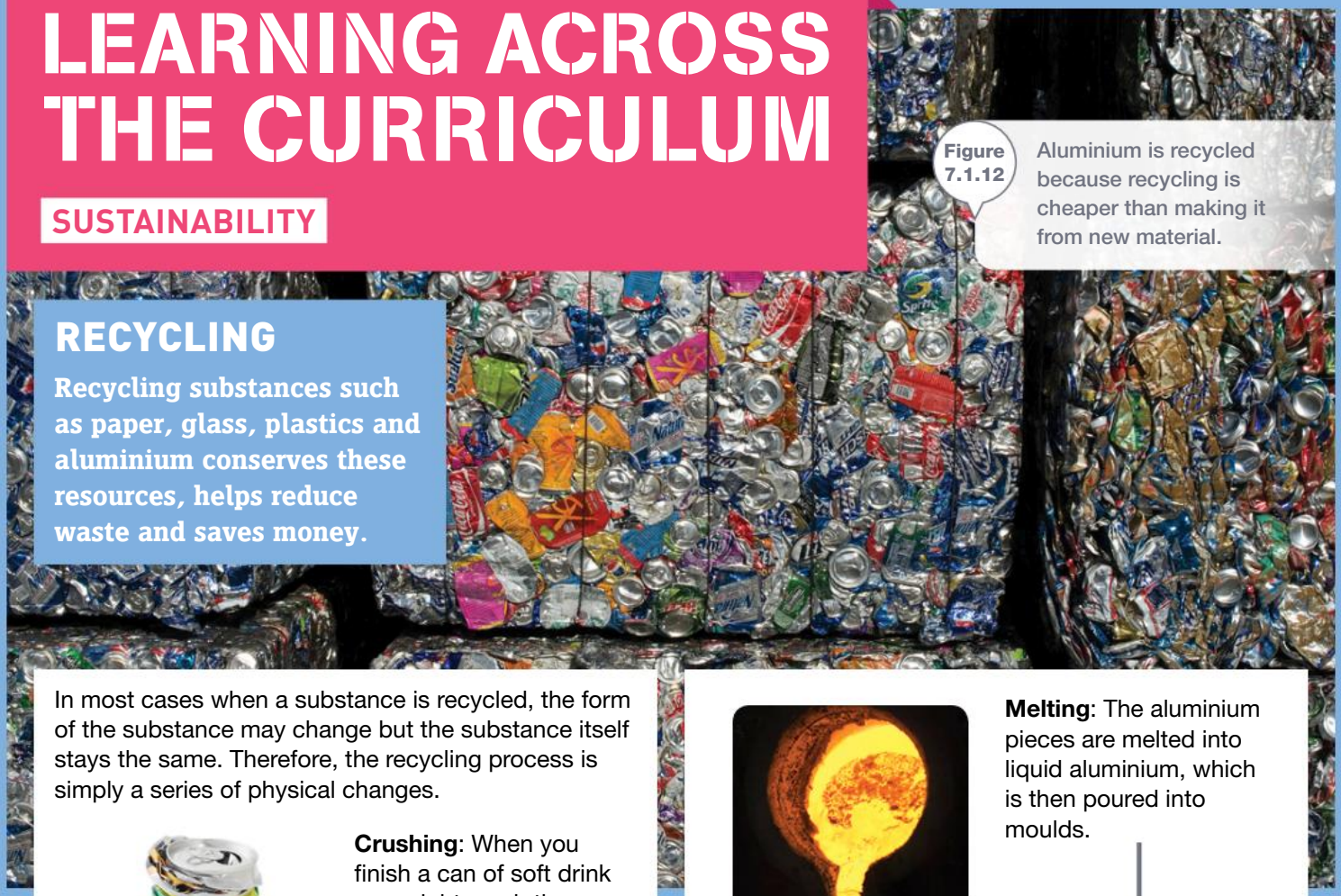


Figure 7.1.12 Aluminium is recycled because recycling is cheaper than making it from new material.

RECYCLING

Recycling substances such as paper, glass, plastics and aluminium conserves these resources, helps reduce waste and saves money.

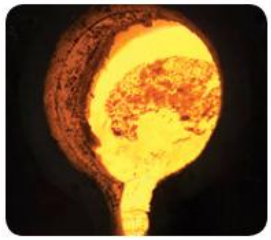
In most cases when a substance is recycled, the form of the substance may change but the substance itself stays the same. Therefore, the recycling process is simply a series of physical changes.

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 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.

Prac 3 p273 7.2

REVIEW

1. **List** the steps involved in recycling aluminium.
2. **Explain** why recycling is a series of physical changes and not chemical changes.
3. **Identify** two physical changes in the recycling of aluminium that involve changes of state.

7.1 Unit review

Remembering

1 **List** four examples of physical changes.

2 **List** four signs of a chemical change.

3 **State** which type of change:
- **a** is easily reversible
- b produces new substances.

4 **Name** the reverse process for the following changes of state.
- **a** condensation
- **b** freezing

5 **State** the two components of a solution.

Understanding

6 **Explain** why heating the air inside a hot-air balloon allows it to float.

7 Mix red and yellow paints and you get orange paint. **Explain** why this is a physical change even though there is a colour change.

8 **Define** the term *precipitate*. L

9 **Explain** how sweating helps to keep you cool on a hot day.

Applying

10 **Identify** three examples of both physical and chemical changes you might observe in the home.

Analysing

11 **Classify** the following as a physical or chemical change.
- **a** a banana goes black after a few days
- b strawberries are blended with milk to make a smoothie
- c wet clothes dry on the clothesline
- d spilt petrol explodes
- e steel roofing expands on a hot day
- f water boils on the stove
- h a sausage is cooked on the barbeque

Evaluating CCT

12 You are performing a chemical reaction and notice condensation on the outside of the test-tube.
- **a** **Deduce** whether the reaction absorbed or released heat.
- **b** **Justify** your answer.

13 Terry spilt some lemon juice on his homework. When he tried to dry it with a hair dryer, the pages quickly turned brown.
- **a** **Classify** the change that Terry observed as a physical or chemical change.
- b **Justify** your answer.

14 Jo says that an aspirin fizzing and dissolving in water is a physical change. Joe says that it is a chemical change. **Discuss** whether Jo or Joe is right or whether they might both be right.

15 **Propose** a way of reversing the following physical changes.
- **a** Sand is mixed with water.
- b Salt is dissolved in water.
- c Iron filings are mixed with sand.

16 It is difficult to get freshly cut 'green' timber to burn. **Use** the idea of physical and chemical change to **propose** a reason why.

Inquiring

1 Find ten images showing examples of physical change and another ten showing chemical change.

Present your images as a collage of photos or digital images. ICT

2 Research how paper is recycled. Find what steps need to be carried out and whether each step is a physical or chemical change. S

Present your findings as a flow chart.

3 Research how water recycling or desalination works. S

Present your findings as a list of the different water treatment processes in which you classify each step as a physical or chemical change.

7.1 Practical investigations

1 A model thermometer

Purpose

To construct a model thermometer that uses the expansion of gases to measure temperature.

Materials

- water
- food dye
- ice cube

- conical flask
- rubber stopper with single hole
- glass tubing
- retort stand
- 2 bossheads and 2 clamps
- clear plastic tubing
- rubber gloves

SAFETY

Food dye can stain your clothing or skin, so wear rubber gloves.

Procedure

1. Build the model thermometer shown in Figure 7.1.13.
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.

Results

Record what happened to the liquid in the tube in both cases.

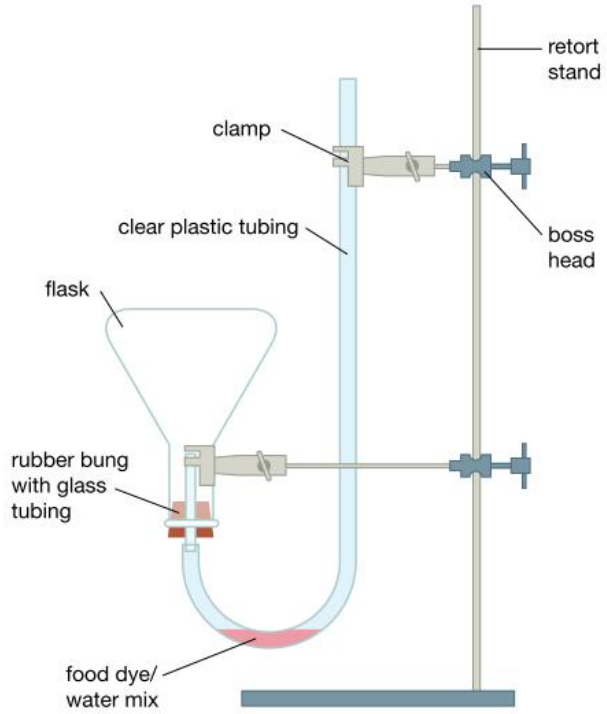


Figure 7.1.13

Practical review

1. **Define** the terms *expansion* and *contraction*. L
2. **Explain** why liquid rises in a thermometer when the temperature goes up, and why the liquid drops when the temperature drops.
3. **Explain** how this model thermometer could be used to measure temperature.

Figure 7.1.14 Medical thermometers like this one depend on the expansion and contraction of liquid mercury or red-coloured alcohol to measure temperature.

2 A precipitation reaction

Purpose

To observe the precipitation of barium sulfate.

Materials

- barium hydroxide ($Ba(OH)_2$) solution
- magnesium sulfate ($MgSO_4$) solution

- large test-tube
- 2 droppers

SAFETY

All chemicals should be treated as toxic, so wear gloves and safety glasses at all times and avoid contact with skin, eyes and mouth.

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.

Practical review

1. **Define** the term *precipitate*. L
2. **Explain** what the formation of a precipitate indicates.
3. **State** what indicated that a chemical reaction took place in this experiment.

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

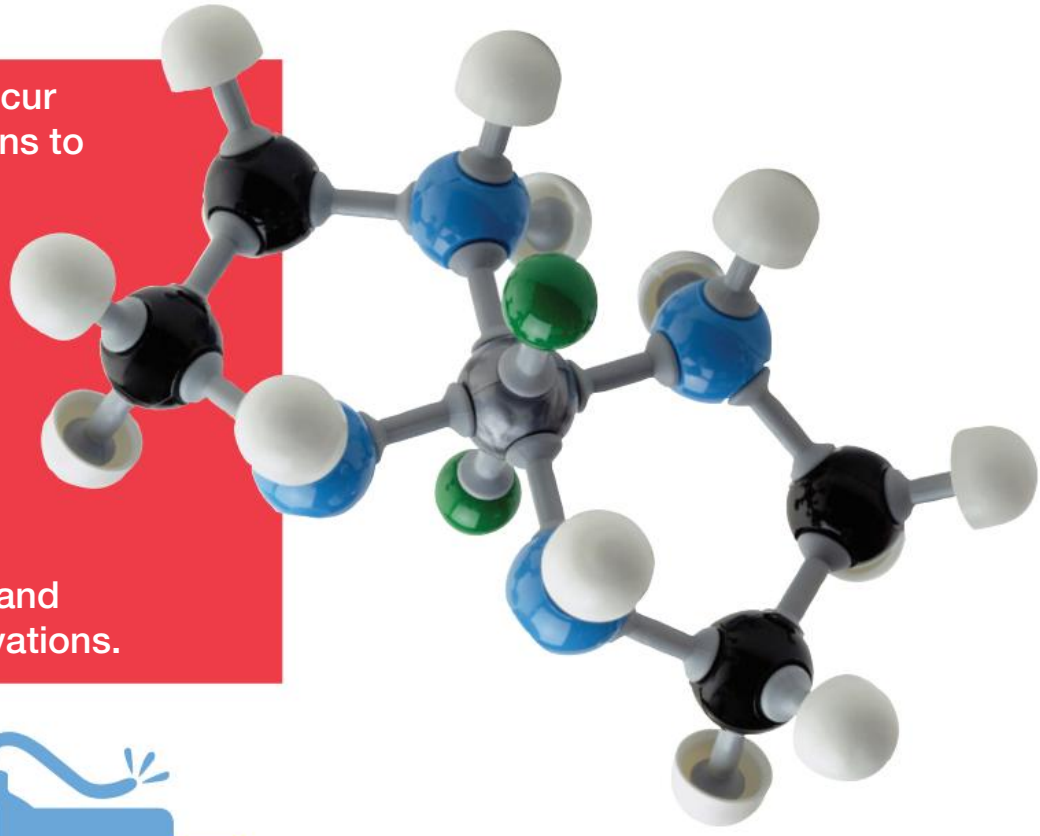
1. Cut or shred the newspaper into small pieces.
2. Create a paper pulp either by placing the shredded paper and warm water in a blender and blending until finely chopped or by allowing the paper to soak in the large bowl overnight and mashing it by hand.
3. Place the frame and mesh in the tray with 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.

Practical review

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.

7.2 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.



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.

Understanding physical change

Most physical changes can be understood by using the **particle model**, as shown in Figure 7.2.1. The particle model is a simplified representation of solids, liquids and gases. It can explain some but not all of their properties.

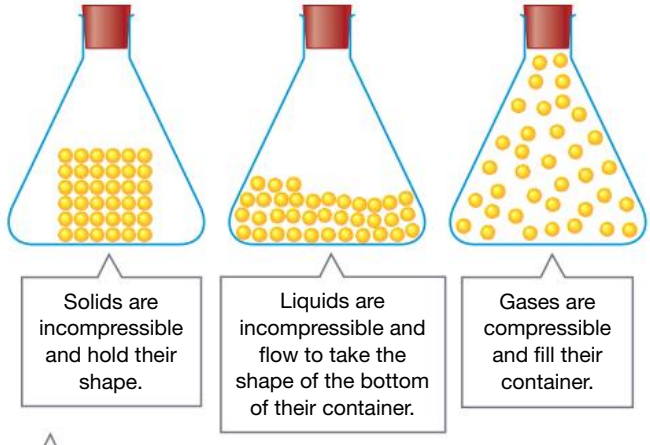


Figure 7.2.1 The physical properties of solids, liquids and gases can be explained by the particle model.

The individual particles in solids, liquids and gases are invisible, and so scientists have developed the particle model through indirect observation. This means that scientists use their observations about the behaviour of solids, liquids and gases to deduce information about the particles that make up each state.

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 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.

In liquids, the particles are packed tightly together, which makes liquids incompressible. However, the particles in a liquid are not stuck to each other as much as they are in solids. This gives liquids the ability to flow and take on the shape of the bottom of their container. Particles in a liquid vibrate but can also move freely through the liquid.

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 (able to be squashed). The particles are free to move anywhere within their container. The particles move in straight lines until they collide with another gas particle or the side of the container. This is why gases always fill their container.

Expansion and contraction

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). This is shown in Figure 7.2.2. 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 (like the balloon in Figure 7.2.3 on page 276) then increasing the temperature of the gas will cause the balloon to expand.

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. If the gas is cooled in a flexible container, then the container will contract.

Prac 1 p279

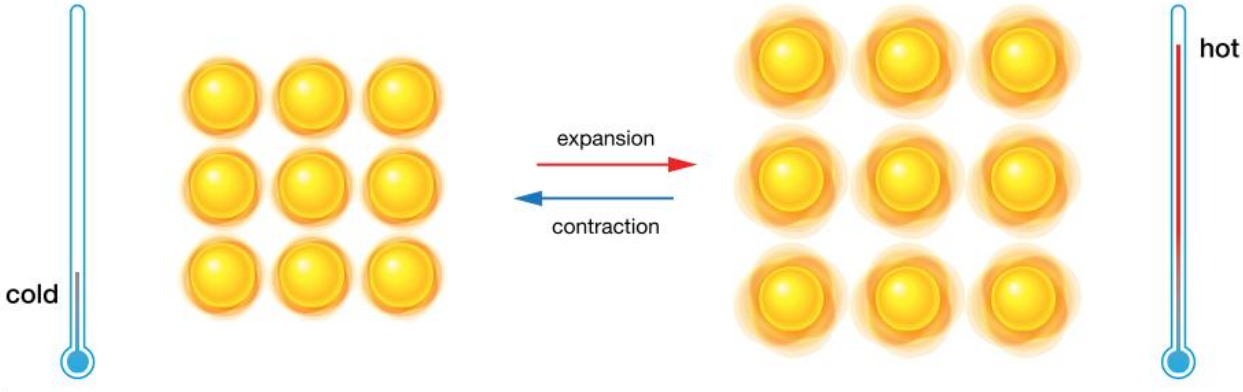


Figure 7.2.2 Increasing temperature causes the particles in solids and liquids to vibrate more. As are result, solids and liquids expand with increasing temperature.

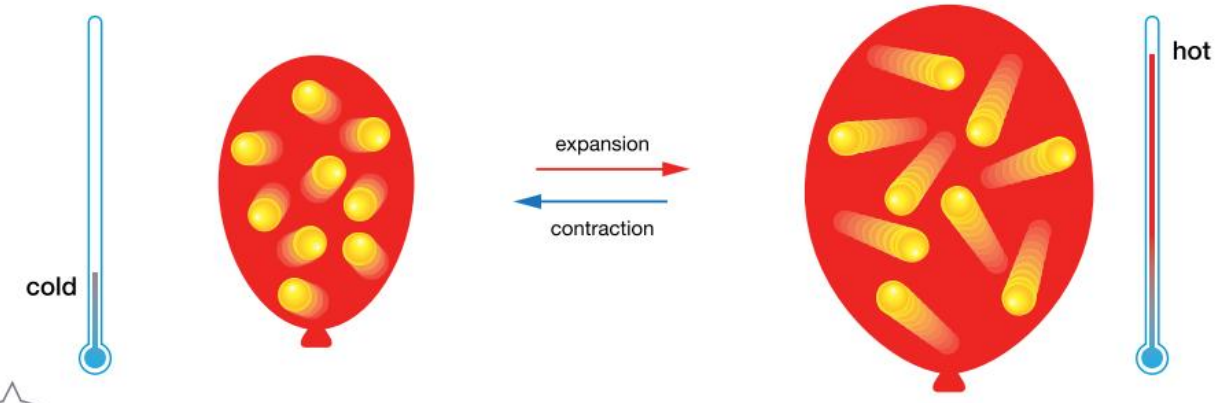


Figure 7.2.3 When the temperature of a gas is increased, the particles travel faster, hitting the sides of their container more frequently and with more force. This causes a balloon to expand.

ADDITIONAL

Gas pressure

A gas cylinder has rigid walls and so it doesn't expand like a balloon when the gas inside warms up. Instead, the pressure of the gas inside the cylinder increases. Pressure measures the force on a container's walls. When a gas is heated, its particles travel faster and so they slam into the walls with greater force and greater frequency. This increases the force on the walls and the pressure within the container. In contrast, cooling a gas slows its particles. Fewer collisions occur and the force of each collision is less. This results in a drop in the pressure inside the container.

7.3

GO TO Pearson science NSW 7 Unit 2.2

ADDITIONAL

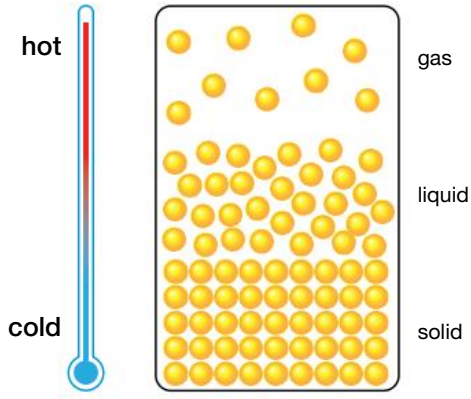


Figure 7.2.4 When a solid is heated to its melting point, the particles break away from their fixed positions to form a flowing liquid. When a liquid is heated to its boiling point, the particles escape from the liquid to form a gas.

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 7.2.4).

Melting

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 increases further, the solid melts. This is because the vibrations become so energetic that the attraction between the particles can no longer hold the particles 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

Freezing is the opposite of melting. As the free-moving particles in the liquid are cooled, they slow and become less energetic. Eventually the attraction between the particles is able to fix them in position, forming a solid.

Evaporation

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 but only weakly. As the liquid particles are heated, they move faster until some are able to break free from the other particles at the surface of the liquid. The escaped particles have formed a gas. They have evaporated. At the boiling point, the particles within the liquid are moving so fast that they fly apart and form bubbles within the liquid.

Condensation

Condensation is the reverse. As a gas is cooled, the particles move slower until the forces of attraction between the particles can hold and stick them together to form liquid droplets.

GO TO Pearson science NSW 7 Unit 2.3

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 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. You can see this in Figure 7.2.5. 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 seem invisible. The individual solute particles are so small that they cannot be seen with even the most powerful optical microscope.

Pearson science NSW 7 Unit 4.1

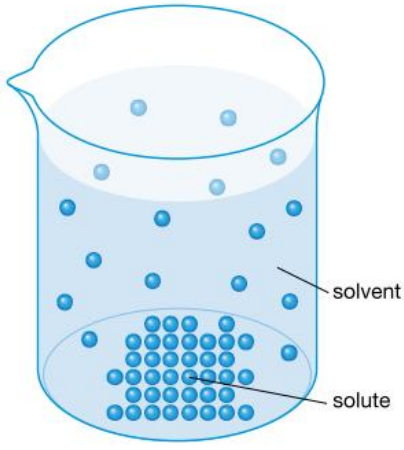


Figure 7.2.5 When a solute dissolves, its particles are spread evenly through the solvent. The particles are so small that they are invisible—even with the most powerful optical microscope.

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 soon smell the perfume on the other side of the room.

During diffusion, gas particles travel in a zig-zag fashion. This is shown in Figure 7.2.6. Each particle moves in a straight line until it collides with another particle and then changes direction. However, eventually the particles will be distributed evenly throughout the space. Increasing the temperature speeds up diffusion because the particles will travel faster.

Diffusion is even faster if there is a gust of wind or convection currents caused by differences in temperature. Even when you move or exhale you can send air particles flying across the room, making them diffuse faster through it.

Diffusion in liquids occurs less rapidly because the liquid particles are packed closer together. However, the liquids will ultimately spread evenly through one another.

Pearson science NSW 7 Unit 2.2

Prac 2 p279 7.4
Prac 3 p280 7.5

Figure 7.2.6 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.

INQUIRY science 4 fun

What smells?

YES

How quickly 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.

7.2 Unit review

Remembering

1 **List** the assumptions made by the particle model.

2 **List the** changes that occur when the temperature of a gas inside a balloon is increased.

3 **Name** the reverse process for the following physical changes.
- **a** expansion
- **b** melting
- **c** evaporation
- **d** dissolving

Understanding

4 **Define** the following terms. L
- **a** solution
- b diffusion
- c compressible
- d incompressible

5 **Describe** the arrangements of particles in solids, liquids and gases.

6 **Outline** how the particle model explains expansion and contraction.

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 The liquid in a thermometer rises as the temperature increases. **Use** the particle model to **explain** why.

11 **Use** the particle model to **explain** why your bike tyres may seem deflated on a cold day.

Analysing

12 **Compare**:
- **a** solute and solvent
- b 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 CCT

14 **Propose** reasons why the smell of a scented candle spreads quickly through a room while the candle is burning but not when the candle is unlit.

15 When pepper is sprinkled over a pool of water, it spreads across the surface evenly. However, when a drop of detergent is put into the middle of the pool, the pepper is pushed to the edges of the pool. **Use** the particle model to **propose** a reason why.

Creating CCT

16 **Construct** 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. L

Inquiring

ADDITIONAL

Research gas pressure and how it affects the performance of tyres. Find:

- a definition for the term pneumatic
- the advantages of air-filled tyres over hard-rimmed wheels
- recommended tyre pressures for bikes, motorbikes, cars and trucks
- what happens to the shape of tyres when they have too much or too little pressure
- what happens to tyres as they heat up while being used.

Present your findings as a brochure to be handed out at tyre dealerships.

ADDITIONAL

7.2 Practical investigations

1 Expansion and heat

Purpose

To observe how changing temperature affects the air inside a balloon.

Hypothesis

What do you think will happen to a balloon as the air inside it cools—will it expand or contract? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- hot tap water

- glass bottle
- 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.

Practical review

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 **Use** the particle model to **describe** what is happening inside the balloon.

4 a **Construct** a conclusion for your investigation.
b **Assess** whether your hypothesis was supported or not.

2 Rate of diffusion

Purpose

To test whether the rate of diffusion changes with temperature.

Hypothesis

What do you think will happen to the rate of diffusion as temperature increases—will the rate increase or decrease? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- hot and cold water
- food colouring

- shallow tray
- overhead transparency with a grid of 2 cm × 2 cm squares printed on it
- dropper
- stopwatch
- rubber gloves

SAFETY

Food colouring can stain, so wear rubber gloves and avoid contact with skin and clothing.

Procedure

This prac should be performed in pairs or small groups.

1. Copy the table from the Results section into your workbook.
2. Place the gridded transparency on the bottom of the shallow tray.
3. Fill the tray with cold water.
4. 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.
5. Repeat the experiment with hot water.

Results

Record all measurements in your Results table.

	Number of squares		
	After 5 s	After 10 s	After 20 s
Cold water			
Hot water			

Rate of diffusion continued on next page

7.2 Practical investigations

Rate of diffusion continued

Practical review

1 **Name** the process that allows the food colouring to move through the water and **state** whether this is a physical or chemical change.

2 **Compare** your observations for cold and hot water.

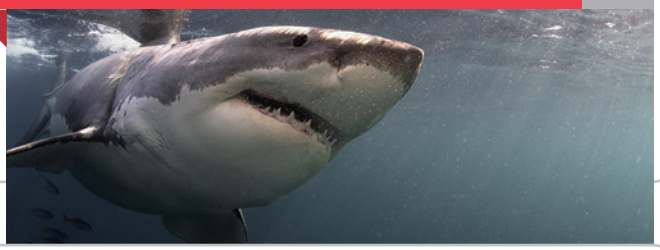
3 **Explain** your results in terms of the particle model.

4 a **Construct** a conclusion for your investigation.
b **Assess** whether your hypothesis was supported or not.

Deadly diffusion

SciFile

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 extremely powerful sense of smell.



STUDENT DESIGN

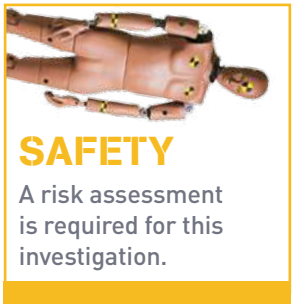
3 Temperature of water and solubility

Purpose

To investigate how water temperature influences how much solute can be dissolved.

Hypothesis

What do you think will happen as water temperature increases—will you be able to dissolve more or less solute in it? Before you go any further with this investigation, write a hypothesis in your workbook.



SAFETY

A risk assessment is required for this investigation.

Materials

- as selected by students

Procedure

1 The amount of solute that can be dissolved in a certain amount of water depends on the temperature of the water. Design an investigation to test how the temperature of water affects how much solute can be dissolved.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.

3 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risk. If your teacher approves, then collect all the required materials and begin your investigation.

Hints

- Choose a solute that can be obtained easily and is easy to dissolve, such as salt or sugar.
- Avoid using large amounts of solute and only use a small amount of water.
- Consider how you will change the temperature of the water and measure the water's temperature.
- Consider how you will measure how much solute has dissolved and determine accurately when no more solute can dissolve at a certain temperature.
- Consider how you will record and display your results.

Practical review

1 **Describe** how the amount of dissolved solute changes as the temperature of water increases.

2 a **Construct** a conclusion for your investigation.
b **Assess** whether your hypothesis was supported or not.

3 **Discuss** how your procedure could be made more accurate if you did it again, or had different equipment or more time.

4 **Compare** your results with others in the class and explain the differences and similarities.

5 **Use** your results to **predict** how much solute will dissolve at 80°C and 10°C.

7.3 Chemical reactions

Chemical reactions play a vital role in your everyday life. When you take a deep breath, you are providing fuel for 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

The key difference between a physical change and a chemical change is that new substances are produced during a chemical change. You can usually determine that new substances have been produced by observing one or more of the following:

- a permanent colour change occurs
- a gas is given off
- a solid precipitates (falls) out of a solution
- a change in temperature happens or light is produced.

GO TO Unit 7.1

These observations are only indicators, because there are exceptions to all of them. In each case, there are examples of physical changes that cause the same observations. Also, some chemical changes might not show any of these effects. Therefore, the only way to truly know if a chemical change has taken place is to understand what has happened to the atoms before and after the change.

Prac 1 p290

Why are substances different?

There are billions of different substances that make up the universe, and each substance is special in its own way. The unique set of characteristics of each substance is known as its properties. The properties of a substance are determined by the types of atoms it contains and how those atoms are arranged. Take graphite and diamond, for example. Both of these substances are made from carbon atoms and so both are different forms of the element carbon. However, graphite is a grey, brittle substance that conducts electricity, while diamond is a clear, very hard substance that is an electrical insulator. The reason for the different properties is that the carbon atoms in the two substances are arranged differently.

The same is true for compounds. Compounds made from the same types of atoms can have very different properties if these atoms are arranged differently. For example, water and hydrogen peroxide are both made up of hydrogen and oxygen atoms. The molecules for these two compounds are shown in Figure 7.3.1 on page 282.

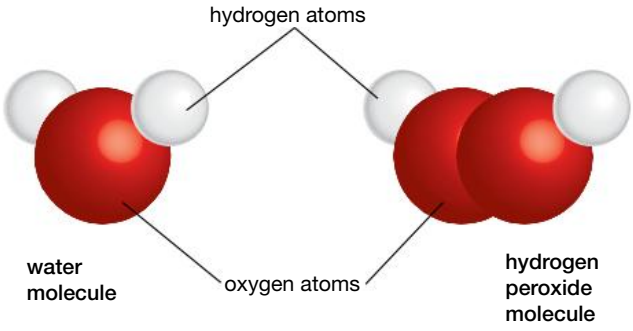


Figure 7.3.1 Water and hydrogen peroxide (bleach) molecules are similar—both are made of oxygen and hydrogen atoms. Despite having similar molecules, these two compounds have very different properties.

Water has two hydrogen atoms and one oxygen atom, and so it has the chemical formula H_2O. Hydrogen peroxide has two hydrogen atoms and two oxygen atoms, and so it has the chemical formula H_2O_2. Despite water and hydrogen peroxide having very similar molecules, water is safe for drinking, bathing and washing whereas hydrogen peroxide is a type of bleach that attacks your eyes, skin and hair and reacts explosively with some metals.

GO TO Units 6.1, 6.2

Chemical reactions

During a chemical change, old substances disappear and new substances form. The only way this can occur is if the atoms in the old substances rearrange to form the new substances during the change. The process of rearranging atoms to form new substances is known as a **chemical reaction**. In a chemical reaction, the old substances are known as the **reactants**. The new substances that form are referred to as the **products**.

An example of a simple chemical reaction is the reaction that happens when magnesium is burnt in air. In this reaction, magnesium metal (Mg) and oxygen gas (O_2) are the reactants. Magnesium is a light and soft, silver-grey metal and when it burns in oxygen gas it produces large amounts of light and heat. At the end of the chemical reaction, the magnesium metal has gone but a light grey powder has formed in its place. This is a new substance called magnesium oxide (MgO). Magnesium oxide is the product of the reaction.

There is little doubt that this reaction is a chemical change, because heat and light are produced and the resulting magnesium oxide looks very different to the original magnesium metal. However, you can also examine what happens to the atoms during this chemical reaction. Figure 7.3.2 shows how the atoms are arranged before and after the chemical reaction. Before the reaction, there is a crystal lattice of magnesium atoms surrounded by oxygen molecules. After the reaction, the oxygen atoms have been incorporated into the magnesium lattice. A new substance has formed—magnesium oxide.

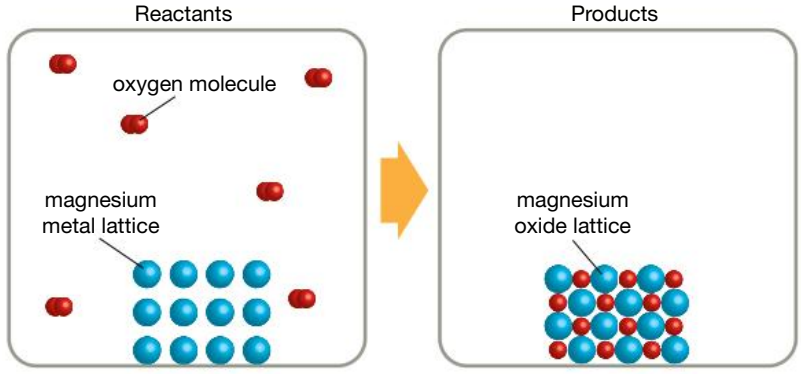


Figure 7.3.2 During the chemical reaction between magnesium metal and oxygen gas, the atoms on the magnesium metal lattice and the oxygen molecules rearrange to form a compound—magnesium oxide. This is a completely different substance.

Now consider a chemical reaction between hydrogen gas (H_2) and chlorine gas (Cl_2). When hydrogen gas and chlorine gas are heated together, they react to produce a different substance—hydrogen chloride gas (HCl). This relatively simple chemical reaction is an extremely important industrial process that is used to produce hydrochloric acid.

Figure 7.3.3 shows a diagram of the hydrogen and chlorine molecules before the chemical reaction and how the atoms are arranged after the chemical reaction. After the reaction, individual hydrogen and chlorine atoms have paired up to create the molecules of hydrogen chloride.

The word equation for this reaction is:

hydrogen gas + chlorine gas ⟶ hydrogen chloride gas

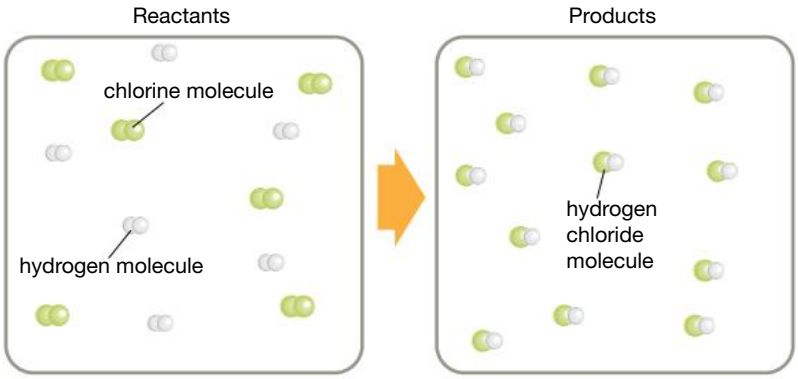


Figure 7.3.3 During the chemical reaction between chlorine and hydrogen, the atoms in the chlorine and hydrogen molecules rearrange to form hydrogen chloride molecules.

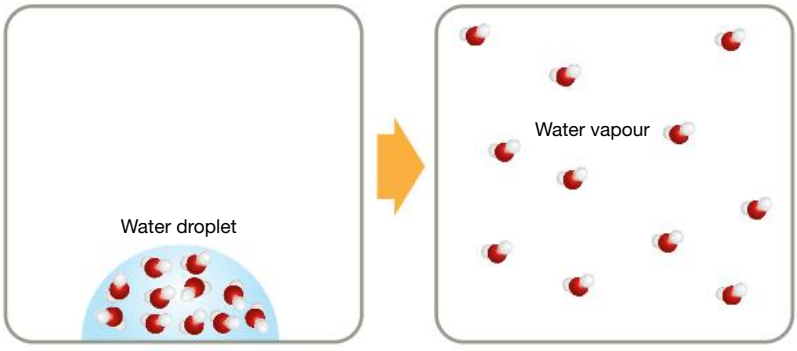


Figure 7.3.4 When water evaporates, the water molecules break away from the liquid to form a gas. The atoms do not rearrange to form different molecules, so evaporation is a physical change.

7.6

In a chemical change, particles rearrange to form new substances. This is very different to what happens in a physical change. For example, Figure 7.3.4 shows what happens to the water molecules during evaporation. Before evaporating, the water molecules stick closely together, moving over and around each other. Afterwards, the water molecules float around as gaseous water vapour. Although liquid water, ice and water vapour appear to be very different, they are made up of exactly the same particles. The atoms haven't rearranged and so no chemical change has occurred. This shows instead that evaporation is a physical change.

Reading word equations

Chemists usually don't use detailed descriptions or diagrams to describe what is happening in a chemical reaction. Instead they use a shorthand description known as a chemical equation. The simplest chemical equation is a **word equation**. A word equation lists the reactants taking part in the reaction and the products that form. All chemical equations are written in the form:

reactants ⟶ products

The arrow indicates that a change has taken place.

WORKED EXAMPLE
Reading word equations

Problem

Identify the reactants and products in the word equation:

magnesium + oxygen ⟶ magnesium oxide

Solution

Reactants are the substances that you start with. Products are what are formed after the chemical reaction has taken place.

In this reaction, the reactants are magnesium and oxygen gas. There is only one product, magnesium oxide.

Practice

Identify the reactants and product(s) in the following word equations.

a hydrogen gas + chlorine gas ⟶ hydrogen chloride gas

b glucose + oxygen gas ⟶ carbon dioxide + water vapour

Everyday chemical reactions

Every day there are thousands of chemical reactions going on around and even inside you. These chemical reactions play an important role in industry, medicine, your home, the environment and your body.

Combustion

Combustion is the term given to any chemical reaction that involves burning with oxygen to release light and heat (Figure 7.3.5). Sometimes combustion releases so much energy so quickly that an explosion occurs. An explosion happens when petrol is ignited. Likewise, hydrogen gas (H_2) burns explosively in oxygen (O_2) to produce water vapour (H_2O). The word equation for this reaction is:

hydrogen gas + oxygen gas ⟶ water vapour

Even metals such as magnesium can undergo combustion. The most common examples of combustion are the burning of fuels like petrol, natural gas, coal, wood and paper. For example, when you light a Bunsen burner, you are burning methane gas (CH_4). It reacts with oxygen gas (O_2) to form carbon dioxide (CO_2) and water vapour (H_2O). This is a combustion reaction:

methane + oxygen gas ⟶ carbon dioxide + water vapour

Combustion allowed prehistoric humans to make light, cook, keep themselves warm and even defend themselves from predators. Combustion was a reaction that was useful and easily controlled. Throwing another log on the fire or fanning the fire added reactants to keep the reaction going. Starving the reaction of its fuel or oxygen would stop it and put the fire out. Since then, combustion has been central to the development of human civilisation, from extracting and forging metals during the Iron Age to running factories and steam engines during the Industrial Revolution. Today, we use combustion to heat and cook, run cars, buses, trains and aircraft, and to generate electricity in coal or gas power stations and diesel or petrol generators.

7.7

Figure 7.3.5 Combustion happens whenever something burns in oxygen.

Figure 7.3.6 shows how humans have used combustion since prehistoric times.

Figure 7.3.6 Combustion has been an important part of civilisation throughout human history.

Photosynthesis

Millions of biological chemical reactions take place every day to help support life on Earth. One of the most important reactions is photosynthesis.

Photosynthesis is a series of chemical reactions that uses sunlight to convert water (H_2O) and carbon dioxide (CO_2) into oxygen gas (O_2) and a form of sugar called **glucose** ($C_6H_{12}O_6$). The word equation for photosynthesis can be summarised as:

carbon dioxide + water ⟶ oxygen gas + glucose

Photosynthesis occurs only in plants because the chemical reaction requires **chlorophyll**—the chemical that makes leaves green, like the leaves in Figure 7.3.7. Chlorophyll captures the sunlight that is required to start the chemical reaction. Plants obtain the carbon dioxide they need from the air and the water they need from the soil.

Photosynthesis is the basis of all life on Earth. Plants use the glucose produced by photosynthesis as food, to provide them with energy to live and grow. Animals eat the plants, and this provides the animals with the energy they need to live and grow. Animals also eat each other as an energy source. However, in all cases, the energy can be traced back to the glucose produced in plants by photosynthesis.

GO TO Unit 2.4

Figure 7.3.7

Green leaves contain chlorophyll, a chemical that collects energy from sunlight. This energy drives the chemical reaction of photosynthesis.

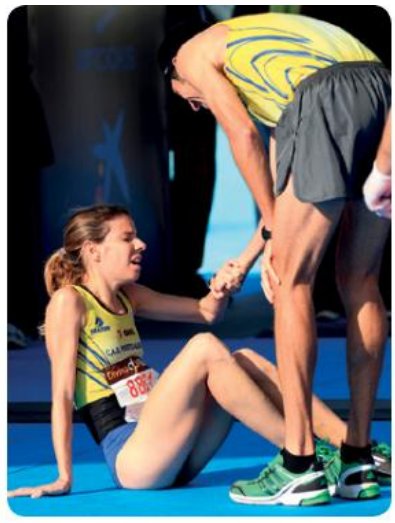


Figure 7.3.8

After a long race, athletes are exhausted because their bodies are starved of oxygen and glucose, so respiration becomes more and more difficult.

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Taking a leaf out of Nature's book

Scientists are researching ways of using solar energy to produce fuels using a process called artificial photosynthesis. This process takes water (H_2O) and carbon dioxide (CO_2) and converts them into fuels such as methane (CH_4). These fuels are known as solar fuels and could supplement or even replace fossil fuels in the future.

Respiration

The process of obtaining energy from food is known as **respiration** and can be thought of as the reverse of photosynthesis. This is because respiration involves a chemical reaction that converts oxygen and glucose into carbon dioxide and water vapour, while releasing energy. The word equation for respiration is:

glucose + oxygen ⟶ carbon dioxide + water vapour

Respiration is a crucial chemical reaction in all living things because it provides the energy for them to live, grow, move and even think. When you take in a breath of air, you provide your body with the oxygen it needs for respiration. When you eat, you provide your body with the glucose it needs for respiration. The oxygen and glucose travel through your bloodstream to each cell, where respiration is going on constantly. The carbon dioxide that is produced is removed from your body when you breathe out, while the water is excreted through your breath, sweat and urine. When you exercise, you need more energy and so respiration has to take place more quickly. This is why you have to breathe more heavily (like the athletes in Figure 7.3.8). It is also why you might feel especially hungry after a lot of physical activity.

INQUIRY

science 4 fun

Naked egg

YES

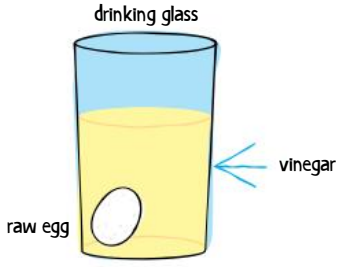
The shell of an egg reacts with acids, so it will dissolve if left in an acid for a long time. This produces a shell-less or naked egg! Can you create a naked egg using the acid found in vinegar?

Collect this …

- an egg
- white vinegar
- a large, clear drinking glass

Do this …

1. Place the egg in the glass.
2. Half-fill the glass with white vinegar.
3. Leave the egg in the vinegar for 24 hours and observe.
4. Gently remove the naked egg from the vinegar by pouring it into your hand over a sink (don't use a spoon or you might break the egg).



Record this …

Describe your observations.

Explain what happened.

Chemical weathering

Chemical reactions are happening in the non-living environment too. These chemical reactions take place in Earth's atmosphere (air), hydrosphere (water) and lithosphere (rocks and soils). Chemical reactions in the atmosphere include the formation of holes in the ozone layer and smog from air pollution. Chemical reactions in the hydrosphere include increasing acidity of our oceans. Examples in the lithosphere include the formation of crystals and minerals deep below the Earth's crust.

A chemical process that involves all three non-living spheres is **chemical weathering**. Chemical weathering is the gradual breaking down of rocks due to reactions with chemicals in rainwater, hail, sleet and snow. Rainwater is slightly acidic because carbon dioxide (CO_2) from the air dissolves in the water droplets to form carbonic acid (H_2CO_3). When the water droplets fall to Earth, they react chemically with rocks such as limestone, marble and chalk. These types of rock are all made of calcium carbonate ($CaCO_3$). This is the same substance that makes up eggshells. Carbonic acid reacts with the calcium carbonate and causes the rocks to dissolve. This occurs because acids are **corrosive**, meaning that they can chemically dissolve many types of substances including some rocks and metals. You can see the result of chemical weathering in Figure 7.3.9.

The change to a rock's surface will be difficult to notice even after several years of chemical weathering. However, over thousands of years chemical weathering can change the face of the Earth.

GO TO Unit 8.2

7.8

Figure 7.3.9 Chemical weathering smoothes limestone rock and creates deep cracks.

ADDITIONAL

Chemical properties of substances

The different characteristics of substances are known as their **properties**. Often, the properties of a substance that first come to mind are its **physical properties**. These include things like:

- colour
- smell
- hardness
- density
- state (solid, liquid or gas)
- melting and boiling points
- whether the substance dissolves in water
- whether the substance can be magnetised, as in Figure 7.3.10
- whether the substance conducts electricity and/or heat.

Figure 7.3.10 One of the physical properties of the metals iron, steel, nickel and cobalt is the ability to be magnetised.

Substances also have **chemical properties**. These properties describe how the substance reacts with other substances. Some examples of chemical properties include whether the substance:

- reacts with water
- reacts with oxygen
- reacts with acids
- is toxic (Figure 7.3.11)
- decomposes, changing chemically over time or if it is heated.

Figure 7.3.11 The toxicity of a substance is an example of a chemical property.

Usually, both the chemical and physical properties of a substance need to be taken into account when determining how it is used.

GO TO Pearson science NSW 7 Unit 2.1

Flammability

The chemical property of **flammability** describes how easily a substance undergoes combustion (burns). Substances that don't burn are said to be non-flammable, while substances that burn easily are said to be flammable. Substances that ignite quickly or explosively might be considered highly flammable.

The flammability of a substance often affects how it is used. For example, fibreglass is non-flammable so it can be used in fire blankets and home insulation. Paraffin wax is flammable but it burns slowly. This is why it is used in candles. Petrol is highly flammable, making it perfect for motor vehicle engines. Hydrogen gas is extremely explosive and so it is used in engines that power rockets like the one in Figure 7.3.12. Examples of flammable substances and their uses are shown in Table 7.3.1.

Prac 2 p291

Figure 7.3.12 Hydrogen combusts so explosively that it has been used in some rockets as fuel. It has the added advantage of producing pure water when it combusts.

Table 7.3.1 Flammable substances and their uses

Flammable substance	Uses
Hydrogen gas	Rocket engines, some welding torches
Natural gas	Generation of electricity, domestic cooking and heating, fuels some cars and buses
Acetylene	Oxyacetylene welding torches
Ethanol	Motor vehicle fuel, added to petrol
Butane	Lighter fluid, added to petrol and liquid petroleum gas
Petrol	Fuel for car and bus engines
Kerosene	Portable stoves for camping and for cooking in some countries
Diesel	Heavy duty motor vehicles, truck engines, military vehicles
Coal	Generation of electricity
Paraffin wax	Candles

Corrosion

Corrosion is a chemical reaction that can happen between metals and the chemicals of their environment. For example, iron (Fe) and steel (an alloy of iron) have chemical properties that cause them to react slowly with water and the oxygen gas in air. The product is iron oxide (Fe_2O_3), commonly known as rust. The word equation for this reaction is:

iron + water + oxygen gas ⟶ iron oxide

Iron and steel are strong and relatively cheap, so they are commonly used to build cars and ships, nails and pins. They are also used for reinforcing concrete for everything from bridges to skyscrapers. Rust weakens and eventually destroys anything made of iron and steel. For this reason, iron and steel objects must be protected by a coating of paint or even oil. Galvanised iron is protected by a layer of the element zinc (Zn). The chemical properties of zinc cause the zinc to corrode faster than the iron and steel. Zinc corrodes before the iron does, even when the iron is exposed to the weather because of a scratch or dent. In this way zinc is sacrificed to save the iron. It is only after the zinc has all gone that the iron begins to rust. You can see this in Figure 7.3.13.

7.9

Figure 7.3.13 Galvanised iron is common in Australia. It starts to rust when its protective layer of zinc has corroded away.

Painting the bridge

The Sydney Harbour Bridge is a steel structure. Without its protective layer of paint, the bridge would have rusted badly since it was opened in 1932, making it unsafe. To stop this happening, the bridge was first painted with three coats of paint, totalling an amazing 270 000 litres! Since then, a permanent workforce of painters continually re-coats the bridge with new paint, starting again as soon as they finish the other end!

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7.3 Unit review

Remembering

1 **State** the key difference between a chemical change and a physical change.

2 **Name** the particles that make up all substances.

3 **State** the chemical formula for:
- **a** water
- b hydrogen peroxide.

4 **a** **Name** the chemical reaction that involves burning a substance in oxygen.
- **b** **List** three substances that undergo this type of chemical reaction.

5 **Name** the substance that is produced when magnesium metal reacts with oxygen.

6 **Name** the green chemical needed for photosynthesis to occur.

Understanding

7 **Define** the terms: L
- **a** reactant
- b product.

8 **Explain** why a gas being produced is not always a sign that a chemical change has taken place.

9 **Describe** how you get the reactants you need to carry out respiration in your body.

10 **Describe** the process of chemical weathering.

Applying

11 **Identify** the reactants and products in the following word equation.

methane + oxygen → carbon dioxide + water vapour

12 Every science laboratory should have a fire blanket. A fire blanket is thrown over a fire to put it out. This works because the blanket stops the reaction getting one of its reactants. **Identify** this reactant by writing its chemical formula.

13 **Use** word equations to **explain** why photosynthesis and respiration might be considered the reverse of each other.

14 **Identify** what indicates that a chemical change has happened in the science4fun on page 285.

15 For each of the following indicators of a chemical change, **identify** an example of a physical change that might produce the same observation.
- **a** There is a permanent colour change.
- b A gas is produced.
- c A solid is formed out of a solution.
- d The temperature increases or decreases.

Analysing

16 **Compare** a molecule of water with a molecule of hydrogen peroxide, listing their similarities and differences.

17 **Compare** the terms *chemical change* and *chemical reaction*.

Evaluating CCT

18 **a** **Analyse** the particle diagram in Figure 7.3.14 to **determine** whether it shows a chemical or physical change.
- **b** **Justify** your response.

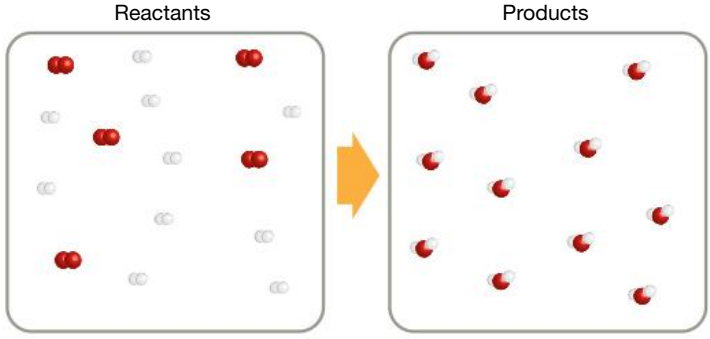


Figure 7.3.14

19 In Figure 7.3.14, the red atoms represent oxygen atoms and the white atoms represent hydrogen atoms. Use this information to:
- **a** determine the chemical formulas for the red and white molecules in the reactants box
- **b** determine the chemical formula for the molecules in the products box
- **c** name the compound in the products box.

20 **Analyse** Figure 7.3.15 and **identify** two things that suggest that a chemical reaction is taking place in the gas flare.

21 Nitrous oxide has the chemical formula N_2O. Nitrogen dioxide has the formula NO_2.

a **State** how many atoms of nitrogen and oxygen are in the molecules of each compound.

b **Evaluate** whether these two compounds will have similar or different properties.

c **Justify** your response.

22 It could be said that all the energy you gain from your food originally came from the Sun. **Use** your understanding of photosynthesis to **justify** this statement.

Creating CCT

23 When solid carbon (C) is heated with oxygen gas (O_2), they undergo a chemical reaction to produce carbon dioxide gas (CO_2). **Construct** a particle diagram to show the arrangement of atoms before and after the chemical reaction.

24 When a water (H_2O) droplet freezes, it undergoes a physical change that turns the liquid into a solid. **Construct** a particle diagram that shows the arrangement of atoms before and after the chemical change.

Inquiring

1 Research different places in industry and at home where combustion is used and collect pictures to represent how combustion is used. ICT

Present your findings as a poster, collage or digital presentation.

ADDITIONAL

2 Choose an element or compound mentioned in this unit and research its following physical and chemical properties.

- Is it solid, liquid or gas at room temperature?
- What is its colour?
- What are its melting point and boiling point?
- Is it flammable?
- Does it corrode?
- Is it toxic?
- How do its properties affect its use?

Present your research as a set of answers to the above questions.

ADDITIONAL

Figure 7.3.15 This flare is the result of gas being burn off in a combustion reaction at an oil refinery

7.3 Practical investigations

1 Observing chemical reactions

Purpose

To observe different examples of chemical change.

Materials

- dilute hydrochloric acid
- blue litmus paper
- piece of magnesium metal
- silver nitrate
- sodium hydroxide solution

- 4 large test-tubes and rack
- 3 droppers
- thermometer

SAFETY

Silver nitrate stains the skin.

Hydrochloric acid and sodium hydroxide are corrosive and burn so wear gloves and safety glasses.

Procedure

1. Copy the table from the Results section into your workbook.
2. Place blue litmus paper in the first test-tube.
3. Use a dropper to place 2 drops of dilute hydrochloric acid on the blue litmus paper. Record your results in the table.
4. Use the dropper to put to 2 cm of dilute hydrochloric acid in each of the next three test-tubes, as shown in Figure 7.3.16.
5. In the second test-tube, add the magnesium metal. Record your results.
6. In the third test-tube, use a separate dropper to add 10 drops of silver nitrate.
7. Use the thermometer to measure the temperature of the hydrochloric acid in the fourth test-tube. Record your results. Rinse the thermometer.
8. 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.

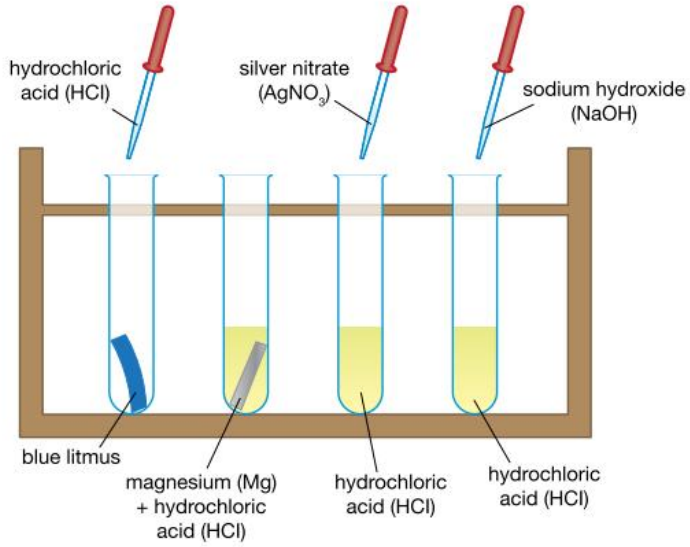


Figure 7.3.16

Results

1. Record all observations in your Results 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	

Practical review

In each case, **identify** the clue(s) that suggests that a chemical change has taken place.

2 Combustion of hydrogen and helium

Purpose

To compare the combustion of hydrogen and helium gases.

Hypothesis

Hydrogen and helium have similar physical properties, both being light, colourless gases. Which do you think will be more flammable—hydrogen or helium? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

This experiment requires at least two people.

1 M acid is very corrosive, so keep the acid away from skin and eyes. Wear safety glasses and rubber gloves at all times.

Keep open flames away from things that burn easily, such as notebooks, paper and hair.

Materials

- 2 cm of magnesium ribbon
- 1 M hydrochloric acid
- helium gas in a helium balloon

- 2 medium-sized test-tubes
- eye dropper
- wooden splint
- gas lighter
- rubber gloves

Procedure

1. Place the magnesium ribbon in one large test-tube.
2. Use the eye dropper to put enough hydrochloric acid into the test-tube so that it completely covers the magnesium ribbon.
3. One person should cover the top of the test-tube with their hand to trap the hydrogen gas that is produced by the reaction.
4. Wait until the magnesium stops reacting or is dissolved completely.
5. Have another person light the end of the wooden splint so that it produces its own flame.
6. Quickly uncover the top of the test-tube and put the burning splint near the mouth of the test-tube.
7. Blow out the burning splint and record your observations.
8. Take the second test-tube and hold it upside down.

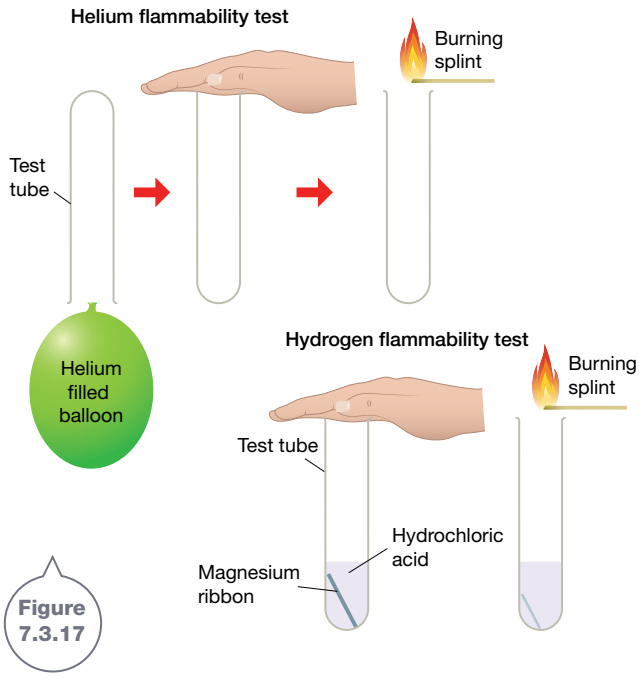


Figure 7.3.17

9. Release helium into the test-tube from the balloon. *Hint*: Because helium is very light, it will flow up into the test-tube and push the air out.
10. Cover the test-tube with your hand and turn it back up the right way.
11. Light the wooden splint once again.
12. Quickly uncover the top of the test-tube and put the burning splint near the mouth of the test-tube.
13. Blow out the burning splint and record your observations

Results

Record your observations from each test.

Practical review

1 a **Identify** the two chemical reactions that take place in this experiment.

b **State** what indications there are that chemical reactions have taken place.

2 **Identify** some of the physical properties of hydrogen and helium that they have in common.

3 a **Construct** a conclusion for your investigation.

b **Assess** whether your hypothesis was supported.

4 Zeppelins were airships filled with hydrogen. The most famous was the Hindenburg. **Use** your observations from this investigation to **propose** reasons why some zeppelins exploded while in flight.

7 Chapter review

Remembering

1 **List** four examples of physical changes and four examples 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 **Name** the chemical needed for combustion to occur.

5 **Recall** the following reactions by writing their word equations.
- a the combustion of magnesium in oxygen
- b respiration

Understanding

6 **Define** the following terms. L
- a expansion
- b evaporate
- c combustion
- d chemical reaction
- e word equation

7 **Outline** the physical changes that aluminium undergoes when it is recycled.

8 **Describe** the chemical and physical changes you would observe while watching a candle burn.

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 **Use** the particle model to **explain** why solutes seem to disappear when dissolved by a solvent.

11 When methane gas is burnt in oxygen, carbon dioxide and water are produced. **Use** a word equation to **describe** this reaction.

Analysing

12 **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.

13 **Compare** photosynthesis with respiration.

Evaluating CCT

14 **Analyse** the particle diagram in Figure 7.4.1 to **determine** whether it shows a chemical or physical change, and **explain** your response.

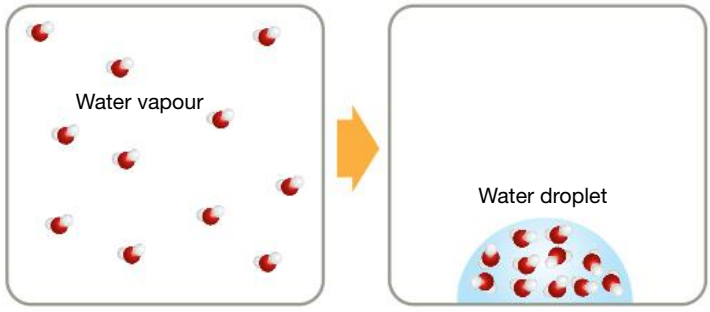


Figure 7.4.1

15 Janet heats a mixture of two liquids in a test-tube and observes bubbles forming. **Propose** two possible explanations for her observation.

16 Samuel ties a balloon over the mouth of an empty 2-litre soft-drink bottle, then places the bottle in very hot water.
- a **Predict** what will happen to the balloon.
- b **Use** the particle model to **justify** your prediction.

17 a **Determine** whether you can or cannot answer the questions on page 263 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

Creating CCT

18 **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

7.10

Thinking scientifically

Q1 During a physical change, no new substances are produced. Which of these processes is *not* an example of a physical change? CCT

A

B

C

D

Q2 When a chemical change occurs, new substances are produced. This may result in: CCT

- 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

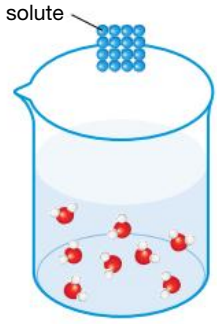
C

D

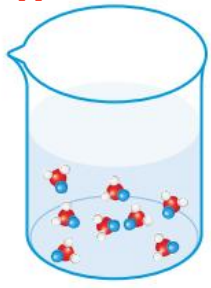
Q3 When Sanjay mixes sodium bicarbonate with vinegar, a chemical reaction occurs that releases a large amount of carbon dioxide gas. What would be the most obvious indication that a chemical change has occurred? CCT

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? CCT



A



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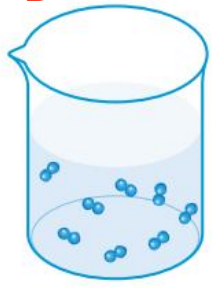

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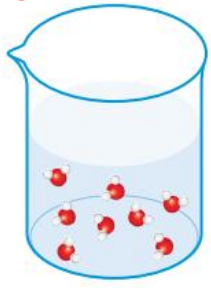

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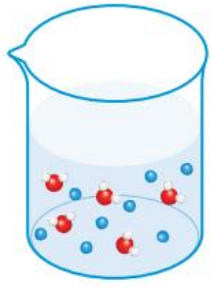


Glossary

Unit 7.1 L

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

Crystallisation: evaporation of solvent from a solution to leave solute behind as crystals

Deposition: a change of state from gas to solid

Evaporation: the change of state where a liquid changes to a gas at the surface of the liquid

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

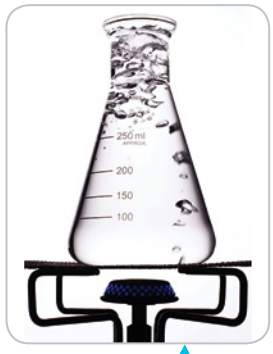
Physical change: a change that does not result in a new substance being produced

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

Precipitate

Unit 7.2 L

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

Unit 7.3 L

Atoms: the basic particles that make up all substances

Chemical properties: the characteristics of substances that determine how they react chemically with other substances

Chemical reaction: the process of rearranging atoms in substances to form different substances

Chemical weathering: the gradual erosion of rocks and buildings that occurs when limestone and marble react chemically with the carbonic acid in rainwater

Chlorophyll: the substance found in plant leaves that make leaves green and collects energy from the Sun for photosynthesis

Combustion: any chemical reaction where a substance burns in oxygen to produce light and heat

Corrosion: when a metal reacts with the chemicals in its environment

Corrosive: describes a substance that can chemically dissolve other substances; examples are acids

Flammability: the chemical property of a substance that describes how easily the substance undergoes combustion

Corrosion

Glucose: a form of sugar that is produced during photosynthesis and used in respiration to produce energy

Physical properties: the characteristics of a substance that describe how it looks, feels, smells and responds to external forces

Photosynthesis: the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun

Products: the substances formed in chemical reactions

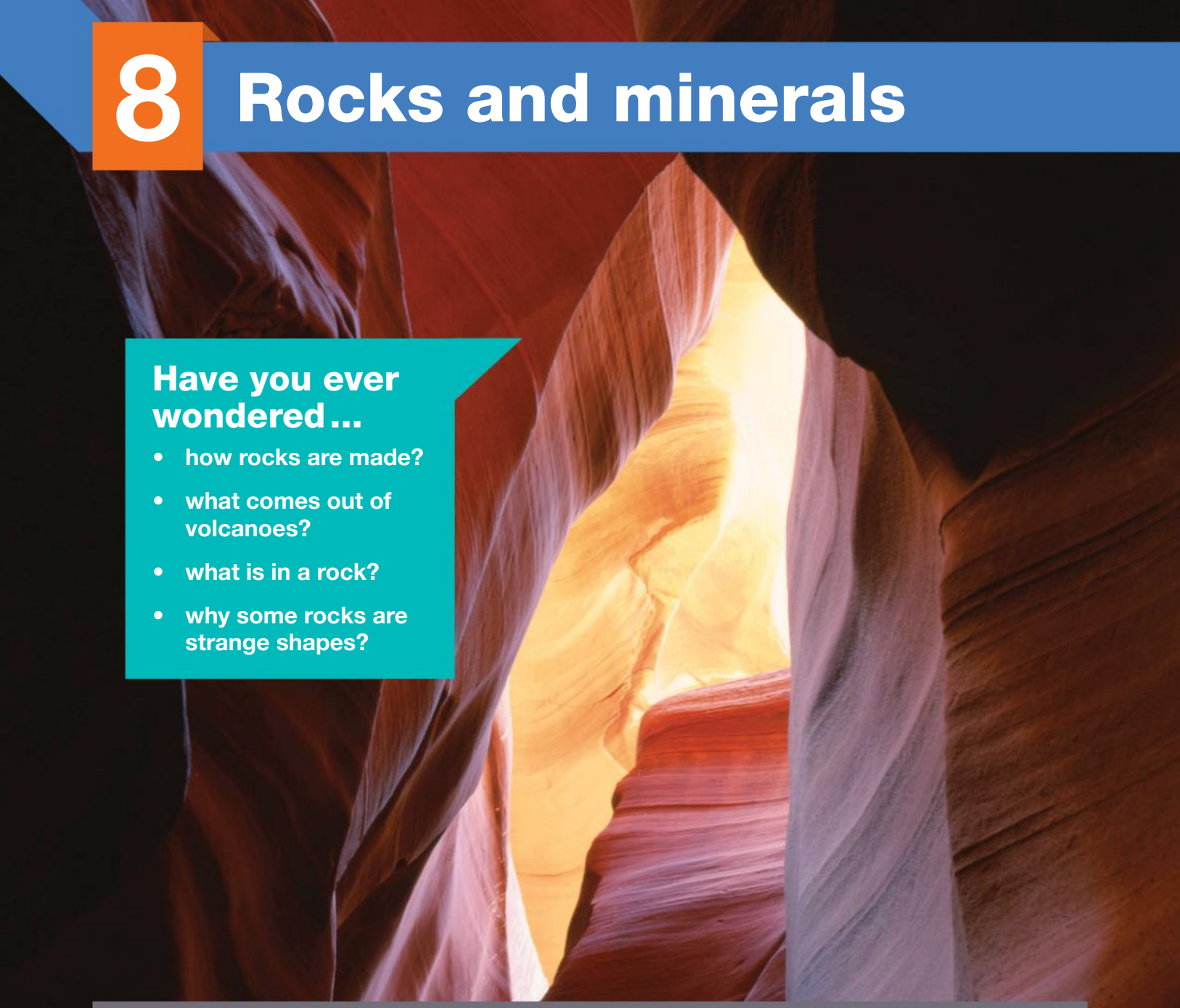
Properties: the characteristics of a substance; they can be either physical or chemical

Reactants: the starting substances in chemical reactions

Respiration: a chemical reaction that occurs in all living cells. In this reaction, oxygen and glucose are converted into water and carbon dioxide while releasing energy. The energy released can be used by living things to live, grow and move.

Word equation: a simple chemical equation where chemicals are represented by their names

8 Rocks and minerals



Have you ever wondered ...

- how rocks are made?
- what comes out of volcanoes?
- what is in a rock?
- why some rocks are strange shapes?

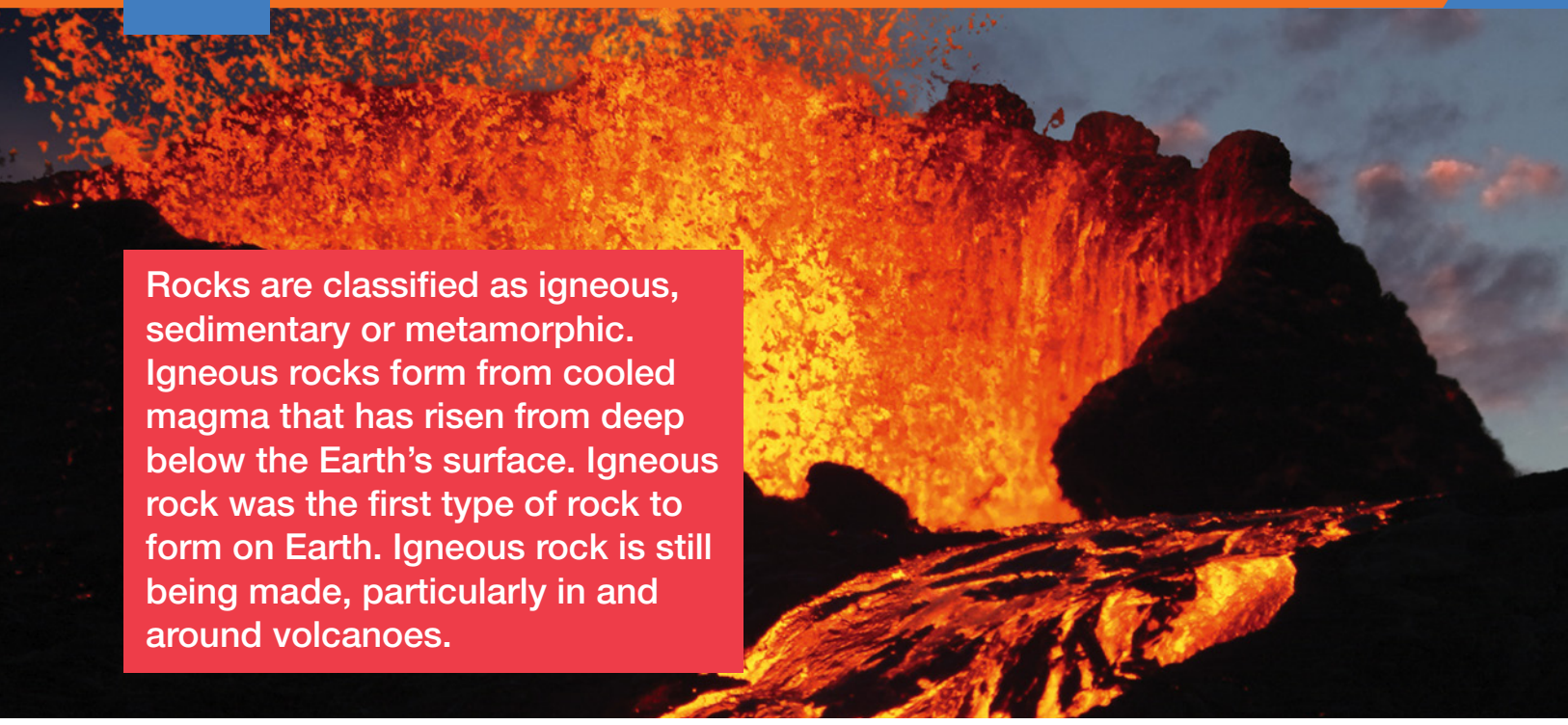
After completing this chapter students should be able to:

- describe the structure of the Earth in terms of core, mantle, crust and lithosphere
- outline how landforms form by weathering, erosion and deposition
- outline the origins of sedimentary, igneous and metamorphic rocks
- describe the conditions under which fossils form
- outline how geological history can be interpreted in a sequence of horizontal sedimentary layers CCT
- identify that rocks contain minerals
- classify common rocks and minerals into groups according to their observable properties L
- outline features of resources including metal ores
- describe how people use understanding and skills from across the disciplines of science in occupations related to the exploration, mining or processing of minerals in Australia WE CC

ADDITIONAL

- describe methods used to determine the relative age of rock layers
- investigate the nature of mineral crystals
- debate the economic and environmental impacts of mining and resource exploration CCT PSC S
- investigate the role of forces and energy in the formation of different rock types and minerals.

8.1 Igneous rocks



Rocks are classified as igneous, sedimentary or metamorphic. Igneous rocks form from cooled magma that has risen from deep below the Earth's surface. Igneous rock was the first type of rock to form on Earth. Igneous rock is still being made, 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, every earthquake, earth tremor and volcano provides them with a little more information about its structure. From this data, they have concluded Earth consists of layers. This structure is shown in Figure 8.1.1.

The **crust** is the outermost solid layer of the Earth. The crust varies in thickness from about 5 kilometres under the oceans to about 30 kilometres under the continents.

Beneath the crust is a layer called the **mantle**. The mantle is much hotter than the crust and is made of different chemicals. The upper part of the mantle is like the crust in that it too is a rigid (not moving) solid. This means that the crust and the mantle have similar physical properties. For this reason, the crust and the upper mantle are together known as the **lithosphere** (*litho* means rock).

Beneath the lithosphere, the rock of the mantle behaves as a 'plastic' solid. This means the rock can flow very slowly, similar to plastic that has been heated. This 'plastic' layer of the mantle is known as the **asthenosphere**. The deepest part of the mantle is very hot. The rock flows much more slowly than in the asthenosphere, so slowly that the rock here can be considered rigid.

The **core** of the Earth is very dense and so geologists think that it is composed mostly of iron and nickel. The inner core is solid, but the outer core is liquid and can flow. Scientists believe this gives Earth its magnetic field.

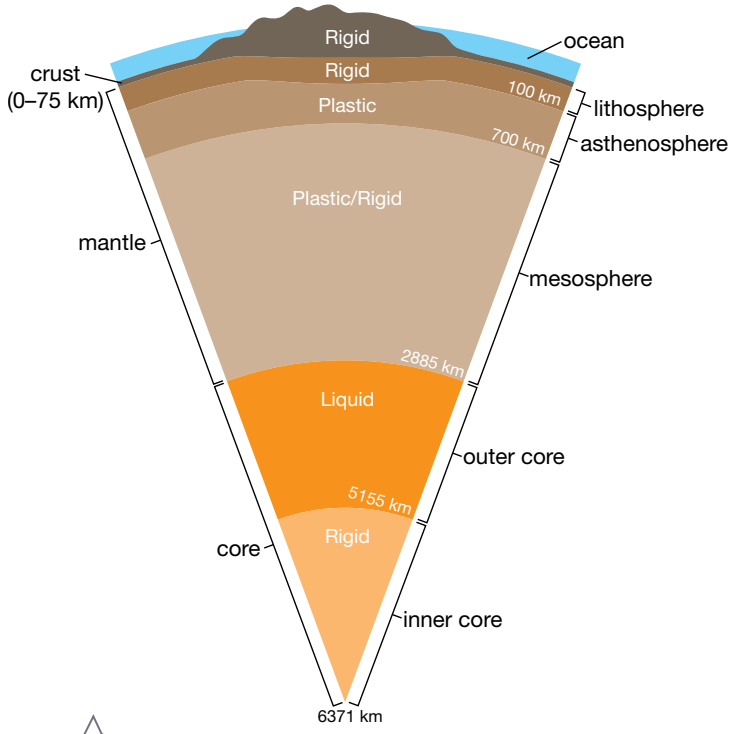


Figure 8.1.1 The Earth is composed of layers.

The first rocks

The first rocks of the lithosphere 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. This magma then pushes up through any fault or crack in the crust above. On the way, magma melts more rock from the upper mantle and crust. When magma reaches the surface, it is known as **lava**. Lava has a temperature of about 1200°C as it erupts at the surface of the Earth. Below the surface, the magma is even hotter. Eruptions form volcanoes. One type of volcano is shown in Figure 8.1.2.

Igneous rocks

Magma rising into the crust cools as 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 (freezes). 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 at the surface by lava are classified as **extrusive igneous rocks**. Some are shown in Figure 8.1.3. Rocks formed from magma cooling below the ground surface are classified as **intrusive igneous rocks**.

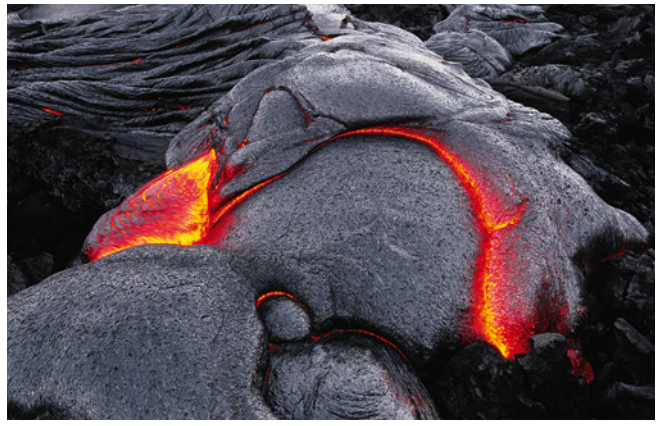


Figure 8.1.3 Lava cools to form extrusive igneous rocks.

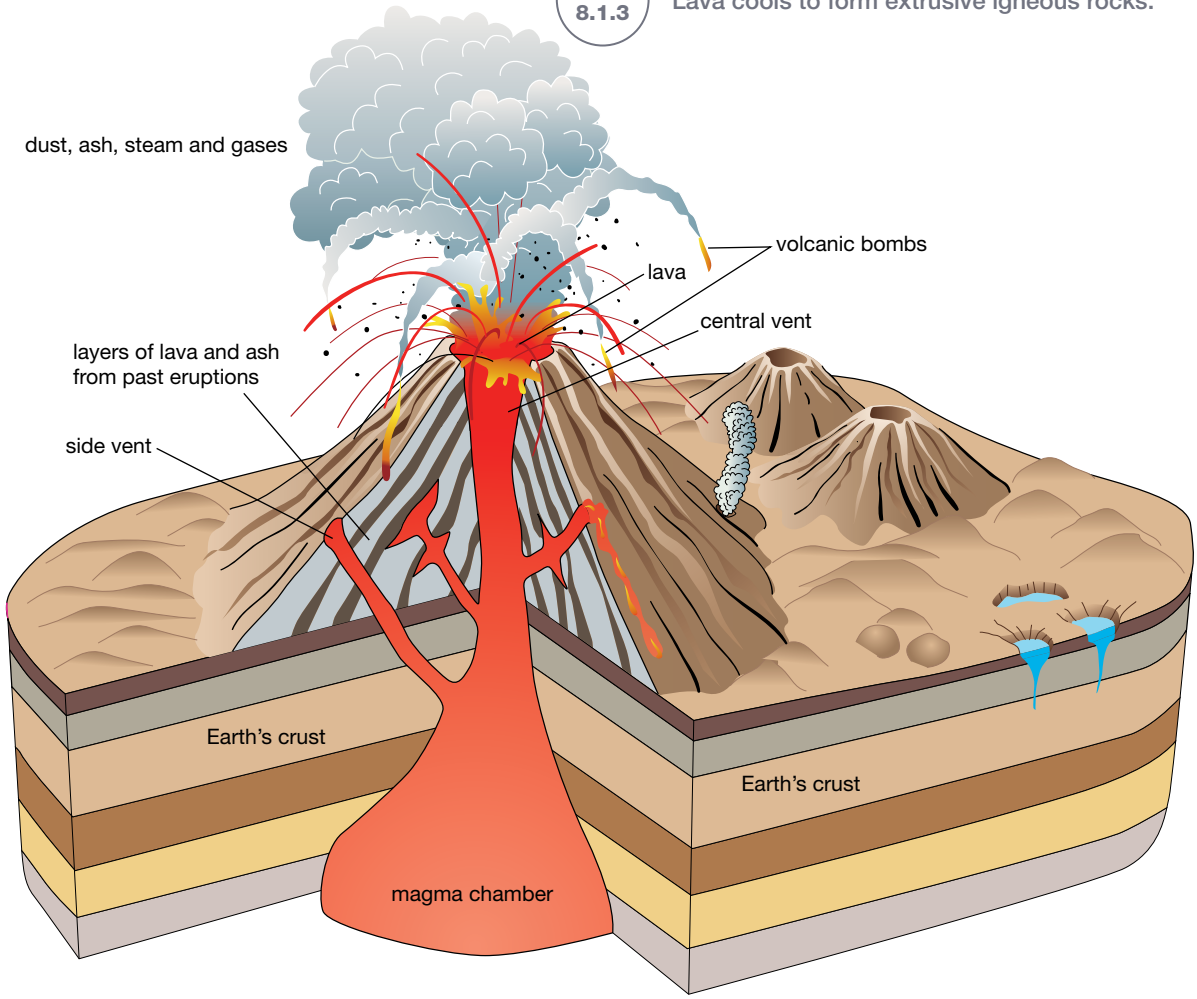


Figure 8.1.2 Structure of a volcano

Crystals

When magma is solidifying, particles in the liquid rock 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, 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 grow 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.

Prac 1 p304

Minerals

Rocks are made up of minerals. **Minerals** are chemical substances with 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.

GO TO Unit 8.5

A sea of lava

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.

SciFile

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
- methylated spirits
- 4 test-tubes in a test-tube rack
- 4 eye-droppers or Pasteur pipettes
- petri dish
- stereomicroscope or monocular microscope (40×)
- 4 glass slides
- access to marking pen

SAFETY

Treat all chemicals as if they are toxic.

Wear safety glasses at all times.

Methylated spirit is flammable, so keep it away from naked flames.

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, then 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.

Characteristics of igneous rocks

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.

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 interlocking crystals are in the igneous rock peridotite.

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 such as quartz and feldspars. These have lighter elements, such as silicon, oxygen and aluminium. Figure 8.1.6 shows examples of igneous rocks.

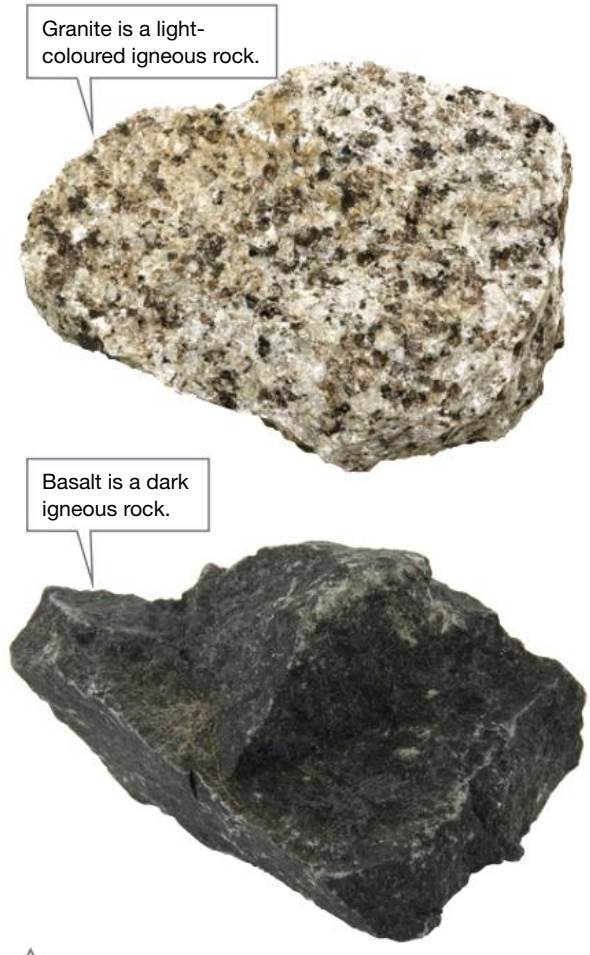


Figure 8.1.6 Colour is a characteristic that can be used to classify igneous rocks.

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 have lots of holes or spaces in them. These are caused by gas bubbles, trapped when the magma cooled very quickly. This gives the rock a rough bubbly texture. An example is pumice. 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 magma cooling slowly. 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 299. 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.

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.

Table 8.1.1 Uses of igneous rocks

Igneous rock	Use
Basalt	Buildings (e.g. 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 (Figure 3.1.11)
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 A pumice stone being used to remove dead skin from a foot

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

Prac 2 p305 Prac 3 p306 8.1

8.1 Unit review

Remembering

1 **List** the layers of the Earth in order from the outer one on which we live to its centre.

2 **Name** the layers that make up:
- a the lithosphere
- b the asthenosphere.

3 **Name** two igneous rocks that are:
- a extrusive
- b intrusive.

4 **List** the three minerals in granite.

5 **List** the three main characteristics of igneous rocks.

Understanding

6 **Define** the terms: L
- a geology
- b igneous rock.

7 **Explain** what is meant by the term *plastic rock*. L

8 **Explain** why some extrusive igneous rocks are found buried underground while some intrusive igneous rocks are found above ground.

9 **Explain** how and why crystal size is affected by how fast rocks cool.

10 Pumice can be formed by lava cooling in water. **Explain** why igneous rocks such as this do not have any visible crystals.

11 **Explain** why dark-coloured igneous rocks tend to be heavier than light-coloured ones.

Applying

12 **Use** information in Figure 8.1.1 on page 296 to **calculate** the approximate diameter of Earth. N

13 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).
- 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

14 **Compare** the thicknesses of the crust, mantle and core and arrange them in order from thickest to thinnest.

15 **Contrast**:
- a lava with magma
- b extrusive and intrusive igneous rocks.

16 **Contrast**:
- a the mineral composition of dark-coloured and light-coloured igneous rocks
- b the appearance of extrusive and intrusive igneous rocks.

17 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 CCT

18 **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.

19 With a depth of 3.9 km, the TauTona gold mine in South Africa is the deepest mine in the world.
- a **Use** Figure 8.1.1 on page 296 to **determine** whether this mine is completely in the crust or whether it enters the mantle.
- b Temperatures at the bottom of the TauTona mine can reach 55°C. **Propose** reasons why.
- c **Propose** what might need to be done for mining to occur at these depths.

20 Crystal formation can usually be started by dropping a crystal into a solution. However, a super-saturated solution is a solution that has so much solute dissolved in it that it takes very little for crystals to form. You can simply put some drops of the solution onto a glass microscope slide.

- **a** In the science4fun on page 298 it is suggested that you look at the edge of the solution for crystals, and not the centre. **Propose** reasons why.
- **b** **Propose** what might have started the crystals growing in this activity.

21 Dolerite is an intrusive igneous rock. 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.

22 Porphyry is an igneous rock that has a mixture of crystal sizes. It has large crystals set in a rock of fine grains that are often too small to see. You can see an example in Figure 8.1.12. Geologists have suggested that porphyry forms in two stages. Use your knowledge of crystallisation and cooling rates to **propose** how this type of rock most likely formed.

Figure 8.1.12 Porphyry

Creating CCT

23 **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 Research the following uses of igneous rocks and find how the properties of the rocks relate to their use:

- obsidian in scalpel blades
- quartz in piezo igniters
- pumice in health care
- scoria in filters
- granite in buildings.

Present your findings in digital form. ICT

ADDITIONAL

2 Investigate the nature of mineral crystals:

- find images of different shapes that crystals can take
- name the different crystal shapes
- explain why crystals have different shapes
- explain why crystals can grow to any size, whereas molecules have a fixed size.

Present your findings in digital form. ICT

ADDITIONAL

8.1 Practical investigations

1 Cooling and crystal size

Purpose

To investigate how cooling rate affects the size of crystals.

Hypothesis

Which conditions do you think will grow the largest crystals—quick cooling or slow cooling? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- a sample of about 25 g of potash alum
- ice

- rubber gloves
- oven mitt or towel
- 3 × 50 mL test-tubes and test-tube rack
- 4 × 250 mL beakers
- cotton wool
- hotplate or Bunsen burner, tripod, bench mat, gauze mat
- stirring rod
- filter funnel

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 bench top. 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 8.1.13.

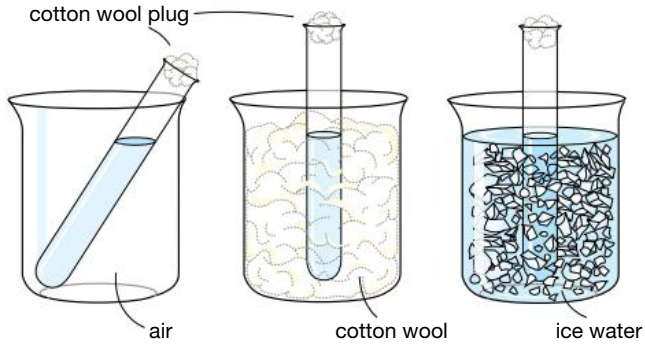


Figure 8.1.13

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 science class. Record your observations.

Practical review

1. **State** which test-tube had the smallest crystals and which test-tube cooled the fastest.
2. **Name** the independent, dependent and controlled variables in this experiment.
3. **Assess** whether your hypothesis was supported or not
4. **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
- smashed up granite rock grains

- access to stereomicroscope, hand lens or magnifying glass
- margarine lid or white tile
- blunt probe or mounted needle
- graph paper

Procedure

1 Copy the table below into your workbook. Draw as many rows in as you have rock samples.

2 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.

3 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 8.1.14. 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.

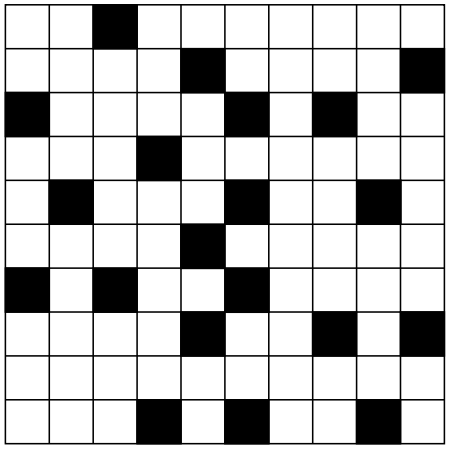


Figure 8.1.14

4 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

Record all your observations in your Results table.

Practical review

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					

3 Classifying igneous rocks

Purpose

To classify igneous rocks.

Materials

- selection of igneous rocks or objects made of igneous rocks
- hand lens or stereomicroscope

SAFETY

A risk assessment is required for this investigation.

Procedure

1. In your workbook, construct a results table like that shown in the Results section.
2. Move around the class from one sample of igneous rock to another. Observe each sample carefully. Use the hand lens or stereomicroscope to get a better view of the structure of each sample. Record your detailed observations as you go.

Results

For each sample of igneous rock, record in your Results table:

- its name (if known)
- its colour
- whether it is dark or light
- its texture (e.g. rough, smooth, glassy)
- whether it has visible crystals or not
- whether any crystals are small or large
- whether there are visible holes in its surface
- what you see when you observe the rock with a hand lens or stereomicroscope.

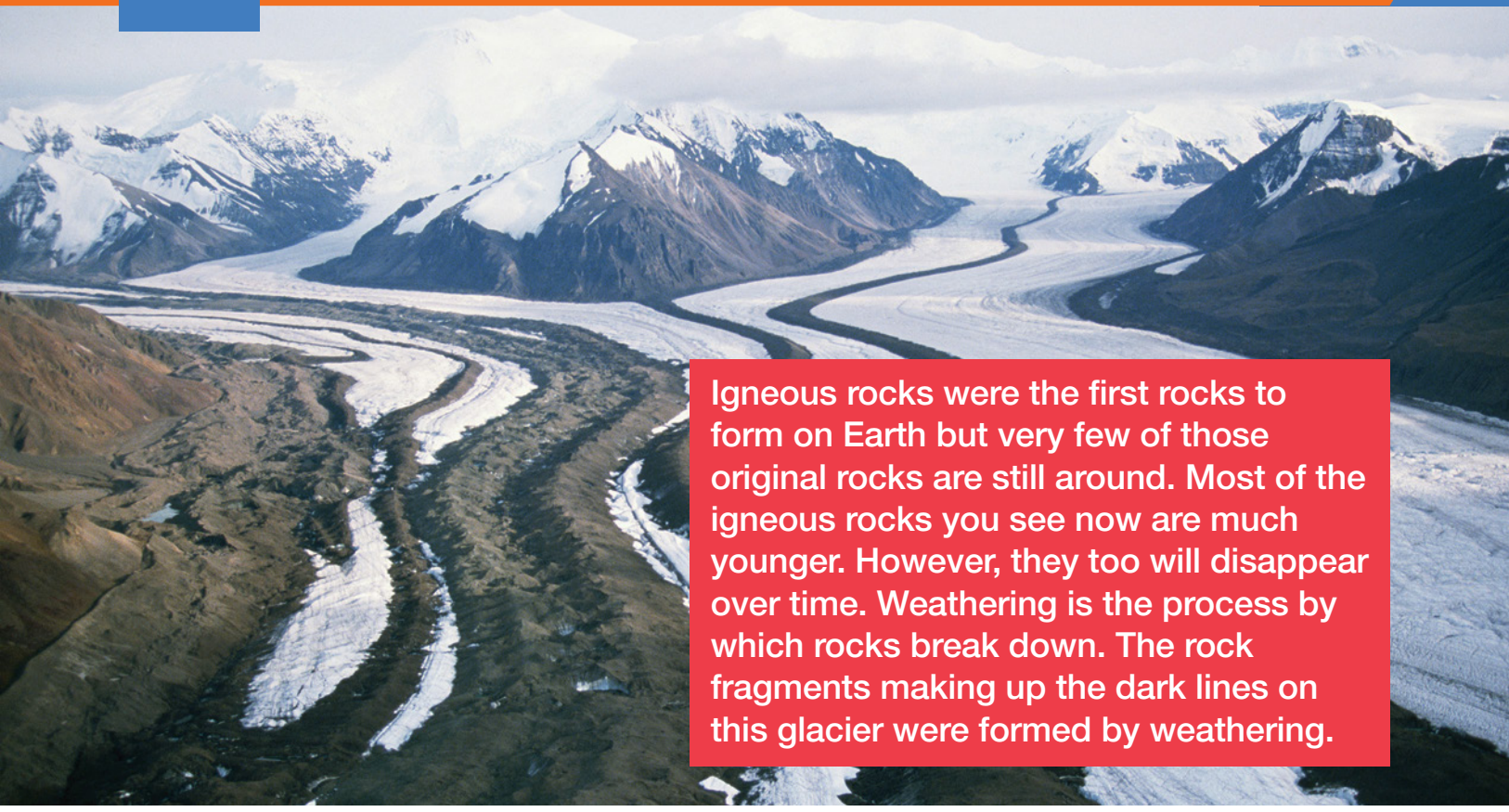
Name of rock	Colour	Dark/ light	Texture	Visible crystals	Crystal size	Holes

Practical review

1. **Classify** each of your rock samples as extrusive or intrusive igneous rock.
2. **Justify** each of your classifications.

Figure 8.1.16 Melbourne was built largely on basalt and so this stone is used in many of its buildings and laneways. Basalt like this is commonly called bluestone.

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 the dark lines on this glacier 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. In geology, **weathering** means the physical and chemical processes that break rocks down. Rocks do not last forever because weathering breaks them down into smaller pieces.

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 change

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. 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.

Figure 8.2.1 This large granite rock has been split by temperature changes. The grey section shows where a piece has broken away.

The action of water and ice

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 307. 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 the Himalayas, the Andes and in New Zealand. They also occurred in Australia in the past, when the climate was much, much colder.

INQUIRY

science 4 fun

Stretching water

YES

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.

Water running or washing over rock can also gradually wear away 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 (Figure 8.2.3).

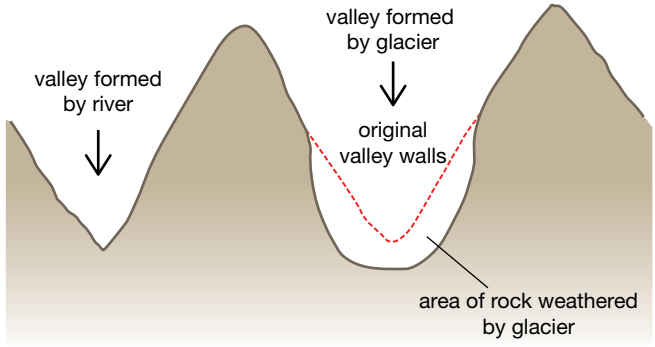


Figure 8.2.2 The characteristic U-shaped valley is caused by rocks being scraped away by a glacier.

Figure 8.2.3 This rock near Bondi in Sydney has been shaped by physical weathering caused by the action of the water making up the waves that crash upon the shore.

Crystallisation of 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.

Wind

Fine particles of rock carried by wind can cause physical weathering. These fine rock particles blast the rock surface, wearing pieces away.

Living 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.

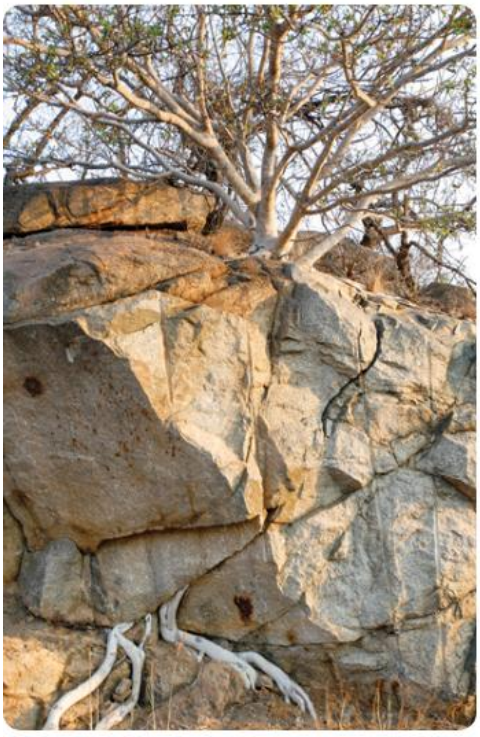


Figure 8.2.4

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 react with the rock and 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 can attack rock. These acids naturally form in the air during lightning. Pollution also forms acids in the air. This is known as **acid rain**.

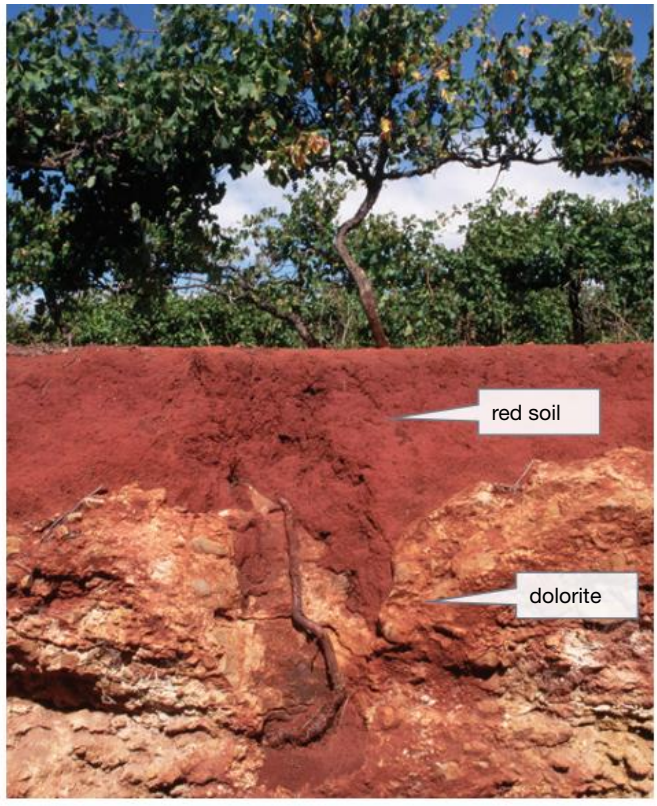


Figure 8.2.5

Red soil and dolerite rock are clearly visible in this pit. The red soil at the top is formed from chemical weathering of the dolerite beneath it.

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.

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SciFile

Red ochre

Australian Aborigines discovered that some rocks break down into coloured clays called ochres. Red and yellow ochres come from weathering of iron-rich rocks. If the clay formed is well-drained and relatively dry, then the colour of the ochre will be red. If the clay is wet, then the ochre will be yellow. Ochres can be mixed with other materials to change their colours. They are then used to paint bodies and caves and to make bark paintings.

GO TO Unit 7.3

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**. 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.

Deposition

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 **deposition** or sedimentation.

Deposition occurs where the moving water, wind or ice that is carrying the particles slows down. In rivers, this slowing down occurs at bends, and where rivers leave the mountains and enter plains. In these places, the rivers slow down dramatically and larger rock particles are deposited.

On flatter land, the path of the river begins to meander (bend and curve). You can see a river meandering in Figure 8.2.6. This pattern occurs because any slight curve in a rivers flow means the river will erode the outside of the curve more than the inside. The slower flow on the inside means that more sediment is deposited there. Over time this causes the river to bend even more.

Figure 8.2.6 Rivers slow down as they travel across plains and begin to meander.

A river slows and stops once it has entered a lake or sea. The smaller particles can no longer be carried and so they settle at the bottom. This is why lakes gradually fill up with sediment (Figure 8.2.7), and why new land often builds up at the mouth of a river.

This sometimes causes a delta to form. For example, large deltas have formed at the mouth of the Mississippi (USA) and the Nile (Egypt), shown in Figure 8.2.8. Rivers can also break their banks in a flood and deposit sediment on any plains that surround them.

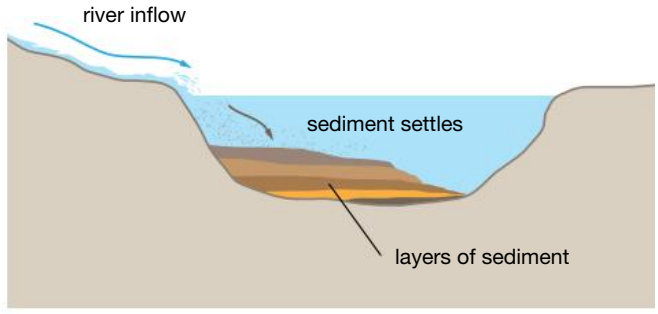


Figure 8.2.7 Deposition occurs where rivers slow down.

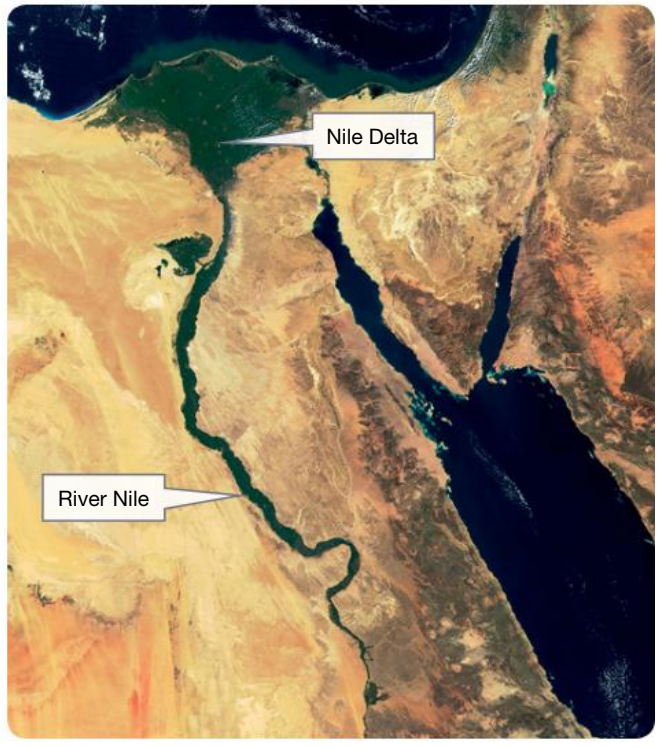


Figure 8.2.8 As the River Nile enters the Mediterranean Sea, it slows and deposits the soil it has been carrying. Over thousands of years, this has created the fertile farming area known as the Nile Delta.

GO TO Pearson science NSW 7 Unit 3.1

Prac 2 p313 Prac 3 p313 8.3

8.2 Unit review

Remembering

1 **List** the main causes of:
   a physical weathering
   b chemical weathering.

2 **List** the agents of erosion.

Understanding

3 **Define** the following terms. L
   a weathering
   b deposition

4 Igneous rocks exposed at the Earth's surface are not identical to how they were just after they were formed. **Explain** why.

5 If you put a glass bottle full of drink in the freezer, then you will probably find that the bottle has broken after a few days.
   a **Explain** why.
   b **Explain** how this relates to weathering.

6 **Explain** why sand suspended in water will eventually settle on the bottom of its container.

7 **Explain** why sediments carried by a river will be deposited when the river flows into a lake or sea.

8 **Explain** why:
   a soil is most likely to deposit on the inside of the curve of a meandering river
   b erosion is most likely to happen on the outside of the curve.

Applying

9 Figure 8.2.9 shows a satellite image of the coast of New South Wales on a very windy day. Note that there were no significant bushfires that day.
   a **Identify** the process occurring in this image.
   b **Explain** what is happening.

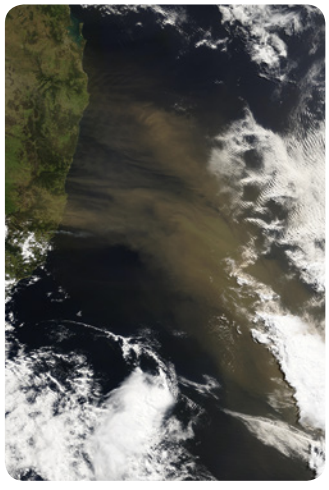


Figure 8.2.9

Analysing

10 **Contrast** erosion and weathering.

11 Old brick walls are often stripped back and cleaned by sandblasting them. This involves blasting the bricks with a jet of sand that rips paint, grime and the top layer of brick off the wall.
   a **Identify** what actually caused the 'weathering' of the wall.
   b **Classify** the process as an example of physical or chemical weathering.

Evaluating CCT

12 It is an advantage for builders, architects and engineers to know something about rocks. **Propose** reasons why.

13 **Propose** ways in which you could minimise soil erosion when camping, bushwalking or boating.

14 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.

15 a **State** what caused the grey colouring in the rock in Figure 8.2.1 on page 307.
   b **Propose** what caused the red colouring.

Creating CCT

16 a **Construct** a diagram showing a river flowing from mountains across a plain, where it meanders before reaching a delta at the sea.
   b **Label** the places where major weathering, erosion and deposition would occur along the way.

Inquiring

Research the formation of landforms, giving examples of places in Australia (preferably from New South Wales) that show the influences of the following processes:

- physical and chemical weathering
- erosion
- deposition.

Present your findings as a digital presentation. ICT

8.2 Practical investigations

1 Simulating weathering

Purpose

To investigate how ice and chemicals can cause weathering.

Materials

SAFETY
Do not mix plaster with bare hands. Mix with a spoon or spatula or use rubber gloves.

Part A: The effect of acid and water

- vinegar
- 2 small samples each of granite, limestone and sandstone (to fit test-tubes)
- 6 test-tubes and a test-tube rack

Part B: The effect of temperature

- plaster of Paris
- 2 margarine containers or milk cartons
- small water balloon
- spoon or spatula
- rubber gloves

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 8.2.10.

2 Add water to test-tubes 1, 3 and 5.

3 Add 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.

Practical review

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 containers left in the freezer.

b **Explain** what happened.

3 **Justify** the choice of this procedure in investigating the weathering of rocks.

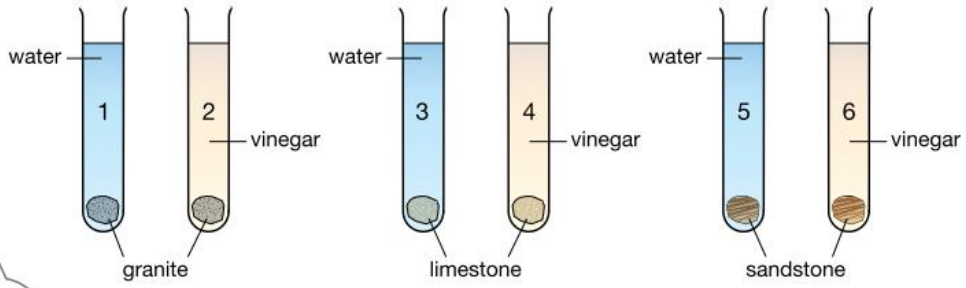


Figure 8.2.10

2 Deposition of sediments

Purpose

To investigate how sediments settle in water.

Materials

- about 200 mL of a mixture of different-sized soil particles, such as gravel, sand and clay
- water

- 2L plastic soft-drink bottle with the top 5 cm cut off
- 2 × 200 mL beakers
- digital camera or mobile phone with camera function (optional)

SAFETY

Perform this investigation outside or in a tray that can catch water and soil as it overflows.

Procedure

1. Pour water into the bottle to a level about 5 cm from the cut-off top.
2. Quickly pour about 200 mL of your mixed soil into the water in the container and let it settle to the bottom of the container. Do not move the container around while the soil is settling.
3. Carefully observe what happens. Leave the bottle in a place where it will be undisturbed until the next science class.

Results

1. Use a labelled diagram to describe the location and layering of sediments.
2. You might also record the appearance of the sediments using a digital camera or camera function of a mobile phone.

Practical review

1. **Explain** the location and layering of the sediments in your bottle.
2. **Use** your results to explain:
   a. why a river meanders
   b. where you can expect different-sized particles to be deposited along the course of a river.

STUDENT DESIGN

3 Erosion and deposition

Purpose

To model erosion and deposition.

Materials

To be selected by students (could include sand, roof guttering/plastic pipe, bucket, hose)

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design a model that will:
   - contrast erosion caused by a river with the landform created by a glacier
   - test how slope affects erosion
   - show how a river will deposit particles it carries as it slows down.
2. Before you start any practical work, assess your model and procedure. List any risks that it might involve and what you might do to minimise those risks. Show your teacher your planned model and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hints

You could use wet sand for mountains and a small plant pot to represent glaciers carving out a valley.

A piece of roof gutter could be used to model a river that is depositing sediment.

Results

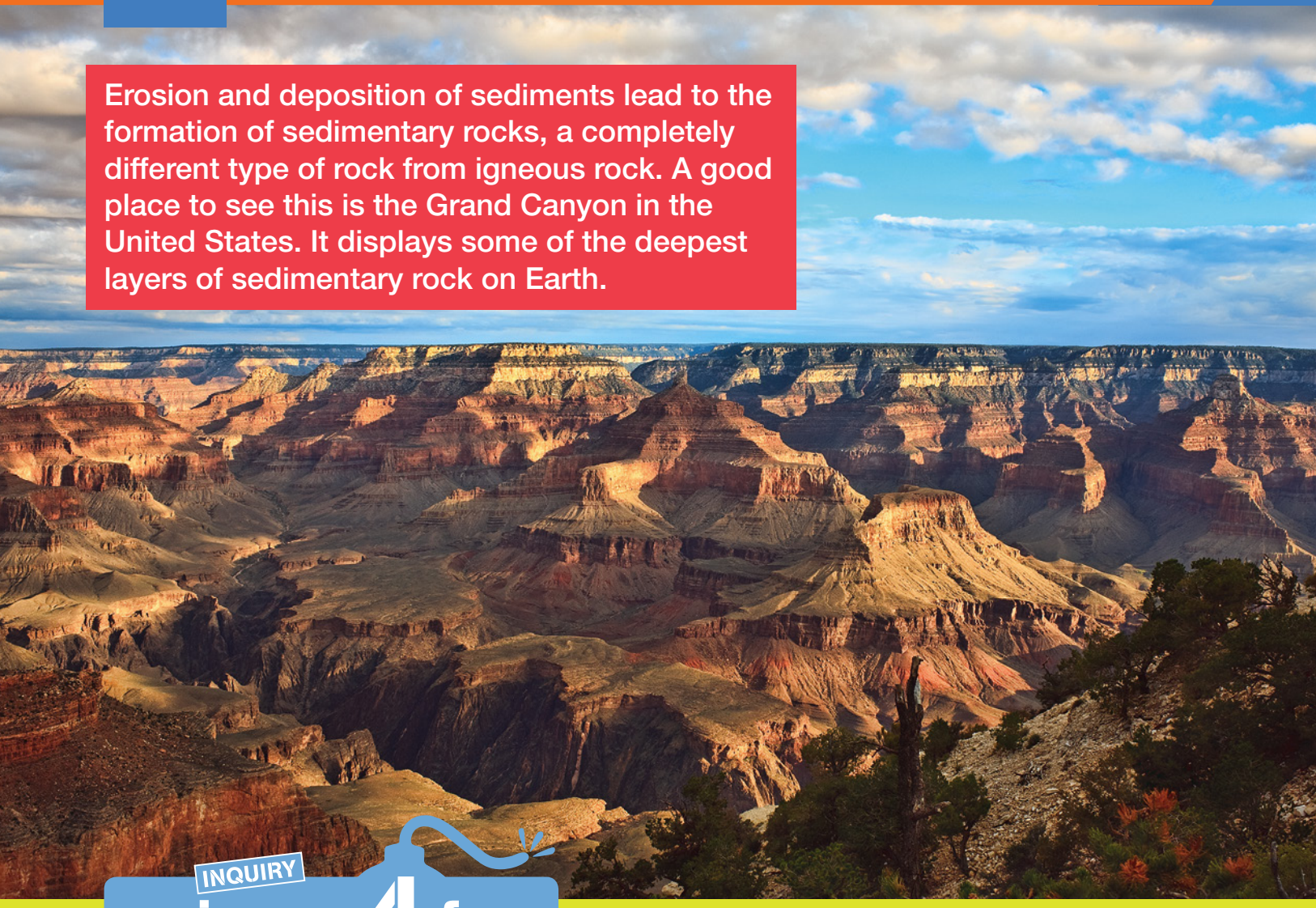
Record all your observations, possibly using a video camera or video function on your mobile phone or tablet.

Practical review

Justify how your model shows what you set out to investigate.

8.3 Sedimentary rocks

Erosion and deposition of sediments lead to the formation of sedimentary rocks, a completely different type of rock from igneous rock. A good place to see this is the Grand Canyon in the United States. It displays some of the deepest layers of sedimentary rock 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 bare hands. Mix with a spoon or spatula or use rubber gloves.

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, based on where the sediments come from:

- 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).

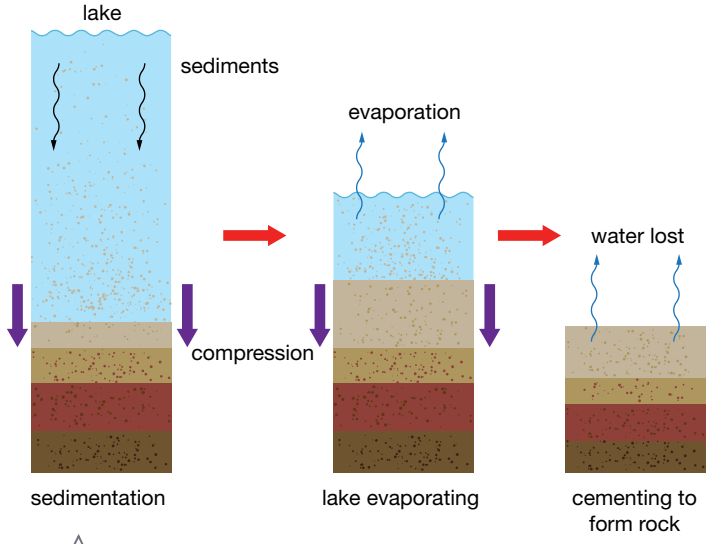


Figure 8.3.2 Formation of clastic sedimentary rock involves sediments, cement and pressure.

Chemical sediments

Chemical sedimentary rocks form when dissolved minerals turn into solid crystals and sink to the bottom of a lake, river or sea. As the water evaporates, these crystals grow. This process is known as crystallisation and is shown in Figure 8.3.3. Some crystals that have formed in a cave are shown in Figure 8.3.5 on page 316.

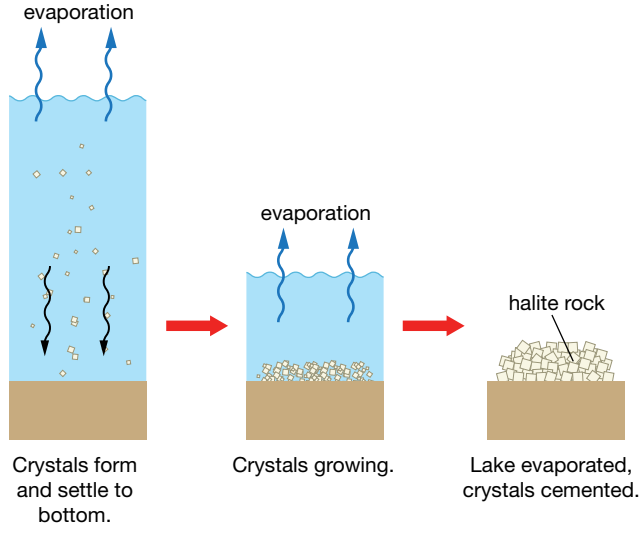


Figure 8.3.3 Chemical sedimentary rocks form by evaporation and crystallisation.

Sydney sandstone

SciFile

Many of Sydney's early buildings such as the art gallery and museum were built from sandstone, a type of sedimentary rock that surrounds the city. The sand that settled to form the sandstone over 20 million years ago came from weathering of rocks in Antarctica. The sand was deposited in Australia when the two continents were connected as part of the ancient continent Gondwana.

Figure 8.3.4 The old Colonial Secretary's Building in Sydney was built from sandstone in 1880.

Figure 8.3.5 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.

Organic sediments

Organic sedimentary rocks form when dead plant matter or animal debris accumulates (builds up) and is then cemented together. The sediments are mostly from organisms, but there may be small amounts of sediment from weathered rock. The formation of organic sedimentary rock is shown in Figure 8.3.6.

Prac 1 p321

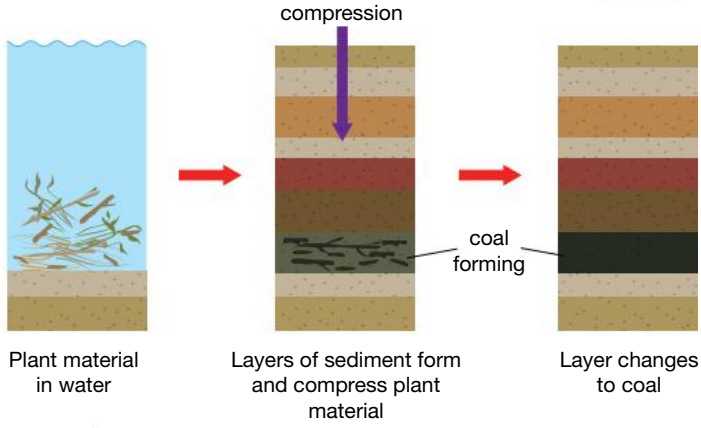


Figure 8.3.6 Coal is an organic sedimentary rock.

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.

Characteristics of sedimentary rocks

There are three types of sedimentary rocks:

- clastic
- chemical
- organic.

All have different characteristics because they contain different sediments and 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, become covered by them, and are preserved in the rock. This is most likely to happen in water.

These characteristics are summarised in Figure 8.3.7.

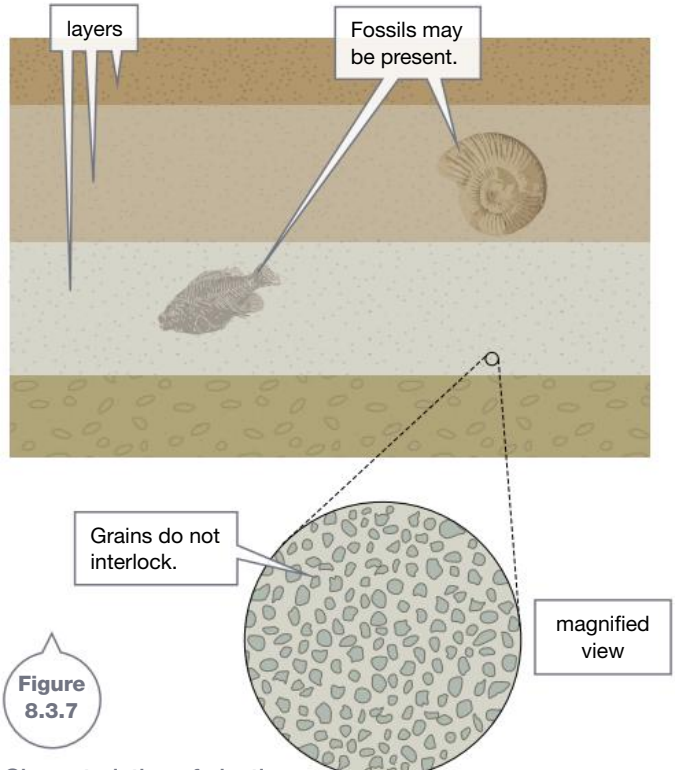


Figure 8.3.7

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 Figure 8.3.8.

Figure 8.3.8

Four different clastic sedimentary rocks

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. Figure 8.3.9 shows some types of these rocks.

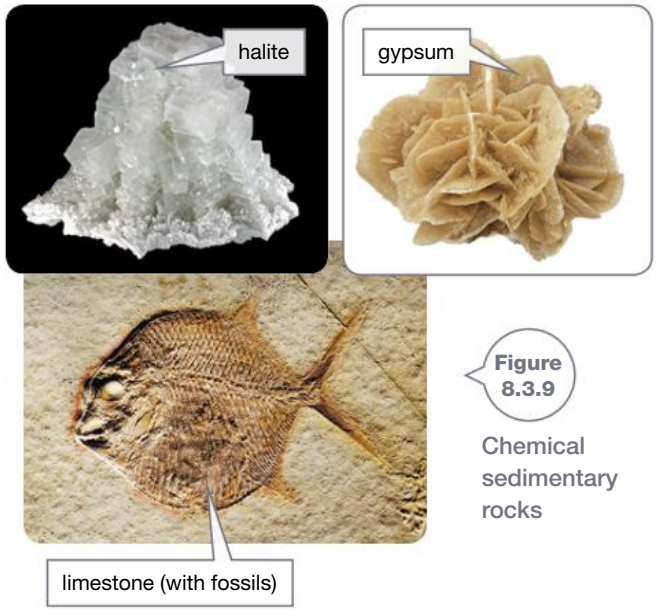


Figure 8.3.9

Chemical sedimentary rocks

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 8.3.10.

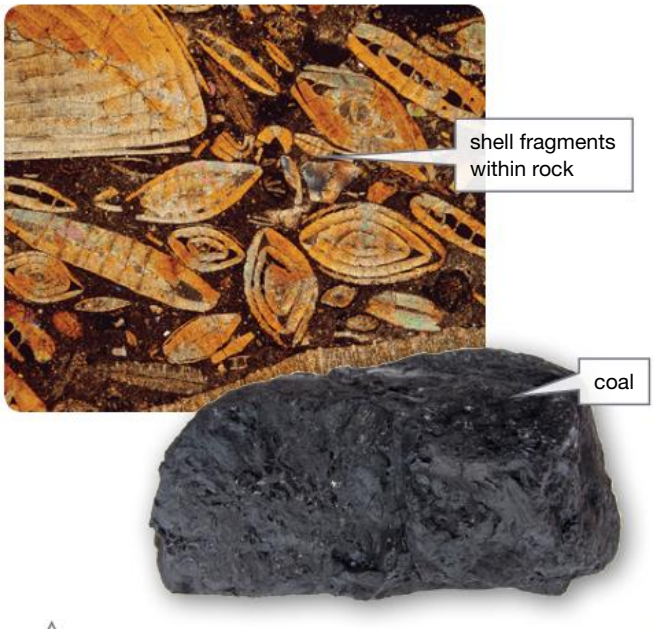


Figure 8.3.10 Organic sedimentary rocks

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Formation of fossils

Fossils are the preserved evidence of organisms that once existed on Earth. A fossil may be the whole body of the organism, part of it, or traces of its activities such as its burrows, tracks or dung. Some are shown in Figure 8.3.11.

To be preserved as a fossil, the dead organism must not be eaten by scavengers and it must then decay slowly. These two conditions are more likely to occur when the dead organism is covered in sediment which then turns into rock.

Soft parts of organisms decay much faster than hard parts. For this reason, it is extremely rare for soft parts to be preserved. Hard parts such as skeletons, shells, teeth or wood are most commonly found as fossils. Therefore, organisms that are only composed of soft parts (such as jellyfish, slugs, algae and mosses) are rarely found as fossils. In contrast, fossils of organisms with hard parts (such as dinosaurs, giant kangaroos, crabs, shellfish and trees) are more common.

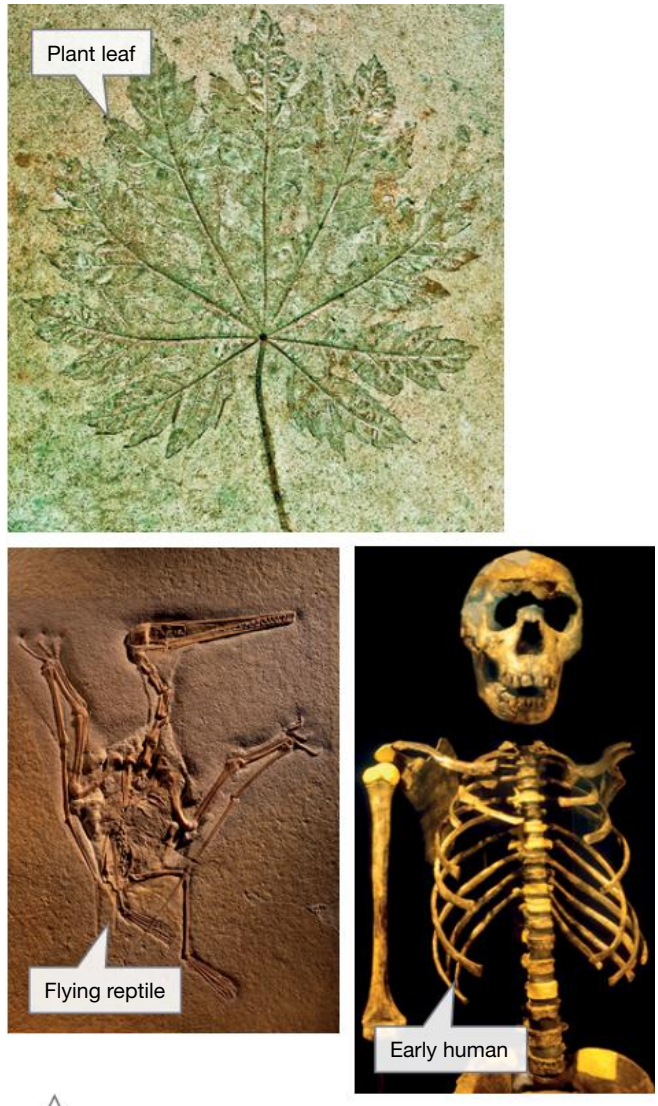


Figure 8.3.11 Different types of fossils

Being quickly covered by sediment will stop a dead organism from being eaten and will slow or even stop its decay. These conditions usually occur at the bottom of an ocean, lake or river. Sediments in the water sink to the bottom and cover any dead organisms lying there. The sediment slowly builds up, and natural cements and the drying of the sediment eventually turn it into rock. A similar process can also happen on land if wind-blown sediment covers the body.

Earth movements and weathering can then expose the rock layers containing the fossil or bring the layers to the surface. Fossils are found in sedimentary rock and not in igneous rocks. The heat needed to form igneous rocks also destroys any traces of organisms in them. In contrast, sedimentary rock simply traps the remains for future discovery (Figure 8.3.12).

Figure 8.3.12 Weathering progressively exposes deeper and deeper layers of sedimentary rock, sometimes exposing a fossil trapped there long ago.

Sedimentary rocks and geological history

Sedimentary rock forms in layers called **strata**. A single layer is called a *stratum*. Sediment always settles to the bottom, and so the first and oldest stratum is found there. Newer sediment then settles on top. This gives us a way of determining which layers are older and which organisms lived earlier than others in that particular site. The rock strata and fossils from the bottom layers of rock are usually oldest. The youngest are those near the surface.

However, in some places the lowest stratum may not be oldest. This is because the layers of rock have been folded over each other or even turned upside down by movements in the crust.

8.4

Figure 8.3.13 Rock strata are clearly visible as horizontal layers of sandstone in the Blue Mountains, NSW. The top layers were formed almost 300 million years after those layers at the valley floor.

ADDITIONAL

Relative age of rock strata

The relative age of a rock layer refers to whether it is older or younger than another layer. Relative age is not the actual age of a rock, but only indicates that it is older or younger than another rock.

Relative ages in same location

If two rock layers are in one particular location, then their relative ages can be determined from their position in the rock strata—layers lower down should be older.

Relative ages in different locations

The relative ages of rocks from different locations can be compared using index fossils (Figure 8.3.14). An index fossil must:

- be found over a widespread area (for example, on different continents)
- have lived in a narrow period of time in the past
- have been abundant (having a very large population).

If a particular index fossil is found in rock layers in two different locations, then you can be sure that the rocks in the layers are the same age.

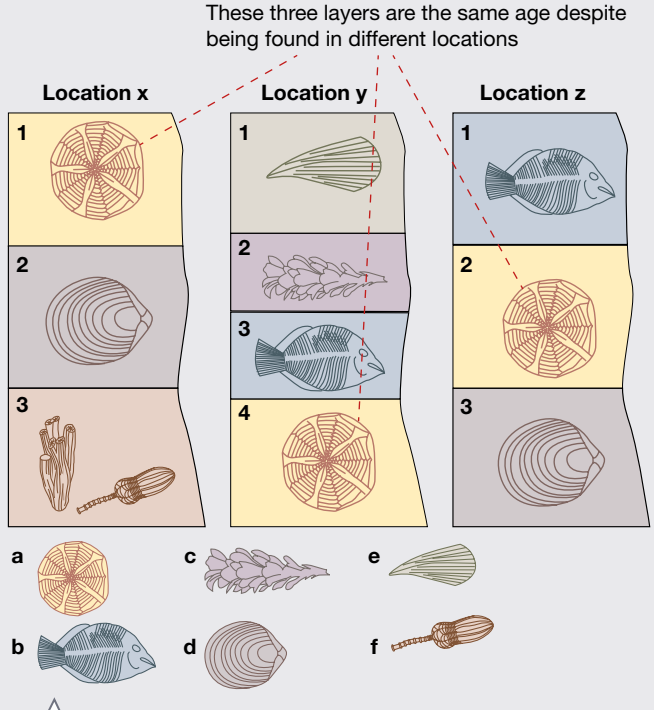


Figure 8.3.14 The presence of index fossils (a to f) in rock layers at different sites allows scientists to determine the relative age of the rock.

ADDITIONAL

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** the body parts that are most likely to be fossilised.

5 **State** which layer in a sedimentary rock is most likely to be:
   a oldest
   b youngest.

Understanding

6 **Define** the terms: L
   a fossil
   b strata.

7 **Explain** how pressure from overlying sediments contributes to the formation of clastic sedimentary rocks.

8 **Explain** the reasons for the general characteristics of clastic sedimentary rocks.

9 **Account** for the presence of chemical sedimentary rocks in salt lakes.

10 **Outline** the conditions needed for fossilisation.

11 **Explain** why there are far more fossil remains of dinosaurs than there are of jellyfish.

Applying

12 The layers in a sedimentary rock do not necessarily indicate which layer is oldest and which is youngest. **Demonstrate** how rock layers might change order.

Analysing

13 a **Explain** the role of the plaster of Paris in the formation of the 'rock' made in the science4fun on page 314.
   b **Classify** the 'rock' formed as a clastic, chemical or organic sedimentary rock.

14 **Contrast** a breccia and a conglomerate.

15 Igneous rocks and chemical sedimentary rocks often have crystals in them. **Distinguish** between them.

16 **Classify** each of the following sedimentary rocks as clastic, chemical or organic.
   a mudstone
   b coal
   c chalk
   d gypsum
   e sandstone

17 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 that are now long extinct but 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 CCT

18 **Propose** reasons why:
   a animals that die in a desert are unlikely to be fossilised
   b plants living in swamps have a good chance of being fossilised
   c single-celled organisms are unlikely to be fossilised.

Creating CCT

19 **Construct** a table summarising the formation and characteristics of the three different types of sedimentary rocks.

Inquiring

Research the formation of the Blue Mountains. In particular:

- state the types of rock found
- draw a sequence of diagrams showing the basic stages in the formation of the mountains
- explain the importance of weathering agents in the formation of the mountains.

Present your findings as text and diagrams to be used at a lookout in the Blue Mountains.

8.3 Practical investigations

1 Making sedimentary rocks

Purpose

To investigate what factors affect the strength of an artificial sedimentary rock.

Hypothesis

Which do you think will make an artificial rock stronger:

- using rock such as blue metal or gravel, or just sand?
- using Portland cement or plaster of Paris?

Before you go any further with this investigation, write two hypotheses (one for each question) in your workbook.

Materials

- plaster of Paris
- Portland cement
- gravel (about 5 mm diameter) and bricklayers' sand mix
- blue metal (similar size to gravel) and bricklayers' sand mix
- bricklayers' sand

- ice-cream container
- 4 margarine containers
- spoon or spatula
- setting box (see Figure 8.3.15)
- water
- 250 mL plastic beaker with volume scale
- G-clamp
- 6 × 500 g mass sets
- wire 15 cm long by 1.5 mm 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.

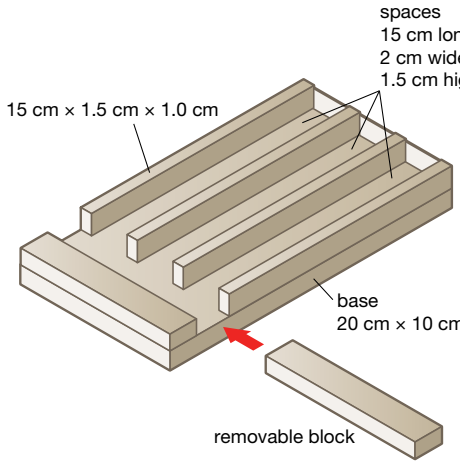


Figure 8.3.15

Procedure

1. Copy the team results table from the Results section on page 322 into your workbook.
2. Each prac team will be given one cement type (either Portland cement or plaster of Paris). Collect about 150 mL of your cement. Collect about 100 mL of each of gravel/sand and blue metal/sand mixes and sand only. Place each sample in a different margarine container.
3. To 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.
4. 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.
5. When your sedimentary 'rocks' are dry, remove them from the setting box.
6. 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 mass holder. Place the towels underneath to catch any masses that fall.
7. Add masses 100 g at a time until the 'rock' breaks. Make sure the rocks don't fall onto your feet. Enter your results in your Team results table.

Making sedimentary rocks continued on next page

Making sedimentary rocks continued

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			

Practical review

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 was weakest.

b **Justify** your decision.

3 **Assess** whether your hypothesis was supported or not.

4 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, to fix decorative edges on ceilings, and to 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

- numbered set of sedimentary rocks such as breccia, conglomerate, sandstone, limestone, coal, shale, mudstone, rock salt and gypsum
- stereo microscope and/or hand lens

Procedure

1 In your workbook, construct a table like the one shown in the Results section.

2 Choose a rock and write down its number. In your table, write a brief description of what it looks like. (This is called a macroscopic view.) Note features such as colour, texture, layering and fossils.

3 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.

4 Try to classify your rock into one of the three types of sedimentary rocks. Then give your rock a name.

5 Repeat with the next rock until you have examined them all.

Results

Record all your observations in a table like the one shown below.

Rock number	Macroscopic view	Microscopic view	Classification

Practical review

Justify your classification of each rock.

STUDENT DESIGN

3 Testing mortar mixes

Mortar is a mixture of Portland cement, bricklayer's sand and water. It dries quickly to form a solid that holds bricks or stones together in a building.

Purpose

To determine the strongest mortar mix.

Materials

As selected by students (probably similar to the materials used in Prac 1)

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that will test the strength of different mixes of Portland cement and bricklayers' sand.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Results

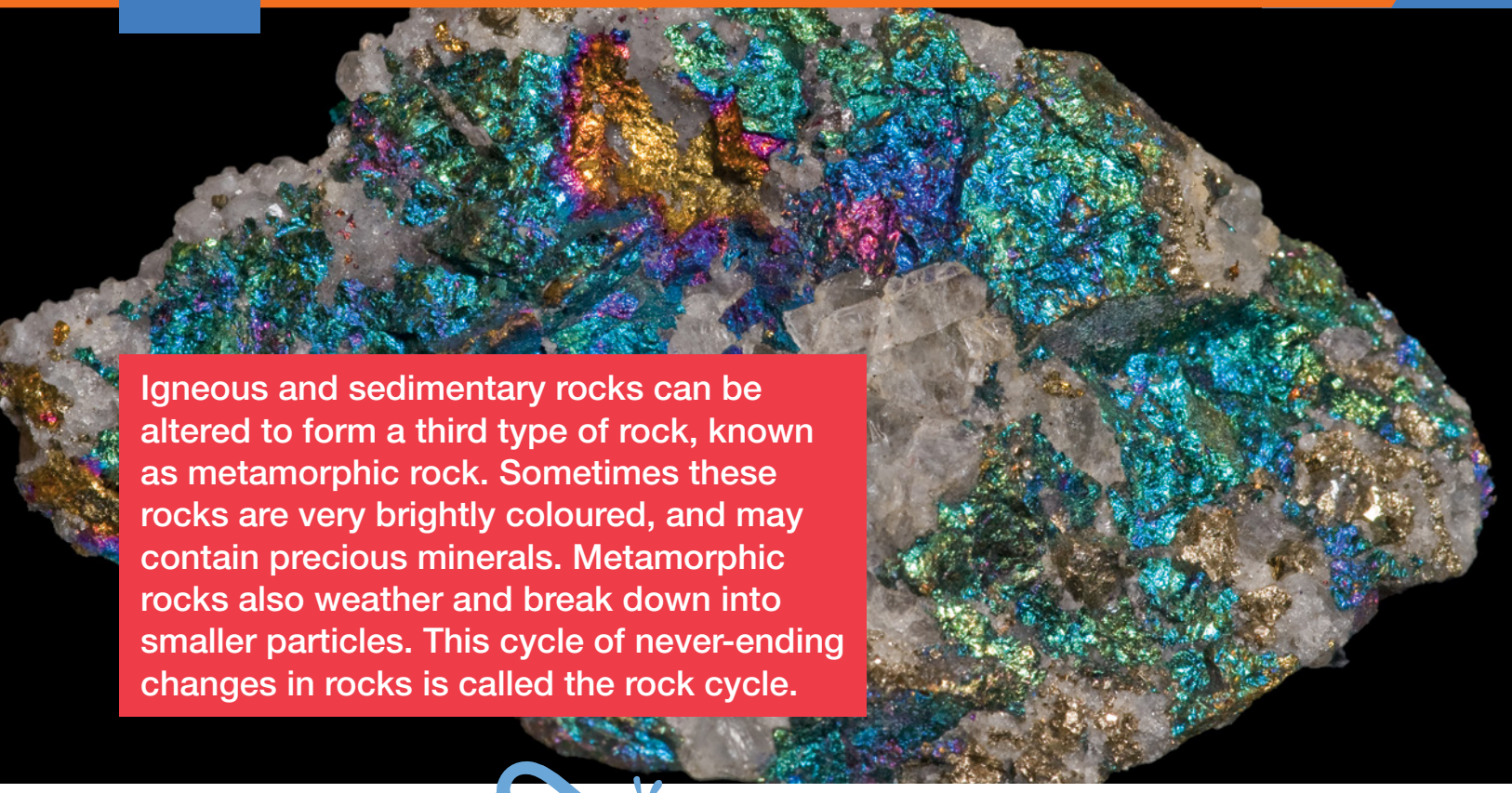
1. Construct a table showing your results.
2. Collect results from other groups and express the class results as an average.

Practical review

1. **Compare** the strongest mix obtained here with the recommended mix on the bag.
2. **Construct** a report on the experiment.
3. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.
4. **Propose** how the results of this investigation could be of use in the building trade.

Figure 8.3.16 Bricks are usually held together with mortar.

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

NO

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.

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.

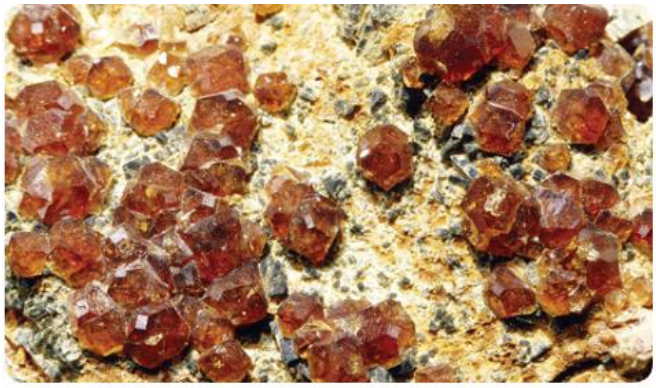


Figure 8.4.1 Garnets are semiprecious stones that can form in metamorphic rocks.

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 where 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 contain many more different minerals than igneous rocks.

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.

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.

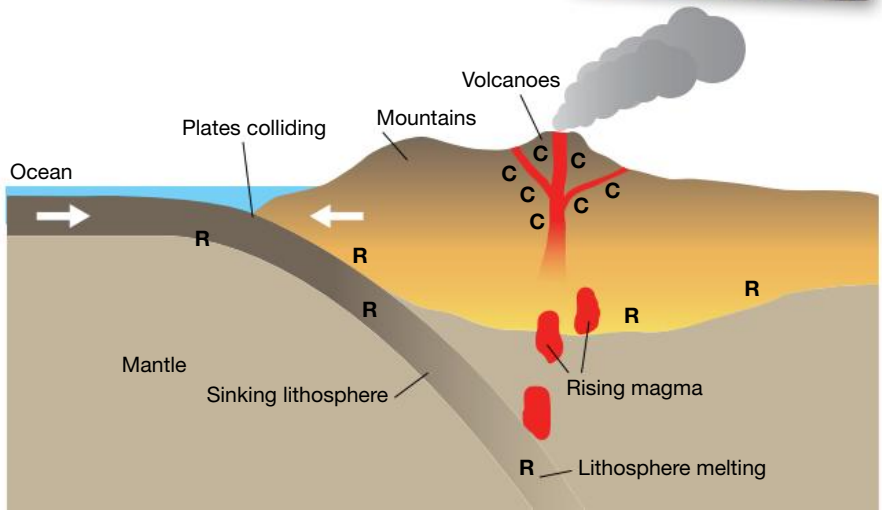


Figure 8.4.2 Metamorphic rocks form in two main ways.

R Regional metamorphism
C Contact metamorphism

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.

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.

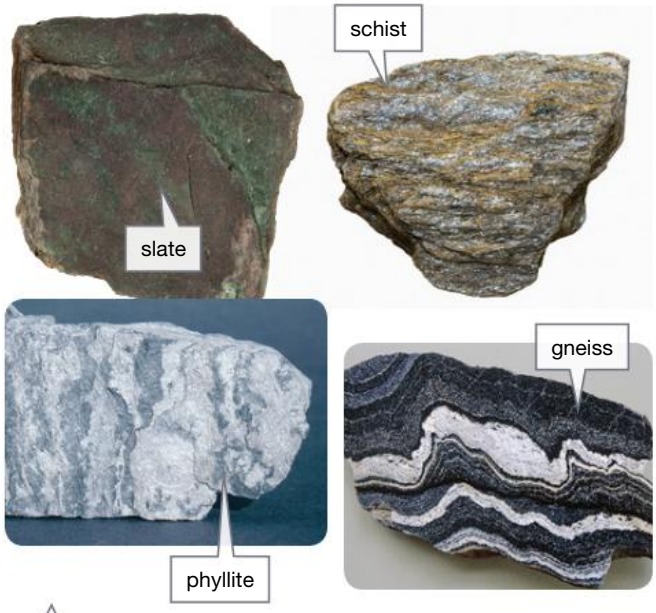


Figure 8.4.4 Some metamorphic rocks

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 8.4.5.

Figure 8.4.5 Unbanded (non-foliated) metamorphic rocks

Prac 1 p328

SciFile

Big diamond

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 8.4.6) and the Cullinan II.

Figure 8.4.6 The Great Star of Africa (or Cullinan I) is part of the British Crown Jewels

8.5

The rock cycle

The **rock cycle** is a model geologists use to explain the endless cycle of change that rocks undergo. Figure 8.4.7 shows how it works. Rocks do not always stay the same after they are formed. Weathering continually breaks them 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.

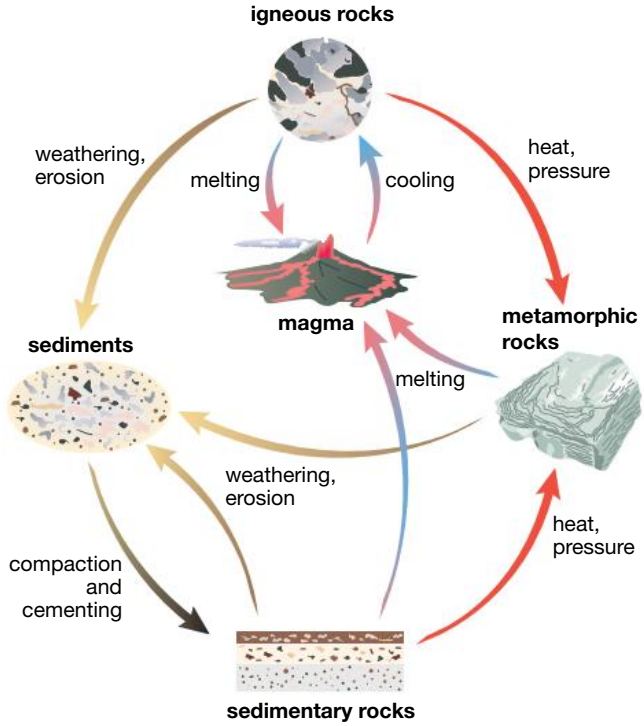


Figure 8.4.7 All the rocks of the Earth are part of the rock cycle.

Prac 2 p328 8.6 8.7

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.

9
- a **Predict** which clay figure will be strongest—one that is fired in a kiln or one that is left unfired.
- b **Explain** how this relates to the formation of metamorphic rock.

Applying

10 **Identify** the feature of a sedimentary rock that 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 CCT

12 It would be possible for metamorphic rocks to form at the Earth's surface. **Propose** how this might happen.

13 From the information in Question 11, **justify** your decisions by explaining how the rock probably formed.

14 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 CCT

15 **Construct** 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 Research an Australian landform such as Uluru, the Olgas, the Warrumbungles, the Bungle Bungles, or a different landform of your choice. In your answer:

- discuss the geological history (including age) of the landform
- include diagrams or photos
- identify the types of rocks in the formation
- explain how the rock cycle is relevant to the geological history of the landform.

Present your research findings in digital form. ICT

2 Research how long it takes igneous, sedimentary and metamorphic rocks to form. In your answer:

- use a rock cycle diagram
- state the times taken to form different rock types
- relate the time taken to form the rock to the processes that formed it.

Present your findings as an annotated diagram.

8.4 Practical investigations

1 Metamorphic rocks

Purpose

To compare metamorphic rocks 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.

Practical review

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 classify unknown rock samples as igneous, sedimentary or metamorphic.

Materials

- numbered but unlabelled rock samples
- stereo microscope
- hand lens

Procedure

1. In your workbook, construct a table like the one shown in the Results section.
2. 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.
3. Repeat step 2 for each rock.

Results

Record all observations in your Results table.

Rock number	Description	Classification	Reasons	Rock name

Practical review

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.

8.5 Mineral resources

Rocks are made of minerals. Minerals such as this gold nugget are very important to Australia as they help to employ people and help drive Australia's economy.

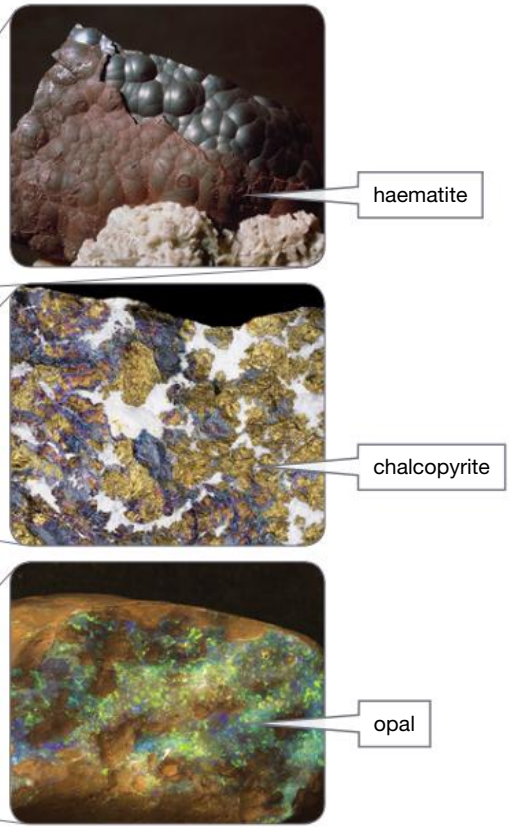
Minerals

Rocks are made up of chemical substances called minerals. A **mineral** is a naturally occurring solid or liquid in the Earth's crust, but not including coal or oil.

While some minerals are pure elements such as gold and silver, most minerals are compounds made up of different elements. Examples are shown in Table 8.5.1.

Table 8.5.1 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



Rocks containing naturally occurring minerals that are valuable are known as **ores**. For example, copper is found in copper ore. Three types of copper ores are shown in Figure 8.5.1.

Figure 8.5.1 'Native copper' is found as pure copper. More commonly, copper is found as an ore. Three copper ores are bornite, azurite and malachite.

Beauty in the rocks

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.

Scitile

Figure 8.5.2 This rhodochrosite (manganese carbonate) sample is called 'The Alma Queen'. It is one of the most famous mineral samples ever discovered.

Sometimes the whole mineral is extracted from the ore and used. At other times, the metallic element needs to be extracted from its compound within the ore. For example, the mineral titanium oxide can be:

- used as a whole mineral to colour paints white
- separated into titanium metal and oxygen. The titanium can then be used in making steel alloys.

Properties of minerals

The main physical properties used to identify minerals are:

- hardness
- colour
- lustre
- streak colour.

Hardness

Hardness is assessed by comparing minerals using Mohs scale. The scale is given in Table 8.5.2. A set of minerals is used to try to scratch the surface of an unknown mineral to determine its hardness.

Table 8.5.2 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 8.5.3. 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 8.5.3 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 8.5.2 and 8.5.3. 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

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.

Practice

N

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.

a **State** the approximate hardness of the unknown mineral.

b **Identify** what the mineral could be.

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 (searching) 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 8.5.3.

Figure 8.5.3 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.

Prac 1 p336 Prac 2 p337

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 (Figure 8.5.4).

Figure 8.5.4 Minerals glow in a flame, giving out a distinctive colour.

INQUIRY

science 4 fun

Flaming minerals

Do different 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.

From Earth to final product

Humans have been digging up minerals and using them for thousands of years. Minerals that are dug up and used are known as **mineral resources**. Some, such as gold, only need a little cleaning before they can be used. 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.

The process of obtaining minerals 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.
3. *Enrichment:* this concentrates the resource, increasing how much there is of it in a particular volume of the mined material. This process 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. For iron to be extracted, iron atoms and oxygen atoms need to be separated from one another.

ADDITIONAL

Resources and the economy

Minerals are not the only valuable resources we dig from Earth's crust. Other resources are coal (an organic sedimentary rock) and oil (from which petrol, lubricating oils, kerosene, aviation fuel, bitumen and natural gas are extracted).

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, 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.

ADDITIONAL

GO TO Pearson science NSW 7 Unit 3.1

LEARNING ACROSS THE CURRICULUM

WORK AND ENTERPRISE

MINERAL EXPLORATION

Mineral resources need to be found before they can be mined. Mineral exploration is complex and requires the skills and knowledge of people from a variety of science disciplines. Geologists, geophysicists and geochemists all have vital roles in the three common exploration methods—aerial, on-site and satellite surveys.

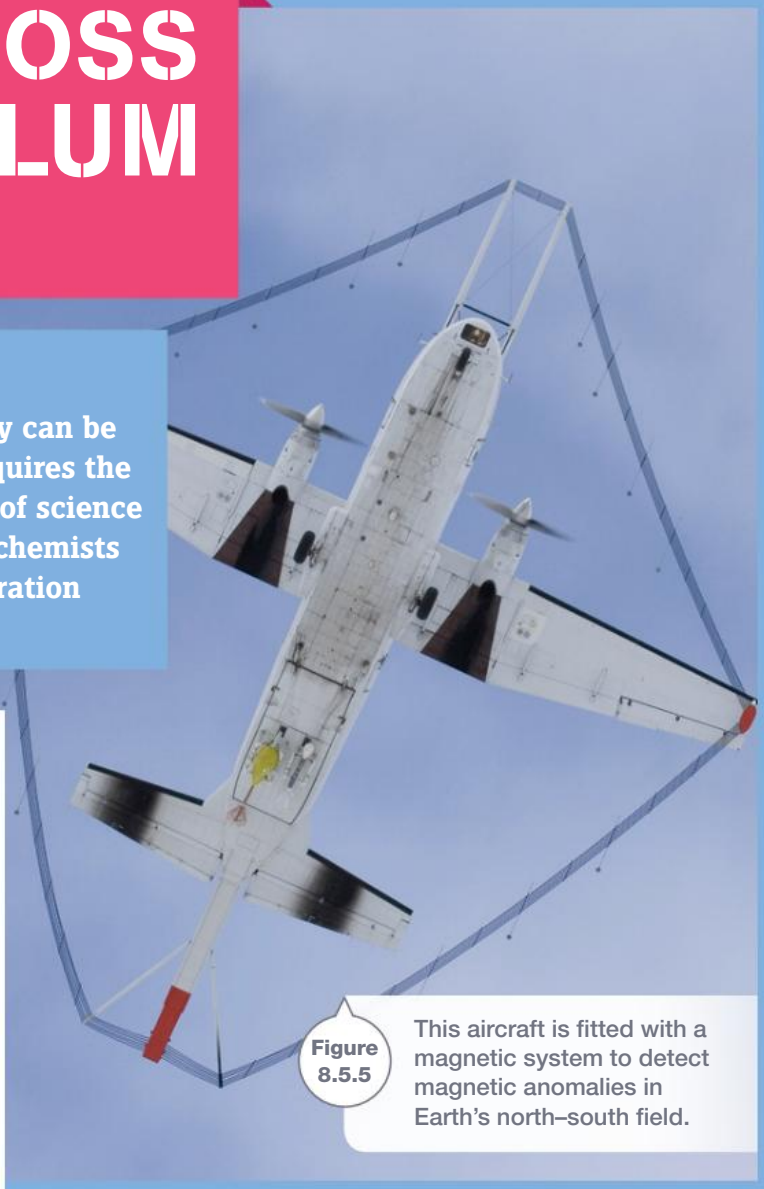


Figure 8.5.5 This aircraft is fitted with a magnetic system to detect magnetic anomalies in Earth's north–south field.

AERIAL METHODS OF EXPLORATION

A quick way of exploring vast areas of land fairly quickly is to survey it from the air using aircraft or helicopters. There are three common ways this is done.

Magnetic surveys

Minerals containing iron, nickel or cobalt change Earth's magnetic field in their vicinity. Sensitive instruments called **magnetometers** detect this change and show the effect as a disruption to the normal field or 'magnetic anomaly'. An example is shown in Figure 8.5.6.

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 likely to contain iron, nickel or cobalt.

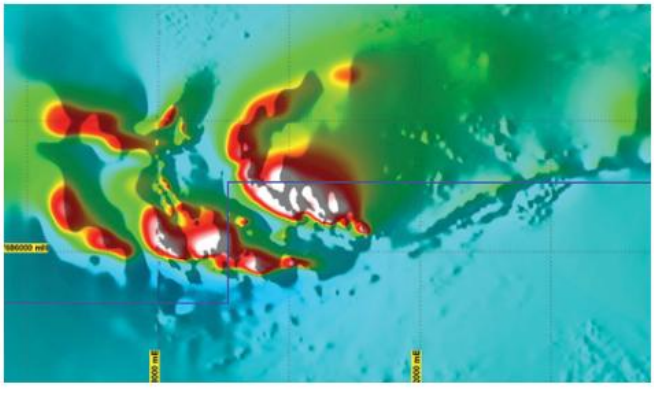


Figure 8.5.6 This map of magnetic anomalies near Mt Oscar in the Pilbara region of Western Australia helped in discovering a mountain made of magnetite iron ore. White and red areas are more magnetic than the other colours.

Gravity surveys

Small differences in the gravitational pull of the Earth can be detected by very sensitive instruments called **gravimeters**. Dense rocks and minerals affect the gravitational pull on the aircraft and gravimeters on board can detect this. Variations in gravitational pull can give geologists clues about where particular minerals may be found.

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. 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 how this works in Figure 8.5.7 on page 334.

Prac 3 p338

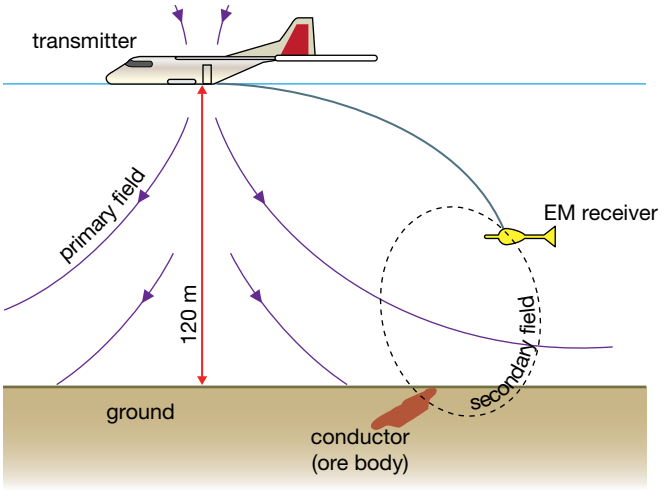


Figure 8.5.7 Airborne electromagnetic methods apply a magnetic field to the Earth and detect the secondary field created by the eddy currents in the ore body.

Prac 4 p339

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 image can be created from the reflections. Explosives can be used to create the shockwave, but mechanical vibrators give a better picture and can go deeper. Detectors called geophones detect the reflected sound waves. The data obtained helps geologists predict likely areas where minerals can be found.

Geochemical surveys

Geochemistry uses chemistry to show what minerals are present. Rock and soil samples from the surface may be used, but generally holes are drilled into the rocks. The rock that is removed is called a **core sample**. Some core samples are shown in Figure 8.5.8.

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.

Figure 8.5.8 Core samples of rock from holes drilled into a potential ore body. These will be tested chemically for minerals of interest.

SATELLITE IMAGES

Satellites enable geologists to create images using forms of light rays that the human eye cannot see, such as infrared. The **satellite images** produced often help geologists see features in the landscape that they cannot see in satellite photos produced with visible light. These features often contain particular minerals. Typical satellite images can be seen in Figure 8.5.9.

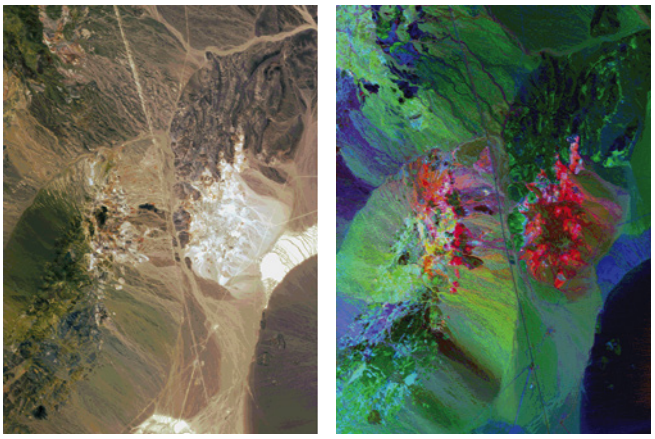


Figure 8.5.9 These two satellite images show the same area, in natural and infrared light. The red parts indicate deposits of azurite (an ore of copper).

REVIEW

8.8 8.9

1. **Describe** how a magnetometer and gravimeter are useful to a geologist or a geophysicist.
2. Aerial surveys don't just use the skills of scientists. **Describe** some jobs of other people likely to be involved in aerial surveys.
3. **Describe** two exploration methods used by geochemists.
4. **Explain** how a geologist could use data from a satellite.

8.5 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** what a flame test is and what it shows.

Applying

7 **Use** Mohs scale to **identify** minerals that could:
a be scratched by a fingernail
b scratch a fingernail.

8 An unknown mineral was scratched by fluorite, but not calcite. **Use** Mohs scale to **state** the likely value for its hardness. N

9 One of the minerals in Table 8.5.2 on page 330 was scratched by topaz but not by an iron nail. **Identify** what mineral it probably was. N

Analysing

10 **Compare** a rock, a mineral and an ore.

Evaluating CCT

11 Two unknown white, lustrous minerals were tested for hardness and streak. Both had a hardness of 4, and had a white streak. **Deduce** a conclusion from these tests.

12 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 CCT

13 Imagine you are given two large white crystals labelled U1 and U2. **Design** a method that would compare whether these two crystals are different minerals or the same mineral.

Inquiring

1 Discuss the research being done into the role of bacteria in the formation of gold. In particular:
- state the observation that led Australian scientist Frank Reith to investigate the bacterium called *Cupriavidus metallidurans*
- describe the research done by Reith and his team
- outline Reith's conclusions
- discuss any current research being done on the bacterium.

Present your research in digital form. ICT

ADDITIONAL

2 Research mineral, petroleum and coal deposits in Australia. In particular:
- draw a map showing the major deposits of gold, copper, iron, uranium, diamond, coal and petroleum
- choose a particular minesite and outline any benefits gained from the mine and the resource extracted from it
- discuss any concerns about the mine, especially its environmental effects (or potential effects) on the area.

Present your findings as a poster.

3 Research how forces and energy are involved in the formation of rocks and minerals:
- describe what is meant by hydrothermal fluids
- explain how hydrothermal fluids form gold deposits
- explain how coal is formed
- explain how iron ore is formed as a chemical sedimentary rock.

Present your findings in digital form. ICT

ADDITIONAL

8.5 Practical investigations

1 Comparing minerals

Purpose

To compare the physical properties of different minerals.

Materials

- minerals
- white unglazed tile
- stereo microscope or hand lens
- steel nail
- copper washer or nail
- cast iron

Procedure

1. In your workbook, copy the table shown in the results section. Include enough rows for all the minerals.
2. Choose one mineral sample. Record its name from the label or identify it using Figure 8.5.10. Describe its colour and lustre.
3. Use the stereo microscope 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 8.5.2 and 8.5.3 on page 330 and enter the result in your table.
6. Repeat for all other mineral samples.

Results

Record all observations in your Results table.

Mineral name	Colour and lustre	Crystal shape	Streak colour	Approximate hardness

Practical review

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.

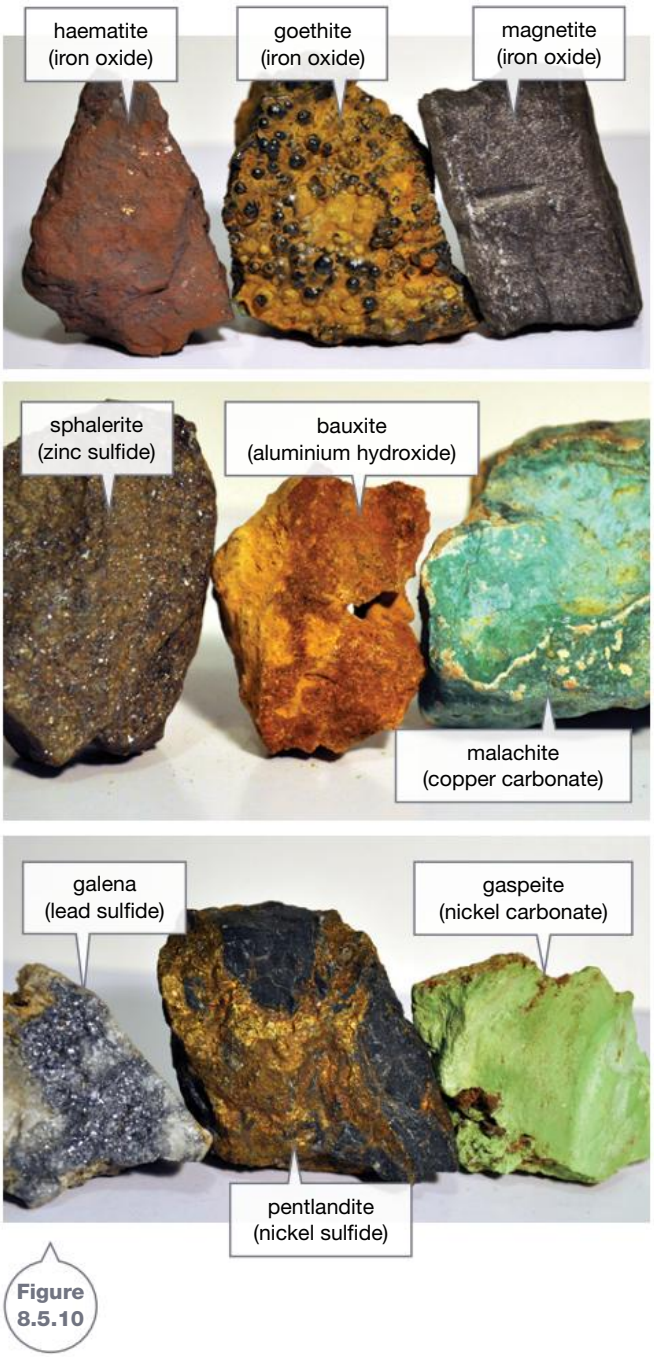


Figure 8.5.10

2 Chemical properties of a mineral

Purpose

To investigate the composition of malachite, a green-coloured copper carbonate mineral found in rock.

Materials

- copper carbonate powder (or powdered malachite), 2 g
- 0.1 M sulfuric acid (about 50 mL)
- limewater
- steel wool

- 250 mL conical flask with one-hole stopper and delivery tube
- test-tube and test-tube rack
- video camera or mobile phone with video function (optional)

SAFETY

1 M sulfuric acid is corrosive.

Wear safety glasses at all times.

Wear rubber gloves at all times.

Procedure

1. Place about 1 g of the malachite or powdered copper carbonate in the conical flask 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 50 mL of sulfuric acid to the conical flask containing malachite. Replace the stopper and delivery tube, and bubble the gas through a limewater solution for no more than 30 seconds (Figure 8.5.11). Remove the end of the delivery tube from the limewater.
4. Let the conical flask stand for a few minutes until a definite colour can be seen in the conical flask containing the malachite. Record your observations of the conical flask and the test-tube.
5. Place some steel wool into the liquid in the conical flask with the malachite and leave it for 2 minutes.

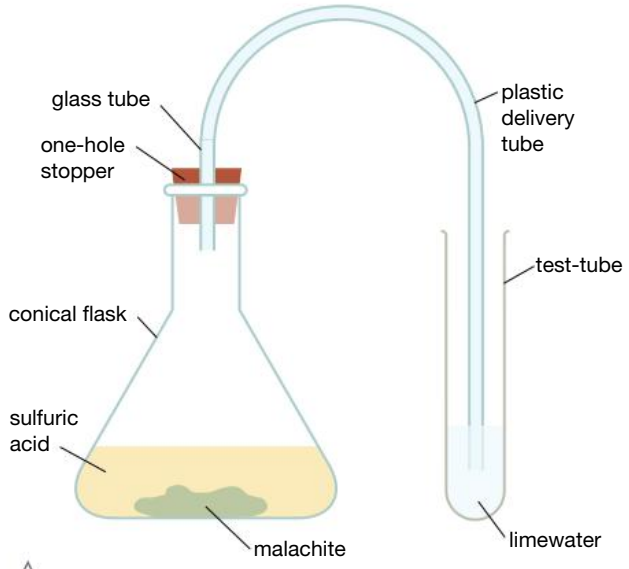


Figure 8.5.11

Results

1. Record or video your observations.
2. Leave the conical flask until the end of the class and again record your observations.

Practical review

1. **Describe** the changes in the conical flask 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 conical flask 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 conical flask.
5. **Identify** the material on the steel wool, based on your knowledge of the elements.

3 Detecting magnetic minerals

Purpose

To model a magnetic survey to detect minerals.

Materials

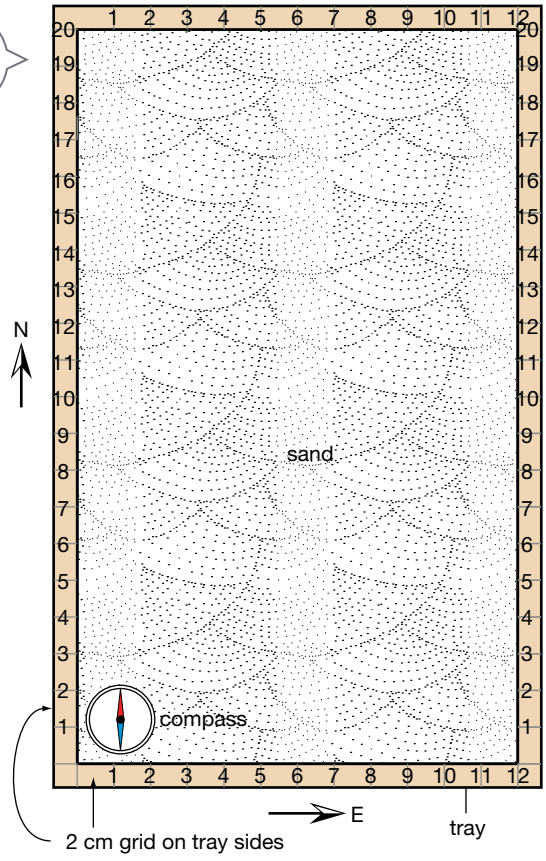
- 3 or 4 pieces of iron/steel (the 'mineral')
- clean sand

- tray
- magnetic compass
- marking pen (non-permanent)

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 8.5.12).

Figure 8.5.12



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.

Practical review

1 **Explain** why the compass needle detects the mineral.

2 **Name** the devices that would take the place of the compass in a real magnetic survey.

3 **Describe** how you predicted the location of each ore body.

4 **Evaluate** your performance in detecting the ore bodies.

4 Electromagnetic surveys

Purpose

To model an electromagnetic survey to detect minerals.

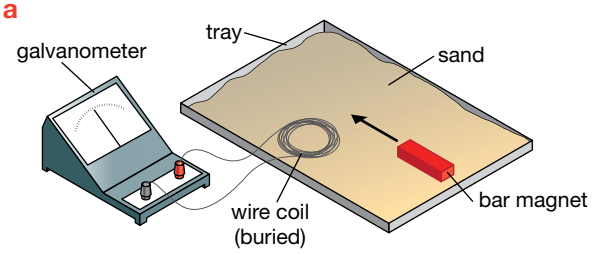
Materials

- laboratory tray
- clean sand
- good-quality magnetic compass
- strong bar magnet
- copper coil (ore body)—varnished
- galvanometer
- 4 V 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 8.5.13a.

a



b

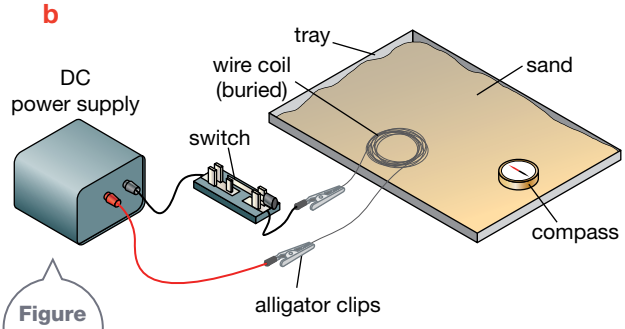


Figure 8.5.13

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 4 V. Your set-up should look like Figure 8.5.13b.
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.

Practical review

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.

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 **List** some reasons why mining is important to Australia.

9 **List** the following steps in the correct order when extracting a metal from the Earth: enrichment, mining, exploration, extracting.

Understanding

10 **Define** the term *geology*. L

11 **Discuss** whether it would be possible to mine into the Earth's mantle.

12 **Explain** the difference in crystal sizes of intrusive and extrusive igneous rocks.

13 **Outline** the weathering processes that act on rocks.

14 **Describe** the process of deposition.

15 **Outline** the formation of clastic sedimentary rocks.

16 **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.

Applying

17 a 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.
- b 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

18 **Compare** the formation of igneous, sedimentary and metamorphic rocks.

19 **Contrast** foliated (banded) and non-foliated metamorphic rocks.

Evaluating CCT

20 **Propose** a reason why it is unwise to plant trees too close to a house.

21 a **Determine** whether you can or cannot answer the questions on page 295 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

Creating CCT

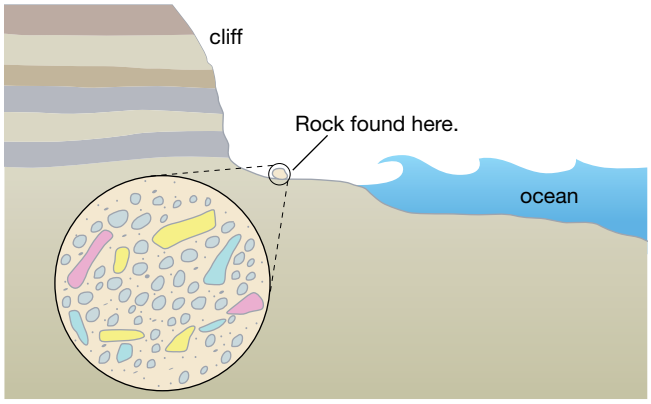
22 a **Construct** a diagram of the rock cycle
- b **Explain** why it is a useful model in geology.

23 **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
deposition	crystals
mineral	magma

Thinking scientifically

Questions 1 and 2 refer to the following information.



Q1 Clastic sedimentary rocks have the following characteristics. CCT

- 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?

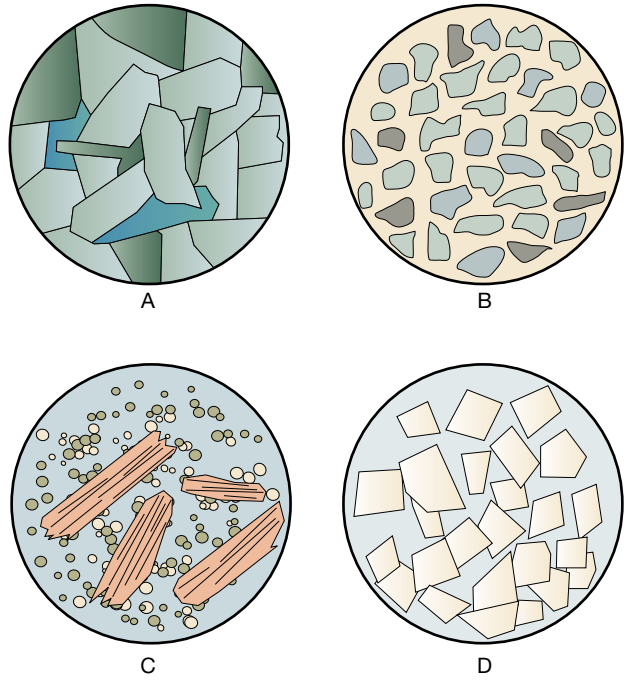
A The rock has layers in it.
B The grains are not interlocking.
C The crystals are large.
D There are no fossils in it.

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. CCT

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 that 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 from the following. CCT

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: CCT

A A and B
B A and D
C C and D
D B and C.

Q5 Fool's gold (iron pyrites) and gold are a similar colour, and people are often fooled by this similarity. However, when a streak test is done, fool's gold has a greenish black streak and gold has the same colour streak as the lump of gold. What can be concluded from this example? CCT

A Gold and fool's gold are the same mineral but with a different structure.

B The streak test does not prove that these two minerals are the same.

C Streak tests are very unreliable as a means of deciding whether two minerals are different.

D The streak test can show that two minerals are different, but not that they are the same.

Q6 Consider the key below, which shows how to distinguish between four black minerals. CCT

Which of the following is correct?

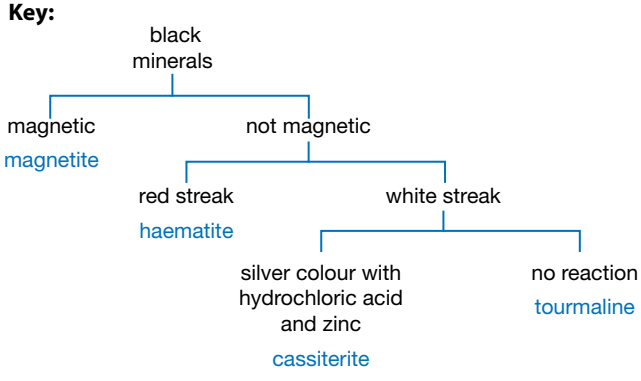
A Cassiterite can only be distinguished from tourmaline by checking the streak.

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.

Key:



Q7 Dean and Erin were experimenting with a model stream and how much soil it can wash away. They changed the angle of a slope and measured the soil loss in a 10-minute period. They made the following measurements.

Steepness of slope	Stream speed (m/s)	Mass of particles lost (g)	Largest particle size (mm)
Gentle	1	48	10
Moderate	4	283	40
Steep	8	640	100

A reasonable deduction from these results is that

A fast streams will carry 640 g of sediment.

B a moderate slope will lose 275 g of sediment every 10 minutes.

C faster streams will cause more erosion.

D twice as much sediment is carried if a stream flows twice as fast.

Glossary

Unit 8.1 L

Asthenosphere: top layer of the mantle, composed of 'plastic' rock

Core: the two innermost layers of the Earth

Crust: the outermost layer of the Earth, composed of solid rock

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

Interlocking crystals

Intrusive igneous rocks: igneous rocks that form below the surface of the Earth

Lava: molten rock reaching the Earth's surface

Lithosphere: layer of the Earth composed of the crust and the upper mantle

Magma: molten rock that does not reach the Earth's surface

Mantle: layer of the Earth below the crust

Minerals: chemical substances found in rocks

Unit 8.2 L

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

Deposition: the process of water ice or wind dropping eroded rock particles

Erosion: removal of weathered rock particles from the site of the weathering

Physical weathering: breakdown of rocks by physical processes

Weathering: the physical and chemical processes that break rocks down into smaller pieces

Physical weathering

Unit 8.3 L

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

Strata: layers of sedimentary rock

Unit 8.4 L

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

Glossary

Unit 8.5 L

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

Flame test: the colour a mineral glows when heated to a high temperature in a flame

Geochemistry: the use of chemistry to show what minerals are present in an area

Gravimeter: very sensitive instrument that measures small differences in the gravitational pull of the Earth

Hardness: physical property based on ability to scratch particular minerals

Lustre: how shiny a mineral is

Magnetometer: device that measures magnetic field strength

EM survey

Flame test

Mineral: a naturally occurring liquid or solid in the Earth's crust but not including oil or coal

Mineral resources: minerals that are dug up and used

Ore: rocks containing valuable minerals

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

Streak: the colour of the mark left by scraping the mineral on a white unglazed tile

Satellite image

Streak

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Acknowledgements

We thank the following for their contributions to our text book:

AAP: Mick Tsikas, p. 142b.

Aboriginal Affairs Victoria: p. 217bl.

Airliners: Ivan Kresanek, pp. 333t, 344(EM survey).

Alamy Ltd: Frederic Cirou, p. 28t; BSIP, p. 106tl; Scott Camazine, p. 125br; imagebroker, p. 145; Jason Edwards, p. 152r; Christian Hütter, p. 146bl; Medical-on-Line, p. 141l; Roland Birke, p. 149bl; Sergey Bogomyako, p. 176; dpa picture alliance archive, p. 195; Kim Karpeles, p. 212bl; Tommy Trenchard, p. 236l; Carl Court, p. 235b; GL Archive, p. 250r; David Paterson, p. 295; Scenics & Science, p. 300tl; Ken Welsh, p. 309br; Hilary Morgan, p. 325tr; AfriPics.com, p. 309l; David Hancock, p. 316tl; Bill Bachman, pp. 334tr, 310l; Jeffery Drewitz, p. 319; David Keith Jones, p. 318(early human); Alessandra Sarti, p. 151; Graphic Science, p. 149tr; Ola Moen, p. 289.

Alexander Cable/Apollo Minerals: p. 333b.

Animals Animals: p. 325(marble).

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Corbis Australia Pty Ltd: James Leynse, p. 251tr; Layne Kennedy, p. 318tr; Jonathan Blair, p 318 (flying reptile).

DK Images: pp. 125tr, 126tl, 149tl, 147br, 172(asexual reproduction), 217br; Harry Taylor, p. 325(hornfels); Clive Streeter, p. 344(flame test).

Dreamstime: pp. 2b, 40(first-hand data), 42, 87r, 88l, 108l, 116b, 113b, 179(waterslide), 181(car), 226(energy flow), 226(kinetic), 226(light), 215br, 218(hammer, scales), 214(steering wheel), 181(toaster), 244bl, 263, 266bl, 266br, 265, 267(leaf), 270(all), 316br.

Dr Jill A. Miwa: pp. 230l, 261(atoms).

Energyrating.gov.au: p. 193b.

Fairfax Photo Sales: Glenn Hunt, p. 142t.

Flickr: Roberts Division of Natural Science and Mathematics, p. 16; Brian Bouchard, p. 219bl.

Fotolia: pp. 19, 5b, 47tl, 103, 189b, 205, 243b, 287l, 300bl, 66tr, 66l, 303r.

Getty: pp. 54br, 54bl, 163(fertilised egg), 173(blastocyst); Steve Taylor, p. 5t; Martyn F. Chillmaid, p. 6; Jordi Escandell, p. 22; Stefan Diller, p. 50; Andrew Syred, p. 41; Photolibrary Pty Ltd, p. 70cr; CNRI, p. 63tr; Prof Miodrag Stojkovic, p. 74t; Mauro Fermariello, p. 75l; Photolibrary Pty Ltd, p. 52br; Eric V Grave, p. 57bl; Dr John Runions, p. 53r; Franz Waldhäusl, p. 113t; Photolibrary Pty Ltd, p. 126br; Science Photo library, p. 106br; a. Edward Kinsman b. Rolf Nussbaumer c. Photo Researchers d. Kenneth M Highfill, p.139l; Photo Researchers, p. 162br; Andrew Syred, p. 148bl; Charles D. Winters, pp. 231(chlorine), 261(non-metal), 231(iodine), 267(bubbles), 267(precipitate), 294(precipitate), 298; Edward Kinsman, p. 241tr; Carolyn A. McKeone, p. 269br; Dirk Wiersma, p. 299l; Edward Kinsman, p. 299(granite); Gary Retherford, p. 325t; Photo Researchers, p.301bl; Charles D Winters, p. 301cl; Photo Reseachers, p. 317(brecia); Doug Martin, p.317(conglomerate); Joyce Photographics, pp. 325(phyllite), 325(quartzite); Oliver Gerhard, p. 329(opal); Cordelia Molloy, p. 330t; H.Moysich, pp. Cover, title page; IMAGEMORE Co. Ltd, p. 1; Comstock Images, p. 18; Glenn van der Knijff, p. 3; Dr Kessel & Dr Kardon/Tissues & Organs, p.109; Matt Blyth, p. 128; Loungepark, p.156t; Zia Soleil, p. 162t; Bloomberg, p. 189t; William West, p. 216tl; Andrew Bain, p. 219r; David Nardini, p. 280; Simon Battensby, p. 323; Robert Harding, p. 325tr; Klaus Honal, p. 317(limestone); Leonard McCombe, p. 166b; Steve Hathaway, Safety dummy icon.

Greg Linstead: p. 336(all).

IBM Research: p. 249br.

iStockphoto: pp. 29t, 52tr, 70tl, 52cr, 53(diatom), 53(rotifer), 79, 60(amoeba), 60(daphnia), 60(diatoms), 60(paramecium), 116t, 94t, 133, 125tl, 179(bungee), 226(potential), 104.

Mark Steinmetz: pp. 331t, 344(streak).

NASA: p. 311; Image courtesy of NASA Visible Earth, Jacques Descloitres, MODIS Land Science Team, p. 310br.

New Scientist: Reed Business Information Ltd, p. 40(URL).

Newspix: Ross Swanborough, p. 329t.

Photoshot: NHPA, p. 140.

Panos Pictures: Robin Hammond, p. 236r; Paul Lowe, p. 235t.

Pearson Australia: Alice McBroom, p. 29b; Michelle Jellett, pp. 214tl, 213tr, 214bl, 214(screwdriver, sardines).

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