Science Focus 2

second edition

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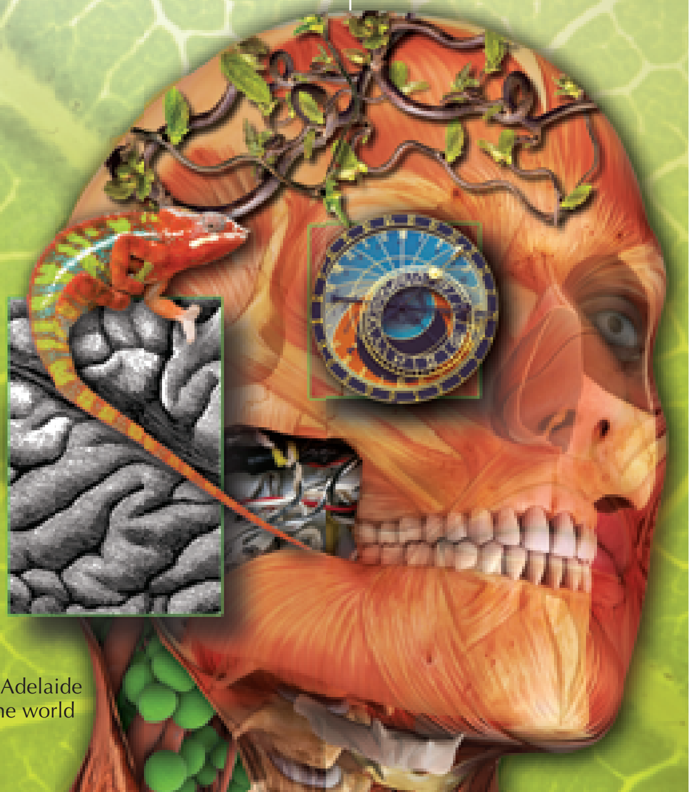

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Contents

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Series features

Science Focus Second Edition

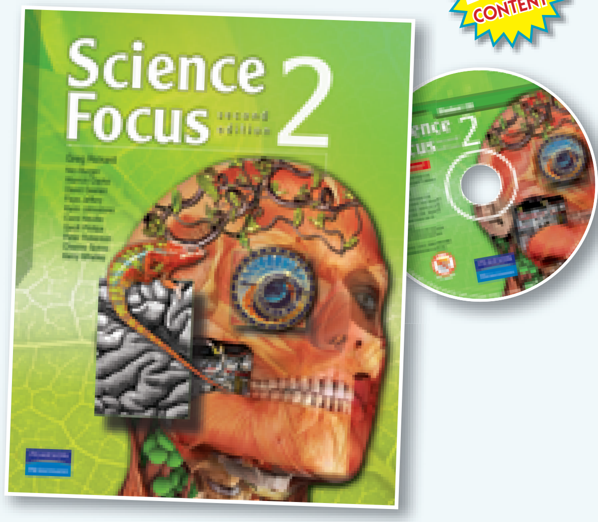
The **Science Focus Second Edition** series has been designed for the revised NSW Science Syllabus, Stages 4 and 5. This fresh and engaging series is based on the essential and additional content.

Student books with student CD

NEW CONTENT

The student book consists of chapters with the following features:

- A science **context** at the beginning of each chapter encourages students to make meaning of science in terms of their everyday experiences.
- **Science Clip** boxes contain quirky and fascinating science facts and provide opportunity for further exploration by students.
- **Unit** and **chapter review questions** are structured around Bloom's Taxonomy of Cognitive Processes. Questions incorporate the key verbs, so that students can begin to practise answering questions as required in later years.
- **Investigating** sections incorporate ICT and research skills. These tasks are designed to push students to apply the knowledge and skills they have developed within the chapter.
- **Practical activities** are placed at the end of each unit to allow teachers to choose when and how to incorporate the practical work.
- **Science Focus spreads** use a contextual approach to focus on the outcomes of the prescribed focus area. Student activities on these pages allow for further investigation into the material covered.

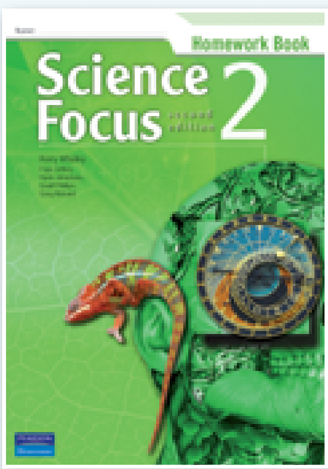


Each student book includes an interactive student CD containing:

- an electronic version of the student book
- a link to Pearson Places for extensive online content.

Homework books

NEW CONTENT



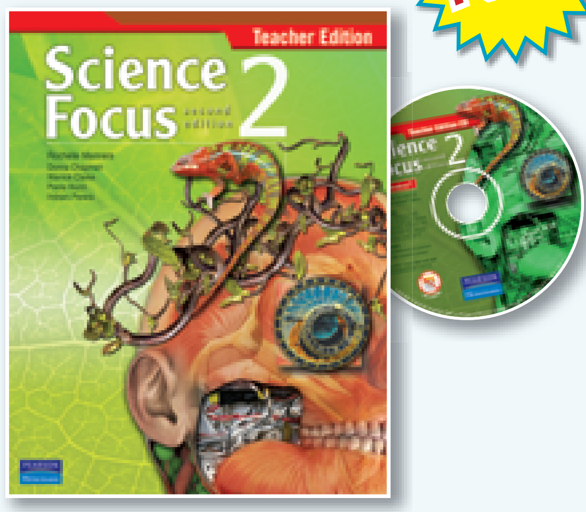
The homework book has a fresh new design and layout and provides the following features:

- A **syllabus correlation grid** links each worksheet to the NSW Science Syllabus.
- Updated **worksheets** cover consolidation, extension and revision activities with explicit use of syllabus verbs so that students can begin to practise answering questions as required in later years.
- Questions are clearly graded within each worksheet, allowing students to move from lower-order questions to higher-order questions.
- A **crossword** for every chapter spans across a double-page spread so students can easily read the clues and instructions.
- **Sci-words** are listed for each chapter in an easy-to-follow tabulated layout.

Teacher editions (including teacher edition CD and student CD)

NEW

The innovative teacher edition contains a wealth of support material and allows a teacher to approach the teaching and learning of science with confidence. Teacher editions are available for each student book in the series. Teacher editions include the following features:



- pages from the student book with **wrap-around teacher notes** covering the learning focus, outcomes and a pre-quiz for every chapter opening
- approximately 10 different **learning strategies** per unit in addition to the activities provided in each unit of the student book
- **assessment ideas**
- **answers** to student book questions
- **practical activity support** including a safety spot, common mistakes, possible results and suggested answers to practical activity questions
- **Teacher Resource boxes** highlighting additional resources available, such as worksheets, online activities and practical activities.

Each ***Science Focus* Second Edition *Teacher Edition CD*** includes:

- student book answers
- homework book answers
- chapter tests and answers
- curriculum grids
- teaching program for each chapter
- student risk assessments
- lab technician risk assessments

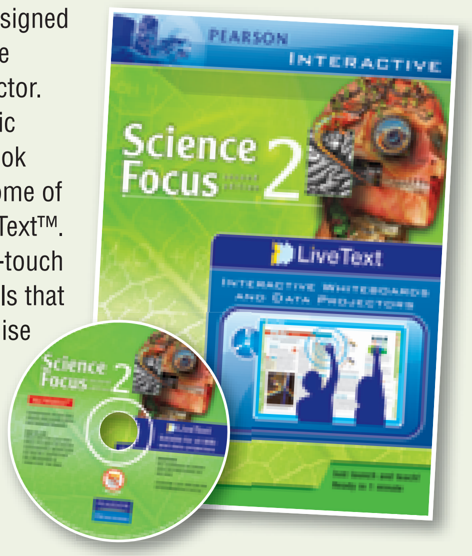
safety notes

- lab technician checklist and recipes.

LiveText™ DVD

NEW

The LiveText™ DVD is designed for use with an interactive whiteboard or data projector. It consists of an electronic version of the student book with component links, some of which are unique to LiveText™. The features include one-touch zoom and annotation tools that allow teachers to customise lessons for students.



Pearson Places

NEW

www.pearsonplaces.com.au

Pearson Places is the online destination that is constantly evolving to give you the most up-to-date educational content on the Web. Visit **Pearson Places** to access educational content, download lesson material, use rich media and connect with students, educators and professionals around Australia.

- **Pearson Reader**
  More than an eBook, Pearson Reader provides unique online student books that allow teachers and students to harness the collective intelligence of all who participate. Search for a unit of work and contribute by adding links and sharing resources.
- **Student Lounge**
  One location for student support material—interactives, animations, revision questions and more!
- **Teacher Lounge**
  One location for teacher support material—curriculum grids, chapter tests and more!

For more information on the **Science Focus Second Edition** series, visit the Bookstore at: **www.pearsonplaces.com.au.**

How to use this book

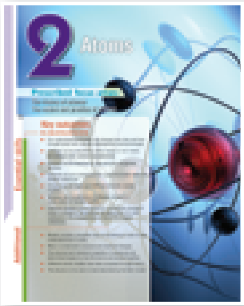
Science Focus 2 Second Edition

Science is a fascinating, informative and enjoyable subject. Science encourages us to ask questions and helps us understand why things happen in our daily lives, on planet Earth and beyond. Scientific knowledge is constantly evolving and challenges us to think about the world in which we live. Science shows us what we knew, what we now know and helps us make informed decisions for our future.

***Science Focus 2* Second Edition** has been designed for the revised NSW Science Syllabus. It includes material that addresses the learning outcomes in the domains of knowledge, understanding and skills. Each chapter addresses at least one prescribed focus area in detail. The content is presented through many varied contexts to engage students in seeing the relationship between science and their everyday lives.

The student book consists of nine chapters with the following features:

Chapter opener



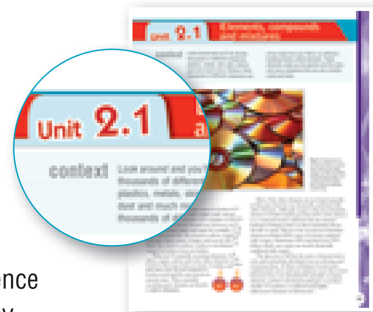
The key **prescribed focus area** addressed within the chapter is clearly emphasised.

The **learning outcomes** relevant to the chapter are clearly listed.

A clear distinction between **essential** and **additional** outcomes is presented in student-friendly language.

Units

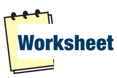
Context



The **context** section appears at the beginning of each unit to encourage students to make meaning of science in terms of their everyday experiences.

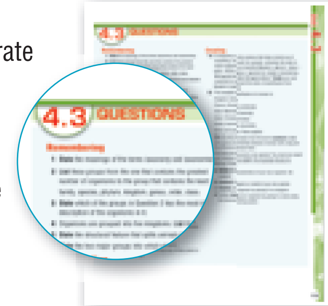
Unit content

The unit includes illustrations, photos and content to keep students engaged and challenged as they learn about science. A **homework book icon** appears within the unit indicating a related worksheet from the supporting homework book.

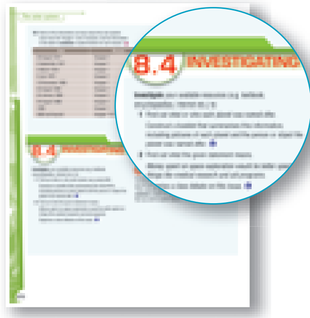


Unit questions

A set of questions related to the unit are structured around Bloom's Taxonomy of Cognitive Processes. The questions move from straightforward, lower-order **remembering**, **understanding** and **applying** questions, through to more complex, higher-order **evaluating**, **analysing** and **creating** questions. Questions incorporate a variety of verbs, including the syllabus verbs. All verbs have been bolded so students can begin to practise answering questions as required in examinations in later years.



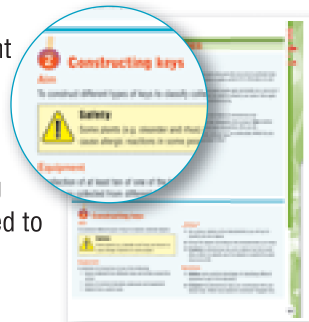
Investigating



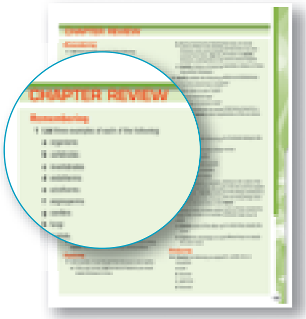
The **investigating** activities can be set for further exploration and assignment work. These activities may also include a variety of structured tasks that fall under the headings of **reviewing** and **e-xploring**.

Practical activities

Practical activities are placed at the end of each unit, allowing teachers to choose when and how to best incorporate practical work into the teaching and learning. A **practical activity icon** will appear throughout the unit to signal suggested times for practical work. Within some practical activities a safety box appears that lists very important safety information. Some practical activities are **design your own** (DYO) tasks and others may be conducted using a **data logger**. Icons are inserted to indicate these options.



Chapter review



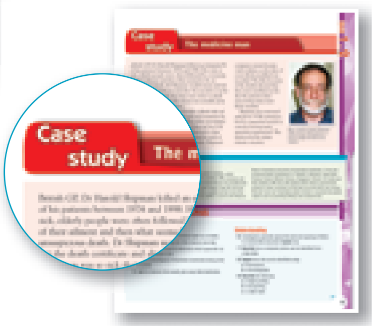
Chapter review questions follow the last unit of each chapter. These questions are structured around Bloom's Taxonomy of Cognitive Processes and cover the chapter learning outcomes in a variety of question styles to allow students the opportunity to consolidate new knowledge and skills.

Other features or icons

Science Fact File boxes contain essential science facts relevant to the topic.

Science Clip features contain quirky information related to the topic that students will find interesting.

Career Profile boxes appear throughout the book, covering information about specific careers in science.



Case study boxes cover an in-depth exploration of a single case or topic.

Science Focus spreads appear throughout the book. These are special features on various aspects of science including history, the impact of science on society and the environment and current research and development. The features allow students to explore science in further detail through a range of student activities.

Literacy and **numeracy icons** appear throughout to indicate an emphasis on literacy or numeracy. N L

Go to icons direct students to a unit within the same stage of the NSW curriculum. This unit reference allows students to revisit or extend knowledge. Go to

Aboriginal flag icons denote material that is included to cover Indigenous perspectives in science.

Pearson Places icons direct students to the ***Science Focus 2 Second Edition Student Lounge*** on Pearson Places. The Student Lounge contains animations, video clips, web destinations, drag-and-drop interactives and revision questions.

Sci Q Busters appears after Chapter 9 and provides answers to student questions. Students are able to email questions that come up during class time to the Q Busters team at SciQBusters@pearson.com.au

The Science Focus 2 Second Edition package

Don't forget the other ***Science Focus 2*** **Second Edition** components that will help engage and excite students in science:

Science Focus 2 Second Edition Homework Book

Science Focus 2 Second Edition Teacher Edition**, with CD**

Science Focus 2 Second Edition Pearson Reader

Science Focus 2 Second Edition LiveText™

Stage 4 Syllabus Correlation

Outcomes	1 Science skills	2 Atoms	3 Plant systems	4 Body systems	5 Microbes	6 Ecology	7 Electricity	8 Machines	9 Astronomy
4.1		▲							
4.2	▲	▲	▲						
4.3				▲			▲	▲	
4.4					▲	▲			
4.5				▲					▲
4.6							•	•	
4.7		•							
4.8			•	•	•				
4.9									•
4.10						•			
4.11						•		•	
4.12						•		•	•
4.13	•	•	•	•	•	•	•	•	•
4.14	•	•	•	•	•	•	•	•	•
4.15	•	•	•	•		•	•	•	•
4.16	•	•		•	•	•	•	•	•
4.17	•		•	•	•	•	•	•	•
4.18	•	•	•	•	•	•	•	•	•
4.19	•	•	•	•	•	•	•	•	•
4.20	•			•		•	•	•	•
4.21	•	•	•	•	•	•	•	•	•
4.22	•		•	•	•	•	•	•	•
4.23	•				•		•		
4.24	•		•			•			
4.25	•	•	•	•	•	•	•	•	•
4.26	•	•	•	•	•	•		•	•
4.27			•		•	•			

Note: ▲ indicates the key Prescribed Focus Area covered in each chapter.
Chapters may also include information on other Prescribed Focus Areas.

Verbs

***Science Focus 2* Second Edition** uses the following verbs in the chapter questions under the headings of Bloom's Taxonomy of Cognitive Processes. The verbs in black are the key verbs that have been developed to help provide a common language and consistent meaning in the Higher School Certificate documents. All other verbs listed below feature throughout the book and are provided here for additional support to teachers and students.

Remembering

List	write down phrases only without further explanation
Name	present remembered ideas, facts or experiences
Present	provide information for consideration
Recall	present remembered ideas, facts or experiences
Record	store information and observations for later
Specify	state in detail
State	provide information without further explanation

Understanding

Account	account for: state reasons for, report on. Give an account of: narrate a series of events or transactions
Calculate	ascertain/determine from given facts, figures or information (simply repeating calculations that are set out in the text)
Clarify	make clear or plain
Define	state meaning and identify essential qualities
Describe	provide characteristics and features
Discuss	identify issues and provide points for and/or against
Explain	relate cause and effect; 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 of
Predict	suggest what may happen based on available information
Produce	provide
Propose	put forward for consideration or action
Recount	retell a series of events
Summarise	express, concisely, the relevant details

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
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
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
Draw	draw conclusions, deduce
Evaluate	make a judgement based on criteria; determine the value of
Extrapolate	infer from what is known
Investigate	plan, inquire into and draw conclusions
Justify	support 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

1 Science skills

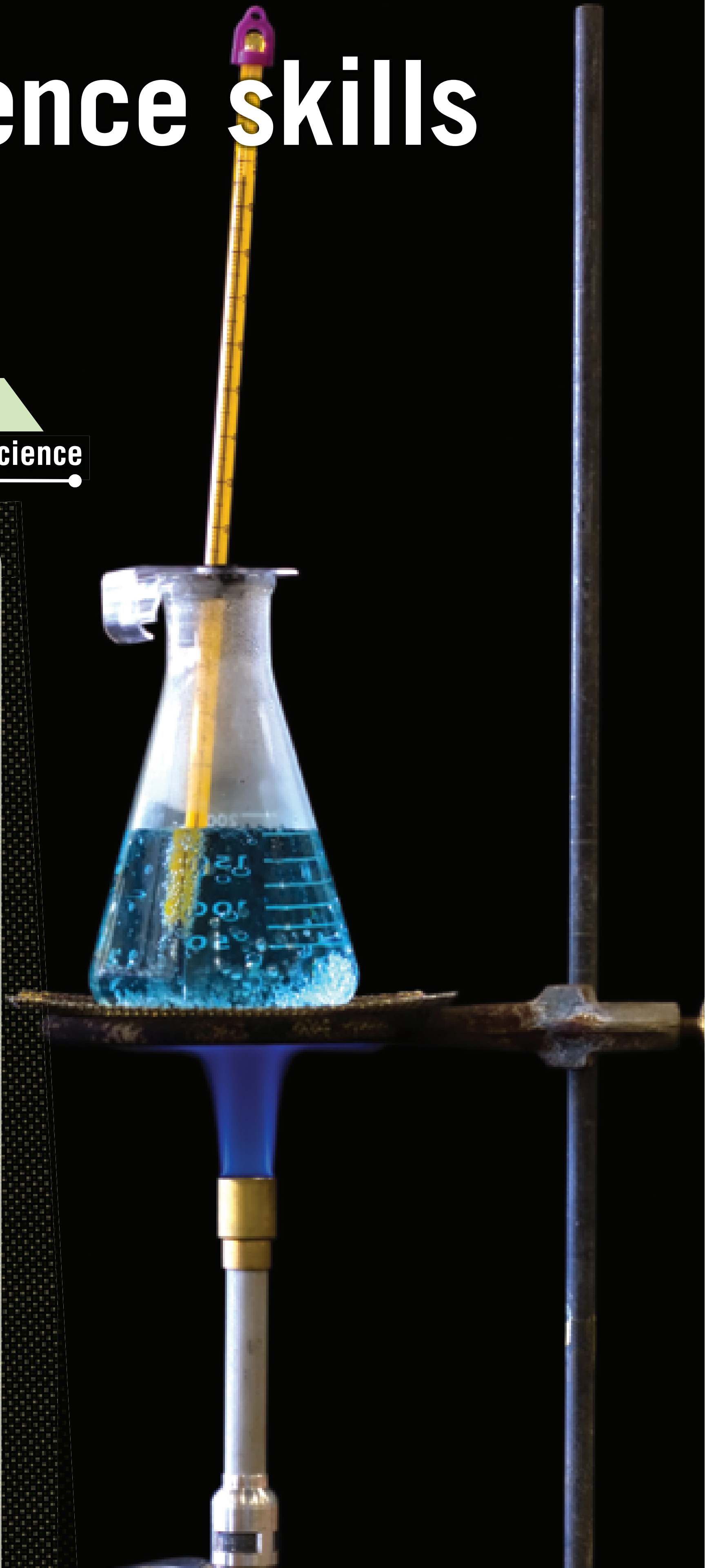
Prescribed focus area:
The nature and practice of science

Essential skills

Key outcomes

4.2, 4.13, 4.14, 4.15, 4.16, 4.17, 4.18, 4.19

- Scientific processes test whether ideas are valid or not.
- A question can lead to the development of a hypothesis that can be tested or researched.
- Data need to be recorded with appropriate units.
- When planning experiments, dependent, independent and controlled variables need to be specified.
- A logical procedure needs to be developed that changes only one independent variable at a time.
- A number of trials increases the accuracy of any measurements taken.
- Information can be gathered from a range of secondary sources.
- Information can be drawn from graphs of different types, other texts, audiovisual resources, CD-ROMs and the Internet.
- The reliability of data and information should be compared with that obtained from other sources.
- Trends, patterns, relationships and contradictions can be sought from data and information.
- Inferences can be justified in light of gathered information.



Unit 1.1 Planning a practical investigation

context

At some stage we have all asked questions about what's going on around us. Although some of these things seem puzzling, they do have an answer. For example, green balloons can be blown bigger than red balloons because of their different dyes and their effect on the rubber that makes up the balloon.

The answers to other questions remain a mystery, however. Dead cockroaches always end up on their backs—a mystery that no-one yet has solved. If you are to answer such questions, you need to think, research, and plan before you actually start doing any practical work.

PP Quick Quiz

Fig 1.1.1 The height to which a ball rebounds depends on many factors. These factors are known as **variables**.

Fig 1.1.2 Science will eventually solve the mystery of dead cockroaches always ending on their backs.

Asking questions

A practical investigation usually begins with a scientific question. To answer the question you will probably need to ask a number of other questions.

If your question is '*How high will a ball bounce?*', then some other questions might first need to be asked in order to get an answer. Some of these questions might be:

- What happens if the height from which the ball is dropped is changed?
- What happens if the ball is changed from one type (e.g. a tennis ball) to another (e.g. a basketball)?
- Does the shape of the ball matter?
- Does the surface (e.g. grass, concrete etc.) on which the ball bounces matter?
- Does the temperature of the day matter?
- Does the number of bounces change the height of the bounce?

To answer questions such as these, you might first need to learn more about what you want to investigate. You will probably need to conduct some **research**. This may involve a search of the Internet, asking parents and teachers, contacting organisations or going to the library to check out the encyclopaedias and newspapers there or textbooks on the subject.

Researching using the Net

Research is an important part of any science project and the Internet will be one of your most convenient and important ways of collecting information. But be warned as many websites contain information you cannot trust as they contain information that is scientifically wrong. Therefore, it is very important to be able to analyse the websites and the webpages you access for accuracy, bias and reliability.

To help you successfully surf the Net, always ask yourself these questions.

1 *Who wrote the information?*
Check the website address or URL. It can tell you a great deal about the source of the information. Elements of the address to check include:

- **personal name (name, ~, %, 'users', 'people', 'members').** This means that the site was put together by an individual person, and that no publisher or organisation was involved. Information from this type of site should be treated with caution. Try to confirm that the information provided is correct by verifying it on other, more reliable sites.
- **information about the server and domain.** Information is more likely to be accurate if it comes from a government or a relevant organisation. The end of the main part of each URL ends with information that tells you where the information comes from, as shown in the table below.

Ending of URL	Refers to
.edu	an education establishment (such as a college, university or school)
.org	a non-profit organisation (such as the Red Cross)
.net	a public network (such as the ABC or SBS)
.gov	government resources (such as the NSW Department of Health)
.au	indicates that Australia is the country of origin
.gov.au	indicates an Australian government site
.gov	indicates a US government site
.com	a company or commercial publisher

For example, the address *boardofstudies.nsw.edu.au* tells you that the name of the organisation is Board of Studies (*boardofstudies*), the State is New South Wales (*.nsw*), it is an educational site (*.edu*) and its country of origin is Australia (*.au*).

Any information you find on the Net needs to be assessed carefully before you use it. Some sites cannot be trusted. A commercial organisation or business might not necessarily give a balanced point of view, as its main aim is probably to get you to buy its products. For example, it is unlikely that the website *http://www.theherbalist-shop.com* can be relied on for a complete set of facts about herbal medicine.

2 *Why was the website page created?*
You must try and work out whether the website has been created to inform, entertain, give facts or data, explain, persuade, sell or present someone's point of view. The address can assist you in coming to your answer. For example, it is unlikely that you would get an unbiased view about wood chipping from *http://www.chipstop.forests.org.au*.

3 *How old is the information?*
It is important to know the age of the information in scientific research. You should also know whether the website is updated regularly. Look on the home page for this information.

4 *Why is it spelt differently?*
When searching, sometimes you do not get what you are actually looking for. This is often because Australians and Americans spell certain words differently, as shown in the table below.

Australian ending	Australian spelling	American ending	American spelling
–our	colour, flavour	–or	color, flavor
–ise	summarise, recognise	–ize	summarize, recognize
–re	centre, metre	–er	center, meter

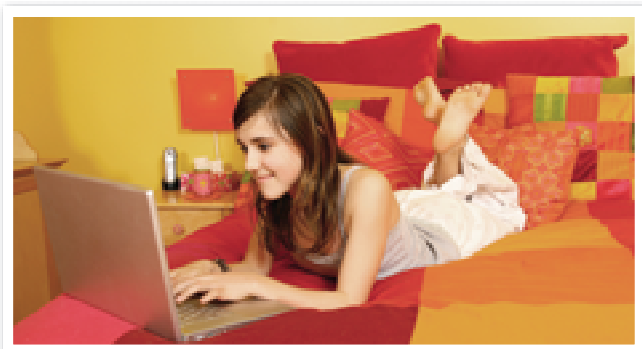


Fig 1.1.3 Not all webpages can be trusted as reliable sources of information.

Fair tests and variables

The factors that can change in an experiment are known as **variables**. Changing variables can change the results of an experiment and so they need to be controlled carefully. Usually there are a number of variables that will affect the results of any experiment.

Variables can be classified into three groups:

- **independent variable**—the variable that is changed
- **dependent variable**—the variable that is being measured
- **controlled variables**—the variables that are kept the same throughout an experiment.

The results obtained depend upon what you change—whatever you measure or record is the dependent variable. For a bouncing ball, the height to which a ball rebounds will depend on lots of other variables, and so bounce height is the dependent variable in this experiment.

When designing an experiment you need to run a **fair test**. Careful planning is required so that you change only one variable. All other variables must be kept constant, otherwise you will not know which variable is causing the result.

In the bouncing ball experiment, for example, you might test how the height from which the ball drops affects the height to which it rebounds. The height from which it drops is, therefore, the independent variable. All other variables need to be held exactly the same: the ball must always be the same type, the temperature must be constant and the surface on which it bounces must be the same. These are your controlled variables.

Go to Science Focus 1, Unit 1.5

Aim and hypothesis

Once all the variables have been identified, an **aim** can be constructed. The aim outlines what you want to investigate. For the bouncing ball experiment, your aim would probably be something like: *To determine how the height a ball drops from affects the height to which it rebounds*.

Fig 1.1.4 An artist's impression of *Beagle 2* entering the Martian atmosphere.

Science Clip

A dog of a mission!

Not all investigations go to plan. The $100 million spacecraft *Beagle 2* certainly did not! *Beagle 2* was sent to Mars by the United Kingdom's space agency and is thought to have crashed onto the surface of Mars on Christmas Day 2003. A recheck of the data showed that the Martian atmosphere was thinner than the team had thought. This means the parachutes probably opened too late and the craft did not slow down enough for a soft landing, the impact probably smashing *Beagle* into bits.

A **hypothesis** can then be developed. A hypothesis is a prediction or 'educated guess' about what you think you might find out in an experiment. A hypothesis is something that can be tested by an experiment. For the bouncing ball experiment, your hypothesis might be something like: *The higher the drop height, the higher the bounce height*. It might even be more specific: *If the drop height is doubled, then the height to which the ball rebounds will also double*.

Method

In any experiment, a step-by-step list of instructions is needed to help guide you through it. This set of steps is known as an **experimental procedure** or **method**. This should be detailed enough so that other students or scientists could do your experiment without needing any more information from you.

Any good scientist will repeat their experiment a number of times so that the conclusion they make from their results will be as accurate as possible. This process of repeating experiments is known as **replicating** the experiment. Repeating an experiment also allows you to calculate averages of all your measurements. This is far more accurate than just one set of results. It also increases the chances that other scientists can reproduce your results.

Results

You will need to record any observations and measurements that you take. A results table is useful here. Any table must include headings and the units in which the measurements were taken.

Scientific research

Scientists generally do not perform just one experiment—they usually carry out many experiments, each one investigating one particular variable.

In the ball bounce experiment, for example, separate experiments might determine the effect of changing:

- drop height
- the type of ball
- the type of surface onto which the ball is dropped
- the temperature
- the number of bounces the ball undergoes.

All of these experiments are investigating the one topic and are known as **scientific research**. Scientific research can take a long time, as experiments do not always give the desired results the first time.

Worksheet 1.1 Planning an investigation

Prac 1 p. 8

Prac 2 p. 9

Prac 3 p. 9

1.1 QUESTIONS

Remembering

1 **State** whether the following are true or false:
   a Asking questions is the last part of planning an investigation.
   b Research can include asking parents and teachers.

2 **State** what in a URL indicates that a website is:
   a from an Australian government organisation
   b from a commercial business
   c from a school.

3 **Name** the three types of variables.

Understanding

4 **Explain** why you should do some initial research before you start designing an experiment.

5 **Outline** two questions you should ask about information you find on the Internet.

6 **Outline** what is a hypothesis.

7 **Explain** why you should repeat an experiment a number of times.

Analysing

8 **Contrast**:
   a a hypothesis with an aim
   b an experiment and scientific research.

Evaluating

9 Examine the following website addresses and **state** whether they have reliable scientific information or not. **Justify** your answers in each case.
   a www.abc.net.au/quantum
   b www.eskimo.com/~billbembers
   c www.science.uniserve.edu.au/school/forensic.html
   d www.csiro.au/helix
   e www.greens.net.au/boycottwoodchipping
   f www.greenhouse.gov.au/.

10 You find two websites that present conflicting information. **Propose** how you could determine which is more accurate.

11 *Only one variable should be changed at any time in an experiment.* **Justify** this statement.

>>

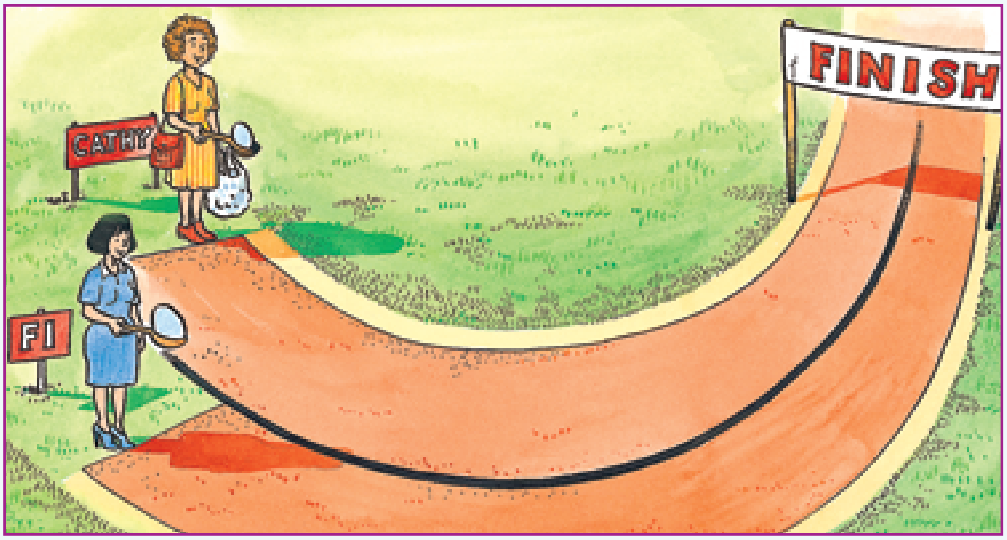


Fig 1.1.5

12 Fiona and Cathy were in an egg-and-spoon race (see Figure 1.1.5).

a **Identify** the variables in the race.

b **Assess** whether the race was fair.

c **Describe** ways of making it a fair race.

13 **Propose** an aim for the following experiments:

a A scientist placed various types of plastic in direct sunlight for two months. The scientist came back every week and observed the plastics.

b Bean seedlings were planted, and each seedling had equal amounts of different brand fertiliser added. The growth of the seedlings was recorded for three weeks.

14 For each of the experiments in Question 13 **identify**:

a the independent variable

b the dependent variable

c the controlled variables.

Creating

15 **Design** an experiment that tests the effect that different amounts of fertiliser have on plant growth. You have the following equipment available: tomato plants, pots of soil, water, a ruler, a measuring cylinder, fertiliser.

a **Construct** an aim for this experiment.

b **Construct** a hypothesis.

c **Identify** the independent and dependent variables.

d **Name** the variable(s) that would need to be controlled.

e **Outline** any observations you would make.

f **Outline** any measurements you would take.

g **List** the steps in this experiment.

h **Construct** a table to record your results.

1.1 INVESTIGATING

e-xploring

PP Web Destination

Some scientific discoveries are made by accident. Research the discovery of penicillin and how it revolutionised the treatment of infection by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

1.1 PRACTICAL ACTIVITIES

1 Happy birthday to you!

Aim

To determine how many candles will cause the water's height to rise

Equipment

- six to eight birthday candles
- box of matches
- plasticine or Blu Tack
- two elastic bands
- a shallow pan
- a gas jar or tall and narrow drinking glass

Method

1 Construct a two-column results table or spreadsheet with the headings 'Number of candles' and 'Rise in height (mm)'.

2 Make a small mound of plasticine or Blu Tack in the centre of the pan and then fill the pan with water.

3 Stick one candle in the plasticine. Place the gas jar or glass over the candle.

4 Place one elastic band around the glass at the level of the water.

5 Remove the jar, light the candle and quickly place the jar over the candle.

6 Allow the candle to burn until it goes out. Wait a short while and observe what happens to the water level.

7 Place the other elastic band over the glass at the new water level.

8 Measure the change in water level and record the measurements in the table.

9 Repeat the experiment with two, then three, five and seven candles.

10 Plot a line graph showing what happened to the height the water rose as more candles were added. N

11 Use the graph to predict the water rise for four, six and eight candles. N

12 Run the experiment again for four, six and eight candles to check your predictions.

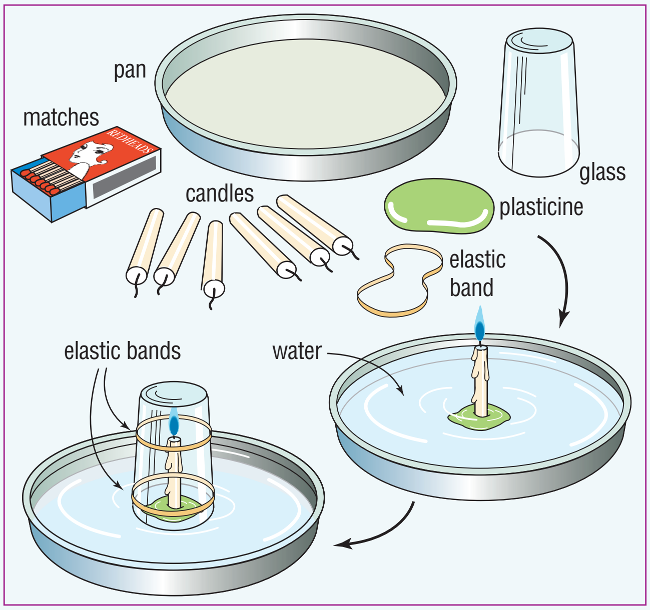


Fig 1.1.6

Science Clip

Flameout!

When candles burn, wax melts and some of it vaporises into a gas. The flame you see is actually burning wax vapour. If you blow out the candle, a trail of smoke will rise from the wick. This, too, is wax vapour but it is unburnt. Can you relight a candle by setting fire to its smoke? Try lighting a candle, then blowing it out. Slowly lower a lit match down the smoke trail. The flame will jump down the smoke to relight the candle. Test how far it can jump.

Questions

1 From the list below, **identify** which variable probably had the most effect on the change in water level:
the volume or depth of water in the tray, the height and diameter of the gas jar, the number or colour of the candles, the amount of plasticine or Blu Tack.

2 **Identify** the chosen variable and the controlled variable in this experiment.

3 **Propose** reasons for the rise in water level in the jar.

4 **Identify** any trend evident from the graph that shows a relationship between the variables you plotted.

2 Drop time

DYO

Aim

To determine what the drop time of a parachute depends on

Equipment

- lightweight materials (e.g. tissue paper, plastic sheet or garbage bags, newspaper)
- fine cotton
- access to a hole punch
- sticky tape
- small masses (e.g. plasticine or paper clips are ideal)
- access to an electronic balance
- stopwatch

Method

1 In groups, brainstorm a list of variables that could affect the drop time of a parachute.

2 Select the two variables that your group thinks will have the most effect.

3 Design two experiments that will test your two variables. Remember to keep everything else the same.

4 When constructing your chutes, reinforce the string holes with patches of sticky tape.

5 Drop your chutes from a height of at least 2 metres.

6 Make repeated measurements of the time they take to hit the ground, recording them in a table or spreadsheet.

7 Write a report of your research, including a line graph for each experiment.

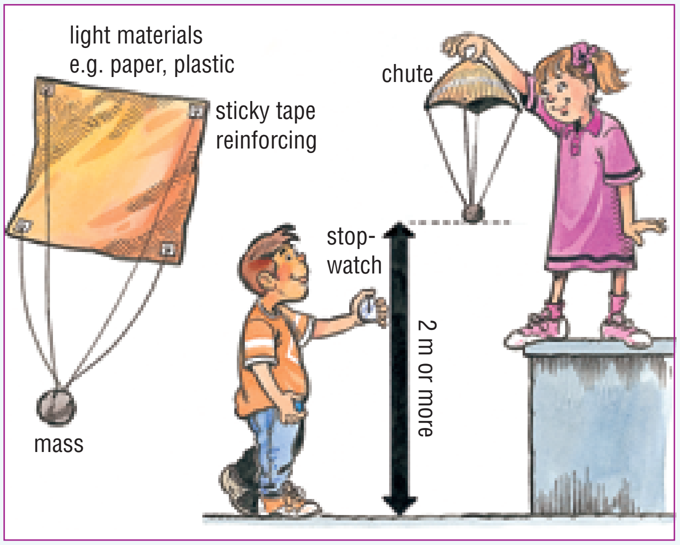


Fig 1.1.7

Go to Science Focus 2, Unit 1.3

Questions

1 **List** the variables that 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 **Write** conclusions for both experiments.

3 Ball bounce

DYO

Aim

To test what affects the bounce of a ball

Equipment

- ball
- measuring tape or metre rule

Method

1 Choose two of the variables discussed in this Unit that can be expected to have some effect on the height to which a ball rebounds.

2 Design your own experiment to test two of those variables.

3 Report on your experiment, setting out your report using the 'normal' headings of a practical report.

Go to Science Focus 1, Unit 1.4
Go to Science Focus 2, Unit 1.3

Unit 1.2 Taking better measurements

context

Practical work in science is usually performed as individual experiments or as longer-term practical investigations. Whichever form your practical work takes, there are certain scientific skills that will make your experiments more accurate and your written reports easier to understand. One vital skill is the ability to take accurate measurements.

Accuracy in measurement

Accurate measurements are often impossible to make. Estimates are often the best we can do. If you wanted to know the amount of water in Sydney Harbour, you would need to estimate it because there is no accurate way of measuring it. The number of people in a shopping centre would constantly change as people left and new people arrived. An exact count would be nearly impossible.

Fig 1.2.1 Not all measurements can be accurate. It would be impossible to measure the exact number of plants in this swamp. At other times, an 'accurate' measurement will be taken, but it will have some uncertainty. This gives rise to errors.

Mistakes and errors

Mistakes are things that could have been avoided if you took a little more care. They can include:

- careless reading of a measurement
- incorrect recording of a measurement
- spillage of material
- use of the wrong piece of equipment.

Errors are things that are unavoidable. Usually they are small and not your fault. Errors will always happen no matter how careful you are. Nothing is exact. Even 'accurate' measurements are, in fact, estimates, all because of errors.

Common errors are:

- **parallax errors**
  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.
- **reading errors**
  Measurements often fall between the markings of a measuring device. Some estimation is required for you to take your measurement.

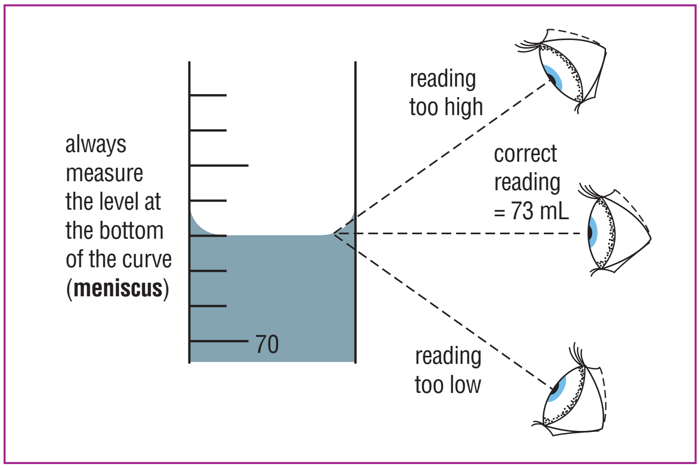


Fig 1.2.2 Reduce parallax errors by keeping your eye in line with the measurement.

Science Clip

Ancient observations

In the year 5 BCE Chinese astronomers noted that there was a star burning with unusual brightness for 70 days. What they saw was probably the exploding star or supernova DO Aquilae. Many believe that 5 BCE was also the birth year of Jesus Christ in Bethlehem. Many astronomers believe that the star that led the three wise men there was actually the supernova seen in China.

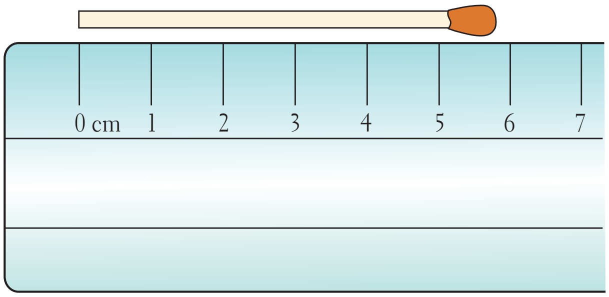


Fig 1.2.3 Not quite 6 cm long, but is it 5.7, 5.8 or 5.9 cm?

- **instrument errors**
  Sometimes the instrument you are using is faulty and will never give the correct reading. Some instruments give correct readings only at certain temperatures and will give small errors if used at any other temperature. A metal ruler expands when hot, causing the markings to move further apart. This makes measurements taken on a hot day slightly smaller than those made on a cold day.
- **human reaction time**
  A stopwatch normally reads to one-hundredth of a second (i.e. 0.01 s). Humans are not as accurate as this—we simply can't react quickly enough. Measurements of time will vary among people because we all have different reaction times. Data loggers have faster reaction times than humans and are more accurate, but there are still errors involved.

Prac 1 p. 15

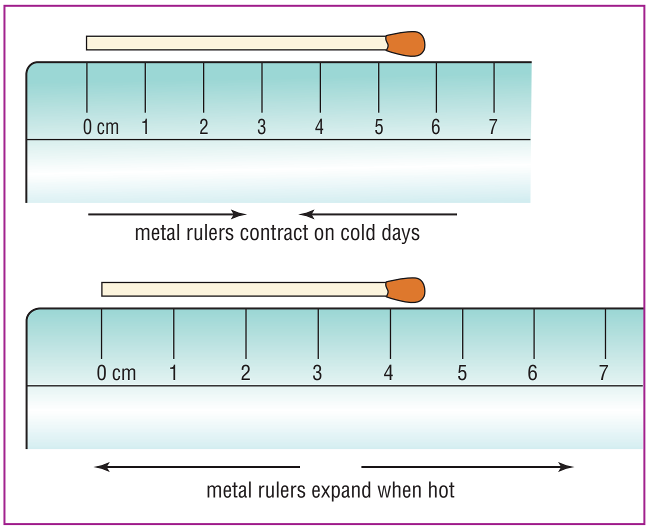


Fig 1.2.4 Same match, different days, different measurements

Repeated measurements

Because errors always exist, people can measure the same thing differently. This means that no-one can take a perfectly 'correct' measurement. Unless someone made a silly mistake, there is no wrong answer. Repeating measurements is a good way to improve accuracy. Once a collection of different measurements is taken, an **average** or **mean** can be obtained.

> **Science Fact File**
>
> **To find an average**
>
> 1 Add all the measurements together to get a total.
> 2 Divide this total by the number of measurements taken.

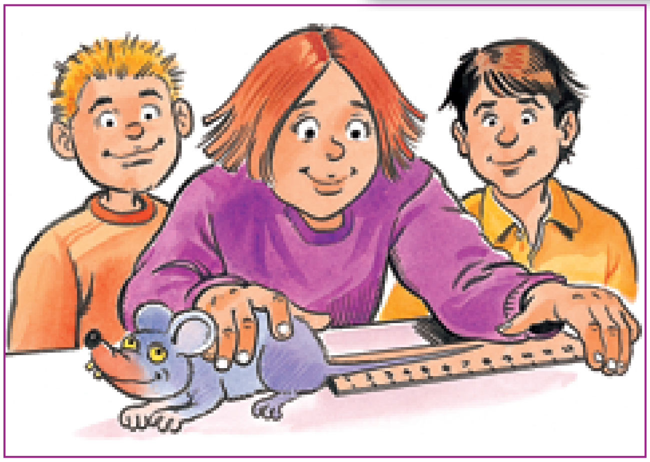


Fig 1.2.5 Everyone will get slightly different measurements.

Various members of a group measured the length of a mouse's tail and each got different results:

- Anna 8.1 cm
- Lee 8.4 cm
- Millai 8.5 cm
- Nicole 8.2 cm
- Steve 12.9 cm.

Steve's result is too far away from the rest of the results. It looks like he made a mistake, so his result should be ignored.

To obtain the most accurate measurement it is best to average the other four results; that is, add the four results:

$8.1 + 8.4 + 8.2 + 8.5 = 33.2$

and divide the total by the number of readings:

$33.2 \div 4 = 8.3$ cm

Prac 2 p. 16

Notice that no-one in the group actually took a measurement that was the same as the average.

A little give and take

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

The mouse tail measured earlier averaged 8.3 cm, even though no-one actually measured it as that. The mouse tail could be said to be between 8.1 and 8.5 cm. This could be written as 8.3 cm 'give or take' 0.2 centimetres, or 8.3 ± 0.2 cm.

Prac 3 p. 16

Prac 4 p. 17

Worksheet 1.2 Extreme units

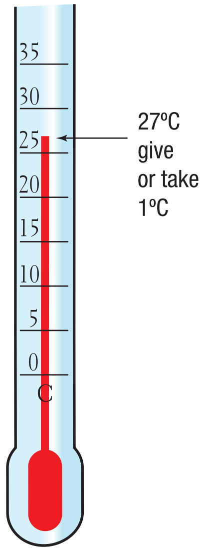


Fig 1.2.6 The exact temperature shown on this thermometer needs a little guesswork. Although it looks as if it should be about 27°C, it could be a little higher or lower, perhaps as much as 1°C. The measurement could be written as 27°C 'give or take' 1°C. Scientists write this as 27 ± 1°C.

PP Drag-and-drop

Science Clip

Chaos at play!

Have you ever noticed that professional tennis players are always 'on their toes' when they are about to receive a serve? The unstable nature of their footing seems to quicken their response, making them more likely to return the ball. Accurate measurements of heartbeats show that they are roughly the same, but are all slightly different. The slightly unstable beat helps keep our heart 'on its toes'. It can then respond to any sudden need for increased blood supply when we exercise. This is the scientific theory called chaos at work.

Science Clip

100 milliseconds away from death

Detailed studies by Saab have shown that a head-on collision of a car with a solid wall takes less than 100 milliseconds, or 0.1 second. How does this compare with your reaction time? If less, then the car accident is over before you can react to it! There is no chance of 'getting ready' or bracing to avoid injury—a good case for wearing seatbelts.

Science Clip

Measuring a sheep's fart!

Methane is a greenhouse gas that most believe contributes to enhanced global warming, causing our climate to change. It is also the main gas in burps and farts, and an average sheep releases about 25 L of it each day! How do scientists know this? CSIRO researchers have fitted sheep with a device that measures the gas released.

Fig 1.2.7 Sheep with their special methane-measuring devices.

1.2 QUESTIONS

Remembering

1 **State** whether the following are mistakes or errors:

a A 56.7°C reading on a thermometer when the actual temperature is 56.6°C.

b A reading of 12.3 mL of solution in a measuring cylinder, but 2 mL has already been spilt.

2 **State** whether the following statements are true or false:

a All measurements are exact.

b A mistake is an error.

c A measurement of 56 ± 2°C actually goes from 58°C to 56°C.

Understanding

3 **Define** the following terms:

a error

b mistake

c average

d parallax.

4 **Explain** why it is difficult to avoid errors.

5 **Outline** four different types of errors.

6 **Explain** why scientists try to avoid or minimise errors.

7 **Explain** why a measurement should be ignored if it is way out from all the other measurements of the same thing.

8 **Explain** why the following will always produce some error:

a using a metal ruler on a hot day

b a scale that reads 0.1 gram when nothing is on it.

c trying to measure the length of an ant with a ruler that only has centimetre markings.

9 **Predict** whether a measurement made with a metal ruler will be too high or too low on:

a a hot day

b a cold day.

10 Re-write these measurements by **modifying** them so that they use the symbol ±. Ⓝ

a 25.5 give or take 0.5°C

b The average measurement was 19 mm. The highest measurement was 23 mm and the lowest was 15 mm.

c 55 cm, 60 cm, 65 cm

d 94 mL, 74 mL, 84 mL.

Applying

11 From the following, **identify** the measurements that could be taken accurately:

a the number of kangaroos in Australia

b the number of kangaroos in the zoo

c the length of the science laboratory at school

d the number of cloudy days in the next month.

12 A group measured the temperature of some ice-water. Their temperatures ranged from 2°C to 4°C, but had an average of 3°C. **Identify** the best way of writing this measurement from the following options: Ⓝ

A 2 ± 4°C

B 3 ± 2°C

C 3 ± 4°C

D 3 ± 1°C.

13 **Calculate** the average of these values to obtain the most accurate measurement. Ⓝ

a 60, 70 and 50 km/h

b 39 mm, 38 mm, 40 mm, 41 mm

c 12.1, 12.9, 12.3, 12.7 and 12.5°C

d 45 mL, 47 mL, 46 mL, 58 mL (Be careful!)

14 **Identify** the types of errors shown in Figure 1.2.8.

Fig 1.2.8

Analysing

15 **Clarify** the difference between an error and a mistake.

16 **Classify** each of the following as either a mistake or an error:

- **a** Liz poured water from a measuring cylinder, but could not get every drop out.
- **b** Jon didn't bother cleaning the dirt off the beam balance he used.
- **c** Liana found it difficult to decide on measurements that fell between the markings on a tape measure.
- **d** The temperature of the room was 30°C and not its normal 25°C.
- **e** A tape measure was used to measure the length of a room, but the first 10 cm of the tape was missing without anyone noticing.
- **f** Tom measured the mass of a mouse as 126.1 grams and the rest of his group measured it as 126.2 grams.

17 Each member of a group measured the atmospheric pressure of the air in a laboratory. Their results were: Rhys 760 mmHg, Jen 870 mmHg, Sally 765 mmHg, Jacinta 758 mmHg.

- **a** **Name** the person whose result should be ignored.
- **b** **Explain** why it shouldn't be included in the average.
- **c** **Calculate** the average of the good results.
- **d** **State** the unit the group used to measure atmospheric pressure.

18 A group got this series of measurements of the amount of water in a measuring cylinder: 27 mL, 25 mL, 26 mL, 28 mL and 24 mL.

- **a** **Calculate** the average of these measurements.
- **b** **Calculate** what the maximum error is likely to be.
- **c** Write the average and error as *average ± error*.

Evaluating

19 Objects must be allowed to cool before the mass is measured using an electronic balance. **Propose** reasons why.

20 Police give accurate estimates of crowd numbers at sporting events.

- **a** **Propose** a way of determining the number of people in Figure 1.2.9 without counting every one.

Fig 1.2.9

- **b** **Use** your method to obtain an estimate.
- **c** **Use** your method to **estimate**:
  - **i** the number of grains of sand that would fit in a shoebox filled with sand
  - **ii** the number of leaves on a tree
  - **iii** the number of words and individual letters printed in this chapter
  - **iv** the number of threads of cotton in a T-shirt
  - **v** the number of hairs on your head.

21 In a group and using a ruler, **propose** a way of estimating:

- **a** the thickness of a single page in this textbook
- **b** the size of ex-Olympian swimmer Ian Thorpe's foot. (He wears size 18 shoes.)

22 **Use** Figure 1.2.10 to **propose** definitions for the terms *accuracy* and *precision*.

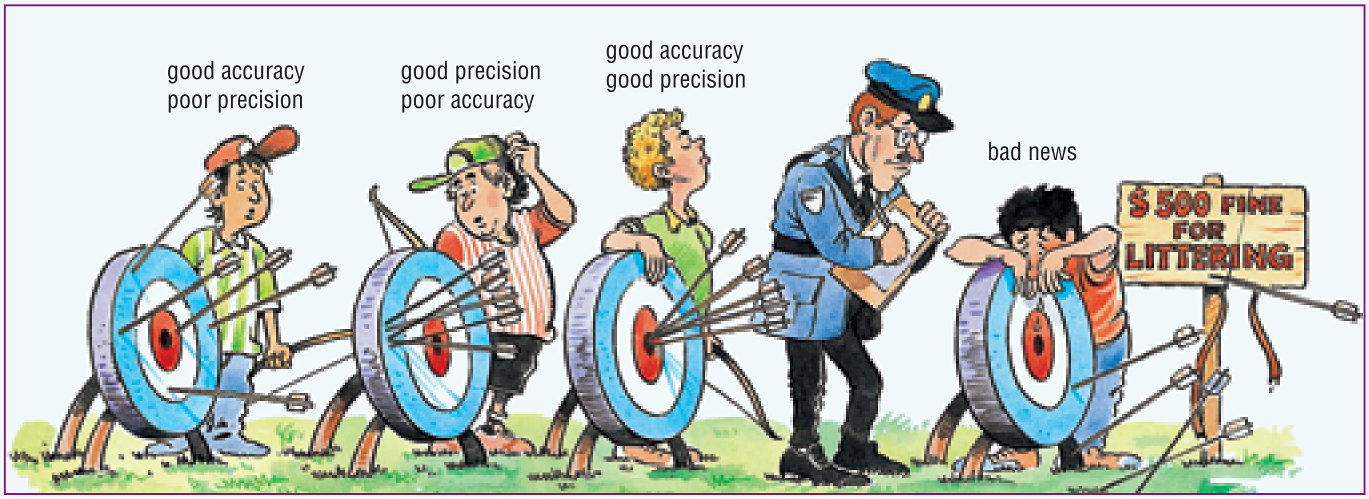


Fig 1.2.10

1.2 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Research information on other instruments that can measure small quantities very accurately. Find:
   - **a** other devices that are used to measure thicknesses and distances accurately
   - **b** how the world's most accurate clock works
   - **c** how very small quantities of chemical pollutants are measured
   - **d** how small signals from space are 'amplified' so that they can be measured.

2 Research the discovery of penicillin. Find:
   - **a** how it was found by accident
   - **b** who discovered it, when and how
   - **c** what it is used for and its importance to society.

3 Imagine that you are the person who discovered penicillin. Write a letter to the Royal Society of Medicine that outlines your discovery. L

e-xploring

PP Web Destination

Find tasks that test your reflexes by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Alternatively, use 'reflex tester' as Internet search words.

1.2 PRACTICAL ACTIVITIES

1 How quickly can you react?

Aim

To find your reaction time

Equipment

- ruler (for most people a 30 centimetre ruler will do)
- access to a calculator

Method

1 Hold a metre ruler vertically—the zero must be level with the top of your partner's hand (see Figure 1.2.11).
2 Without warning, let go of the ruler. Your partner must catch it as quickly as possible.
3 Note the reading of the ruler (in centimetres) level with the top of your partner's open hand.
4 Have two trial runs and then record the next three runs.
5 Calculate the reaction time by dividing the average ruler drop by 490. Now 'square root' (√) your answer. The final answer is the time in seconds that your partner took to react.
6 Repeat the experiment, but this time count down (i.e. 5-4-3-2-1) before dropping the ruler.
7 Try again, but this time get another student to distract your partner (e.g. by talking to them, tickling them etc.).

Questions

1 **Identify** the degree of accuracy of a normal stopwatch.
2 **Contrast** the reaction time with the accuracy of a stopwatch.
3 **Identify** factors that affected the reaction time in this experiment.
4 **Outline** factors that affect your reaction time in everyday life.

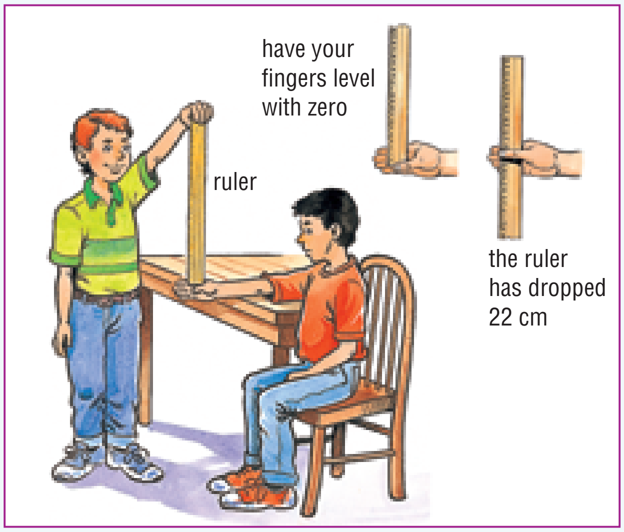


Fig 1.2.11

>>

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

2 Repeated measurements

Aim
To examine why taking a number of measurements is important

Equipment
- measuring tape
- thermometer
- stopwatch

Method
1 Measure each of the following as carefully as you can. Have each member of your group do the same.
- the length of the laboratory
- the temperature of tap water
- the number of heartbeats in a minute
- the time it takes for a pen to drop 2 metres to the floor.
- the time it takes for a flat piece of A4 paper to flutter from a height of 2 metres to the floor.

2 Calculate the average for each measurement.

3 Record this average with a ± error.

3 A useful tool: The micrometer

Aim
To use a device that can accurately measure the thickness of objects to within a fraction of a millimetre

Equipment
- micrometer
- various common school items

Method
1 To take a measurement, place the object in the opening of the micrometer and screw down the barrel until the knob starts to slip. Do not over-tighten; you don't want to squash the object.

2 There are two measurement scales—one on the **shaft** (in millimetres, just like a ruler) and another on the rotating **barrel** (usually numbered from 0 to 100). Read the millimetre measurement off the shaft of the micrometer.

Fig 1.2.12 A micrometer

3 Along the shaft is a line. Read off the barrel measurement where it meets the barrel—it will be a number between 0 and 100.

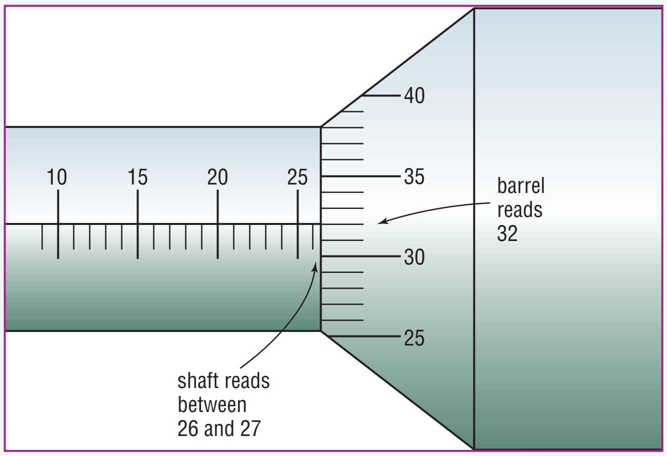


Fig 1.2.13 This micrometer reads 26.32 mm.

4 Use a micrometer to measure the:
- thickness of your little finger
- thickness of this textbook
- thickness of five sheets of paper
- diameter of the ball of a ballpoint pen
- thickness of a pencil
- thickness of a coin.

Questions

1 **Construct** a two- or three-frame cartoon that explains how to use a micrometer.

2 **Record** the measurement shown on each of the micrometer scales illustrated in Figure 1.2.14. N

3 **Compare** the use of a micrometer with the use of a ruler for the measurements in this experiment.

4 **Propose** a method in which a normal ruler could be used for the measurements in the experiment.

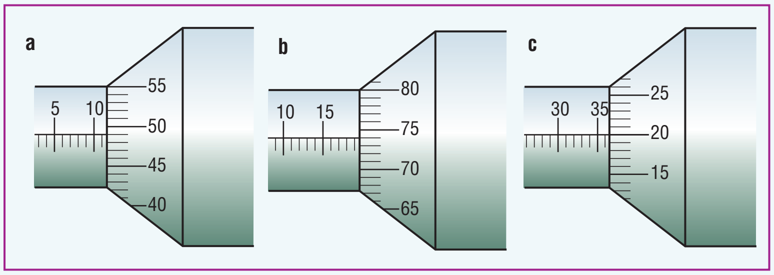


Fig 1.2.14

4 Does nature follow rules?

As a tree grows, does it follow any rules of nature? If a branch is twice as long, does this mean the base gets twice as thick?

Aim

To determine if there is a relationship between the length of a stick and its diameter

Equipment

- 1 metre ruler or tape measure
- micrometer
- permanent marker or chalk

Method

1 Collect a branch or long twig off a tree, preferably an old twig from the ground. The branch needs to be 80 cm to 1 m long, no more than 2 cm thick at its base and should not be broken off before its small end.

2 Strip the branch of any side twigs and leaves.

3 Use the permanent marker or chalk to make ten regularly spaced markings along the length of the branch. The spacing must be the same for each marking, so you should make them 8 to 10 cm apart.

4 Construct a table or spreadsheet like that shown below. You will need eleven lines.

5 Use the micrometer to measure the thickness of the branch at each marking (see Figure 1.2.15).

6 Have all partners in your group measure the diameters at each marking, too.

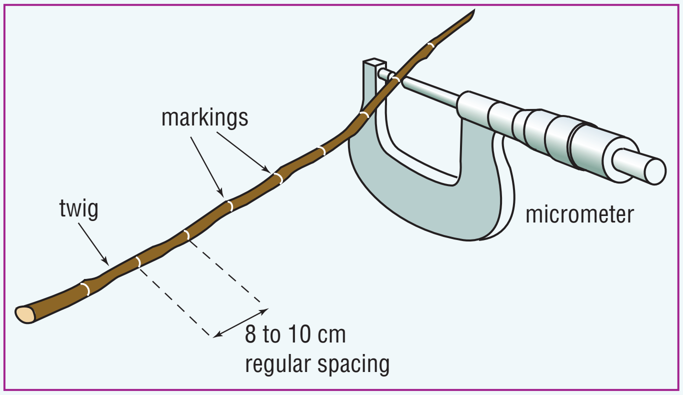


Fig 1.2.15

7 Cross out any measurements that are very different from the rest, and then calculate the average diameter for each marking.

Questions

1 **Identify** which set of measurements, 'Distance along the branch' or 'Diameter of the branch', you chose and controlled.

2 The controlled measurements should be placed on the horizontal axis of a graph. **Name** the measurement that should be on the horizontal axis.

3 **Construct** a line graph to show your results. Look for any pattern to your points and draw a smooth curve or straight line through the middle of them. If the graph is a logical curve or straight line, it suggests that nature does follow some rule of its own.

4 **Assess** whether there are any points on the graph that seemed not to follow the general pattern. If you find any, inspect the twig to see if there is some reason for it.

5 **Present** your work as an experimental report. Include all the normal features like aim, materials, method, results and conclusion.

Distance of marking (cm)	Diameter or thickness (mm)				Average diameter or thickness (mm)

Unit 1.3 Scientific conventions

context

Scientists follow conventions or 'rules' when they present their data, graphs and reports. This is so that other scientists know exactly what was observed, and how the information was interpreted. It also allows them to repeat the experiment if necessary. As a scientist, you should follow these conventions too.

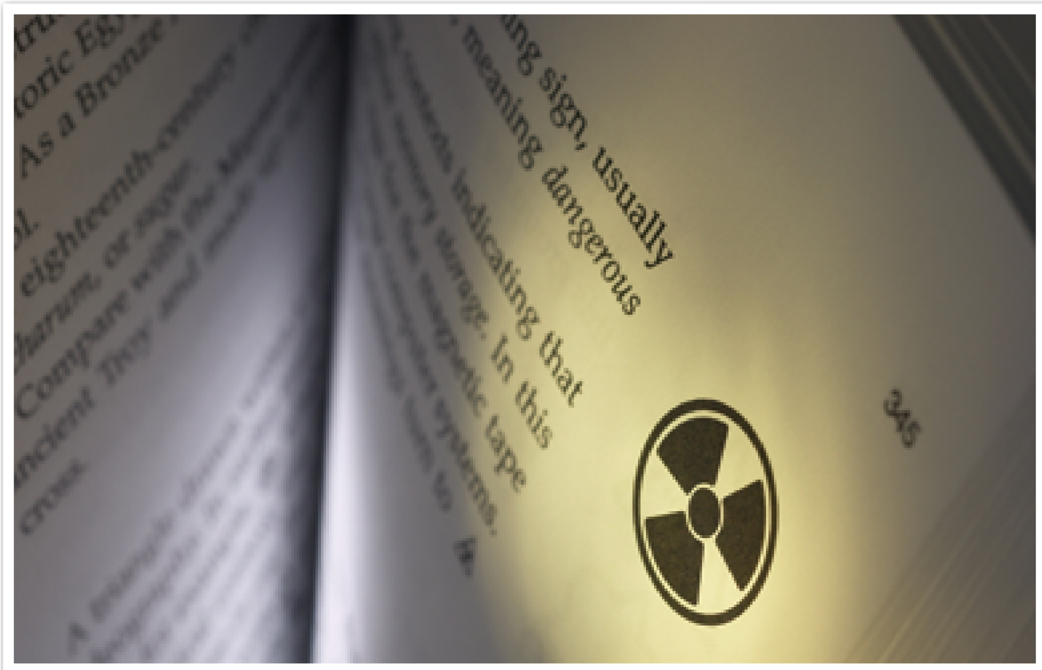


Fig 1.3.1 When scientists write their reports, textbooks and web pages, they must set their material out in a standard way so that other scientists can understand what is happening.

Writing practical reports

When you write a report you need to include the following:

- a **heading**, the date of the experimental work and a list of partners who assisted you
- your **aim**—a statement of what you intended to do or find out
- a **hypothesis** (optional)—your prediction or 'educated guess' about what you thought might be found out
- a list of **equipment** or **materials** used
- your **method**—an explanation of what was done in the experiment, including the quantities used. A diagram can be useful here, too
- your **results** and **observations**—a complete list of measurements and observations that were taken, preferably displayed in a table
- a **discussion** or **analysis**—in which you discuss what you think your results show. This also includes what you have found about the experiment from secondary sources. It could include graphs, ideas for further experiments, a description of problems encountered and what was done to overcome them
- a **conclusion**—a summary of what was found out in the experiment. It must be short and must relate to the aim.

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

Go to Science Focus 1, Unit 1.4

Organising results

Data is the word used for a lot of measurements or observations. Data are usually placed in a table (tabulated), sometimes as a computer spreadsheet or database. This makes any patterns that may exist more obvious. Headings and units should be at the top of each column.

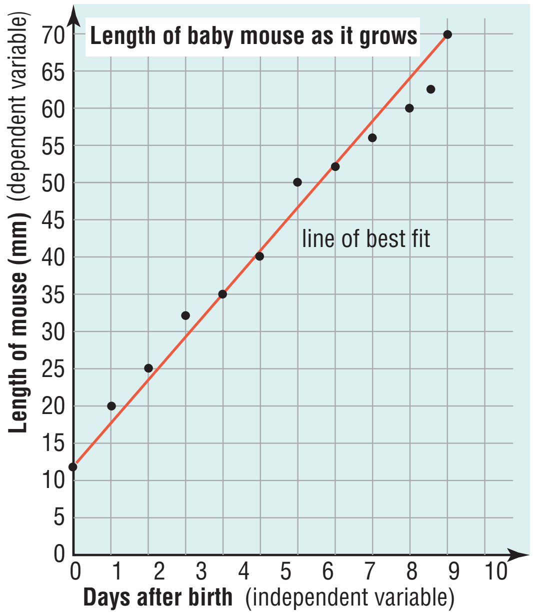


Fig 1.3.2 A line of best fit is not dot-to-dot, but shows the overall trend in the data. In this graph, the number of days after birth is the independent variable and the length of the mouse is the dependent variable.

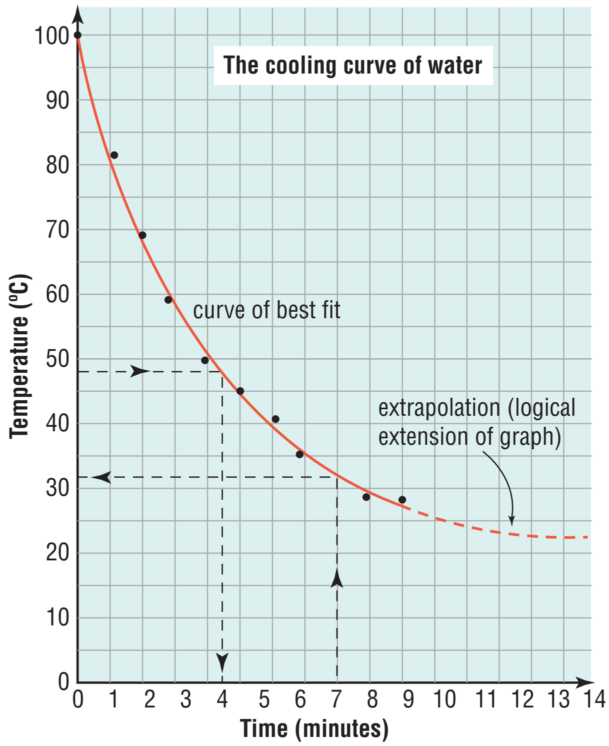


Fig 1.3.3 Line graphs can be used to predict missing values. For example, the temperature was 29°C at 8 minutes, and took 4.5 minutes to reach 48°C. What do you predict the temperature to be at 15 minutes?

Drawing line graphs

Patterns become even more obvious when data are plotted as a **line graph**. Line graphs can be used to predict patterns and measurements that were never actually taken in the experiment. Pie charts, bar graphs and histograms are useful, but cannot be used to predict missing measurements.

When drawing a line graph you must always include:

- a **heading**, explaining what the graph is about
- ruled vertical and horizontal **axes**
- **labels** and **units** on the axes
- regular markings for the scale along the axes
- all your points clearly marked on the graph itself.

The independent variable is placed on the horizontal axis. The **independent variable** is the variable you have chosen to change in your experiment. You decide how large it should be and by how much it should change.

The **dependent variable** is placed on the vertical axis. This is the variable that depends upon the independent variable and is measured throughout the experiment.

All experiments include errors, and 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** approximately through the 'centre' of your points: this is called the **line of best fit** or **curve of best fit**. Patterns and results can then be predicted. You can predict extra results by continuing the shape of the line or curve. This is called **extrapolation**. In Figure 1.3.3 the curve has been extrapolated to allow us to predict that the temperature after 14 minutes would be 22°C.

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Describing patterns

Graphs of straight lines or smooth 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 1.3.4.

Worksheet 1.3 Graphing skills

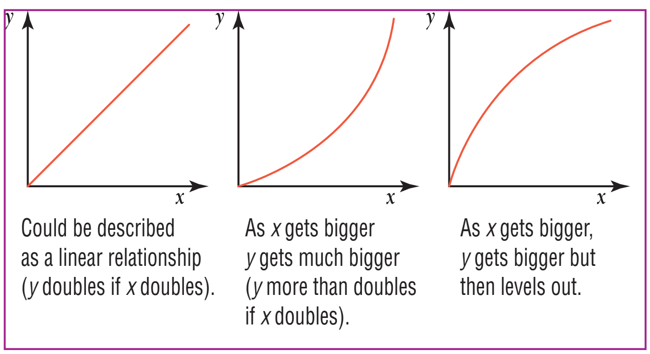

Fig 1.3.4 Graphs showing common relationships.

Using and converting metric units

Scientific measurements are based on the metric system. Length is measured in metres (m), mass in grams (g) and volume in litres (L). Other units, such as newtons (N) for weight and force, and joules (J) for energy, depend on these units.

Sometimes measurements are too big or too small to be measured sensibly with these units. Other units have been developed from them using a series of **prefixes**. The prefixes you have probably already met are centi, milli and kilo in units such as centimetre (or cm) (i.e. 100 are required to make up a metre), millilitre (or mL) (i.e. 1000 make up one litre) and kilogram (or kg) (equal to 1000 grams).

You have probably never heard of the other prefixes, although all of them are used for very small or very large quantities.

Prefix symbol	Name of prefix	Size	Decimal notation	Example
G	giga	one billion	1 000 000 000	GL
M	mega	one million	1 000 000	ML
d	deci	one-tenth	1/10 = 0.1	dL
μ	micro	one-millionth	1/1 000 000 = 0.000 001	μm
n	nano	one-billionth	1/1 000 000 000 = 0.000 000 001	nm

Worksheet 1.4 Body mass index

PP Drag-and-drop

1.3 QUESTIONS

Remembering

1 **List** seven main sections of a report and two optional sections.

2 **List** all the details that must be included on a graph.

3 **Name** two things that must go on the axes of a graph.

4 **State** the basic metric unit for:

- **a** length
- **b** time
- **c** volume
- **d** mass
- **e** force
- **f** energy.

Understanding

5 **Describe** what should be included in the following sections of a report:

- **a** aim
- **b** hypothesis
- **c** analysis
- **d** bibliography.

6 **Define** the following terms: L

- **a** convention
- **b** line of best fit
- **c** data
- **d** relationship
- **e** tabulated.

7 **Describe** two places where diagrams would be useful in a practical report.

Analysing

8 **a** Trace Figure 1.3.5 and connect the points to show any pattern that may exist.

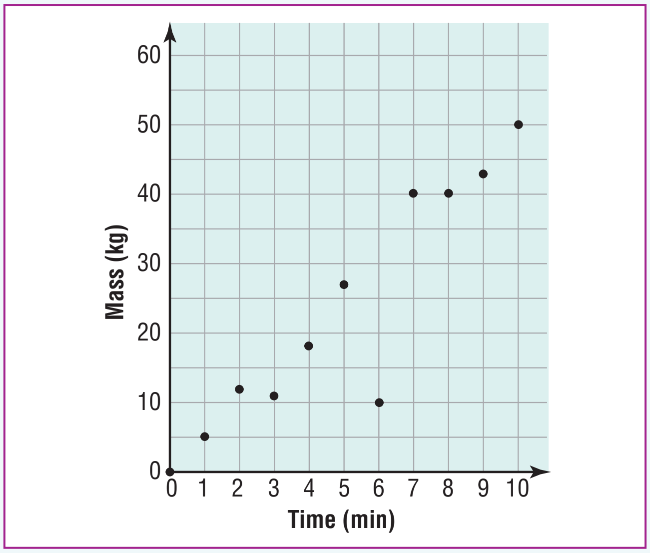

Fig 1.3.5

b **Identify** the point that was a probable mistake by circling it on your graph.

9 **Identify** five things that are wrong about Figure 1.3.6 and the way it is plotted.

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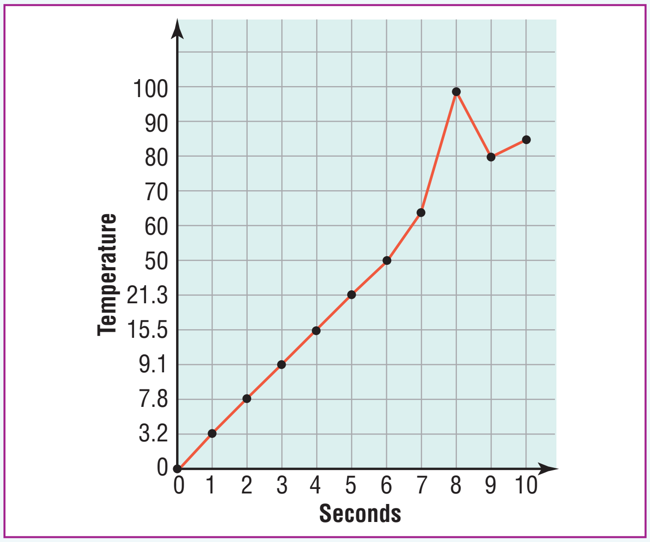


Fig 1.3.6

10 **Calculate** how many: N

a litres are in 5 ML

b litres are in 375 mL

c metres are in 500 000 mm

d metres are in 6 000 000 000 nm.

11 Metric prefixes are not usually used for time. **Calculate** how many seconds (s) would be in: N

a 1 kilosecond (i.e. 1 ks)

b 1 centiminute (i.e. 1 cmin)

c 1 kiloday (i.e. 1 kday)

d 1 megasecond (i.e. 1 Ms).

Evaluating

12 **Propose** a reason why scientists all around the world use the metric system for units.

Creating

13 Sam measured the times it took for a feather and a stone to fall from different heights so that she could compare them. She obtained the graph shown in Figure 1.3.7.

a **Propose** an aim for Sam's experiment.

b **Construct** a table of results for the experiment. N

c Use the graph to **identify** the drop time for the feather and stone from these heights: N

i 1.5 m

ii 2.5 m

iii 3500 mm.

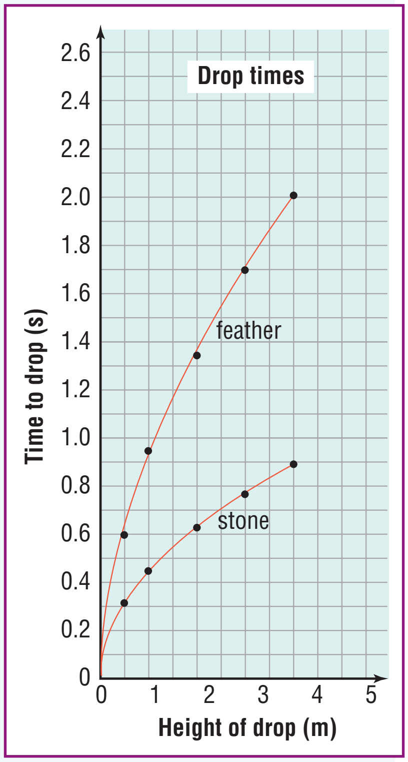


Fig 1.3.7 Sam's graph

d **Use** the graph to find the height from which the feather and the stone was dropped if it took these times for them to fall:

i 0.5 s **ii** 1.3 s **iii** 1.9 s. N

e **Use** the graph to find the values of the following measurements: N

i time taken to drop the feather 5 metres

ii time taken to drop the stone 5 metres

iii the position of the feather after 2.5 seconds.

f **Construct** a conclusion for the experiment.

1.3 INVESTIGATING

1 Ask your librarian about how to write a resource list (sometimes called a bibliography). Present your work as a resource list that includes the details for:

- this textbook
- an encyclopaedia
- a novel
- a website
- a newspaper
- a magazine.

2 **Investigate** your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

a Research:

- where, when and why the metric system was developed
- how the length of a metre was originally decided
- what a measurement 'standard' means. Give an example.

b Find out what metric units are used for measurements of:

- air pressure
- force
- energy
- electrical current
- electrical voltage.

c Find out where the following units are commonly used:

- megatonne (Mt)
- decibel (dB)
- gigabytes (Gb).

1.3 PRACTICAL ACTIVITIES

Science Fact File

The pendulum

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

The *period* of a pendulum is the time it takes to complete one entire swing, back and forth.

A grandfather clock has a pendulum that keeps the clock on time. Many machines have 'arms' and parts that also act like pendulums. Their timing is important and scientists must know what affects the period so that these machines and devices stay accurate.

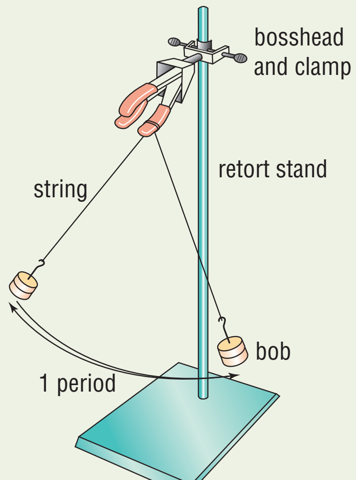


Fig 1.3.8

1 Testing the variable: Mass

Aim

To determine what effect mass has on the period of a pendulum

Equipment

- materials to construct a pendulum (see Figure 1.3.8)
- stopwatch or appropriate data-logging equipment
- clock or watch
- protractor (optional)

Method

1 Before you start you need to decide:
- what masses should be used (e.g. 50 gram masses, paper clips or metal washers?)
- what length your pendulum is to be
- what angle your pendulum needs to be swung from each time, and a method of making sure the angle is always the same.

2 Construct a results table or spreadsheet, as shown below.

Mass	Time for 10 swings (s)	Average time for 10 swings (s)	Period (s)
Mass #1			
Mass #2			
…			

3 Tie one mass on the end of the pendulum, measure the length of the string and draw the mass out to the angle you have decided on.

4 Let go and time ten swings

5 Write your results in the table, add another mass and repeat. Keep adding until you have tested five different masses.

6 Plot a graph of period versus mass, with mass on the horizontal axis (see Figure 1.3.9).

7 Draw a line or curve of best fit 'through' the centre of the points.

Questions

1 **List** the variables that were controlled in this experiment.

2 **Describe** how you made sure the angle was always the same.

3 **Explain** why ten periods were measured and not just one.

4 **State** whether the period changed as the mass changed. **Explain** any pattern.

5 **Identify** other variables that could affect the period. (Think about the bob and the string itself.)

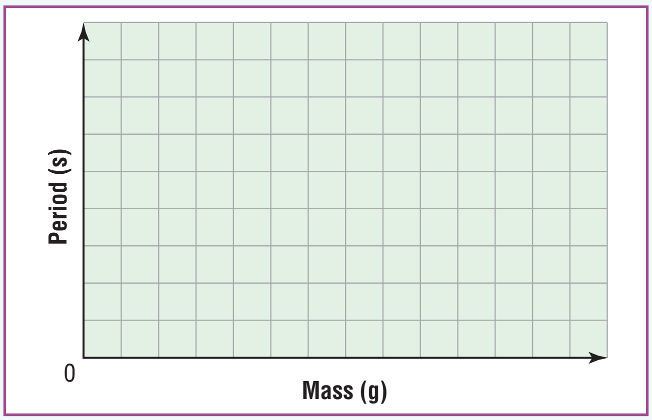


Fig 1.3.9 Use these axis markings.

2 Testing the variable: Length

Aim

To investigate if the length of a pendulum affects its period

Equipment

- materials to construct a pendulum
- stopwatch or appropriate data-logging equipment
- clock or watch
- protractor (optional)

Method

1. You need to keep constant the mass and the angle from which the pendulum is swung. Decide what values you will use.
2. Decide on the lengths that you will test. At least five different lengths should be tested.
3. You need to repeat measurements for the time taken for ten complete swings. Decide how many times you will repeat each experiment.
4. Construct a table or spreadsheet for the measurements you take.
5. Perform the experiment, recording the time taken.
6. Calculate the average time for ten swings and for one swing (i.e. the period). N
7. Plot a graph of period versus length. N

Extension N

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 this.

8. 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.
9. Plot a new graph of period versus square root length.

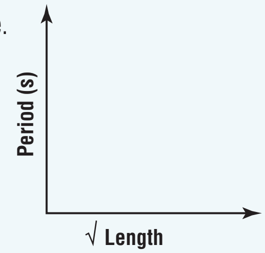


Fig 1.3.10

Questions

1. **Discuss** any precautions taken in the experiment to reduce errors.
2. **Identify** the controlled variables.
3. **Identify** the independent and dependent variables.
4. Use the shape of the curve obtained in the graph to **outline** any relationship evident between the dependent and independent variables.
5. **Draw** conclusions from the data obtained.

3 Testing the variable: Angle

Aim

To investigate the effect of angle on the period of a pendulum

Equipment

- materials to construct a pendulum
- stopwatch or appropriate data-logging equipment
- protractor

Method

1. Bigger angles could mean longer periods, shorter periods or no change in period. Construct your hypothesis about the effect of angle on period.
2. Design an experiment to test your hypothesis.
3. Construct a graph showing the relationship between period and angle of pendulum swing. N

Questions

1. **Explain** how you controlled variables that you did not want to test.
2. Does the shape of the graph support your hypothesis? **Justify** your answer.
3. **Propose** further questions that arise from this experiment.

Unit 1.4 Team research

context

Working together requires the sharing of ideas and resources and can lead to better results. For scientific research to be effective, team members need to understand their role in finding a solution to the question being investigated.

Fig 1.4.1 We are all very different. We are good at some things and not as good at others. When working as a team, the best of each person works towards a common goal and improves the final result.

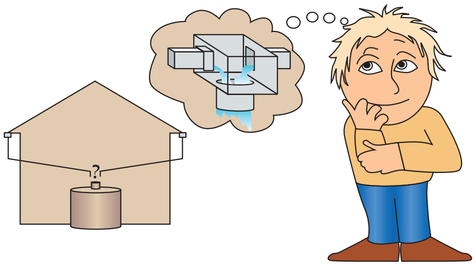
Team work

At school you will most likely work as part of a team. Everyone is good at something and most members in a team will bring with them certain skills. Some members of your team might be terrific at maths, whereas others will be good at IT. Some will be good speakers and others will have drawing and artistic skills that can be used when constructing a poster. Likewise, everyone has something that they hate or are bad at.

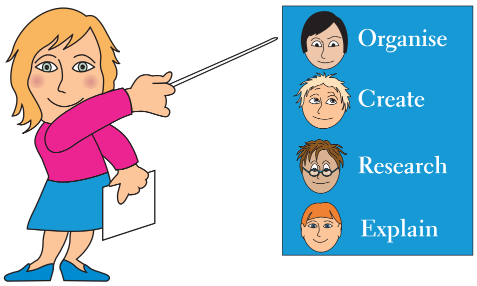
Team roles

It is pointless and confusing if everyone in your team tries to carry out every job in an investigation. It is better to assign different jobs to different team members so that you can use their individual strengths to solve the problem. As a group, you need to distinguish between team members, assess their skills and try and issue different jobs to each team member. We are all different, but by working as a team, these special skills are shared with other team members, making the whole team stronger.

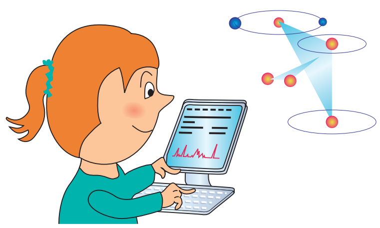
Team roles can be classified into six different types. As your team might have only a couple of people, each member might need to carry out more than one role.



Explorers/Creators: look for better ways to do things. They are always thinking about how to improve or change things. This means that they are often thinking one or more steps ahead of where the research is at that very moment. They use their imagination to create new ideas. They often solve difficult problems and invent things in unusual ways. Because a creator looks at the big picture, they may miss some of the detail. The organiser (described below) needs to work closely with the creator to catch these missed details.

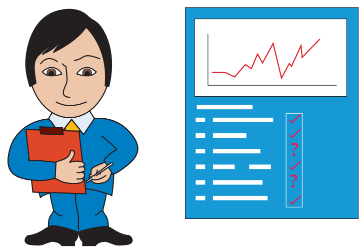


Leaders: keep the team together and working productively and cooperatively. They match tasks to suitable people and make sure the job is started and completed. A leader should set clear goals that can be achieved, and motivate people to keep going. They should monitor progress and keep track of timelines.



Scientists: provide explanations on how things work. They like to experiment and try different ideas. They are good at analysing and making models to explain things.

Researchers: provide information from many sources. They enjoy the hunt for new ideas and learning about new things and are often good communicators. The researcher must work closely with the scientist.



Organisers: like organisation and planning. They maintain an accurate record of all experimental data, the successes and the failures. The organiser identifies the correct procedures and tries to keep all others working towards the goal.

Fig 1.4.2 Team roles

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p. 27

Team skills

By working as a group you will develop important **skills**, including:

- using creativity and logical reasoning to solve questions
- constructing and testing a hypothesis
- applying scientific processes when testing your ideas
- deciding on the role of each team member
- working safely as a team
- maintaining a project results workbook, outlining the investigation and results collected
- evaluating how well the team worked together
- evaluating the team's contribution to solving the problem.

Choosing an investigation

When deciding on a topic to investigate, your team will need to make sure that:

- it can be solved experimentally
- it is safe and does not pose a danger to people or the environment
- you can get the required materials
- it can be finished on time.

The scientific question your team decides on should be **open-ended**. This means that it cannot be answered with a simple answer because there are many possible solutions. A good research project is one that is open-ended.

Some examples of open-ended questions are listed below.

- Does exercise affect heart rate?
- Does reaction time increase with age?
- Is the performance of batteries affected by the age of battery?
- Is the life of batteries related to their brand?
- Do some nuts contain more energy than others?
- How can you protect a raw egg from breaking when it is dropped from a height of 5 metres?
- Does the amount of sugar dissolved in water increase in different temperatures?
- What is the strength of a lolly snake?

Worksheet 1.5 Working in teams

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Fig 1.4.3 Scientists generally do not work alone. They are involved as part of a team, all working on the same problem.

Science Clip

Did scientists create AIDS?

A virus called SIV has always infected the monkeys of Africa, but they never became ill from it. Most scientists believe SIV sprang from monkey to human from a scratch or from eating infected monkey meat. The SIV then mutated to become HIV, the virus that causes AIDS. Some think, however, that infected monkey kidneys were used in the development of a polio vaccine called CHAT. Polio was devastating the world in the 1950s and the experimental CHAT vaccine was given to thousands of people in Africa between 1957 and 1960. The first outbreaks of AIDS were in the same region that the vaccine was given, the first death being in 1959. Did the CHAT vaccine cause the AIDS outbreak? Did scientists take enough care in their research? As scientists we have a responsibility to take extreme care in everything we do.

1.4 QUESTIONS

Remembering

1 **Specify** the roles of members of a team.

2 **State** the special skills that each role member in a team is required to have.

3 **Name** three everyday occupations that rely on teamwork.

Understanding

4 **Explain** what a team would look like if everyone had the same role.

5 **Explain** what an open-ended investigation is.

6 *A soccer team will never win a game if they don't play as one.* **Explain** this statement.

Analysing

7 You and a group of three friends arrive home after a large storm and notice that the television set isn't working. There is a puddle of water on top of it and another underneath it. Your friend John asks you if you thought the storm may have caused the television to not work. You realise that you need to work as a team to find a solution.

a **Summarise** your observations.

b Assign different roles to your friends to find a solution.

c **Outline** how you work together to find a solution to the problem.

Creating

8 In groups of five, **construct** an 'open-ended question' and use one of the following to try and determine the solution:

a practical experiment

b research investigation

c open discussion.

In your answer, **define** the roles of the team members and what they are trying to achieve.

1.4 INVESTIGATING

Choose one of the occupations listed opposite. **Investigate** your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to research what areas of science a person would need to know to work effectively and safely in that occupation. Present your findings as a pamphlet to be displayed in the careers information centre at your school. Ⓛ

- architect
- industrial chemist
- optometrist
- firefighter
- car mechanic
- structural engineer
- nurse
- racing car driver
- pilot
- physiotherapist

1.4 PRACTICAL ACTIVITIES

1 Why do cooks add salt to water?

Teams: researcher, scientist, leader, creator.

Before you begin this experiment, you need to allocate the four different roles to your team members. What questions are they going to try and find solutions to? What is each team member going to do to achieve the aim of the experiment?

Aim

To determine if salt affects the boiling temperature of water

Equipment

- three 100 mL beakers
- 100 mL measuring cylinder
- Bunsen burner
- bench mat
- tripod
- retort stand
- bossheads and clamps
- gauze mat
- thermometer or appropriate data-logging equipment
- timer
- table salt
- beam balance or electronic scale

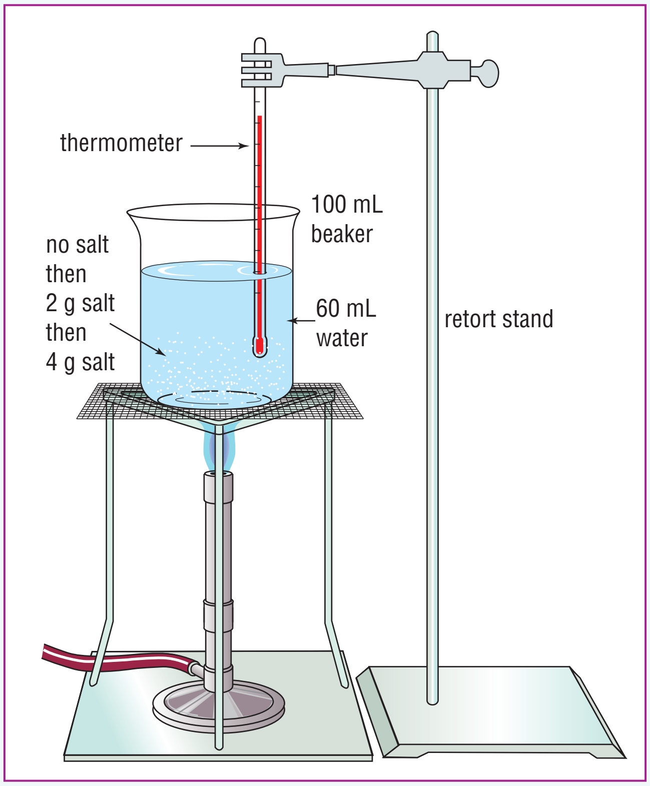


Fig 1.4.4

>>

Method

1 Set up the Bunsen burner with a beaker containing 60 mL of water (see Figure 1.4.4).
2 Heat the water and record the temperature every 30 seconds until the water boils.
3 Add 2 grams of salt to another 60 mL of water and repeat the experiment with the same Bunsen flame.
4 Repeat with 4 grams of salt.
5 Record your results in a table or spreadsheet, as shown below.

	Temperature (°C)		
Time (s)	No salt	2 g salt	4 g salt
0			
30			
60			

Questions

1 Were the observations made qualitative or quantitative? **Justify** your answer.
2 Based on your observations, did working in a team help you achieve the required results? **Justify** your answer.
3 Based on your observations, **deduce** why cooks add salt to water.

Extension

4 **Construct** a line graph for the temperatures recorded without any salt. On the same graph plot heating curves for the beaker with 2 grams and 4 grams of salt added. N

2 Team research project

DYO

In a group, **design** your own set of experiments that will investigate one of the topics listed. You will need to:

- decide who in your group will do what roles
- identify any variables that might affect the investigation
- identify variables that you think will have the most effect
- design experiments that will test those variables
- change only one variable at a time
- prepare equipment lists
- keep accurate results
- carefully analyse your results.

Present your work as a set of experimental reports. Include all the normal features, such as aim, materials, method, results and conclusion.

Possible investigations

- What influences the time a balloon stays in the air when it is inflated and let go?
- What material is the best thermal insulator?
- Sausages contain fat. Which type contains the most?
- Soft drink contains dissolved gas. Which has the most?
- What influences the amount of sugar or salt that is able to dissolve in water?
- What variables influence the time it takes for bread to go mouldy?
- Fruit contains a lot of water. Which fruit contains the most per serving or per 100 grams?
- What colour absorbs heat the most?
- What affects the growth of a plant seedling?
- What changes the time it takes for four sheets of newspaper to burn?
- What affects the absorbency of a paper towel?
- What factors affect the strength of a strip of sticky tape?
- A thin piece of wood bends when weights are added. What influences the size of its bend?
- Exercise, stress and diet all increase heart rate. What influences heart rate?

CHAPTER REVIEW

Remembering

1 **List** the different roles of team members undertaking a research task in a laboratory.

2 In order, **list** the features normally included in an experimental report.

Understanding

3 Draw diagrams to **explain** the following types of errors:

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

4 Use an example to **distinguish** a dependent from an independent variable.

5 Use an example to **explain** how human reflex can add errors to an experiment.

6 **Explain** why it is important to work in a team rather than alone in answering open-ended questions.

Analysing

7 **Contrast** the work of scientists with that of other workers.

8 **Contrast** each of the following terms:

- **a** an experiment and research
- **b** an aim and a hypothesis
- **c** an error and a mistake.

9 Sarah wrote the length of an insect as 2.1 ± 0.1 cm. **State** the biggest and the smallest length of the insect.

10 **Record** the following measurements correctly, showing the errors. N

- **a** The time a stone took to drop to the ground was measured by Kim as 2.5 seconds, give or take half a second.
- **b** Jess measured the temperature at which salt water boiled as somewhere between 102°C and 108°C.

11 **Calculate** the average value for the following measurements: N

- **a** 87 mL, 90 mL, 86 mL and 93 mL
- **b** 115 g, 123 g and 125 g.

Evaluating

12 **Propose** a reason for all scientists using the same units for their measurements.

13 **Recommend** appropriate metric units for the following measurements:

- **a** the length of a sugar ant
- **b** the amount of water in Botany Bay
- **c** the distance from here to the next galaxy.

Creating

14 **Design** a controlled experiment that would test the hypothesis that adding salt to water causes an increase in the boiling point of water.

15 Copy Figure 1.5.1 into your workbook and:

- **a** **identify** the independent variable
- **b** **identify** the variable that changed naturally
- **c** **identify** what is missing from the axes
- **d** **construct** a table of results for the experiment N
- **e** **construct** a line or curve of best fit through the data N
- **f** **predict** the sound intensities for the following distances: N
  - **i** 1.5 m
  - **ii** 2.8 m
  - **iii** 350 cm
  - **iv** 6000 mm
  - **v** 0 m
- **g** **predict** the distances for the following sound intensities: N
  - **i** 45
  - **ii** 32
  - **iii** 20
  - **iv** 55

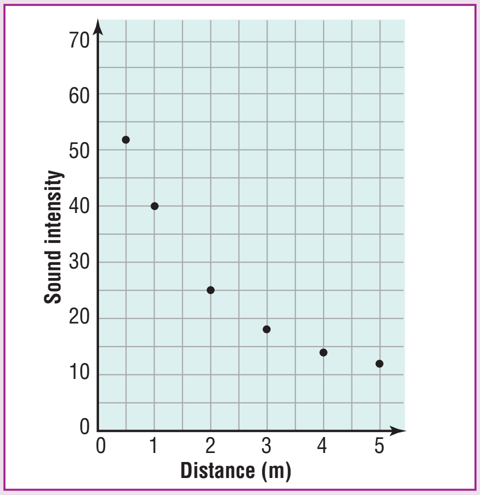


Fig 1.5.1

Worksheet 1.6 Crossword

Worksheet 1.7 Sci-words

PP Chapter Review Questions

2 Atoms

Prescribed focus areas:

The history of science
The nature and practice of science

Key outcomes

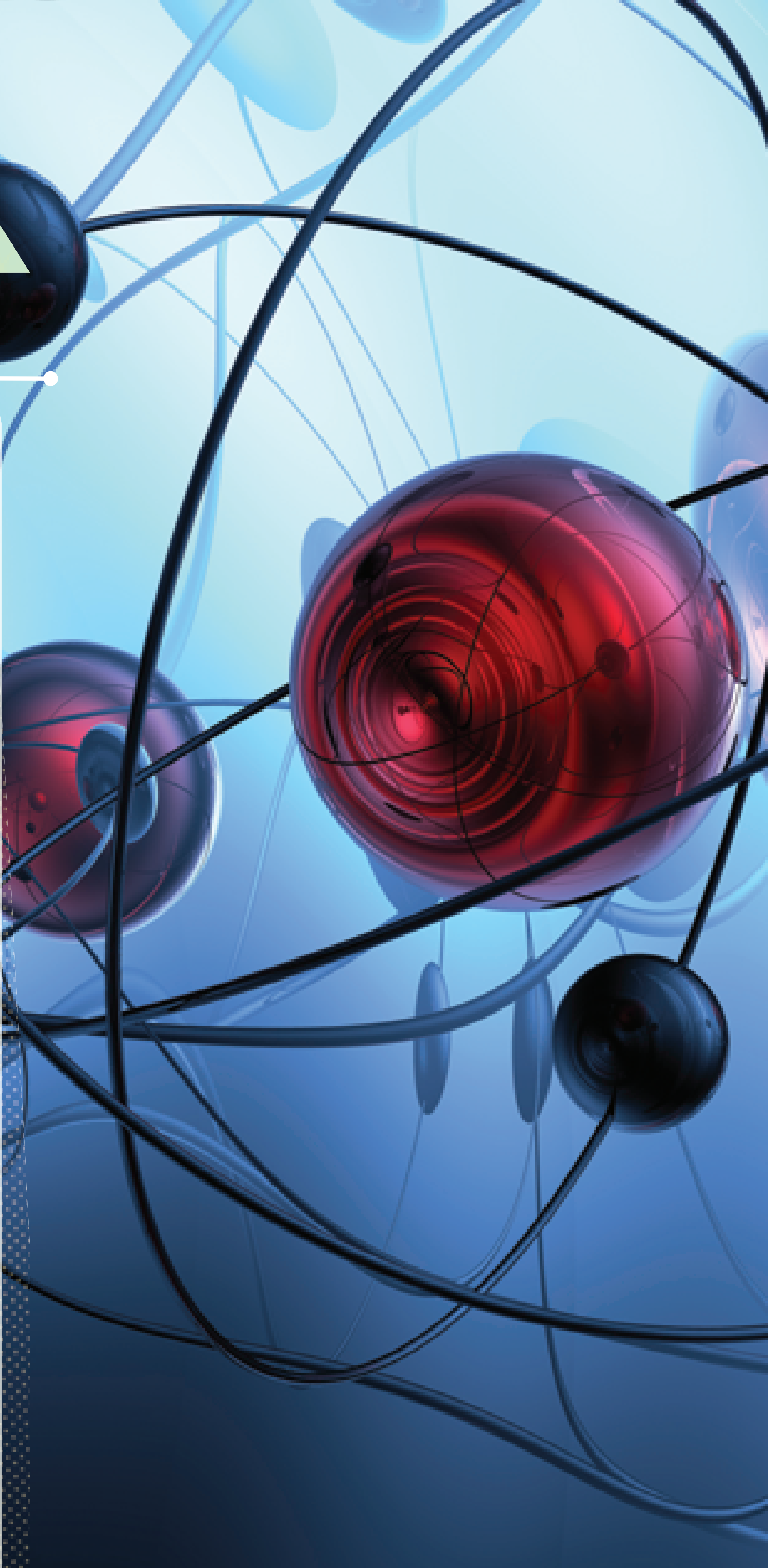
4.1, 4.2, 4.7.4, 4.7.5, 4.7.6

Essentials

- Our understanding of matter has changed over time and has brought about new scientific developments and technologies.
- Elements can be classified as either metals or non-metals, according to their common characteristics
- Elements can be identified by internationally recognised symbols.
- Elements are pure substances that cannot be broken down into simpler substances.
- Compounds are made up of different elements bonded together.
- Mixtures are a combination of different elements or compounds not bonded together.
- Chemical change is accompanied by a permanent change of colour, a change in temperature, the appearance of a new substance or the disappearance of one of the original substances.

Additional

- Models provide a simplified view of something in order to help understand how it works.
- Mass is conserved in physical and chemical changes.
- The physical and chemical properties of substances are determined largely by how the atoms are bonded together.
- Different atomic models have been proposed through history.



Unit 2.1 Elements, compounds and mixtures

context Look around and you'll see literally thousands of different substances, plastics, metals, skin, glass, fabrics, dust and much more. However, these thousands of different substances can all be made from just 100 or so different building blocks called elements. These elements make up the planets and the stars and every substance that you see, breathe, smell and taste.

PP Quick Quiz

Fig 2.1.1 Aluminium is an element that is used to store sound and video images on CDs and DVDs. Polycarbonate plastic is a compound that makes their surfaces relatively scratch-free.

Elements

Elements are substances that cannot be broken down into simpler substances. Iron, copper, gold, nitrogen, helium and chlorine are just a few examples of elements. Most substances you see around you, however, are not elements. Plastics, paper and sugar, for example, can all be broken down into the elements carbon, oxygen and hydrogen. Burn a piece of paper and you are left with black ash, which is carbon. Carbon is an element—it cannot be broken down any further.

There are 92 naturally occurring elements. Gold, silver, copper, carbon and a few other elements can be found in their pure forms in nature. It makes sense then that these were the first elements to be discovered and the ones known in ancient times. These naturally occurring, pure elements are known as **native elements**.

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Most of the other elements are not found naturally in their pure form but are chemically combined with other elements. Although oxygen is the most abundant element on Earth (making up about 47% of the planet), it is commonly found combined with the element hydrogen (forming water) or silicon (forming silicon dioxide or sand). Silicon is the second most abundant element on Earth (28%), most of it being combined with oxygen. Aluminium (8%) and then iron (5%) follow, which once again, are mostly chemically combined with oxygen.

The discovery of all but the native elements had to wait until technology developed ways to release and extract them. As these techniques became more sophisticated, more and more elements were discovered. Scientists have now identified 92 naturally occurring elements, and have developed techniques to produce another 25 synthetic or artificial (and highly radioactive) elements in laboratories.

Science Clip

Pee for phosphorus!

In medieval times, people known as alchemists worked on potions and spells. They attempted to find the legendary 'philosopher's stone' that would turn base metals, such as lead, into gold. A German alchemist, Henry (or Hennig) Brand (1630–1710) thought that urine could contain gold since both were yellow. In 1673, he stored fifty buckets of human urine for many months in his cellar, and then worked on the urine until it became smelly, sticky goo and then a waxy paste. The paste glowed in the dark and sometimes burst into flame! He had accidentally discovered the element phosphorus (nowadays given the symbol P).

Fig 2.1.2 Hennig/Henry Brand found phosphorus in a brew of urine!

Element names and symbols

Each element has a unique **symbol** made up of one or two letters that is used to refer to the element quickly and easily rather than writing out the name in full. For example, carbon is given the symbol C, chlorine is given Cl, cobalt is Co and calcium Ca. To ensure that all scientists use the same symbol for the same element, symbols are written in a very specific way.

The first letter of a symbol is always a capital. If there is a second letter in the symbol, it is always written in lower case. Using this convention, calcium is always given the symbol Ca, never ca or CA. Likewise, helium is He and not he or HE.

Sometimes, the symbol for an element does not seem to correspond to its name. This is because the symbols have come from their Latin names and not from their English names. Some examples are:

- The symbol for copper (Cu) comes from its Latin name *cuprium*.
- Potassium symbol (K) comes from the Latin word *kalium*.
- Gold symbol (Au) comes from its Latin name *aurum*.

Science Clip

Easier in another language

Although the symbols of some of the elements don't make much sense in English, they often make more sense in other Latin-based languages. For example, the French word for silver (Ag) is *argent*, and in Italian it is *argento*. Likewise, iron (Fe) is *fer* in French and *ferro* in Italian and Portuguese.

Worksheet 2.1 The elements

Metallic and non-metallic elements

Although each element is unique, they can share certain characteristics or **properties**. These properties are either chemical or physical:

- The chemical properties of an element are how the element reacts when exposed to different chemicals. For example, when bicarbonate of soda is mixed with vinegar it produces lots of bubbles, but when it is mixed with water nothing happens.
- The physical properties of an element are how the elements act when put under pressure, are exposed to light or whether they conduct electricity or not. Their melting and boiling points are physical properties, as is their appearance and hardness—anything non-chemical can be considered to be a physical property.

By studying the chemical and physical properties of the elements, scientists have classified them as **metals** or **non-metals**. Of the 118 known elements, 94 are metals and 23 are non-metals.

Science Clip

Synthetic elements

Synthetic elements can be made by colliding two naturally occurring atoms together. This requires huge amounts of energy, so these elements can be made only inside nuclear reactors or particle accelerators. However, as the synthetic elements get bigger they become extremely unstable, and so may exist for only a short time. Atoms of the biggest synthetic nucleus, called ununoctium, exist for less than one-thousandth of a second.

Fig 2.1.3 Particle accelerators are used to create synthetic elements. They use strong magnets and electric fields to accelerate atoms to extremely high speeds before making them collide. To reach such high speeds, the particle accelerators must be very large. The largest in the world, the Large Hadron Collider, is 27 km in circumference.

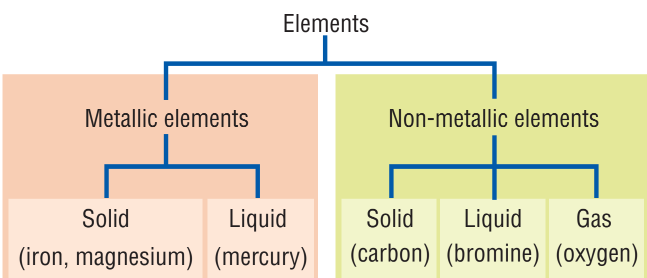
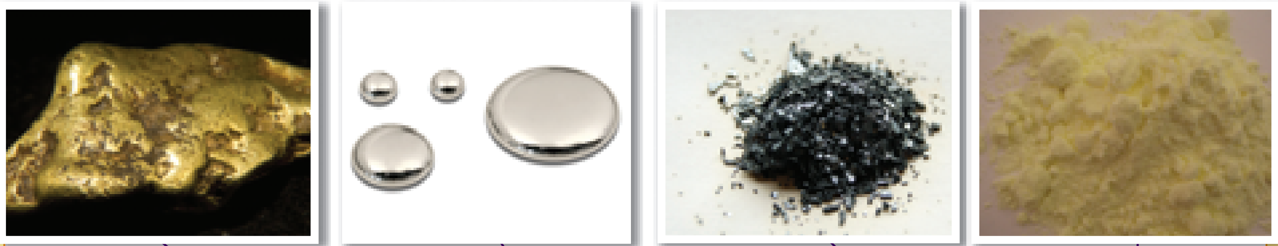


Fig 2.1.4 Metals and non-metals are classified according to their properties.



I	II											III	IV	V	VI	VII	VIII
H hydrogen 1																	He helium 2
Li lithium 3	Be beryllium 4											B boron 5	C carbon 6	N nitrogen 7	O oxygen 8	F fluorine 9	Ne neon 10
Na sodium 11	Mg magnesium 12											Al aluminium 13	Si silicon 14	P phosphorus 15	S sulfur 16	Cl chlorine 17	Ar argon 18
K potassium 19	Ca calcium 20	Sc scandium 21	Ti titanium 22	V vanadium 23	Cr chromium 24	Mn manganese 25	Fe iron 26	Co cobalt 27	Ni nickel 28	Cu copper 29	Zn zinc 30	Ga gallium 31	Ge germanium 32	As arsenic 33	Se selenium 34	Br bromine 35	Kr krypton 36
Rb rubidium 37	Sr strontium 38	Y yttrium 39	Zr zirconium 40	Nb niobium 41	Mo molybdenum 42	Tc technetium 43	Ru ruthenium 44	Rh rhodium 45	Pd palladium 46	Ag silver 47	Cd cadmium 48	In indium 49	Sn tin 50	Sb antimony 51	Te tellurium 52	I iodine 53	Xe xenon 54
Cs cesium 55	Ba barium 56	La* lanthanum 57	Hf hafnium 72	Ta tantalum 73	W tungsten 74	Re rhenium 75	Os osmium 76	Ir iridium 77	Pt platinum 78	Au gold 79	Hg mercury 80	Tl thallium 81	Pb lead 82	Bi bismuth 83	Po polonium 84	At astatine 85	Rn radon 86
Fr francium 87	Ra radium 88	Ac** actinium 89	Rf rutherfordium 104	Db dubnium 105	Sg seaborgium 106	Bh bohrium 107	Hs hassium 108	Mt meitnerium 109	Ds darmstadtium 110	Rg roentgenium 111	Cp copernicium 112	Uut ununtrium 113	Uuq ununquadium 114	Uup ununpentium 115	Uuh ununhexium 116	Uus ununseptium 117	Uuo ununoctium 118

*Lanthanides 58–71	Ce cerium 58	Pr praseodymium 59	Nd neodymium 60	Pm promethium 61	Sm samarium 62	Eu europium 63	Gd gadolinium 64	Tb terbium 65	Dy dysprosium 66	Ho holmium 67	Er ersium 68	Tm thulium 69	Yb ytterbium 70	Lu lutetium 71
**Actinides 90–103	Th thorium 90	Pa protactinium 91	U uranium 92	Np neptunium 93	Pu plutonium 94	Am americium 95	Cm curium 96	Bk berkelium 97	Cf californium 98	Es einsteinium 99	Fm fermium 100	Md mendelevium 101	No nobelium 102	Lr lawrencium 103

Fig 2.1.5 The periodic table shows all of the known elements and their symbols.

PP Drag-and-drop

Physical properties of metals and non-metals

Metals

Almost all metallic elements are solid at room temperature (25°C). Mercury is the only exception because it exists as a liquid at room temperature.

The physical properties of metallic elements make them very useful. Their ability to conduct heat makes them ideal for use in the kitchen, and their electrical conductivity makes them perfect for electrical wires and circuits. They are malleable and so can be formed into pipes and bent into shape to cover the bodies of cars and aircraft and for the hulls of ships.

Fig 2.1.6 The ability of metals to be shaped and moulded, while at the same time being very hard and strong, makes them very useful for a range of objects.

Properties	Metals	Non-metals
Physical state	Solid (except mercury)	Solid liquid or gas
Appearance	Shiny	Dull
Melting point	High	Low
Density	High	Low
Malleability (i.e. ability to be shaped)	Malleable	Brittle (i.e. easily broken)
Ductility (i.e. ability to be stretched into wires)	Ductile	Not ductile
Conductivity of electricity and heat	Good	Poor

Non-metals

Non-metallic elements can be solids, liquids or gases at room temperature. The air you breathe is mainly made up of two very important non-metallic elements—nitrogen (78%) and oxygen (21%). Bromine is the only non-metallic element that is liquid at room temperature, and solid non-metals include carbon, sulfur and phosphorus.

Non-metals provide very good insulators for heat and electricity. Most importantly, non-metals can be used to make a huge number of different substances with different properties, such as water, plastics, paper and cloth. Indeed, your body is almost entirely made up of non-metallic elements.

Fig 2.1.7 Sulfur displays all the typical properties of a non-metal. It is used for making sulfuric acid and fertilisers, it has antibacterial and antifungal properties and its compounds are used to preserve food.

Atoms

Elements are made up of incredibly tiny particles called **atoms**. Atoms are so tiny that they are invisible to the naked eye and to a normal light microscope. They can be seen only using a highly sophisticated piece of equipment called a **scanning tunnelling microscope**.

Atoms are the smallest pieces of a substance. The simplest way to think of them is to imagine them to be tiny marbles. These 'marbles' are the building blocks that form the elements, which in turn are the building blocks that make up all matter.

Each element is made up of just one type of atom. For example, a nugget of gold (Au) is made up of individual gold atoms clumped together. In other words, an atom is the smallest piece of a substance. There are 118 different types of atoms and so there can be only 118 different elements.

Science Clip

Fire, earth, air and water

Even in ancient times, the Greek philosophers believed that everything in the universe was made up of small indivisible particles. In fact, the word 'atom' comes from the Greek word *atomos*, meaning 'that which cannot be divided'. However, the Greeks also believed that all matter was made up of just four elements—fire, earth, air and water.

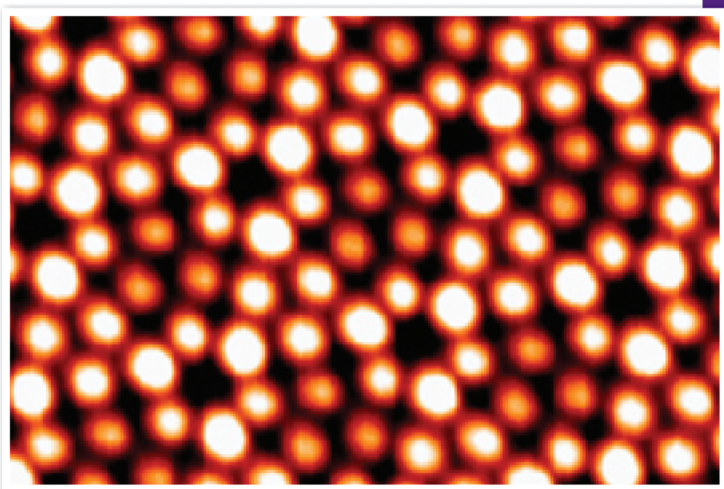


Fig 2.1.8 The only way to see atoms is by using a special piece of equipment called a scanning tunnelling microscope (STM). Individual silicon atoms are distinguishable in this STM micrograph of a silicon surface.

Compounds

Although there are only 118 different types of atoms and 118 different elements, there are millions of different substances that can be made from them. This is because the 118 different types of atoms can be combined in many different ways and in different numbers. Carbon, hydrogen and oxygen atoms, for example, can be combined in different proportions to make vinegar, alcohol, plastics, methane gas, carbon dioxide and food flavourings called esters. The different combinations that atoms can form are known as **compounds**.

Our bodies are made up of only 16 different elements, but these 16 elements form hundreds of different compounds. The Earth's crust contains hundreds of different compounds, as do trees, and the many human-made or synthetic materials, such as medicines and plastics.

Compounds usually have quite different properties (e.g. colour, texture, smell and density) than the elements whose atoms they contain. For example, although the compound water (H_2O) is a liquid at room temperature, it contains atoms of the elements hydrogen (H) and oxygen (O). These elements exist in air as colourless gases, which is quite different from water! Likewise, sodium is an explosive metal and chlorine is a poisonous gas, but these elements combine to form sodium chloride (NaCl), a solid that you safely sprinkle on food.

Worksheet 2.2 Body elements

Prac 2 p. 42

Prac 3 p. 43

Science Clip

Body elements

Most of your body is made from the elements oxygen (65%), carbon (18%) and hydrogen (10%).Thirteen other elements are there too, but in much smaller amounts. These 16 elements combine to form the hundreds of different compounds in you. When they die, many people are cremated. Although most elements go up in smoke, the carbon stays behind as ash. Diamonds are 100 per cent carbon, and a company in the United States, LifeGem Memorials, is converting human ashes into diamonds! A cup of ash, intense heat and pressure, and up to $10 000 is all you need. The diamonds can be yellow, blue or orange-red and can be set into jewellery. At least 12 Australians have already been converted into diamonds!

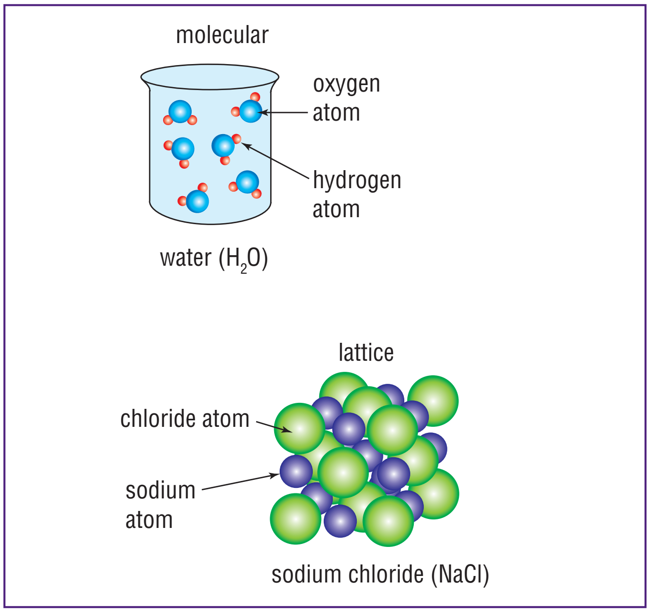


Fig 2.1.9 Two types of compounds—molecular and lattice. A glass of the compound water contains billions of identical water molecules. The compound sodium chloride (table salt) consists of crystals made up of a lattice of billions of sodium and chlorine atoms that is held together by atomic bonds.

Molecules and lattices

When two atoms meet they may attach themselves to each other, making a very strong **atomic bond**. Atoms can link to form small clusters known as **molecules**, or larger structures known as **crystal lattices**. Elements and compounds can both be found as either molecules or crystal lattices.

Molecules

Molecules are small groups or clusters of atoms bonded tightly together. They can have as few as two atoms (e.g. hydrogen and oxygen) or can have millions of atoms (e.g. a molecule of DNA). There are two basic types of molecules:

- Some molecules contain only one type of atom. These molecules are one form that elements can take. For example, oxygen gas is a molecule made up of two oxygen atoms and nitrogen gas is made up of two nitrogen atoms.

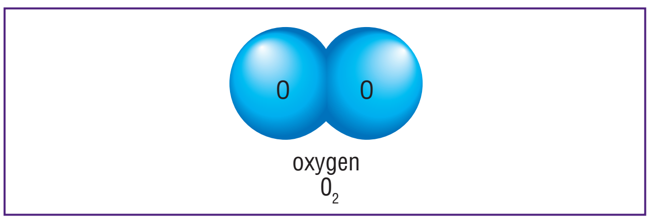


Fig 2.1.10 Oxygen is a molecule and an element because it contains only oxygen atoms.

- Most molecules contain more than one type of atom. In a compound, all the molecules are identical. In a glass of water, for example, every molecule of the water is the same, each one containing one oxygen atom joined to two hydrogen atoms.

Crystal lattices

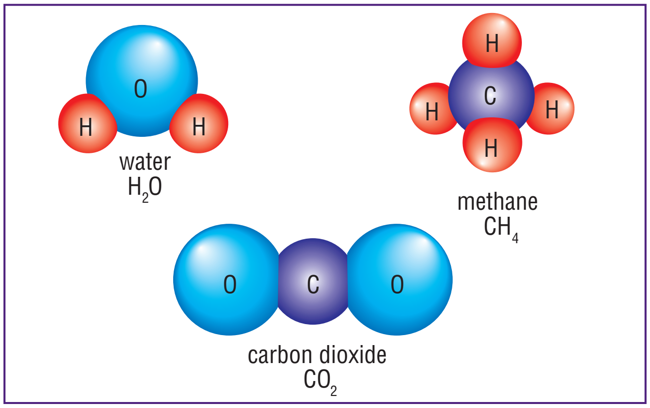


Fig 2.1.11 Water, methane and carbon dioxide are both molecules and compounds because each contains the atoms of different elements.

Other atoms bond together in large grid-like structures to form crystals. These are known as crystal lattices. All metallic elements form crystal lattices, but carbon is the only non-metal element that forms a crystal lattice in diamond or graphite. Nevertheless, there are many compounds that form crystal lattices. These usually result when a non-metal combines with a metal. An example of this is common table salt. In table salt, every crystal is made up of a lattice of sodium and chlorine atoms, giving its scientific name sodium chloride.

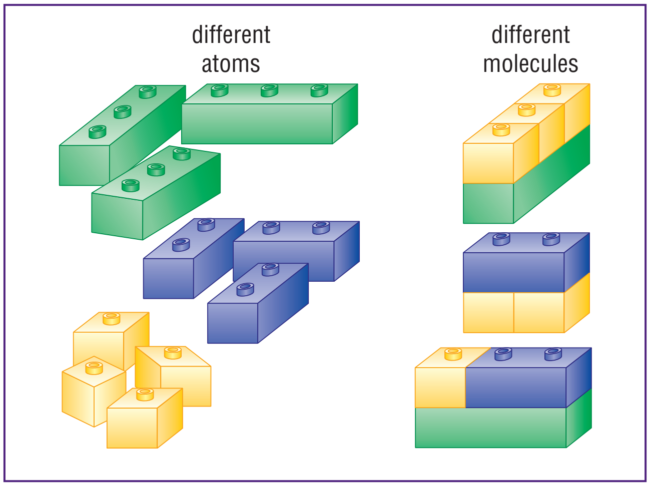


Fig 2.1.12 Atoms are like blocks of Lego, joining together to make up a substance. Put many single-coloured Lego blocks together and you have molecules of an element. Put different coloured Lego blocks together and you get molecules making up a compound.

Compound formulae

Scientists write **chemical formulae** as a shorthand way of describing which atoms are bonded in a molecule or crystal lattice. Element symbols show what types of atoms are in the compound and the subscript values (i.e. the small numbers under each element symbol) show how many of each atom there are.

Fig 2.1.13 Most of the materials you see in your everyday life are made of compounds.

For example, a water molecule is made up of two hydrogen atoms (symbol H) and one oxygen atom (symbol O). This gives water the chemical formula H_2O. Note that the lack of a number on the O indicates that only one of those atoms is needed.

This table gives the formulae for some compounds.

Compound (common name)	Scientific name	Formula	Structure	Number of atoms of each type per group
Water	Dihydrogen oxide	H_2O	Molecule	2 hydrogen, 1 oxygen
Oxygen	Oxygen	O_2	Molecule	2 oxygen
Ozone	Ozone	O_3	Molecule	3 oxygen
Table salt	Sodium chloride	NaCl	Lattice	1 sodium, 1 chlorine
Natural gas	Methane	CH_4	Molecule	1 carbon, 4 hydrogen
Hydrochloric acid	Hydrogen chloride	HCl	Molecule	1 hydrogen, 1 chlorine
Sugar	Sucrose	$C_{12}H_{22}O_{11}$	Molecule	12 carbon, 22 hydrogen, 11 oxygen
Petrol	Octane	C_8H_{18}	Molecule	8 carbon, 18 hydrogen
Table salt	Sodium chloride	NaCl	Lattice	1 sodium, 1 chlorine
Quartz	Silicon dioxide	SiO_2	Lattice	1 silicon, 2 oxygen
Rust	Iron oxide	Fe_2O_3	Lattice	2 iron, 3 oxygen

Mixtures

A **mixture** contains two or more substances that are not bonded together. The substances that make up a mixture can be elements or compounds and no new substance is formed when they are combined. This also means that a mixture can be separated easily into its ingredients, using simple techniques such as sieving, decanting, filtration, evaporation, distillation or chromatography. Soft drink is an example of a mixture. It contains sugar, water, flavouring, colouring and carbon dioxide gas. Other examples of mixtures are mud (a mixture of sand and water) and cake mix (a mixture of flour, sugar, salt, egg and milk). Even your blood is a mixture.

Worksheet 2.3 Wordfind

PP Video Clip

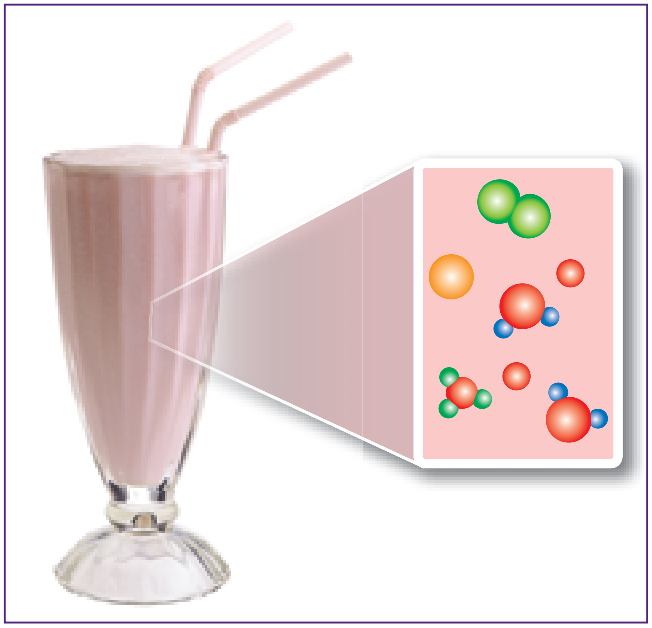


Fig 2.1.14 A strawberry milkshake is a mixture of milk and flavouring, which themselves are mixtures of water, fats and sugars.

2.1 QUESTIONS

Remembering

1 **State** the number of:
   a naturally occurring elements
   b artificial or synthetic elements.

2 **Name** and give the element symbols for:
   a the two most abundant elements in the Earth's crust
   b four non-metallic elements
   c four metallic elements
   d four elements that have symbols starting with C
   e six elements with single-letter symbols
   f six elements that have 'illogical' symbols
   g six elements that have 'logical' symbols.

3 **List** the physical properties of:
   a metals
   b non-metals.

4 **State** the names of the following elements:
   a Pt
   b Hg
   c Fe
   d K.

5 **State** the symbols for the following elements:
   a hydrogen
   b helium
   c sulfur
   d sodium.

6 **Name** the following compounds:
   a H_2O
   b CH_4
   c $C_{12}H_{22}O_{12}$
   d HCl

7 **Recall** how to write chemical formulae by writing the formulae of:
   a oxygen gas
   b table salt
   c petrol
   d rust.

Understanding

8 **Define** the terms: (L)
   a atom
   b element
   c compound
   d mixture.

9 Use examples to **explain** two types of compound structures—molecules and lattices.

Applying

10 **Use** the periodic table to **identify** an element named after:
   a a place
   b a person
   c a planet.

11 In the following molecules, **identify** the types of atoms and how many there are of each:
   a sulfuric acid: H_2SO_4
   b glucose: $C_6H_{12}O_6$
   c vinegar: CH_3COOH (Be careful!).

12 **Identify** the substances likely to make up the following mixtures:
   a sweet, white tea
   b champagne
   c mud.

13 **Identify** each of the following diagrams as either an atom, molecule, element, compound or mixture.

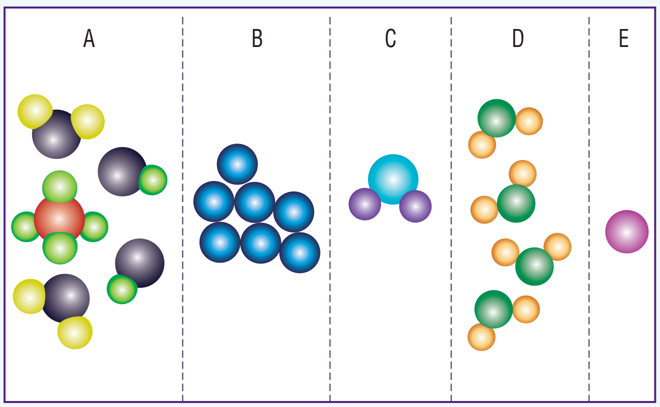


Fig 2.1.15

>>

Analysing

14 Using the descriptions given, **classify** each substance as a metal or non-metal.

- **a** I am used to make bicycle frames. I am light in weight but very strong. I can be polished to a shiny finish.
- **b** I have a density so low that I am found in the air. I am used by your body to make energy.
- **c** I am a solid that breaks easily. I am used to make fertilisers and I am found in gases that smell like rotten eggs. My colour is yellow.
- **d** I can be stretched into wires used to carry electricity. I am also used to make water pipes and can be bent easily in different directions.
- **e** I am a liquid that is used in thermometers. Although I look very shiny and pretty, I am highly poisonous.

15 **Classify** each of these substances as an element, compound or mixture:

- **a** glucose: $C_6H_{12}O_6$
- **b** iron: Fe
- **c** beer
- **d** phosphoric acid: H_3PO_4
- **e** perfume
- **f** tungsten: W
- **g** alcohol: C_2H_5OH

16 **Compare** the following by listing their similarities and differences:

- **a** atoms and elements
- **b** molecules and compounds.

17 **Contrast** a molecular compound with a mixture.

Evaluating

18 **Evaluate** whether you would use a metal or non-metal for the items below. **Justify** your choice in each case:

- **a** ship's hull
- **b** fishing rod
- **c** electrical wires
- **d** barbecue hot plate.

19 The letters of the alphabet can be put together to make up words. Words are put together to make up paragraphs. In this way they resemble elements, compounds and mixtures. **Evaluate** the similarities and decide whether alphabet letters, words or a paragraph best represents:

- **a** a compound
- **b** a mixture
- **c** an element.

Creating

20 **a** **Construct** diagrams of as many atom combinations as possible, using Mathomat circles. (Let each different circle represent a different atom.) You may not use more than four identical circles in each combination.

- **b** Colour each different-sized circle a particular colour. A few possibilities are shown in Figure 2.1.16.

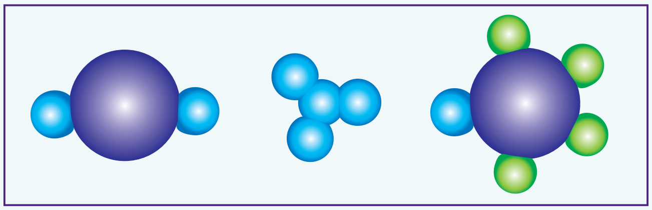


Fig 2.1.16

21 Imagine that you have just discovered a new element. **Construct** a poster or website to present the following information about the element:

- **a** **Describe** how the element was made.
- **b** **Propose** a name and symbol for the element.
- **c** **Describe** some physical and chemical properties of the element.
- **d** **Outline** some potential uses for the element.

2.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Write a short account of how a particular element was discovered, its uses, where and how it is obtained today and any safety issues it may have. L

2 a Find twelve properties of a particular element (e.g. its melting point, colour, atomic number, state at room temperature, density etc.).

b Cut out the pattern for *four* tetrahedrons, like that shown in Figure 2.1.17.

c Write your facts on three triangles of each tetrahedron and the element name and symbol on the last triangle. Fold the patterns into tetrahedrons and glue or tape the sides into place.

d Thread cotton or string through the tetrahedrons to make a mobile.

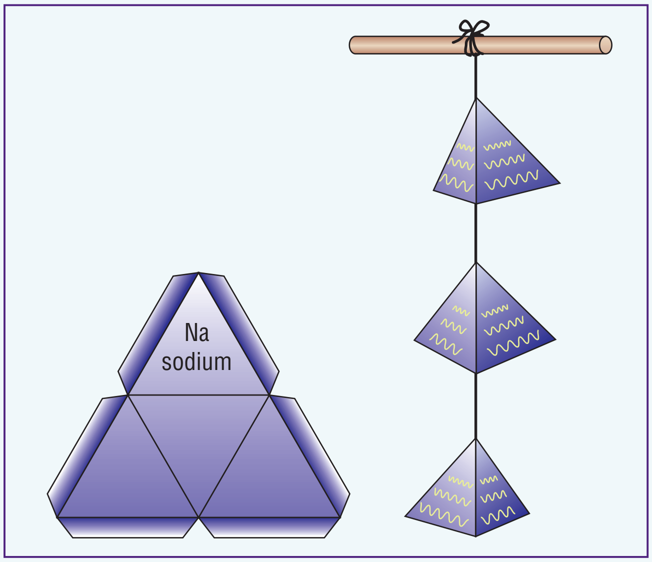


Fig 2.1.17

3 Find the picture-symbols that the English scientist John Dalton gave in the 1800s to all the elements he knew at the time. Present your work as a periodic table with picture-symbols written over the elements Dalton knew.

e-xploring

PP Web Destination

Although the alchemists were more like wizards than scientists, they laid the basis for the future study of chemistry. Find out more about the alchemists by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Find out when they lived in history, what countries they worked in, what they were trying to do and how they went about it. Present your work in one of the following ways:

- a TV interview with one of the alchemists
- an ancient diary in which an alchemist recorded what they did
- a role play, showing how the alchemist worked
- an illustrated book of 'potions' and jobs for the alchemist
- an illustrated biography of the alchemist's life.

2.1 PRACTICAL ACTIVITIES

1 An odd way to burn sugar (Teacher demonstration)

Aim

To create pure carbon by dehydrating sugar with sulfuric acid

Equipment

- white table sugar
- concentrated sulfuric acid
- 200 mL glass beaker
- glass stirring rod
- fume cupboard
- spatula
- bosshead and clamp
- stand
- safety glasses
- gloves

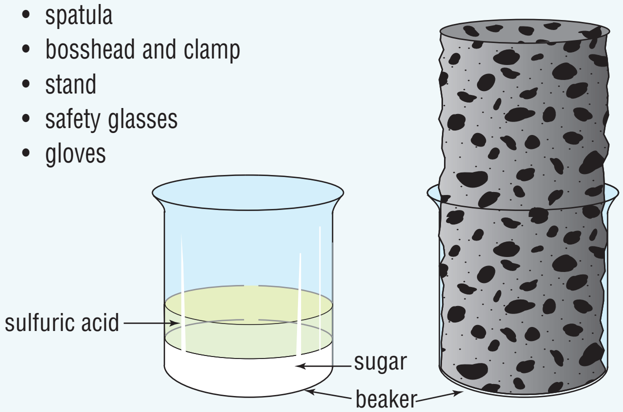


Fig 2.1.18 Concentrated sulfuric acid may be used to break down sugar into carbon and other substances.

Method

1. In the fume cupboard, stabilise the beaker using the bosshead, clamp and stand.
2. Half-fill the beaker with white sugar.
3. Add 10–20 mL of concentrated sulfuric acid to the beaker and use the stirring rod to mix the reactants.
4. Stand back and wait for the reaction to finish (about 5 minutes).

Questions

1. As a class, **discuss** your observations, including anything you could see, hear, feel or smell.
2. A more common way of producing carbon is to burn substances that contain carbon, such as wood or paper. **Discuss** the similarities and differences of these two methods of producing carbon.

Safety

1. This demonstration must be done in a fume cupboard, as the fumes produced may trigger respiratory problems.
2. This is a highly exothermic reaction, so will get very hot.

2 Breaking down substances

Aim

To identify elements present in various substances

Equipment

- small samples of various materials (e.g. paper, plastic straw, aluminium foil, cloth, green leaf, wool, cotton wool, bread, wood (e.g. toothpick))
- Bunsen burner
- bench mat
- metal tongs
- safety glasses
- squares of contact adhesive to stick samples into workbook

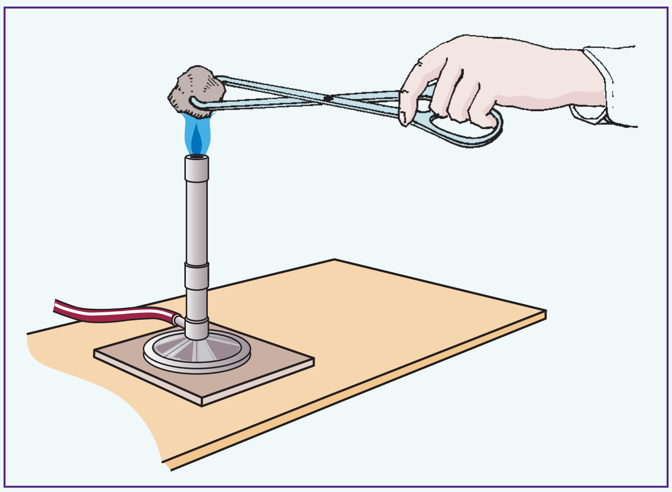


Fig 2.1.19

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Method

1 Hold a sample in the metal tongs and place part (but not all) of it in a blue Bunsen burner flame (see Figure 2.1.19). The sample should be small enough to later stick into your workbook without causing too much of a bulge.

2 Allow the sample to burn only partially before removing it from the flame. If it does not burn, withdraw it from the flame after a couple of seconds.

3 After withdrawing the sample from the flame, put out any flame on the sample (e.g. by prodding with the tongs, blowing or using water).

4 When cool, stick the sample into your workbook.

5 Repeat steps 1 to 4 for the other samples.

Questions

1 **Record** your results in a table, and **describe** your observations for each sample.

2 a **List** any observations that were common to each sample tested.

b Use observations to **identify** an element common to several samples.

3 Flame tests

Aim

To identify various elements using the flame test

Equipment

- paperclips
- tongs
- Bunsen burner
- bench mat
- beaker of water
- various chloride salts (e.g. strontium chloride, sodium chloride, copper chloride, potassium chloride)
- watch-glass

Method

1 Obtain a tiny sample (i.e. enough to cover a match head) of one of the chemicals and place it on a watch-glass.

2 Fill a clean beaker with water.

3 Dip one end of a paperclip into the water and then into the chemical so that some of the chemical sticks to the paperclip.

4 Set the Bunsen burner to a blue flame.

5 Using tongs, place the end of the paperclip containing the chemical into the flame, as shown in Figure 2.1.20. Record the colour produced. (Note: Most flames produce an orange flame with some other colour in them. Look for the other colour.)

6 Rinse the beaker and fill it with clean water. Obtain a new paperclip.

7 Repeat steps 1 to 6 for the other chemicals.

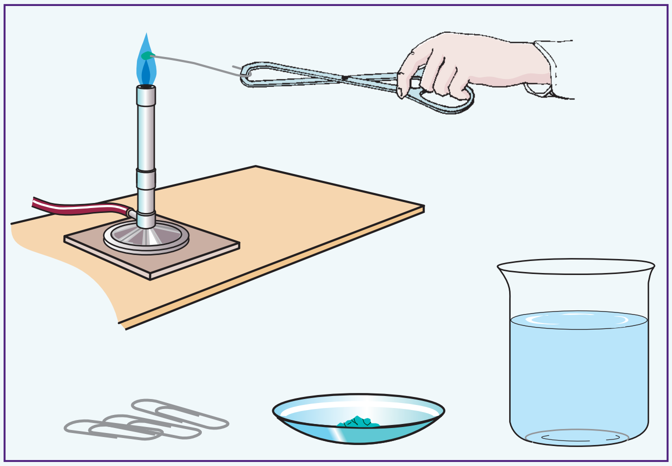

Fig 2.1.20

Extension

8 Your teacher will supply some unknown samples for you to test. Use your results to identify the elements in the unlabelled samples.

Questions

1 **Record** your results in a table. Include the scientific names of each chemical.

2 For each chemical **identify** which elements give rise to colour.

3 **Describe** how flame tests can be used to identify elements in a compound.

4 New water and a new paperclip were used for each chemical you tested. **Explain** why this is important.

5 **Propose** a use for this technique, drawing on the experience gained in this experiment.

Unit 2.2 Physical and chemical change

context

The world and everything in it is constantly changing. These changes may be as simple as a change in shape, such as when an aluminium can is crushed, a window is smashed or a banana is mashed in a blender. Sometimes changes produce new substances; for example, cookie dough is baked to form cookies and iron rusts, producing an orange-red flaky substance that is very different from the original silvery grey metal. Changes like these can be classified as physical or chemical.

Fig 2.2.1 Cooking involves both physical and chemical changes. Heat causes water to evaporate, butter to melt, pasta to soften, and salt and sugar to dissolve. It then triggers chemical changes in the food, causing changes to its colour, texture and taste.

Physical change

A **physical change** occurs when a substance changes in some way without forming a new substance. The original substance might look and act differently after the change, but it is really just the same substance as before.

Physical changes are happening when:

- a plate is dropped and shatters
- Milo dissolves in hot milk
- grass is mown
- branches of a tree are mulched
- a metal knife is sharpened
- finger nails are filed down
- breakfast cereal goes soggy.

Fig 2.2.2 Frozen carbon dioxide in water undergoes a physical change from solid to gas.

Changing state

A **change of state** is a common example of a physical change. A substance changes state when it:

- **melts**—changing from a solid to a liquid
- **freezes**—changing from a liquid to a solid
- **vaporises**—changing from a liquid to a gas
- **condenses**—changing from a gas to a liquid
- **sublimes**—changing directly from a solid to a gas or from a gas to a solid, without going through the liquid state.

Every day you see water undergoing all these changes—water is changing state whenever ice blocks melt, a kettle boils or when dew forms on the grass. Although all the different states of water may have different properties, they are all still made up of water.

Go to Science Focus 1, Unit 2.2

Fig 2.2.3 As fruit ripens it changes colour and releases new substances that you can smell and taste. Eventually another chemical change causes the fruit to rot, causing new and unpleasant substances. Rotting is another example of a chemical change.

Chemical change

A **chemical change** occurs whenever a new substance forms.

Scientists look for clues to know whether a chemical reaction has occurred. If there is a change in colour or if light is produced or heat is released or absorbed, then it is likely that a chemical change has occurred. This change in energy is likely to cause the temperature of the new substance to rise or drop—this then is another sign that a chemical change has probably taken place.

A chemical change is happening when:

- wood burns to form black charcoal (carbon)
- a green tomato ripens and turns red
- an egg is cooked to become a white and yellow solid
- vegetable scraps in the compost bin decompose to produce a rich soil
- a dead mouse stuck in the wall of a house begins to smell awful
- a metal panel on a car rusts, causing it to flake and turn orange-brown
- fireworks explode to produce colourful light and a loud sound.

Word equations

PP Animation

In a chemical change, the atoms in one or more substances rearrange to form new substances. No new atoms are formed in a chemical change—they just rearrange themselves into new combinations and new substances. This rearrangement of atoms is known as a chemical **reaction**. Special names are given to the substances that exist before and after the reaction.

- **Reactants** are the substances present before the chemical reaction.
- **Products** are the new substances formed by the reaction.

Scientists find it useful to represent chemical reactions by **chemical equations**. The simplest form of a chemical equation is a **word equation**. Word equations are shorthand notations that describe what chemicals react and what chemicals are produced. The general word equation for any chemical reaction is:

reactants → products

However, more specific word equations can be written for each individual reaction. For example, when natural gas (known as methane), burns on a stove or in a Bunsen burner, it combines with oxygen gas (in the air) to produce carbon dioxide and water vapour. The chemical change is obvious in the flame it produces and the heat and light released. This chemical reaction can be represented quickly by the word equation:

methane + oxygen gas → carbon dioxide + water vapour

A word equation can be written for every chemical reaction.

Another simple way of showing what is happening in a chemical reaction is to write the chemical formula of each substance instead of their names. This produces an **unbalanced formula equation**. Since methane has the chemical formula CH_4, oxygen is O_2, carbon dioxide is CO_2 and water is H_2O, the equation above could just as easily be written as:

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

Fig 2.2.4 methane + oxygen gas ⟶ carbon dioxide + water vapour

Types of chemical reaction

Chemical reactions can be classified into different types, depending on how the reactants combine to form the products. Some common types of chemical reactions are:

- combination reactions
- decomposition reactions
- precipitation reactions
- combustion reactions.

Combination reactions

In combination reactions, a number of reactants join together to form one new substance.

A common (and annoying) combination reaction is rusting of iron. Rust (iron oxide) is produced by a chemical reaction between iron and oxygen. Iron and oxygen (the reactants) combine to form iron oxide or rust (the product). Its word equation would be:

iron + oxygen gas ⟶ iron oxide
(reactants) (product)

Its unbalanced formula equation would be:

$$Fe + O_2 \longrightarrow Fe_2O_3$$

Fig 2.2.5 Rusting is a combination reaction, combining iron with oxygen to form rust.

Iron oxide is fragile. This exposes new iron to the atmosphere, and so the reaction continues deeper and deeper into the metal until it has all converted into rust.

Aluminium also combines with oxygen in the air to form aluminium oxide. This can be written as:

aluminium + oxygen gas ⟶ aluminium oxide

$$Al + O_2 \longrightarrow Al_2O_3$$

Rust is flakey, whereas aluminium oxide forms a hard and protective coating on the surface of the aluminium. This stops the oxygen from getting past the surface of the metal. In contrast to the rusting reaction that eventually destroys iron (as occurs with steel, which has a high iron content), the reaction of aluminium with air actually protects it.

Worksheet 2.4 Combination reactions

PP Video Clip

Decomposition reactions

Chemical reactions do not always need two reactants. Sometimes, one is enough. A single reactant can break down or decompose to form new substances. For example, carbonic acid puts the fizz in soft drinks by decomposing to form water and carbon dioxide gas.

carbonic acid ⟶ water + carbon dioxide

$$H_2CO_3 \longrightarrow H_2O + CO_2$$

Fig 2.2.6 The bubbles of soft drink are put there by the decomposition of carbonic acid.

Some decomposition reactions need a little help. Water can be decomposed into its elements hydrogen gas and oxygen gas by passing an electrical current through it.

water ⟶ oxygen gas + hydrogen gas

$H_2O \longrightarrow O_2 + H_2$

Fig 2.2.7 Two transparent liquids combine to form a bright yellow precipitate. Some precipitates are very colourful and are often used as paint pigments.

Precipitation reactions

Substances that dissolve in water are referred to as **soluble**, whereas substances that do not dissolve are called **insoluble**. Using these definitions, salt and sugar are soluble, whereas flour and sand are insoluble.

In **precipitation reactions**, two substances that are soluble in water combine to form a new substance that is insoluble. The insoluble substance separates out of the water, making it appear cloudy and murky. With time, the material will fall to the bottom of the container, leaving a clear (or clearer) solution above it. The formation of an insoluble substance in this way is known as **precipitation**. The insoluble substance that is formed is known as the **precipitate**.

A precipitation reaction can be used to detect the presence of carbon dioxide. Limewater is water in which calcium hydroxide has been dissolved. When carbon dioxide is bubbled through it, the carbon dioxide dissolves in the water to form calcium carbonate, which is insoluble and precipitates out as a fine white powder.

Prac 1 p. 51

calcium hydroxide solution + carbon dioxide ⟶ insoluble calcium carbonate + water

$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$

Combustion reactions

Combustion reactions occur whenever a substance reacts with oxygen to release energy. New substances form, accompanied by the release of heat and/or light, sometimes as a flame or explosive flash. Combustion reactions happen whenever something burns or explodes.

When magnesium ribbon burns, it combines with oxygen in the air to produce a white powder; i.e. magnesium oxide:

magnesium metal + oxygen gas ⟶ magnesium oxide

$Mg + O_2 \longrightarrow MgO$

The explosive power of combustion is used to produce energy in coal power stations and even in your car engine. Inside a car engine, petrol is combusted with oxygen to cause mini explosions that turn the motor and the wheels.

Prac 2 p. 51
Prac 3 p. 52
Prac 4 p. 53

Fig 2.2.8 The combustion of magnesium produces so much light energy that it can permanently damage your eyesight if looked at directly.

Science Clip

Combustion in our bodies

Glucose ($C_6H_{12}O_6$) is a type of sugar produced when food is broken down. It undergoes combustion during digestion by combining with oxygen carried in your blood to produce carbon dioxide, water and energy. The carbon dioxide then gets carried back to your lungs to be breathed out. Although the glucose does not 'burn' like methane in a Bunsen burner or petrol in an engine, it does produce energy that is used by the cells for growth and movement.

Fig 2.2.9 Bushfires are combustion reactions which can produce so much heat that they can kill. Remove the oxygen or the fuel and fires quickly extinguish.

Fig 2.2.10 Fireworks react so quickly that they explode, releasing intense heat and light.

Speeding up reactions

Some reactions happen so fast that their reactants are used up all at once. Explosions are fast reactions, using up all their fuel in an instant and releasing lots of energy as they do so. In contrast, iron rusts very slowly, often taking years for the reaction to become obvious. How fast a chemical reaction takes place is known as the **reaction rate**.

Chemical reactions are commonly used in industry to produce the materials, chemicals and products that we take for granted. They need to be able to control the rate at which these reactions proceed. Too slow and the reaction might not be profitable, too fast and the reaction might end up being explosive.

Reaction rate can be affected by:

- the amount or **concentration** of reactants. A stain may be removed more quickly by adding more stain remover, or a more concentrated stain remover. This is because more molecules are available to take part in the reaction, so products are produced more quickly.
- **temperature**. Fruit ripens more quickly in warmer weather and food keeps longer when stored in a refrigerator. This is because higher temperatures make the reactants move faster and with more energy. As a result, the molecules are more likely to collide and have enough energy to react.
- **surface area**. Lots of small pieces of iron (e.g. iron filings) react more quickly with acid than the same amount of iron present as a single lump. Having a greater surface area allows more atoms of iron to be exposed to the acid at any one time.
- **catalysts** (helper chemicals). The element rhodium in a car's catalytic converter helps harmful exhaust fumes react with oxygen to produce less harmful products. This happens by the rhodium attracting the harmful gases and oxygen, resulting in more of each gas coming together and reacting. The rhodium does not actually react with either gas; it just speeds up the reaction by getting more molecules to come together.

Prac 5 p. 53

Prac 6 p. 54

Science Clip

Hardening fillings

Dentists use a special paste to fill holes in teeth. The paste is then hardened quickly by using ultraviolet (UV) light as a catalyst.

2.2 QUESTIONS

Remembering

1 **List** two examples each of a:
 a physical change
 b chemical change.

2 **List** the signs that could indicate that a chemical change is happening.

3 **List** four types of chemical reactions.

4 **State** the name given to the:
 a 'ingredients' of a chemical reaction
 b the substances made by a chemical reaction.

5 **List** four ways of increasing the speed of a chemical reaction.

6 **Recall** how to write word equations by writing them for the reactions below.
 a A strip of magnesium burns and combines with oxygen to produce magnesium oxide powder.
 b Methane reacts with oxygen to form carbon dioxide and water.
 c Iron rusts
 d Carbon dioxide dissolves in limewater.

7 **Recall** how to write unbalanced chemical equations by writing them for each of the reactions in Question 6.

Understanding

8 **Define** the terms: L
 a physical change
 b chemical change
 c precipitate
 d catalyst.

9 **Outline** two examples of chemical reactions happening around your home.

10 **Predict** the effect of each of the following on a wood fire heater:
 a A log is chopped into several small pieces before being added to the fire.
 b A vent is closed so less air gets to the fire.

Applying

11 Copy these equations and **identify** the reactant(s) and the product(s).
 a hydrogen + chlorine ⟶ hydrogen chloride
 b $HCl + NaOH \longrightarrow NaCl + H_2O$

12 **Use** the chemical formulae on pages 45–47 to write chemical equations for each of the following:
 a carbon + oxygen gas ⟶ carbon dioxide
 b hydrogen gas + oxygen gas ⟶ water
 c hydrogen gas + chlorine gas ⟶ hydrochloric acid

13 **Use** the periodic table and the chemical formulae on pages 45–47 to write a word equation for the reaction:

$$HCl + Na \longrightarrow NaCl + H_2$$

14 **Identify** an example of a fast reaction and an example of a slow reaction, other than the ones given in this unit.

15 A catalyst is used in a reaction. **Identify** which of the following best describes the amount of catalyst left at the end of the reaction compared with the amount present at the start:
 A none
 B less
 C the same
 D more.

Analysing

16 **Classify** the following examples as physical or chemical changes:
 a A prisoner breaks up rocks.
 b Leaves turn red in autumn.
 c Food is digested and waste is expelled from your body.
 d A puddle of water evaporates.
 e Juice is squeezed from a lemon.
 f Rain turns the surface of a sports ground to mud.
 g Sugar and water are heated in a saucepan to produce caramel.
 h Sawdust is produced when a circular saw cuts timber.
 i A match is struck and burns.
 j Margarine melts in a saucepan.
 k Butter burns in a frypan.
 l Bread goes mouldy.
 m Water freezes to make ice cubes.
 n After being stored in a cellar for 10 years, a bottle of red wine tastes like vinegar.

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17 **List** and **classify** the changes (i.e. physical or chemical) happening here.

- **a** To cook toast, the bread needs to first dry out then burn.
- **b** To make toffee, sugar first needs to be melted and then burnt.
- **c** A candle burns, the wax dripping down its side.

18 **Classify** each of these reactions as combination, decomposition, precipitation or combustion reactions.

- **a** zinc + sulfur ⟶ zinc sulfide
- **b** $Pb(NO_3)_2 + NaCl \longrightarrow PbCl_2 + NaNO_3$
- **c** $NaCl \longrightarrow Na + Cl_2$
- **d** ethane + oxygen gas ⟶ carbon dioxide + water vapour

Evaluating

19 **Propose** reasons for the following:

- **a** Reaction rates tend to slow as time goes on.
- **b** Capsules containing fine grains relieve a headache faster than a solid tablet containing the same chemical.
- **c** A wood heater has its vent closed overnight.
- **d** You digest food a little faster if you chew it first.

Creating

20 **a** **Describe** what happens when baking soda and vinegar react with each other.

- **b** A lit match placed in the gases produced will soon go out. **Identify** the gas produced by the reaction.
- **c** **Construct** a word equation for the reaction.

21 **Construct** a recipe for your favourite cake, cookies or muffins. At each step indicate whether the ingredients undergo a chemical or physical reaction and **explain** the evidence that supports your argument.

22 **Design** an experiment to compare the rate at which iron nails rust in the following conditions: nail partly under water, nail fully under water, nail in salty water, nail in water with a crushed vitamin C tablet. (Hint: Vitamin C is an 'antioxidant'.)

2.2 INVESTIGATING

e-xploring

PP Web Destination

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find answers to the following questions about physical and chemical changes: L

1. Describe the new substances formed when food decomposes.
2. Outline how you can ensure that vegetable scraps will produce good compost suitable for the garden.
3. Outline how sheet metal is made from raw materials. Identify the physical and chemical changes involved.
4. Describe the process of galvanising, which is used to prevent rust.
5. Describe what exothermic and endothermic reactions are and how they can be used.
6. Name enzymes that are produced in the body, where they are made and what they do.
7. Explain why enzymes are sometimes used in washing powders. Explain how they help.

2.2 PRACTICAL ACTIVITIES

1 A precipitation reaction

Aim

To make and observe a precipitate

Equipment

- potassium iodide solution
- lead nitrate solution
- test tube
- test-tube rack
- filter paper
- funnel
- conical flask
- safety glasses
- gloves

Method

1 Place 2 cm of potassium iodide solution in a test tube.

2 Add a similar amount of lead nitrate solution.

3 Leave the test tube to stand in a rack for several minutes and observe the contents.

4 Use filter paper, a conical flask and a funnel to filter out the precipitate.

5 If possible, leave the solution to filtering overnight.

Questions

1 Observe and **describe** the appearance of the precipitate.

2 One of the products of this reaction is soluble potassium nitrate. **Predict** the name and state of the other product.

3 **Construct** a word equation for the reaction.

4 Determine whether the reaction is a physical or chemical change and **justify** your choice.

Safety

1 Warning: The chemicals in this prac are toxic so avoid contact with eyes, skin and mouth.

2 Clean up spills immediately to prevent slip and trip hazards.

2 Extinguishing fire

Fire is a reaction that always has oxygen as a reactant. The gas carbon dioxide (CO_2) is used as a common fire extinguisher and works by blocking oxygen from the flame.

Aim

To observe the extinguishing effects of carbon dioxide on a flame

Equipment

- two 250 mL beakers
- spatula
- baking soda (i.e. bicarbonate of soda)
- vinegar (i.e. acetic acid)
- long BBQ matches
- birthday candle
- Blu Tack or plasticine

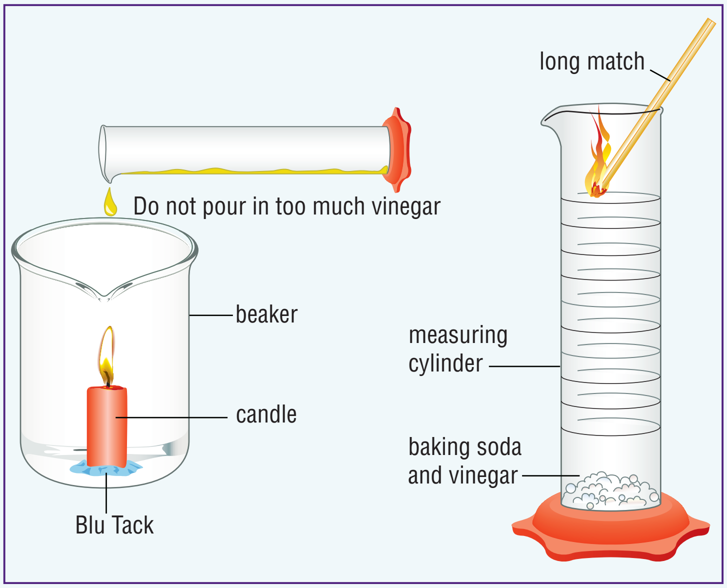

Fig 2.2.11

Method

Part A

1. Put two to three heaped spatulas of baking soda into a 250 mL beaker.
2. Use some Blu-Tack or plasticine to stand a birthday candle in the centre of the beaker, so that it is surrounded by the baking soda.
3. Light the candle and let it burn for 30 seconds or so.
4. Carefully pour vinegar into the beaker until the baking soda is just covered. The gas carbon dioxide (CO_2) is immediately produced.
5. Record your observations.
6. Do not move the beaker or candle. If the candle goes out, try and re-light it using a long BBQ match.

Part B

1. Clean out the beaker and once again stand the candle in the bottom of it. Light it.
2. In the other beaker, make some more carbon dioxide (CO_2) in the same way you did in part A.
3. After a few minutes, 'pour' the carbon dioxide into the beaker with the candle.
4. Record what happens to the candle.

Questions

1. **Describe** how you know that a gas was produced.
2. **Classify** the combination of baking soda and vinegar as a physical or chemical change.
3. **Describe** what carbon dioxide (CO_2) does to a flame.
4. **Explain** how you know that CO_2 was present in this experiment.
5. **Predict** whether CO_2 is heavier or lighter than air. Explain your answer.

3 Ripening fruit

A chemical reaction happens whenever fruit ripens or goes brown. Chemicals called antioxidants slow the ripening process.

Aim

To test the effect of antioxidants on the ripening of fruit

Equipment

- tray or plate (preferably white)
- permanent marker
- ruler
- an apple, banana and potato
- a fresh lemon
- knife for cutting fruit

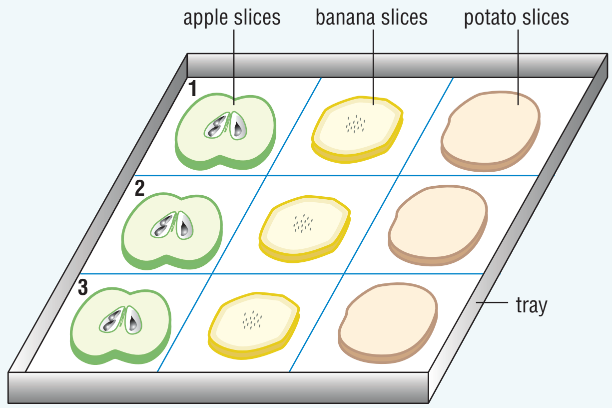

Fig 2.2.12

Method

1. Rule up a grid of nine squares on the plate or tray.
2. Crush the vitamin C into fine powder and squeeze the lemon, collecting its juice.
3. Carefully cut the apple, banana and potato so that you end up with three slices of each. Place them in the squares as shown.
4. Cover the fruit in row 1 with the crushed vitamin C.
5. Dribble the lemon juice over the fruit in row 2.
6. Don't do anything to the fruit in row 3.
7. Leave the fruit un-refrigerated in the air for at least 1 hour.
8. Copy the diagram into your workbook and record which fruit went brown.

Questions

1. How do you know that a physical change happened when the fruit went brown?
2. When it went brown, which gas, contained in air, do you think the fruit reacted with?
3. Was vitamin C and lemon juice effective on all fruit?
4. Vitamin C contains ascorbic acid and lemon juice contains citric acid. Suggest which chemicals make good antioxidants.
5. Suggest why antioxidants are called antioxidants.
6. Suggest other ways of slowing the ripening reaction.

4 Coating nails

Aim

To extract copper from a compound

Equipment

- small iron nails
- copper sulfate solution
- copper nitrate solution
- three test tubes
- test-tube rack
- safety glasses
- gloves

Method

1 Place water in one test tube, copper sulfate solution in another and copper nitrate solution in another, and place the tubes in a rack.

2 Place one iron nail in each test tube.

3 Leave the test tubes to stand for 5 minutes or more, and preferably overnight.

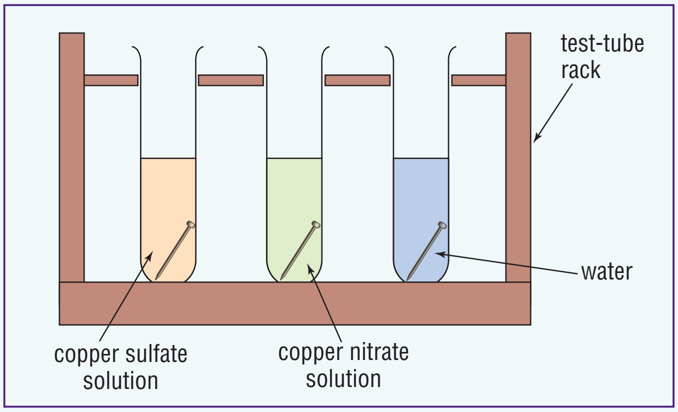

Fig 2.2.13

Questions

1 Observe the nails in each of the test tubes and **identify** if a chemical change has taken place. **Justify** your answer.

2 **Determine** which solution produced the thickest coating on a nail.

3 **Propose** a purpose for the test tube containing a nail and water.

4 Use your observations to **justify** the nature of the coatings formed on the nails.

5 Reaction rate: Effect of temperature and concentration

Aim

To investigate the effect of temperature and concentration on reaction rate

Equipment

- sodium thiosulfate (‘hypo’) solution (0.1 M)
- hydrochloric acid (1 M)
- hydrochloric acid (2 M)
- cold water
- hot water
- conical flask
- 10 mL measuring cylinder
- large beaker
- safety glasses
- timer

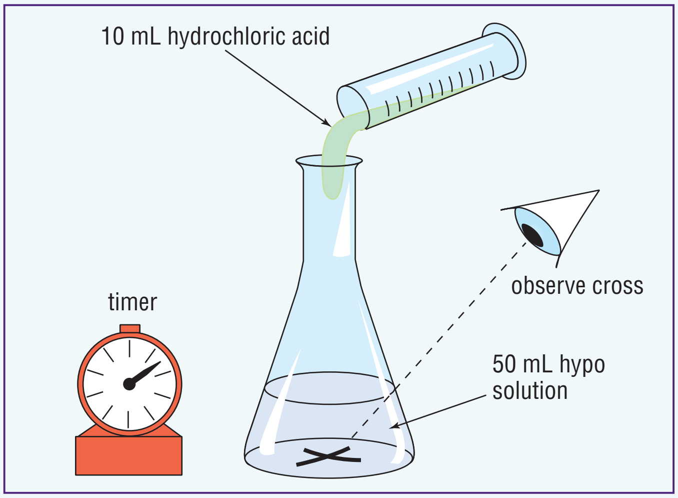

Fig 2.2.14

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Method

1 Place 50 mL of hypo solution into a conical flask.
2 Sit the conical flask in a beaker of cold water for 5 minutes. (Put ice blocks in the water if they are available.)
3 Remove the conical flask from the beaker and dry its base.
4 Draw a cross on a piece of white paper and place the conical flask on top of the cross.
5 Add 10 mL of hydrochloric acid (1 M strength) to the conical flask, and time how long it takes before you can no longer see the cross under the base of the flask. (Alternatively, use a light sensor on one side of the flask and a light source on the other to measure the amount of light transmitted through the contents of the flask as the reaction progresses. Note the time taken for the cloudiness or 'turbidity' of the solution to stabilise.)
6 Repeat steps 1 to 5, but use hot water at step 2 instead of cold.
7 Repeat steps 1 to 5, but use 2 M hydrochloric acid.

Questions

1 Using your own observations, **explain** how temperature affected reaction rate in this experiment.
2 Using your own observations, **explain** how the concentration of the hydrochloric acid affected reaction rate.
3 **Predict** whether these conclusions might apply to all reactions.

6 Reaction rate: Effect of surface area

Aim

To investigate the effect of surface area on reaction rate

Equipment

- two Alka-Seltzer tablets
- water
- two 250 mL beakers
- 100 mL measuring cylinder
- two stirring rods
- mortar and pestle or other grinding tools
- timer

Method

1 Accurately measure 100 mL of water in each beaker.
2 Grind one of the Alka-Seltzer tablets into a fine powder.
3 Place a whole tablet in one beaker and, at the same time, the crushed tablet in the other beaker, stirring for a few seconds.
4 Record the time taken for each to finish reacting with the water.

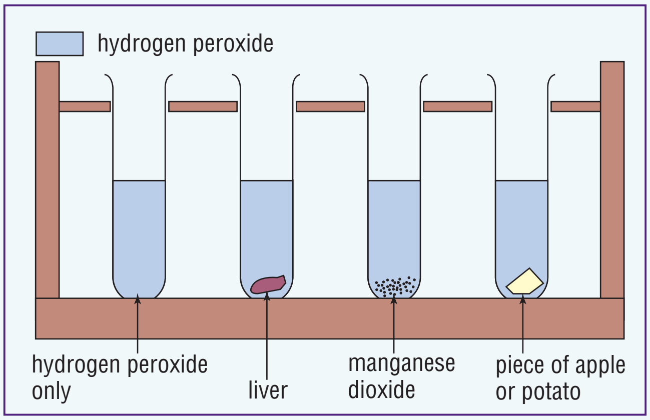

Fig 2.2.15

Questions

1 Dissolving is a physical change. **Discuss** what evidence there is to suggest that when the Alka-Seltzer tablets dissolve, there is also a chemical change taking place. **Contrast** this with dissolving sugar or salt.
2 Determine which tablet (i.e. crushed or whole) had the greater surface area and **justify** your answer.
3 Based on your observations, **explain** the effect of greater surface area on the rate of this reaction.
4 **Identify** the factors that should be kept the same for both beakers.

Unit 2.3 Inside atoms

context It is often convenient to think of atoms as hard, indivisible spheres. However, this view is highly simplified and does not help when trying to understand why the different types of atoms have their own and unique properties. In order to understand this, it is necessary to understand how atoms work on the inside.

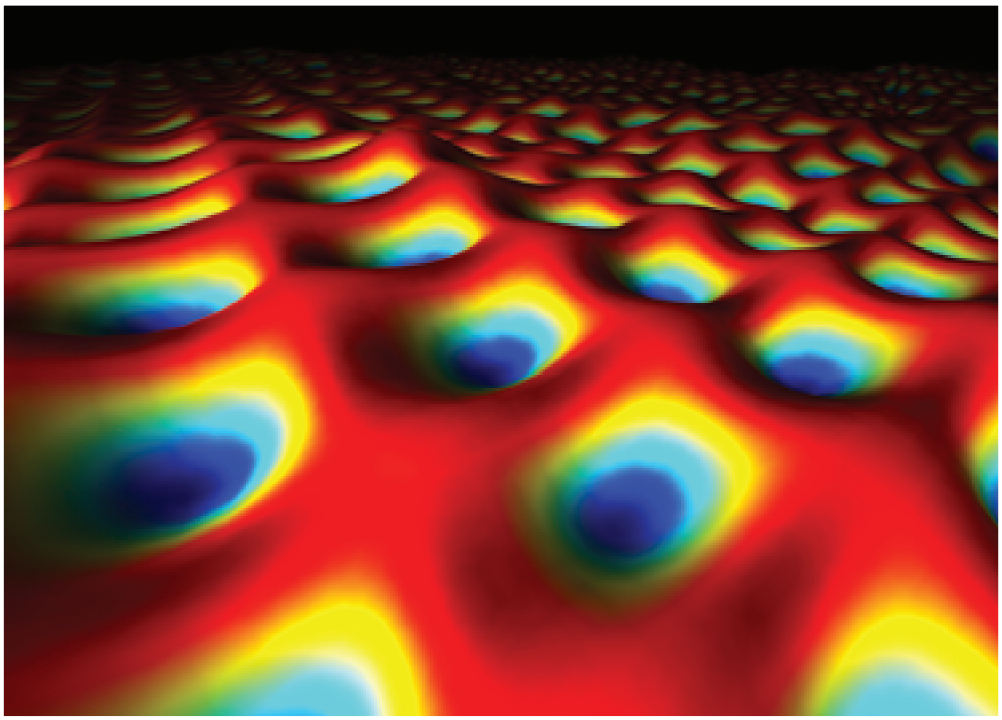

Fig 2.3.1 An image of the surface of a metal showing what it looks like at the atomic level. Each blue centre represents the nucleus of another atom. The red represents a 'sea' of electrons surrounding them.

Subatomic particles

Atoms have a highly complex internal structure made up of even smaller particles. These particles are known as **subatomic particles**. All atoms are made up of types of three subatomic particles:

- **protons**. Protons carry a positive charge (+).
- **neutrons**. Neutrons are a little heavier than protons. They are **neutral**, having no charge.
- **electrons**. Electrons are much smaller than protons and neutrons, only having a mass of about 1/2000th that of a proton or a neutron. This means that 2000 electrons would weigh about the same as a single proton. Another one or two electrons would be needed to weigh the same as a neutron. Electrons carry a negative charge (–).

In an atom, the protons and neutrons form a tiny cluster in the centre of the atom called the **nucleus**. Although the nucleus holds all the heavy subatomic particles in an atom, it takes up only a tiny fraction of the atom's size. Depending on the type of atom, the nucleus is between 1/10 000th and 1/100 000th the size of the atom it belongs to. The protons and neutrons are held together in the nucleus by extremely strong **nuclear forces** that prevent the positively charged protons from repelling each other.

Electrons are negatively charged and so are attracted to the positive nucleus. This keeps the electrons from straying too far from the nucleus or from escaping the atom completely. Electrons spin around the nucleus to form an electron cloud, which takes up the majority of space in an atom. To put it in perspective, if the nucleus was the size of a golf ball, the electron cloud would be the size of a football stadium.

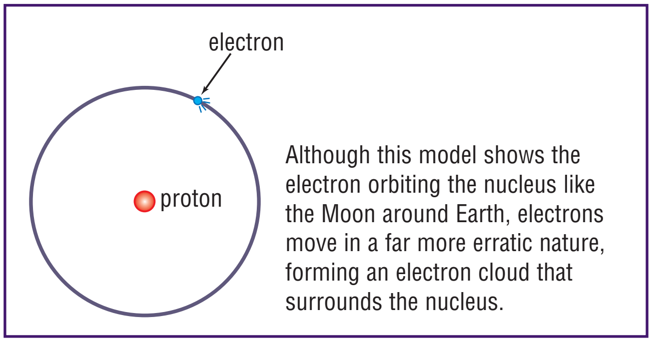

Fig 2.3.2 A hydrogen atom is the simplest possible atom, being made of just one proton and one electron. It is the most common element in the universe.

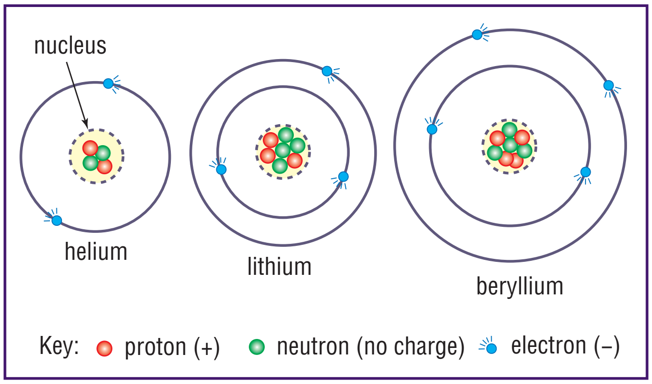

Fig 2.3.3 After hydrogen, the next simplest element is helium. It has two protons, two neutrons and two electrons. Lithium and beryllium are then the next simplest atoms.

Although the protons (+) and electrons (–) have opposite charges, the size of the charge is the same for each. Every atom has an equal number of protons and electrons and so the positive and negative charges balance each other. This means that every atom is **neutral**, with no *overall* charge.

Science Clip

Empty atoms!

Atoms are so small it takes about 10 million of them lined up side-by-side to stretch one millimetre. Nearly all the mass of an atom is due to the nucleus, but the diameter of the nucleus is *only* about 1/10 000th of the diameter of the atom. Atoms really are vacant space!

Atomic and mass numbers

Scientists use two special numbers to describe atoms:

- The **atomic number** is the number of protons in the nucleus.

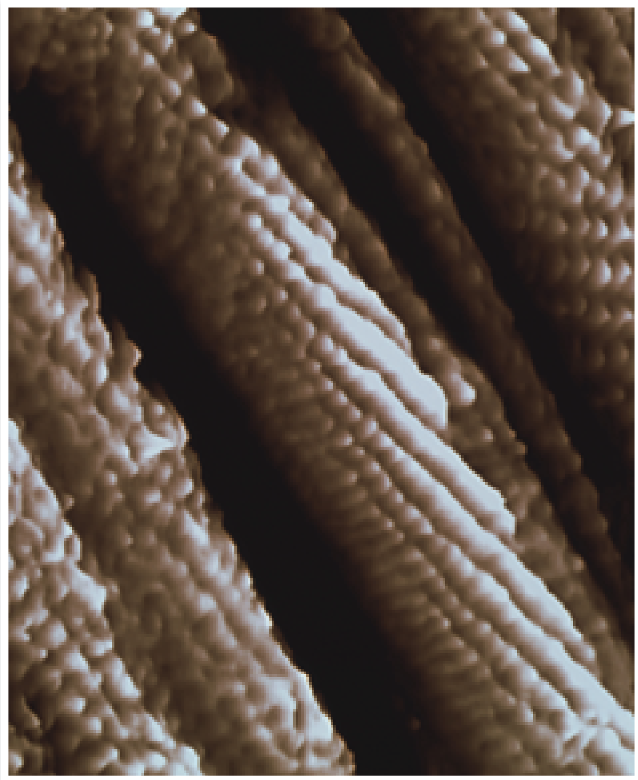

Fig 2.3.4 This scanning tunnelling micrograph (STM) shows carbon nanotubes. It is hoped that these could be used as conducting wires for heat or electricity. They are one-billionth the thickness of a human hair. Individual atoms can be seen as bumps on the surface of the tubes.

Science Clip

Working small, thinking big

Scientists are now trying to manipulate individual atoms and molecules. This has become possible only recently with the development of a new type of microscope called a scanning tunnelling microscope (STM), which allows scientists to see and move individual atoms. Working with atoms on this scale is called *nanotechnology*.

Nanotechnology offers much potential for building nano-sized machines. Useful nanotechnology already exists. The Australian-designed Biosensor enables doctors to obtain results from blood tests in less than 5 minutes. Nanotechnology also has the potential to make computers super-fast and small.

- The **mass number** is the number of protons and neutrons in the nucleus.

The simplest atom is the hydrogen atom, whose nucleus contains only a single proton, orbited by a lone electron. This means that the atomic number of hydrogen is 1, with helium, lithium and beryllium having atomic numbers of 2, 3 and 4, respectively.

Scientists use a special notation to describe how many protons, neutrons and electrons are in an atom.

For example, an atom of potassium (element symbol K) is written as:

mass number

$${}^{39}_{17}\mathrm{K}$$

atomic number

From this information you can determine the number of protons, neutrons and electrons.

The atomic number tells you the number of protons. Atoms are neutral and so the number of electrons is the same as the number of protons:

number of protons = atomic number

To find the number of neutrons, you need to subtract the atomic number from the mass number:

number of neutrons = mass number – atomic number

For a potassium atom, the atomic number is 19 and the mass number is 39. Therefore, this particular potassium atom has:

number of protons = atomic number = 19
number of electrons = number of protons
= atomic number = 19
number of neutrons = mass number – atomic number
= 39 – 19 = 20

Worksheet 2.5 Atomic graphs

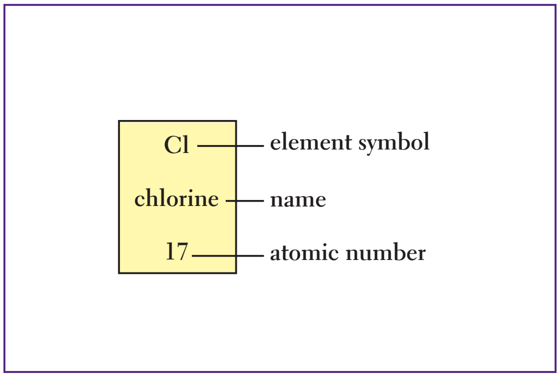

Fig 2.3.5 The number in each element's box in the periodic table is its atomic number.

Science Clip

Now that's strong!

The positive charge on protons means that, ordinarily, they would repel each other. However, in a nucleus, protons and neutrons are held together by the strongest force in the universe, known appropriately as the **strong force**. The force is so strong that it is 100 000 000 000 000 000 000 000 000 000 000 000 000 times stronger than gravity. However, the strong force does not extend very far out from the proton or neutron, and so these subatomic particles must be very close before the strong force can stick them together. As nuclei get bigger, the strong force is unable to hold the protons and neutrons together. As a result, atoms with big nuclei (e.g. uranium) are unstable and radioactive, with some particles escaping the nucleus.

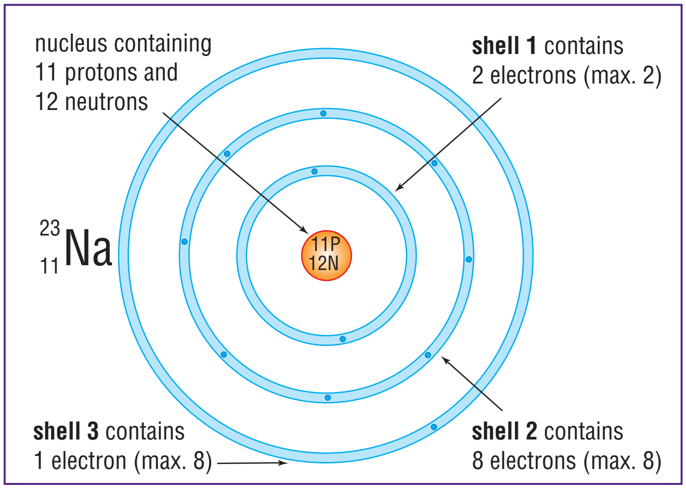

Fig 2.3.6 The sodium atom has 11 electrons in three electron shells. Two of the electrons orbit in the inner shell and eight are in the next shell, leaving one electron to orbit in the third shell.

Atomic structure

PP Interactive

Although it is impossible to see subatomic particles, scientists have been able to deduce the internal structure of an atom by performing experiments that probe inside the atom. From these experiments, scientists have learnt that the electrons not only surround the nucleus but form shells of different sizes around it. These shells determine how big the atom is, as well as most of its physical and chemical properties.

Electron shells

The biggest atoms can have up to seven **electron shells**, whereas the smallest atoms, hydrogen and helium, only have one. These electron shells get bigger and bigger as you move out from the nucleus and can hold more and more electrons. However, each shell can contain only a limited number of electrons. This number depends on their size:

- The innermost shell of any atom is the smallest of the shells and can hold only a maximum of two electrons.
- The second shell is bigger and can hold up to eight electrons.
- The third shell is bigger again and can hold up to 18 electrons, but normally only holds up to eight.
- The fourth shell can hold up to 32 electrons but, like the third shell, normally holds only up to eight electrons.

The shells closest to the nucleus are 'filled' first. This could be compared with filling spaces on a bookshelf—you might fill the bottom shelf first, then move up only as each lower shelf is filled.

Prac 1 p. 59

2.3 QUESTIONS

Remembering

1 **State** whether these statements are true or false.
  - **a** The atomic number is the same as the number of protons.
  - **b** The atomic number is the same as the number of electrons.
  - **c** The mass number is equal to the number of neutrons.
  - **d** The mass number is the number of particles in the nucleus.

2 **State** which subatomic particle(s):
  - **a** is the lightest
  - **b** contribute most to the mass of an atom
  - **c** are in the nucleus
  - **d** form a cloud around the nucleus.

3 **State** the charge on each of the following subatomic particles:
  - **a** an electron
  - **b** a neutron
  - **c** a proton.

4 A chlorine atom (Cl) has 17 protons, 18 neutrons and 17 electrons. **State** its:
  - **a** atomic number
  - **b** mass number
  - **c** symbol.

5 A boron atom has the symbol $^{11}_{5}B$. **State** its:
  - **a** atomic number
  - **b** mass number.

6 **State** the maximum number of electrons that fit in the:
  - **a** innermost shell
  - **b** second shell.

7 A sodium atom has 11 electrons. **State** how many would be in each shell, starting from the innermost.

Understanding

8 Atoms are described as being made up mainly of empty space. Use the structure of the atom to **explain** this statement.

Applying

9 **Calculate** the number of protons, neutrons and electrons for the following: (N)
  - **a** a chlorine atom with atomic number 17 and mass number 35
  - **b** a magnesium atom with atomic number 12 and mass number 24
  - **c** a gold atom with atomic number 79 and mass number 197.

10 **Use** the periodic table on page 34 to find the atomic numbers of each of the following atoms:
  - **a** Ca
  - **b** mercury
  - **c** nitrogen
  - **d** Fe

11 **Use** the periodic table on page 34 to find how many protons would be in an atom of:
  - **a** Ca
  - **b** carbon
  - **c** K
  - **d** plutonium.

12 **Use** the periodic table to find how many electrons would be in an atom of:
  - **a** Na
  - **b** phosphorus.

13 The mass number of aluminium is 27.
  - **a** **State** the number of particles in an aluminium nucleus.
  - **b** **Use** the periodic table to find the atomic number of aluminium.
  - **c** **State** how many protons, neutrons and electrons an aluminium atom contains.

14 **Use** the periodic table on page 34 to **identify** the missing number or element symbol. (N)
  - **a** $^{23}_{X}Na$
  - **b** $^{4}_{2}X$
  - **c** $^{59}_{X}Ni$
  - **d** $^{56}_{26}X$

Evaluating

15 **Propose** a reason why:
  - **a** hydrogen could be considered to be an unusual atom
  - **b** electrons are attracted to the nucleus but never crash into it.

>>

Creating

16 **Construct** diagrams of these atoms, showing the particles in the nucleus and the location of electrons in shells.

a $^{11}_{5}B$ **b** $^{27}_{13}Al$

17 In your workbook, **construct** a table like the one below, filling in the missing information for the first 20 elements.

Atomic number	Mass number	Element	Number of protons per atom	Number of electrons per atom	Number of neutrons per atom
		Hydrogen			
		Helium			
		Lithium			
		Beryllium			

Worksheet 2.6 The periodic table

2.3 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to research and summarise: L

- information about other subatomic particles, such as quarks
- what an ion is and how it differs from an atom
- information on isotopes
- the reason why electrons move in shells rather than in fixed orbits
- what it means when an element is said to be radioactive.

e-xploring

PP Web Destination

Take a trip into the nucleus of an atom by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

2.3 PRACTICAL ACTIVITIES

1 Building atoms

Aim

To construct 3D models of atoms

Equipment

- plasticine in three different colours
- wire
- string
- straws
- skewers or toothpicks

Method

1 Using two different colours of plasticine create models of the nuclei of atoms with atomic numbers 1 through to 10.

2 Choose one of the nuclei and, using wire, string, straws, skewers or toothpicks or other craft materials, add the electrons around the nucleus using a different coloured plasticine.

Questions

1 **Describe** how your 3D model represents characteristics of the inside of an atom.

2 **Explain** the limitations of your 3D model in describing the inside of an atom.

3 **Research** the atom represented by your 3D model and provide a one-page summary of its physical properties and some of its common uses.

Atomic models

Prescribed Focus Area:
The history of science

Indirect evidence

Over 2000 years ago, ancient Greek philosophers thought that everything was made from small particles that they called atoms, from the Greek word *atomos*, meaning 'that which cannot be divided'. Yet, they were confused about what an atom itself could be made from. This was also a difficult question for scientists because, until only recently, no-one could see an atom, let alone see inside one! They needed to carefully interpret evidence from experiments they did on matter. You do this all the time—often you can guess what a parcel contains well before you open it. Its shape, smell, texture and sound when shaken all give you clues. In the past hundred years or so, scientists have used **indirect** evidence to prove that all atoms are made from three basic types of particles—protons, electrons and neutrons.

History of atomic structure

Nevertheless, scientists were confused about how these particles were arranged. Using more indirect evidence, different theories about the structure of atoms were developed, with some scientists being awarded Nobel prizes for their discoveries. Some key dates are:

About 350 BCE
The ancient Greeks believe that atoms are solid balls of matter.

1808 John **Dalton** (an English chemist) supports the idea of atoms as solid balls.

1897 Sir Joseph John **Thomson** (Great Britain) discovers electrons.
The electron is the first known particle that is smaller than an atom.

1903 Sir Joseph John Thomson proposes the 'plum pudding' model of positively charged 'dough' with negatively charged electrons embedded in it.

1908 New Zealand-born physicist and student of Thomson, Ernest **Rutherford**, wins the Nobel prize for chemistry 'for investigations into the disintegration of the elements, and the chemistry of radioactive substances'.

1911 Ernest Rutherford proposes a nuclear model in which negatively charged electrons orbit a positive nucleus, with most of the atom being empty space. This was discovered in his famous gold foil experiment.

1913 Ernest Rutherford discovers that hydrogen is the smallest atom. Niels **Bohr**, a Danish physicist and assistant to Rutherford, extends Rutherford's model to include electron shells—regions in which a given number of electrons may move.

1914 Ernest Rutherford discovers the proton, although he did not name it until 1920.

1920 Ernest Rutherford proposes the existence of a 'neutron'.

1922 Niels Bohr wins the Nobel prize for physics 'for investigations of the structure of the atoms and their radiation'.

1932 James **Chadwick** (Great Britain) discovers neutrons.

Science Clip

School leader

Born in 1766, John Dalton was such a bright student that he was put in charge of his school at the age of 12!

Science Clip

Bohr's escape

During World War II, Niels Bohr escaped German-occupied Denmark, fleeing to America where he assisted with atomic bomb research.

Science Clip

A Nazi piece of work

Rutherford's assistant, Hans Geiger, later became a devoted Nazi who betrayed many of his Jewish friends and colleagues, sending them to concentration camps. He is best known for his invention of the Geiger counter, a device that would detect nuclear radiation.

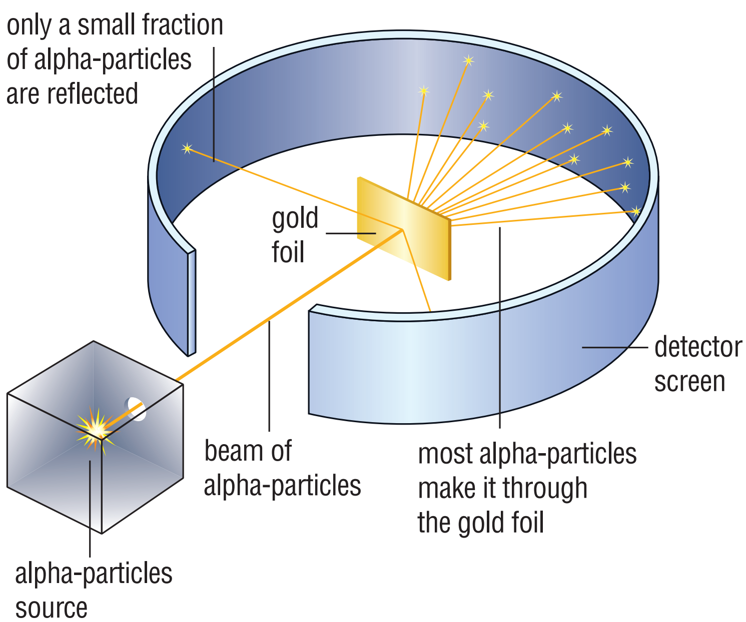

Fig 2.3.7 Rutherford's alpha-particles and gold foil experiment, during which most alpha-particles went straight through, suggested that the gold atoms making up the foil were largely made up of empty space.

Probing the inner atom

Scientists now know that atoms are mostly made up of empty space. Ernest Rutherford first discovered this while working with two other scientists, Geiger and Marsden. They experimented with firing tiny positively charged subatomic particles (called **alpha-particles**) at thin gold foil. Amazingly, many of the alpha-particles went straight through the gold foil, some not even moving from their path! This suggested to Rutherford that most of an atom was empty space, allowing the alpha-particles to go straight through. Some of the alpha-particles were scattered, however, and Rutherford suggested that this was because they were repelled by a concentration of positive charges in the centre of an atom.

In 1911 he presented his theory of the atom as consisting of a small, dense positively charged nucleus with negatively charged electrons orbiting the nucleus. Bohr then improved Rutherford's model of the atom by explaining how electrons orbit around the nucleus. He suggested that the electrons orbit in special regions, or shells, that surround the nucleus.

PP Video Clip

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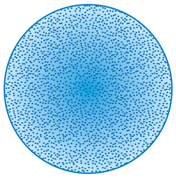
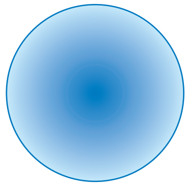


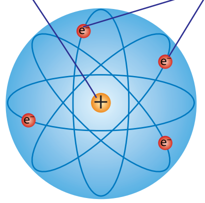
Ancient Greek philosopher, **DEMOCRITUS** (born about 460 BC) describes matter as made up of 'indivisibles' (atomis). These particles were extremely tiny, absolutely solid objects that were eternal.

Matter considered to be made up of EARTH, WATER, FIRE and AIR.
Alchemists try to transmute or change metals into gold.
Scientific method develops in 16th century.



1808 English chemist, **John DALTON** revives the Atomis idea and describes matter as made of solid, indivisible particles he called atoms. Dalton created a list of the different known atoms or elements.

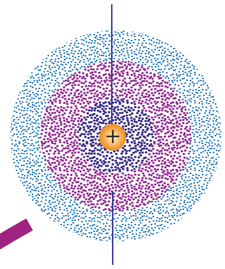
Radioactivity discovered and used to explore the structure of atoms.



Small, extremely dense nucleus with all positive charge of atom and majority of mass.

Tiny electrons moving quickly in orbits around nucleus. Take up the space occupied by the atom.

1911 New Zealand physicist, **Ernest RUTHERFORD** analyses experimental results using radioactive particles to study atoms. He describes the 'nuclear' atom. His model of the atom had a tiny, very dense, positively charged nucleus about 1 ten-thousandth the diameter of the atom. The very tiny negative electrons orbited around the nucleus like tiny planets. The atom was mainly empty space.



Small, extremely dense nucleus containing **protons** (positive charge) and **neutrons** (neutral). Represents nearly all the mass of the atom.

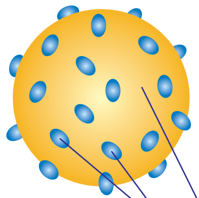
Negative electrons exist in 'quantised energy levels. Electrons are shown as a 'charge cloud' that shows where an electron may be found in an area of space called an energy level.

1932 A new model was developed from previous ideas but with changes based on the contributions of several scientists including Louis Debroglie, James Chadwick, Werner Heisenberg, Erwin Schrödinger and Paul Dirac. The nucleus is where most of the mass of an atom is found and contains the protons and neutrons. The number of protons in the nucleus determines what element the atom is.
The electrons exist in very definite areas (or energy levels) around the nucleus. The movement of electrons are difficult to show on a diagram as they take up an area of space, and do not have a set orbit like the Bohr model. Electrons in different energy levels have a definite amount of energy (quantised) which allows them to stay there.

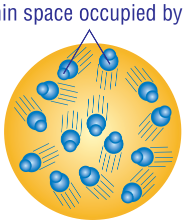
Today The standard model is still based on the previous model but has more complex arrangement of electrons around the atoms.

Fig 2.3.8 There have been many models proposed to explain the structure of the atom. As new evidence has come along, some models were abandoned and others were 'fine-tuned'.

Extensive studies of chemistry and matter through experiments. New elements discovered and electricity becomes readily available. Electron identified as being present in atoms of all elements.

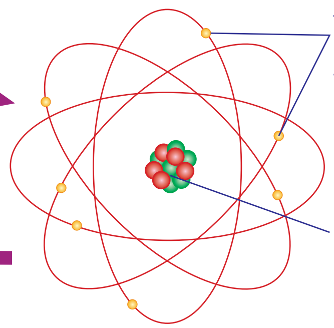


1903 English physicist, **Joseph John THOMSON** describes atoms as like a plum pudding or raisin cake. The atom was a heavy positive pudding with the light negatively charged electrons embedded in it.



1904 German physicist **Philip LENARD** describes atoms as mainly empty space filled with fast-moving, neutral particles he called dynamides. These dynamides were made up of a heavier positive particle joined with a negative electron.

Quantum theory is developed. It indicates that a particle (such as an electron) will have a set amount of energy.



Quantum mechanics is developed using quantum theory, Chadwick discovers and identifies neutron.

1913 Danish physicist, **Niels BOHR**, applies his own ideas to the electrons of the Rutherford nuclear atom. His new model has the electrons in orbits where they are only able to exist at very definite positions with a very definite energy (quantised). This uses quantum theory, which implies that particles have set amounts of energy.

STUDENT ACTIVITIES

1 a **State** two things that are basically the same for all the models described on pages 62–63. **Outline** reasons for your choices.

b **Discuss** your answers with a partner to compare your ideas.

c **Compare** your results with those of other groups and compile a class summary of the features of different models of the atom that have remained the same.

2 Based on the models of the atom, **explain** why atoms of the different elements have different masses.

3 The table below summarises the basic parts found in the current model of the atom. Copy and complete the table by choosing the correct description from the list provided, to fill each box.

Energy levels around nucleus
Negative
1.0
Neutron
Central, dense core
Positive
Approx. 1/2000
Neutral (none)

4 The existence of the neutron was suggested by Ernest Rutherford in 1920, but wasn't finally discovered by experiments until James Chadwick did his Nobel prize-winning work in 1932.

a **Propose** reasons why the neutron was suggested by Rutherford before it had been actually identified.

b **Discuss** with a partner reasons why the neutron was very difficult to detect and **record** your ideas.

5 In small groups, **research** the following very famous experiments:

a the alpha-particle scattering from gold foil used by Ernest Rutherford to develop his nuclear model for atoms

b the discovery and verification of the neutron by James Chadwick.

For each experiment:

i Create a demonstration or model to **demonstrate** how each experiment was conducted.

ii **Compare** the experiments and make a list of the similarities and differences between them.

6 Chadwick's and Rutherford's experiments provided a new and very useful technique to explore atoms. This led to the creation of the particle accelerator.

Research particle accelerators and then:

a Use pictures to **demonstrate** how a particle accelerator works.

b **Outline** some uses and benefits of particle accelerators.

Name	Where found in an atom	Electrical charge	Relative mass (compared with a proton, taken as 1.0)
Nucleus		Positive	Depends upon atom
Proton	In the nucleus		1.0
	In the nucleus		
Electrons			

PRACTICAL ACTIVITY

1 Indirect evidence

Aim

To use indirect evidence to decide what something is

Equipment

- numbered opaque boxes or paper bags, each with an 'unknown' object in it
- numbered and sealed film canisters, each with a ball of cotton wool to which has been added a couple of drops of safe fragrant liquids

Your teacher will have a list of all their contents, which will be kept secret until the end.

>>

Method

1 Take a box/bag and use all of your observation skills to determine what each object is.
2 Record the number of each box/bag and what you thought it contained.
3 Open one of the film canisters and carefully sniff its fragrance.
4 Record the number of each film canister and what you thought the fragrance was.
5 After testing all boxes/bags and film canisters, check with your teacher what was in each.

Questions

1 **State** how accurate your predictions were.
2 **List** the senses used in determining what was in each container.
3 **State** whether you actually needed to see what was in each container to get it right.
4 **Describe** how this experiment relates to the evidence for atoms and the subatomic particles of which they are made.

CHAPTER REVIEW

Remembering

1 **State** which of these statements is correct. In a chemical change:
  A only pure substances combine
  B no new substances are formed
  C one new substance is formed
  D one or more new substances are formed.
2 **State** which of the following substances is the most pure:
  A an element
  B a compound
  C a mixture
  D sugar.
3 **Recall** element symbols by writing the symbols for the following elements:
  a carbon
  b aluminium
  c gold
  d tin.
4 **Name** the elements that have the following symbols:
  a Ag
  b Fe
  c Cu
  d B.
5 **State** whether the following statements are true or false:
  a The nucleus is the central region of an atom.
  b Any number of electrons can orbit in the innermost shell of an atom.
  c Only two protons may orbit in the innermost shell surrounding an atom.
  d Electrons are incredibly small compared with neutrons and protons.
6 **Recall** chemical formulae by writing the formulae for:
  a sucrose
  b hydrochloric acid
  c water
  d carbon dioxide.
7 **a** **List** the four types of chemical reactions.
  b Write the word and unbalanced chemical equation for an example of each type.

Understanding

8 **Describe** the charge and relative size of subatomic particles found in the atom.
9 **Construct** a table to **outline** the properties of metals and non-metals.
10 **Explain** why these metals and non-metals are able to be used for the purpose shown in the table below.

Metal	Use	Non-metal	Use
Copper	Electrical wires	Diamond	Cutting tools
Silver	Jewellery	Liquid nitrogen	Freezing warts
Aluminium	Aeroplane frames	Sulfur	Food preservative

>>

Applying

11 Some eggs are to be scrambled for breakfast. They are broken and milk is added. After being mixed thoroughly, they are cooked by stirring continuously in a hot pan. They are then eaten and digested. **Identify** the physical and chemical changes involved from start to finish.

12 Copy Figure 2.4.1 into your workbook and **identify** the parts of the helium atom indicated.

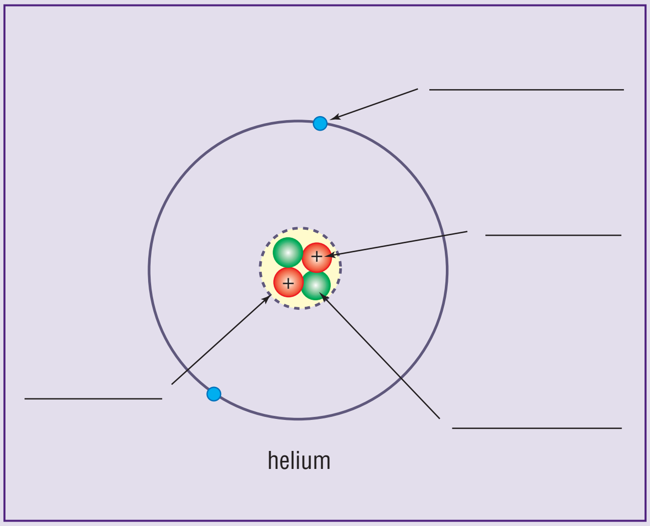


Fig 2.4.1

Analysing

13 **Explain** and **distinguish** a combination reaction from a decomposition reaction. Give an example of each with its word equation.

14 For each of these atoms **calculate** the number of protons and neutrons. (N)

- **a** ${}^{56}_{26}Fe$
- **b** ${}^{64}_{29}Cu$
- **c** ${}^{127}_{53}I$
- **d** ${}^{238}_{92}U$

15 **Use** this list to **classify** each of the diagrams in Figure 2.4.2: atom, element, compound, molecule, mixture.

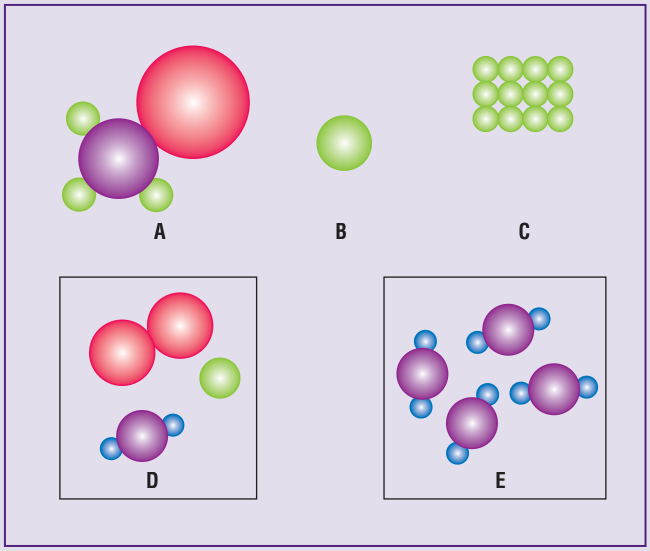


Fig 2.4.2

Evaluating

16 **Propose** whether each of the following would most likely speed up, slow down or not affect the reaction:

- **a** More wood is added to a fire.
- **b** The gas control is set to low on a cooktop when a stir fry is being prepared.
- **c** A 'chlorine tablet' is added to a spa instead of the same chemical in powder form.
- **d** Your digestive system releases enzymes.

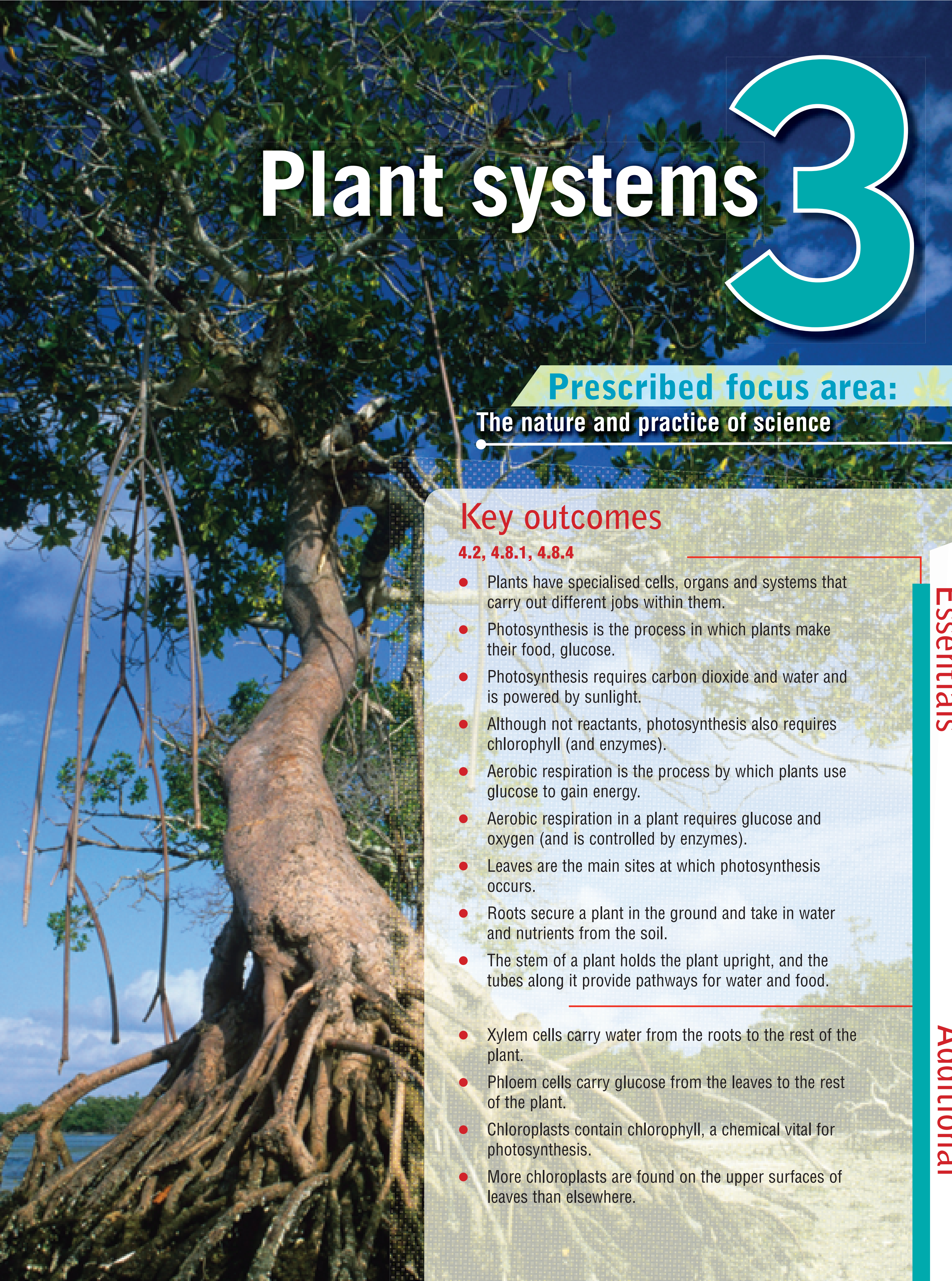
Creating

17 **Design** an experiment to determine how temperature affects the rate of a common chemical reaction, like rusting or ripening of fruit.

Worksheet 2.7 Crossword

Worksheet 2.8 Sci-words

PP Chapter Review Questions



Plant systems 3

Prescribed focus area:
The nature and practice of science

Key outcomes

4.2, 4.8.1, 4.8.4

Essentials

- Plants have specialised cells, organs and systems that carry out different jobs within them.
- Photosynthesis is the process in which plants make their food, glucose.
- Photosynthesis requires carbon dioxide and water and is powered by sunlight.
- Although not reactants, photosynthesis also requires chlorophyll (and enzymes).
- Aerobic respiration is the process by which plants use glucose to gain energy.
- Aerobic respiration in a plant requires glucose and oxygen (and is controlled by enzymes).
- Leaves are the main sites at which photosynthesis occurs.
- Roots secure a plant in the ground and take in water and nutrients from the soil.
- The stem of a plant holds the plant upright, and the tubes along it provide pathways for water and food.

Additional

- Xylem cells carry water from the roots to the rest of the plant.
- Phloem cells carry glucose from the leaves to the rest of the plant.
- Chloroplasts contain chlorophyll, a chemical vital for photosynthesis.
- More chloroplasts are found on the upper surfaces of leaves than elsewhere.

Unit 3.1 Plant transport systems

context

Food gives an organism the energy it needs for movement, growth, repair and reproduction. All food, whether it is a cake, an apple or a sausage roll, comes directly from plants, their seeds and oils, or from the animals that eat them and their produce, such as eggs and cream. In this way, plants are essential to continued life on Earth. Plant material is used for other purposes, too—birds use it to make nests and beavers make dams with it. Humans use wood for fires, for building and for making paper. Cotton and linen are used in clothing and flowers are used in making scents and in the production of some drugs and medicines.

PP Quick Quiz

Fig 3.1.1 Most life on Earth depends on photosynthesis. Animals eat plants directly or eat other animals that eat plants.

Plant systems

Like all living things, plants are made up of cells that group together to form **organs**, which then group together to form **systems**. Leaf cells, for example, group together to form leaves, which are vital organs for a plant. Several leaves form a system for the plant, in this case a food-making system. Some other plant systems are:

- a **reproductive system**, consisting of the parts of a flower
- a **food storage system**, often in the form of a bulb or tuber
- a **root system** for securing the plant in the ground and obtaining water and nutrients
- a **transport system** of pathways and veins, which allow food and water to be moved around the plant.

What do plants need?

Anyone who has grown a plant knows they need sunlight, fresh air and water and nutrients from the soil. If the plant lacks any of these, they will soon wilt, become sickly and die.

Like all living things, plants need energy to live, grow and reproduce. Although animals get their energy from the food they eat, plants don't eat and so they must make their own food. They do this in a process called photosynthesis.

Photosynthesis combines carbon dioxide (CO_2) with water (H_2O) to make glucose ($C_6H_{12}O_6$) and oxygen gas (O_2). Plants are green because they contain a green pigment called **chlorophyll**. Chlorophyll traps energy from sunlight and uses it to power the photosynthesis reaction.

The process of photosynthesis is summarised as the word equation:

carbon dioxide + water + sunlight ⟶ glucose + oxygen

Chemists write this as a balanced chemical equation:

$$6CO_2 + 6H_2O + \text{sunlight} \longrightarrow C_6H_{12}O_6 + 6O_2$$

A plant draws in the required carbon dioxide from the air around it and draws up the water it needs through its roots. The oxygen produced in photosynthesis is released back into the air. The other product, **glucose**, is a type of sugar that acts as food for the plant.

Fig 3.1.2 Each system in a plant carries out a different task. The leaves of this beetroot plant produce the glucose the plant needs as food. The edible bulb stores it for later use. The root secures the plant in the ground and absorbs water and nutrients from the soil.

Plant pathways

A plant needs to transport water and nutrients from its roots to its leaves, and needs to transport the glucose it produces out from the leaves to the cells that need food. This requires a transport system and a set of pathways along which it can occur.

There are two types of tubes that transport food and water inside and around plants—xylem and phloem.

Xylem tubes carry water and minerals (e.g. phosphorous, potassium, nitrogen, sulfur, calcium, iron and magnesium) from the soil, up into the stems and leaves. Xylem tubes are made of dead cells strengthened with a woody substance. Unlike animals, a plant does

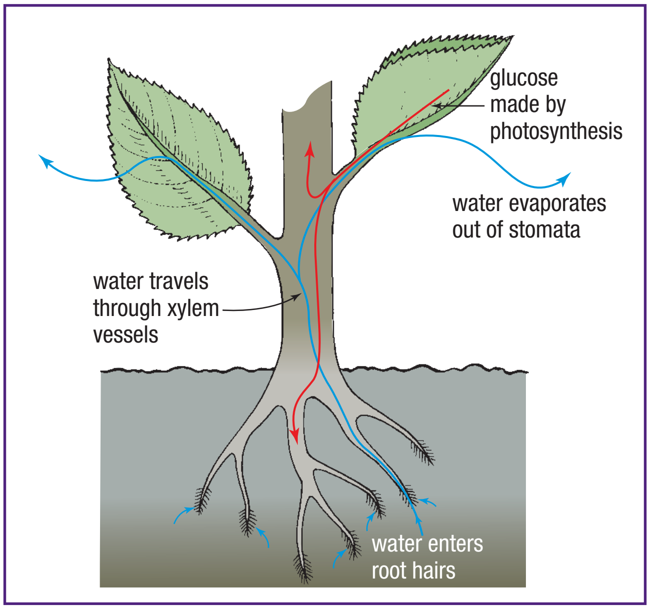


Fig 3.1.3 Plants have pathways that take water from the roots to the leaves and stems (xylem tubes) and other pathways (phloem tubes) that carry glucose from the leaves to the rest of the plant.

not have a heart to pump liquid through its tubes. Instead, water is pushed upwards by pressure in the roots. Evaporation through the stomata (i.e. tiny holes in the leaves) assists further in sucking the water upwards.

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p. 72

Phloem tubes are made from living cells. Their function is to transport the glucose that is produced by photosynthesis in the leaves to where it is needed. Plants use the glucose they make in four different ways. Some of the glucose will be:

- used immediately to provide the plant with energy
- stored in the plant's leaves, stems, roots, seeds and fruits for later use, such as the production of buds in spring
- used to make cellulose to reinforce the cell wall
- combined with minerals to make proteins needed for the plant to grow.

Science Clip

Sweet!

Lettuce and cabbage store glucose directly in their leaves, whereas celery stores it in its stems and carrot plants store it in the tuber that forms their root and the actual carrot. Some plants convert their glucose into starch, instead. Potatoes do this, which explains why they are not as sweet as lettuce, celery or carrots. A green banana contains starch, but ripening changes it back into glucose. This makes ripe bananas sweeter than green ones.

Fig 3.1.4 Root hairs increase the surface area through which water is absorbed into a plant.

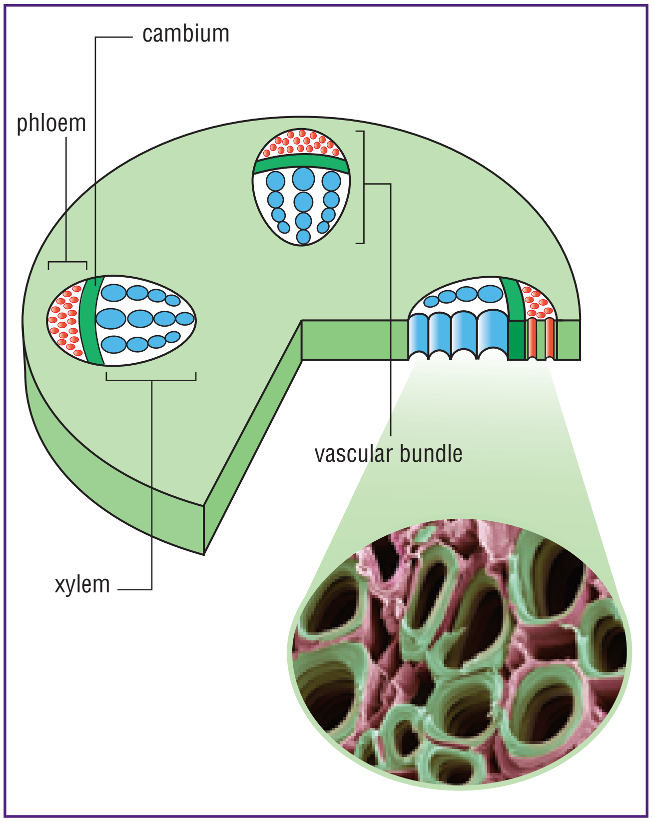


Fig 3.1.5 Xylem and phloem tubes are grouped together in vascular bundles and separated by a layer of cambium cells, which are able to become either new xylem or new phloem cells, whichever is required.

Plant skeletons

Unlike animals, plants do not have skeletons to hold them upright.

Firm or floppy?

In the centre of each plant cell there is a large vacuole that is filled with sap, its main component being water. This water keeps the cells firm and rigid (**turgid**) and stops them from collapsing in on themselves. In this way, the soft parts of plants (such as their stems and leaves) are kept upright. Water moves out of the vacuole when it's dry, causing the cell to collapse and the plant to droop and wilt.

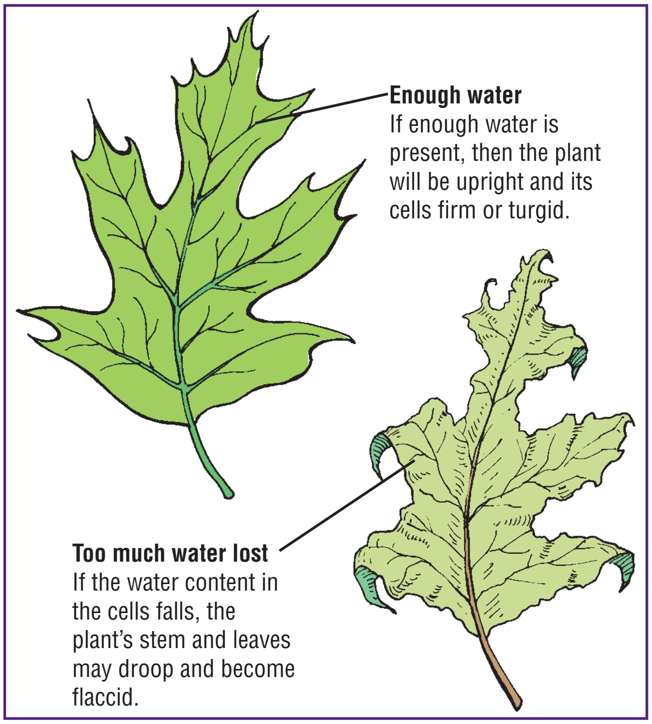
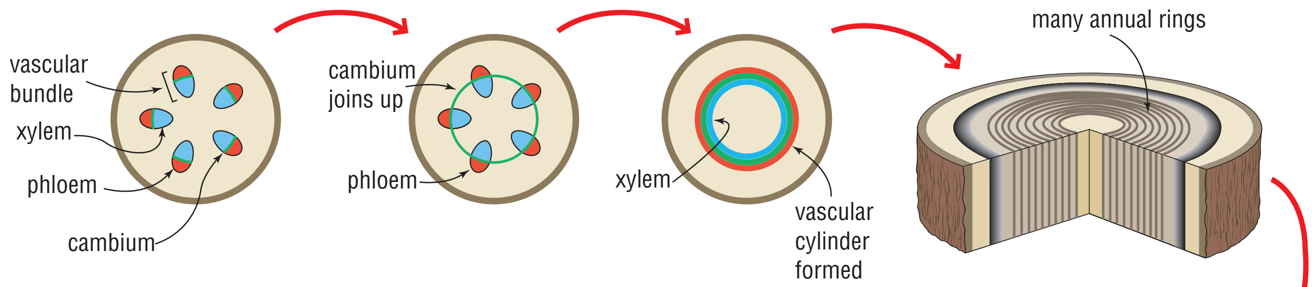


Fig 3.1.6 The leaves and stems of a plant are upright and firm when sufficient water is present in their cells, but wilt and lose shape when water content in the cells fall.

Science Clip

Native cures

Aboriginal expertise in plants has been known for many years. Many Australian plants supply bush medicines. Bitter Bark is used to prepare a tonic that reduces blood pressure and is a tranquilliser. Many plants and some types of honey can be used on sores and wounds, as they provide natural antibiotics to help in healing. A native daisy is used to treat toothache, as it contains a local anaesthetic. Over half the world's supply of two drugs, hyoscine (a muscle relaxant) and scopolamine (for treatment of motion sickness), come from an Australian native tree that was used by Aborigines as an emu and fish poison.



Wood

Trees are just big plants and so they, too, contain xylem and phloem cells. Vascular bundles in the stem eventually link up to form a vascular cylinder. Phloem cells stay in the outer layer of a tree, just under the bark. These phloem cells are the pathways for nutrients to reach all parts of a tree. The tree may die if enough of them are removed or damaged. Ringbarking, for example, removes a layer of phloem cells and will quickly kill a tree. Each year a new layer of xylem cells is produced, and the inner layers of old xylem cells combine with other plant substances to form **wood**.

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Prac 3 p. 73

Worksheet 3.1 Water movement in trees

PP Drag-and-drop

Fig 3.1.7 A tree forms a new growth ring every year. These are seen clearly when the tree is cut down and represent a history of its life. Good seasons are indicated by wide spacing, whereas narrow spacing indicates bad seasons.

3.1 QUESTIONS

Remembering

1 For the process of photosynthesis, **list** what chemicals:
  a need to be taken in by the plant for the reaction to happen
  b are produced by the reaction.
2 **Specify** where the energy for the reaction comes from.
3 **State** whether the following statements are true or false:
  a Water is conducted up and down the plant stem through the xylem.
  b Water is transported around the plant in the phloem.
  c Xylem and phloem are grouped together in the cambium.
  d Dead xylem and phloem cells turn into cambium.
4 **Name** the tubes in plants that carry:
  a nutrients
  b water and minerals.
5 **Name** the cells that turn into wood.

Understanding

6 **Define** the terms: L
  a turgid
  b flaccid
  c cambium cells
  d vascular bundle.
7 **Explain** how water is moved upwards in a plant.
8 **Explain** how plants stay upright even though they don't have a skeleton.
9 Ringbarking a tree is likely to kill it. **Explain** why this occurs.
10 Flowers are usually placed in water in a vase to keep them looking good. **Explain** how this stops them from going flaccid.
11 **Account** for the presence of a large network of root hairs on plants like those shown in Figure 3.1.4.

>>

Applying

12 Refer to the plant shown in Figure 3.1.8 and **identify** which part contains the plant's:

- **a** root system
- **b** reproductive system
- **c** food-making system
- **d** food and water transport system
- **e** food storage system.

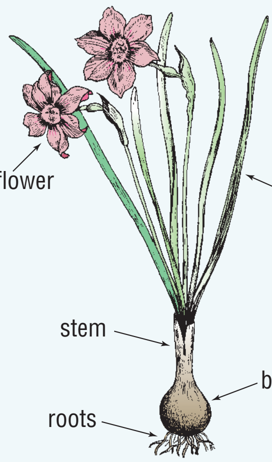

Fig 3.1.8

13 Plants contain a large amount of carbon. **Identify** where this carbon comes from.

14 A rabbit nibbles the base of a small tree. **Identify** the plant tubes that are most at risk.

15 **Calculate** the minimum age of the tree trunk drawn in Figure 3.1.7.

16 **Identify** factors that may change the growth rate of a tree and the spacing of the rings in its trunk.

Analysing

17 The cells in a plant act in a similar way to a balloon.

- **a** **Analyse** what happens as air is let out of a balloon.
- **b** **Compare** this with a plant cell as it dries out.

Evaluating

18 Most of the cells that can carry out photosynthesis are located on the upper surfaces of the leaves. **Propose** a reason why.

19 **Propose** reasons why:

- **a** Most plants from the Northern Hemisphere (e.g. from Europe, North America, Japan or China) have the flat surface of their leaves directly facing the Sun.
- **b** Plants from hot countries, such as Australia and South Africa, have spiky leaves.
- **c** Gum leaves droop, their flat surfaces being vertical. (Hint: Gum trees are native to Australia.)

20 Imagine the Sun suddenly 'turning off'. Most things living on Earth would soon die.

- **a** **List** the order in which the following would most likely die out: gum trees, humans, cows, grass, mushrooms, fleas, cheetah, tinea.
- **b** **Justify** your choice of order.

3.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) and research information about the manufacturing of paper from wood. Construct a labelled poster that shows each step in the process. L

e-xploring

PP Web Destination

Investigate more about the structure of trees and wood by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Use your information to construct a model representing the structure of trees and wood.

3.1 PRACTICAL ACTIVITIES

1 Water transport in celery

Aim

To observe a movement of water in the xylem of celery

Equipment

- celery stick with leaves
- two beakers
- razor blade
- dye

>>

Method

1. Arrange the apparatus as shown in Figure 3.1.9 and leave overnight.
2. Carefully inspect the divided celery stalk the next day or class.
3. Continue inspecting the divided celery stalk by cutting a piece lengthways and another piece across the stalk. Look for any presence of the dye.

Extension

Modify the experiment to investigate what effect the leaves have on the movement of dye.

DYO

Questions

1. **Construct** diagrams of the horizontal slice and of the vertical slice. In each diagram show where the dye was found.
2. **Describe** where the dye got to and the directions in which it travelled.
3. **Propose** reasons why one half of the celery stalk was left in water with no dye.

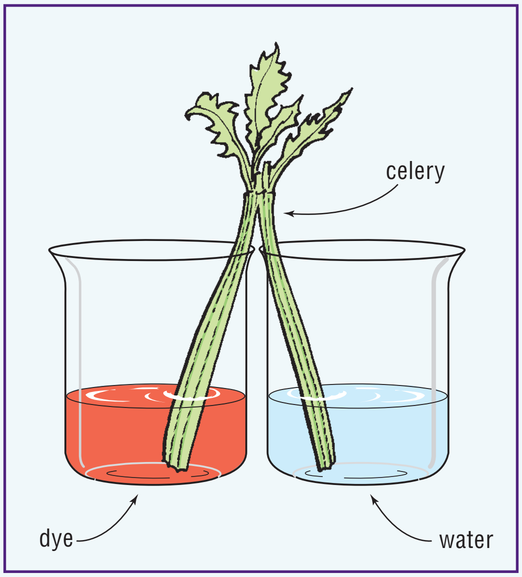

Fig 3.1.9

2 Ringbarking

Aim

To observe what happens when a plant is ringbarked

Equipment

- two geranium shoots
- razor blade
- petroleum jelly
- beaker or conical flask

Method

1. Use the razor blade to carefully ringbark one geranium shoot.
2. Cover the ringbarked area with petroleum jelly to prevent it from drying out.
3. Place the shoot in a beaker or conical flask of water.
4. Also place a similar, non-ringbarked geranium shoot in the container of water.
5. Leave both for two weeks and observe any root growth.

Question

Root growth requires food that is produced in the leaves.
Draw a conclusion about food pathways in geranium shoots.

3 Reddest radishes

Aim

To grow radishes

Equipment

- radish seeds
- Petri dish
- cotton wool
- beaker or saucer

Method

Part A

1. Place some radish seeds on moist cotton wool and observe the roots that develop over a few days.
2. **Contrast** your observations with those you might get if you pulled a similar plant straight out of the ground.

Part B

DYO

Organise a class competition to see who can grow the largest, reddest, tastiest radish. Choose the type of radish seeds carefully, and work out how you will make sure your radish grows up to become a winner. On judging day award various prizes, such as for the largest, longest, reddest, hottest tasting, crunchiest and heaviest radishes.

Growing hints

- Care for your plants—water, weed and talk to them!
- Find out what type of soil radishes like.
- When choosing your seeds, read what the packet says.
- Leave the plants somewhere warm and sunny.
- It may help to add compost or fertiliser to the soil.
- Research the conditions in which seeds and plants like to grow.

Unit 3.2 Photosynthesis and respiration

context

Unlike animals, plants have no mechanism to eat food. They have no digestive systems and cannot go hunting or move about grazing on other organisms. This requires them to make their own food, glucose. They do this in a process called photosynthesis. Yet, the production of glucose is useless unless the chemical energy contained in it can be released. This is the role of another chemical reaction, respiration. Although very different in detail, photosynthesis and respiration are effectively opposites of each other.

Fig 3.2.1 The Sun is the source of energy for all living things on Earth. It allows plants to make their own food. They then become the food of animals, passing this energy on to them.

Photosynthesis makes glucose

Glucose ($C_6H_{12}O_6$) is a type of sugar. It provides all the energy that animals and plants need. Animals get their glucose by digesting food, whereas plants make their own glucose by a set of chemical reactions known as photosynthesis.

Photosynthesis combines carbon dioxide (CO_2, drawn from the air) and water (H_2O, drawn from their roots) to make glucose and oxygen gas (O_2, which is released back into the atmosphere). The energy that powers the process comes from sunlight. This means that photosynthesis can occur only during the daytime.

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Photosynthesis is a series of reactions, but can be summarised by the word equation:

carbon dioxide + water + energy → glucose + oxygen

or as a balanced chemical equation:

$$6CO_2 + 6H_2O + \text{energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

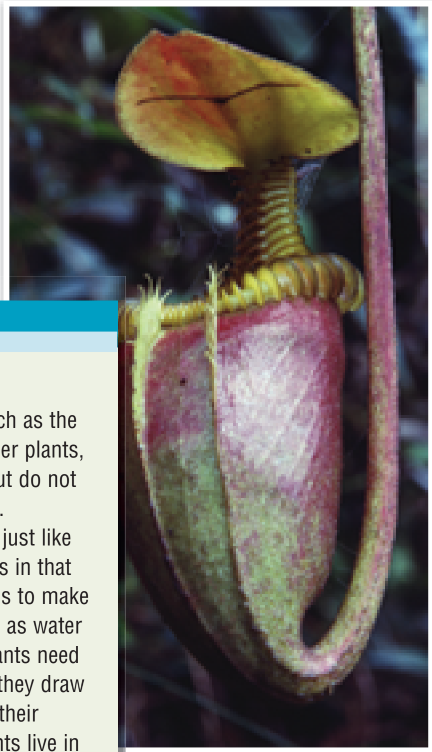

Fig 3.2.2 A pitcher plant does not 'eat' insects to give them energy, but for the nutrients the insects contain.

Science Clip

Carnivorous plants

Carnivorous plants, such as the Venus flytrap and pitcher plants, seem to 'eat' insects but do not gain energy from them. Carnivorous plants are just like most other green plants in that they use photosynthesis to make their own food. As well as water and carbon dioxide, plants need other nutrients, which they draw up from the soil using their roots. Carnivorous plants live in soil with very few nutrients. They get their nutrients from the insects they catch and dissolve.

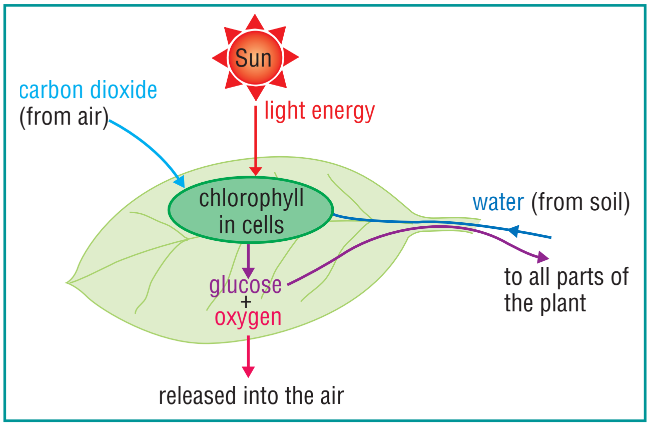

Fig 3.2.3 The green colouring in leaves comes from chlorophyll. Without chlorophyll, the plant would not be able to use the energy in sunlight and photosynthesis would not be able to happen.

Chlorophyll and chloroplasts

Although it doesn't appear in the equation, photosynthesis does not happen unless another chemical, chlorophyll, is present. **Chlorophyll** is a green pigment and is the reason why the leaves of most plants are shades of green. It acts something like a solar cell for the plant, trapping energy from sunlight and converting it into another form.

Chlorophyll is held in structures called **chloroplasts**, which themselves are found within the cells of all green plants. Chloroplasts act as solar-powered 'food factories', producing glucose for the plant. Each plant leaf typically contains tens of thousands of cells, each containing 40 to 50 chloroplasts.

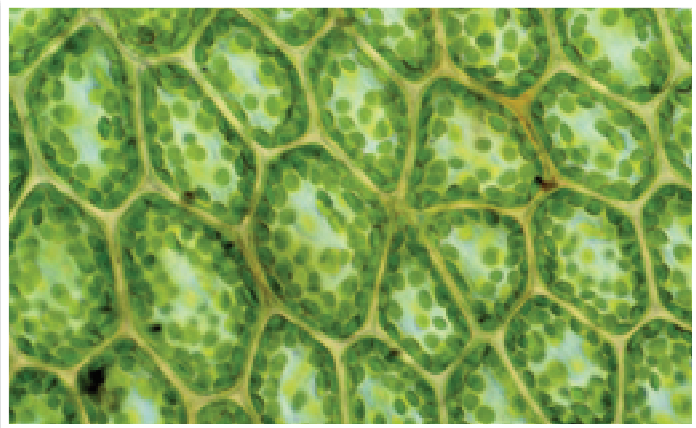

Fig 3.2.4 The cells in this plant are clearly visible when viewed under a microscope. Its chloroplasts appear as small green dots in each cell. Chloroplasts contain the green pigment chlorophyll. Without chlorophyll, photosynthesis would not occur.

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PP Drag-and-drop

Photosynthesis in more detail

The role of enzymes

The photosynthesis equation above gives only a simple summary of what actually happens. Nothing happens, for example, when carbon dioxide, water and chlorophyll are placed in a test tube in sunlight. This is because photosynthesis is a complex chain of smaller reactions, each requiring another chemical called an enzyme. **Enzymes** are complex protein molecules that act as biological catalysts. A **catalyst** is something that speeds up a chemical reaction without itself being used up in the reaction.

Light and dark reactions

The many complex reactions that make up photosynthesis take place in two main stages.

Science Clip

A fungi diet

Although mushrooms, toadstools and mould look like plants, they are more like animals in the way they obtain their energy. Fungi are not green and do not have any chlorophyll, and so cannot use photosynthesis to make their energy. Instead they 'feed' on dead and decaying material, such as wood, leaf litter and the dead skin between your toes!

Stage one: The light reaction

This reaction needs the energy from sunlight, and therefore can happen only throughout the day. The key to this reaction are two molecules—called **ADP** (shorthand for adenosine diphosphate) and **ATP** (adenosine triphosphate). ADP is something like a 'flat' battery that needs to be re-charged. When ADP absorbs light energy, it 'charges up' and changes into ATP. This can be written as a word equation:

ADP + energy ⟶ ATP

ATP is a molecule that stores chemical energy. It acts like a charged battery, storing energy for later use in the dark reaction.

While all this is happening, enzymes split water (H_2O) into oxygen (O_2) and hydrogen ions (H^+). Although this splitting normally needs temperatures of about 2000°C, enzymes allow it to happen in the cell at room temperature.

Stage two: The dark reaction

This is a series of enzyme-controlled reactions that can proceed in the dark. It needs no energy from sunlight, but it does need the energy stored in the ATP produced earlier. This energy is used to form glucose by combining carbon dioxide (CO_2) and hydrogen ions (H^+). As the ATP releases its energy, it changes back into ADP.

ATP ⟶ ADP + energy

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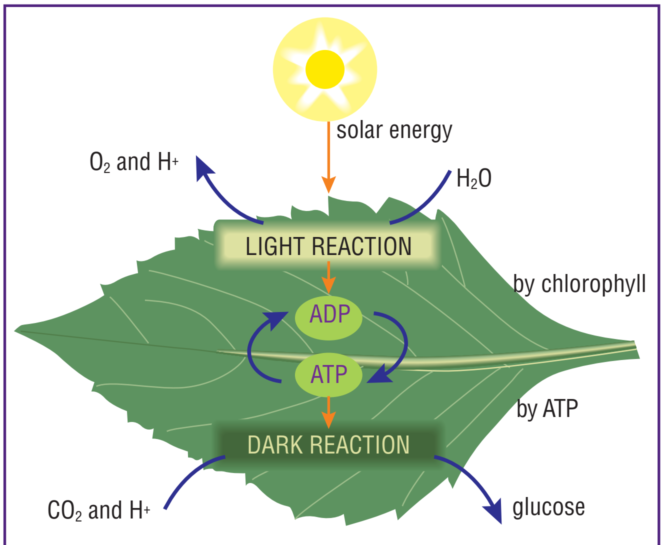

Fig 3.2.5 Photosynthesis occurs in two stages—the light reaction and the dark reaction.

The rate of photosynthesis

The rate at which photosynthesis occurs depends on:

- the temperature
- the amount of light available
- the availability of carbon dioxide.

Increase any of these factors and the rate of photosynthesis will generally increase, too.

As in most chemical reactions, the rate of photosynthesis generally increases as the temperature gets higher. Above 30°C, however, the enzymes no longer function properly and so the rate of photosynthesis starts to drop.

In nature, plants seldom reach their maximum rate of photosynthesis. For example, there is plenty of light on bright, sunny days but there is insufficient carbon dioxide, as air contains only 0.04 per cent carbon dioxide, and so this limits the rate of photosynthesis. Likewise, the rate is limited by the cooler and darker conditions of early morning and late afternoon. At night, there is no photosynthesis because there is no sunlight to power it.

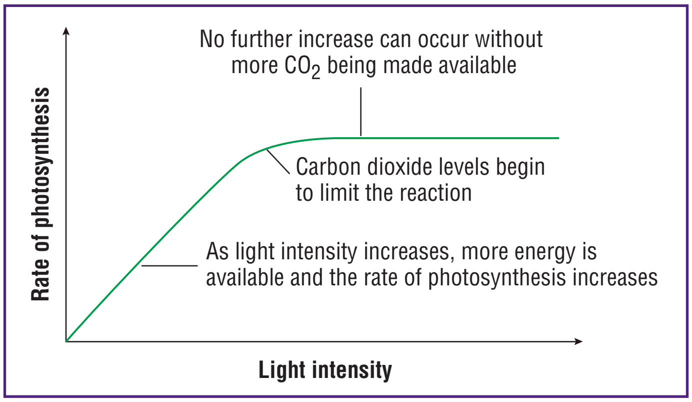

Fig 3.2.6 At first, the rate of photosynthesis increases as light intensity increases. A lack of carbon dioxide stops it increasing any further.

How plants use glucose

Photosynthesis produces glucose in plants and is then converted into:

- energy by a process called respiration
- cellulose for building plant cell walls
- other sugars for transport to various parts of the plant
- substances used for producing oils and proteins
- starch for temporary storage in the leaf. This happens on sunny days when photosynthesis produces glucose at a rate faster than the rate at which it is used. Photosynthesis stops at night, so this stored starch is reconverted to glucose, providing continuous energy to the plant. This process is known as **destarching** the leaf.

Fig 3.2.7 Photosynthesis produces glucose, which is sometimes converted into oils (e.g. sunflower oil, olive oil and safflower oil).

Worksheet 3.2 Temperature and photosynthesis

Respiration burns glucose

Animals get their glucose by digesting the food they eat, whereas plants make their own glucose by the process of photosynthesis. Glucose is their fuel, yet it is useless without another chemical reaction called respiration. Respiration occurs in the cells of all living things. It releases the chemical energy stored in glucose.

Aerobic respiration

If oxygen is present (and it normally is), then most organisms release the energy they need by burning glucose in oxygen. This chemical reaction is called **aerobic respiration**. It produces energy, carbon dioxide gas (CO_2) and water vapour (H_2O). It can be summarised as a word equation:

glucose + oxygen ⟶ carbon dioxide + water + energy

Chemists write this reaction as a balanced chemical equation:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

Go to Science Focus 2, Unit 4.4

Science Fact File

Photosynthesis and global warming

Photosynthesis removes carbon dioxide from the atmosphere, storing the carbon in the plant and releasing the oxygen back into the atmosphere. Every tree, forest and field of crops can be thought of as a carbon sink that removes carbon from the atmosphere, effectively 'burying' it. The oceans are the biggest carbon sink of all. Ninety per cent of photosynthesis is carried out in the ocean by seaweeds and by single-celled organisms called diatoms. When these diatoms die, they drop to the bottom of the ocean, taking their carbon with them.

Carbon dioxide is the greenhouse gas that is contributing most to global warming. Carbon dioxide is released whenever fossil fuels (e.g. petrol, gas and coal) are burnt, and more and more is being released every year. The carbon sinks are not coping with the increase, and so levels of carbon dioxide in the atmosphere are increasing rapidly. Of course, the most effective way of 'burying' carbon dioxide is to keep the fossil fuels in the ground in the first place!

Science Clip

Ouch!

Aerobic respiration needs a plentiful supply of oxygen and provides most organisms with the bulk of their energy. Sometimes, however, animals are exercising too hard and cannot draw in sufficient oxygen for their needs. This is when another type of respiration, anaerobic respiration, tops up their energy reserves. *Anaerobic respiration* does not need any oxygen and produces a chemical called *lactic acid*:

glucose ⟶ lactic acid + energy

$$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3 + \text{energy}$$

Levels of lactic acid build up in their muscles, causing sharp pain and cramps.

Science Clip

Life, but not as we know it!

Sunlight reaches only about 300 metres under the sea and photosynthesis is impossible beyond this depth. No plants could survive and scientists expected that no creatures could survive without this food source. However, in 1977, the deep-sea submersible *Alvin* found abundant giant tube worms, giant mussels and spider crabs at a depth of 2.5 kilometres off the coast of South America. They were gathered around 'black smokers', geothermal vents at the edge of tectonic plates off the coast. These vents spewed out superheated water, blackened with minerals and hydrogen sulfide (H_2S). Chemosynthetic bacteria gain energy from these toxic waters and provide the basis for a thriving food chain.

Fig 3.2.8 Giant mussels recovered from around a 'black smoker'.

Respiration in plants

Prac 4 p. 83

Plants use aerobic respiration to release the energy from their glucose. The energy obtained is used to grow, carry out repairs and reproduce. Plants draw the oxygen they need from the air around them. Likewise, the carbon dioxide produced by the reaction is released back into the air.

The role of enzymes

Prac 5 p. 83

Glucose can burn in air but the reaction is rapid and uncontrolled, releasing heat and light. If this happened in cells, they would be quickly destroyed.

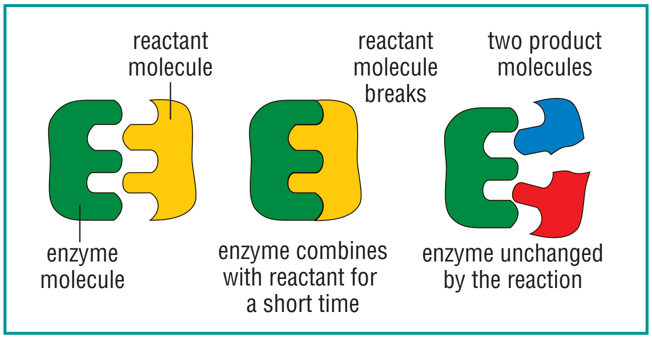

Fig 3.2.9 Enzymes work by using a 'lock and key' mechanism. In this way they target and speed up certain reactions only, ignoring others.

In cells, the reaction is gradual and controlled, releasing energy step-by-step in small amounts. Just how the cell manages this process is still not understood completely. It is known that aerobic respiration occurs as a sequence of at least 30 different reactions arranged in a complicated chain. **Enzymes** are the key to all these reactions.

Enzymes act as **catalysts**, speeding up chemical reactions without being used up themselves. Enzymes can increase reaction speed by as much as ten billion times, which is equivalent to taking one minute to finish a task that would otherwise take 18 000 years!

Comparing photosynthesis and respiration

The process of photosynthesis and respiration are essentially the reverse of one another.

Photosynthesis:

carbon dioxide + water + energy ⟶ glucose + oxygen

Respiration:

glucose + oxygen ⟶ carbon dioxide + water + energy

This is best summarised by the table below.

Photosynthesis	Respiration
Makes glucose	Uses glucose
Makes oxygen	Uses oxygen
Uses energy (sunlight)	Releases energy for use
Uses carbon dioxide	Makes carbon dioxide
Uses water	Makes water
Happens in the cells' chloroplasts	Happens in the cells' mitochondria (energy capsules)

Although the two processes seem to be exact opposites, each involves many different steps, different enzymes and they occur in different locations, making the two reactions very different in reality!

Science Clip

Gooey chocolate centres

The centre in liquid-centred chocolates gets there because of an enzyme. Sucrose ('common' sugar) and flavourings are dissolved in water to create a paste-like solid. An enzyme is also added. The paste is coated with chocolate and kept at a suitable temperature. The enzyme converts the sucrose to two more soluble sugars. These dissolve in the water to form the liquid centre.

Worksheet 3.3 Processes in systems

3.2 QUESTIONS

Remembering

1 **State** whether the following statements are true or false:
- **a** Photosynthesis can be duplicated outside a living cell.
- **b** Photosynthesis is completely understood.
- **c** Water is involved in photosynthesis.
- **d** Photosynthesis occurs during the night.

2 **Name** the energy source that powers photosynthesis.

3 **List** five ways in which the glucose formed during photosynthesis can be used by the plant.

4 **Name**:
- **a** the chemicals that react together (i.e. reactants) in photosynthesis
- **b** the products of respiration
- **c** the products of photosynthesis
- **d** the reactants of respiration.

5 **Recall** the processes of photosynthesis and aerobic respiration by writing their word equations.

6 **Name** the following chemicals:

a CO_2 **b** H_2O **c** O_2 **d** $C_6H_{12}O_6$

Understanding

7 **State** what chlorophyll is, **explain** where it is found and **describe** its role in photosynthesis.

8 **Identify** what time of the day photosynthesis would:
- **a** stop
- **b** proceed the fastest.

9 Photosynthesis does not occur if chlorophyll, water and carbon dioxide are placed in a test tube in sunlight. **Explain** why it does not occur.

10 Most chemical reactions keep getting faster as the temperature increases, but photosynthesis doesn't. **Explain** why.

11 **Outline** the purpose of respiration.

12 **Explain** what a catalyst does to a chemical reaction such as respiration.

13 **Outline** how photosynthesis and respiration complement each other by working together.

Applying

14 **Identify** the photosynthesis reaction (i.e. light or dark) in which the following occur:
- **a** ADP absorbs energy from the Sun
- **b** glucose forms
- **c** water gets used
- **d** the energy contained in ATP gets released.

15 **Identify** which energy change best describes the following processes:

photosynthesis	chemical energy converts into heat and energy for movement and growth
respiration	light energy converts into chemical energy.

Analysing

16 Trees are a valuable resource. They are used for their timber, for woodchips and for pulping into paper. They also release oxygen into the atmosphere, and trap carbon, stopping it from being released into the atmosphere and contributing to global warming. **Discuss** the implications on society and the environment of logging of old-growth forests and of forests specifically grown for logging.

17 An experiment was conducted using the set-up shown in Figure 3.2.10. The set-up was placed in sunlight. **Analyse** what is happening in this experiment and:
- **a** **Name** the chemicals the plant needs to run photosynthesis and **identify** where it would get them from.
- **b** **Name** the gas produced by the plant during the experiment.
- **c** **Recall** the process by writing a chemical equation for the production of the gas.
- **d** **Predict** what would happen to the volume of gas produced if a larger or greater number of plants was used, but the experiment still ran for the same amount of time.

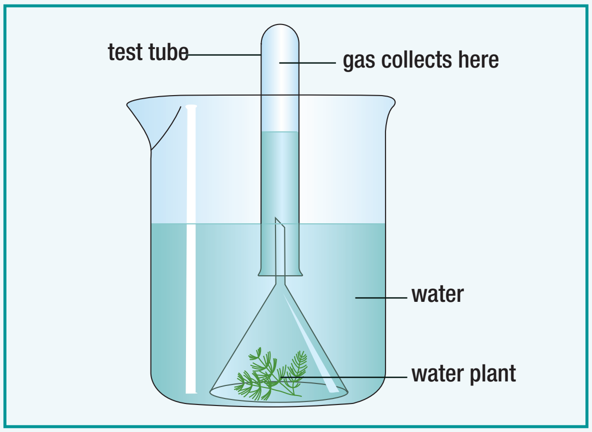

Fig 3.2.10

18 A leaf was picked from a plant that had been kept in the dark for two days. The leaf was placed in water and the apparatus shown in Figure 3.2.11 used to carry out an experiment. The apparatus was placed in sunlight. The sodium hydroxide removed carbon dioxide from the air. After some time the leaf was placed in boiling water, then boiling alcohol, then boiling

>>

water again. A few drops of iodine solution were then added to the leaf. **Analyse** what is happening in this experiment and:

a **Name** the substance that changes colour when iodine is added to it.

b **Outline** the expected result of the iodine test in this experiment.

c **Explain** why this result would be expected.

d **Explain** why it was necessary to keep the plant in the dark for two days.

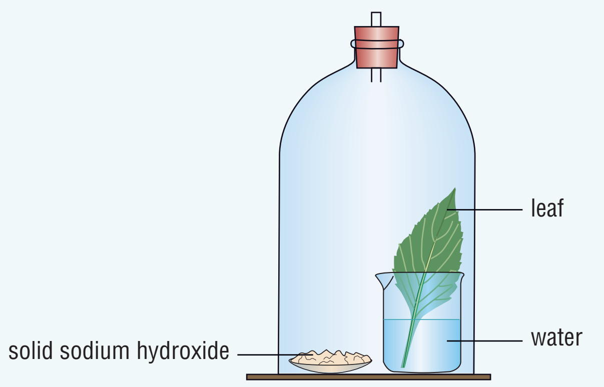

Fig 3.2.11

Evaluating

19 The graph in Figure 3.2.12 shows the amount of oxygen produced by a plant as light intensity was increased under two different sets of conditions. N

a **Name** the process that produces the oxygen.

b **Explain** why the amount of oxygen increases as the light intensity increases.

c **Propose** two possible changes to the experiment that would produce graph Y.

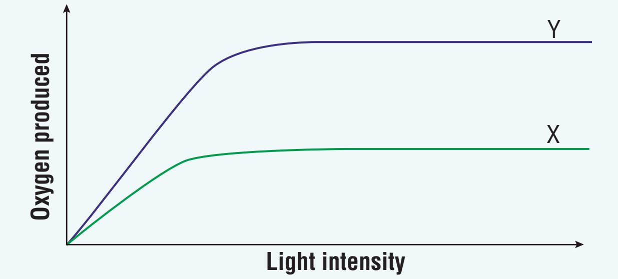

Fig 3.2.12

20 A few life-forms would probably survive if the Sun did turn off. **Predict** which, justifying why each could survive.

Creating

21 **Design** your own controlled experiment to **investigate** the effects of fertilisers on plant growth.

3.2 INVESTIGATING

e-xploring

Web Destination

Complete the following activities on the origins of life by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

1 *Chemosynthetic* bacteria make glucose from carbon dioxide and water, but do not use energy from the sunlight to do so. Instead, they obtain the energy they need from a variety of chemical reactions. *Iron bacteria and nitrifying bacteria* are two examples.

a Research the conditions in which they are found and the kinds of chemical reactions they perform.

b Summarise your information in the form of a brief article for a scientific journal, including diagrams and equations for chemical reactions. L

2 Mud-dwelling *purple and green sulfur bacteria* use hydrogen sulfide instead of water and release sulfur instead of oxygen. This gives mudflats a characteristic 'rotten egg' smell. **Investigate** to find out more about them and their food-production reaction.

3 Research information about the first living things on Earth to discover whether they were photosynthetic.

a Describe some theories of how life on Earth began.

b Present your information as a comic strip or series of diagrams.

3.2 PRACTICAL ACTIVITIES

1 A product of photosynthesis

Aim

To investigate the products of photosynthesis

Equipment

- two 600 mL beakers
- two glass funnels
- two test tubes
- light source
- wooden splint
- safety goggles
- sodium hydrogen carbonate solution (0.5%)
- two pieces of growing pond weed (e.g. elodea)

Method

1 Half-fill each beaker with sodium hydrogen carbonate solution.

2 Place a piece of plant in each beaker and cover the plant with a funnel.

3 Invert a test tube full of water over the stem of each funnel.

4 Place one beaker in the dark and the other in continuous light for several days.

5 Describe any changes in appearance that have developed in each set-up.

6 Test any gas collected. To do this, lift the test tube off the funnel without letting the tube leave the water. Quickly insert a glowing wooden splint into the test tube, making sure not to touch the sides of the wet test tube.

7 Record the results of the gas test.

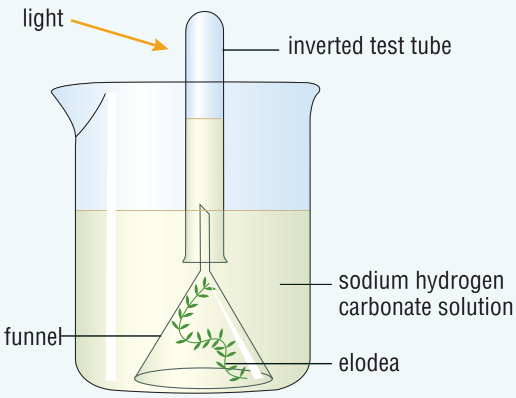

Fig 3.2.13

Questions

1 **State** the purpose of the sodium hydrogen carbonate solution.

2 **Identify** any gas given off.

3 **Account** for any differences in the changes observed for the two procedures in the experiment.

2 Green leaves and photosynthesis

Aim

To examine where the products of photosynthesis are stored in leaves

Equipment

- potted plant with variegated leaves
- potted plant of the same species with completely green leaves (suitable plant types include coleus and geranium)
- three beakers of boiling water (see Safety box)
- two large test tubes containing ethanol or methylated spirits
- forceps
- scissors
- safety goggles
- iodine solution
- two watch-glasses or two glass Petri dishes

Safety

1 Use only an electric hot plate to boil the three beakers of water.

2 Ethanol is highly flammable. At no stage should the test tube containing ethanol be placed near any flame.

Method

1 Cut a leaf from each plant. Cut a small nick in the edge of the variegated leaf so it can be identified later.

2 Sketch two outlines of the variegated leaf side-by-side. Do the same for the green leaf.

3 Drop both leaves into one beaker of boiling water for a few minutes. This kills the leaf cells so that no further reactions can occur.

4 Using the forceps, remove the leaves and place one in each test tube of ethanol.

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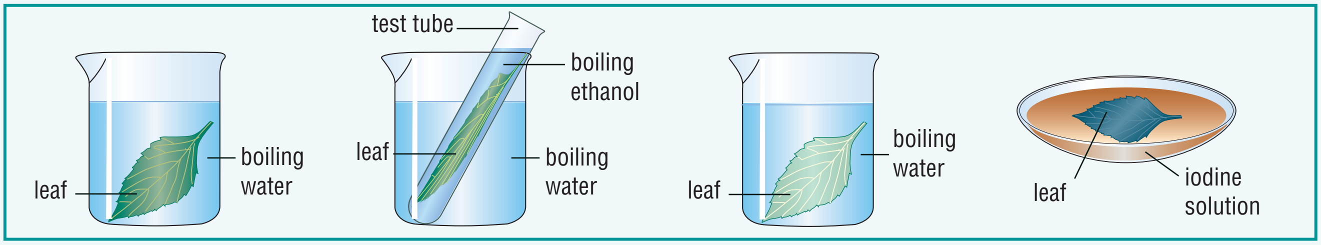
Fig 3.2.14



5 Stand both test tubes in the second beaker of boiling water. The ethanol will start to boil, and green colour will be dissolved from the leaves. After around 10 minutes the leaves should look quite pale.
6 Using the forceps, remove the leaf from one test tube and dip it into the third beaker of boiling water for a few seconds. This removes the ethanol and softens the leaf. Place the leaf on a watch-glass or Petri dish. Repeat this step for the other leaf.
7 Add iodine solution to each leaf. Allow it to stand for 1 minute.
8 On the outlines sketched in step 2, draw and colour in the areas stained blue-black on each leaf.

Questions

1 **State** the name of the substance identified by the blue-black colour obtained with iodine.
2 **Explain** why the leaves were boiled in ethanol.
3 **Describe** any relationship between the presence of green in the leaves and areas that were stained blue-black.
4 **Explain** why the stained areas of the leaf show where photosynthesis is likely to occur.

3 The rate of photosynthesis

Aim

To investigate the effect of light on the rate of photosynthesis in a plant

Equipment

As shown in Figure 3.2.15

DYO

Method

Design your own experiment to investigate the effect of light intensity on the rate of photosynthesis. The apparatus shown in Figure 3.2.15 should give you some ideas to help you get started. Variables that may be changed include distance of light from test tube, power of the light globe and temperature of the water. Account for observations made in terms of effect on photosynthesis.

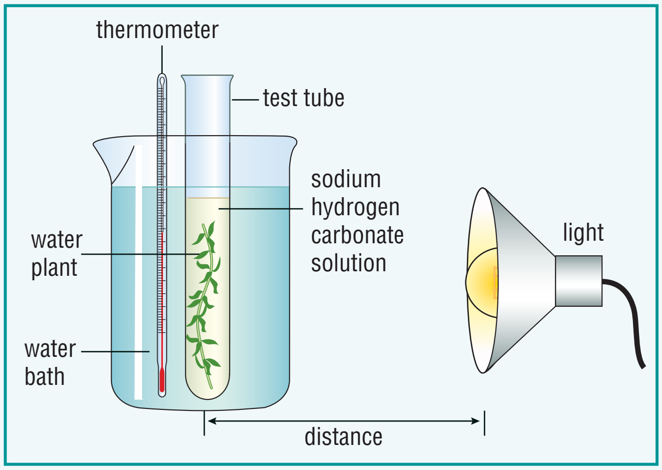


Fig 3.2.15 A possible experimental set-up

4 A product of respiration

Aim

To investigate the products of respiration

Equipment

- flasks and glassware, as shown in Figure 3.2.16
- filter pump
- sodium hydroxide solution
- limewater
- potted plant
- several insects or earthworms

Method

1 Set up the apparatus as shown in Figure 3.2.16.

2 Slowly draw air through the apparatus by means of the filter pump.

3 Record any changes in the colour of the limewater in flasks B and D.

Questions

1 Sodium hydroxide absorbs carbon dioxide from the air. Carbon dioxide dissolves in limewater to form a milky solution. **Explain** the purpose of flasks A and B.

2 **Explain** the purpose of flask D.

3 **Justify** the use of the:

  a plastic bag

  b black paper.

4 **Explain** any changes observed in the limewater during the experiment.

5 a **Modify** the experiment, using an animal (e.g. earthworm) in place of the potted plant in flask C.

  b **Compare** and **contrast** the results of the two experiments.

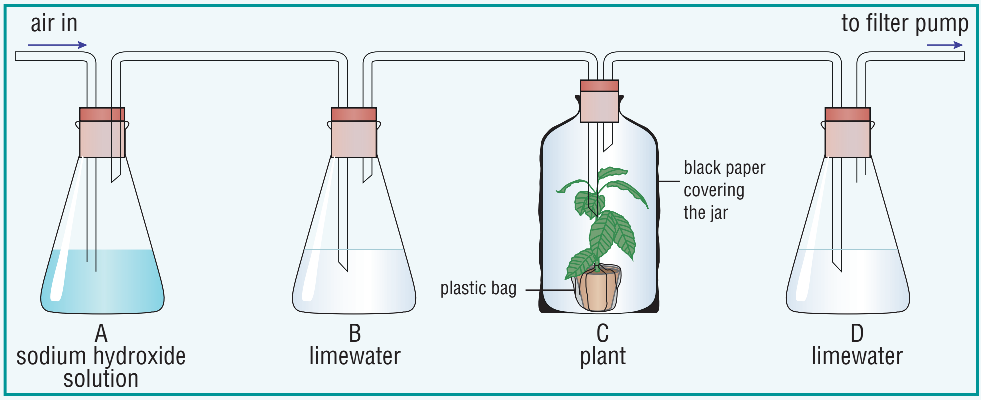


Fig 3.2.16 Testing for the products of respiration

5 Energy production in respiration

Aim

To determine the heat energy produced by respiration in plant seeds

Equipment

- two wide-mouth thermos flasks
- two thermometers
- cotton wool
- germinating pea seeds
- boiling water
- mild disinfectant

Method

1 Divide the germinating seeds into two equal batches.

2 Place one batch in boiling water to kill the seeds.

3 Soak these killed seeds in the disinfectant.

4 Set up the apparatus as shown in Figure 3.2.17.

5 Record the temperature in each flask.

6 After several hours record the temperature in each flask again.

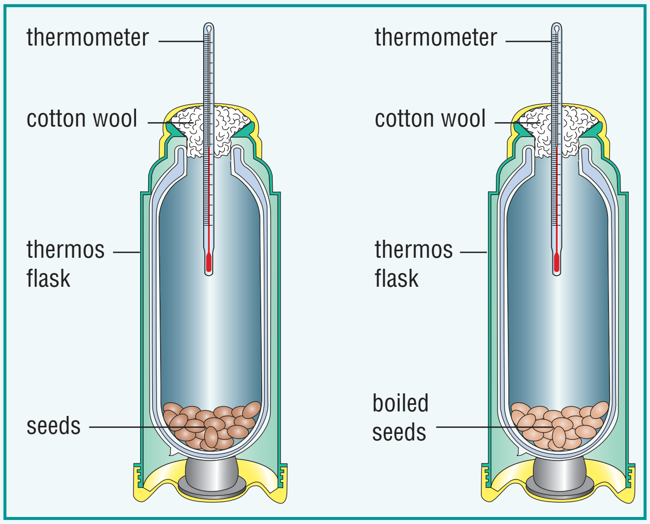


Fig 3.2.17

Questions

1 **Explain** any observed changes in temperature.

2 **Explain** the purpose of the flask containing killed seeds.

3 **Explain** the purpose of the disinfectant.

Prescribed Focus Area:
The nature and practice of science

Photosynthesis

Scientists had long wondered why plants grew. Our current knowledge about photosynthesis and respiration in plants comes after centuries of scientific research. Some of the most important experiments are:

- Jan Baptist **van Helmont** (1580–1644) grew a willow tree in a tub after carefully weighing the plant and the soil. He watered the plant regularly, and after 5 years reweighed the plant and the soil. The mass of the plant had increased by 74.5 kilograms, but the mass of soil had not changed. He concluded that the plant had converted water into wood and leaves.
- Joseph **Priestley** (1733–1804) demonstrated that plants produced oxygen.
- Jan **Ingenhousz** (1730–1799) showed that light was necessary for this production.
- Jean **Senebier** (1742–1809) found in 1782 that plants absorb carbon dioxide from the air.
- Nicolas **de Saussure** (1767–1845) showed in 1804 that water was chemically involved in plant growth.

Although the basics of plant growth have been known for about 200 years, scientists still do not fully understand the process of photosynthesis. There is still much that confuses them. They have not yet, for example, been able to duplicate photosynthesis outside a living cell.

Respiration

Just how the energy within foods is used by the body has been the subject of study for many years.

The first great discoveries were made over 200 years ago by French chemist Antoine-Laurent **Lavoisier** (1743–1794). Lavoisier is best remembered for giving oxygen its name and for showing that fire is a combination of oxygen with a fuel.

In 1783, Lavoisier (and Pierre de Laplace) analysed the air inhaled and exhaled by a guinea pig, and measured the heat given off by the animal's body. Most of the oxygen inhaled disappeared, and was replaced by carbon dioxide. The amount replaced was almost the same as the amount of oxygen needed to burn charcoal to release the same amount of heat as the guinea pig had. Lavoisier concluded that the process was 'a combustion, admittedly very slow, but otherwise exactly similar to that of charcoal'. In other words, the body burns food much like a fire does. Lavoisier then studied human subjects in a series of experiments lasting 10 years.

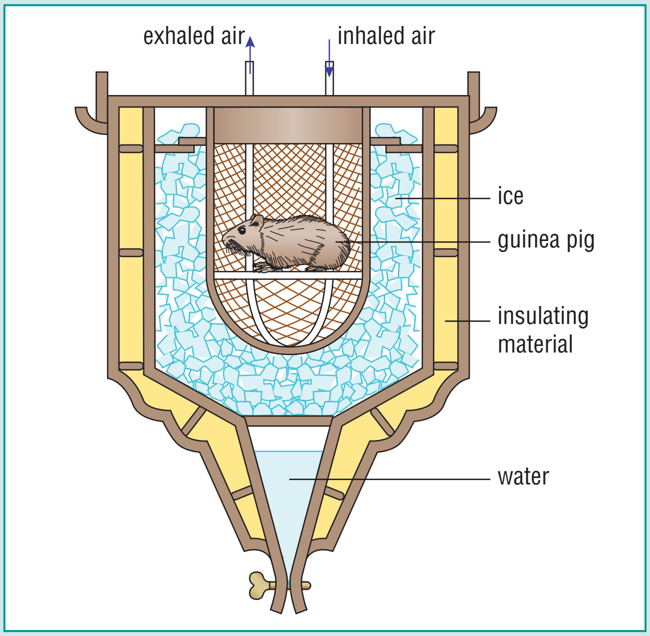


Fig 3.2.18 Lavoisier's experiment. The guinea pig was surrounded with ice. Heat output was estimated by the amount of melted ice.

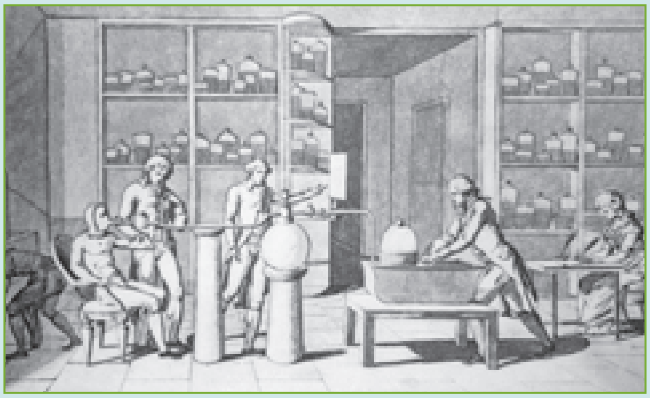


Fig 3.2.19 Lavoisier's experiments showed that humans, as well as guinea pigs, produce heat by 'burning' food.

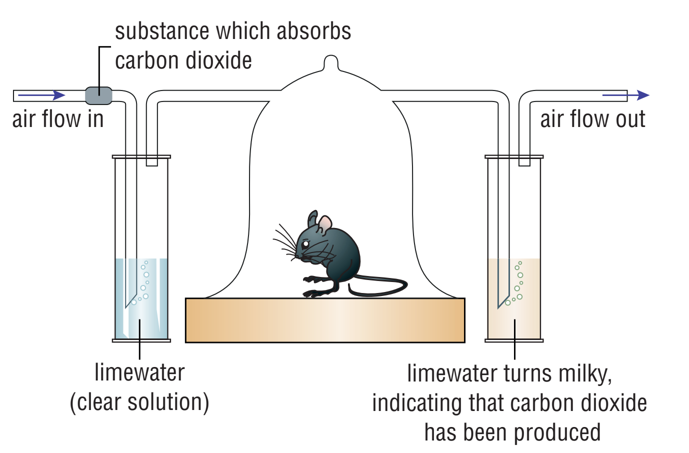


Fig 3.2.20 Experiments have shown that a mouse placed in a sealed jar will drastically reduce the oxygen content of the air while increasing the carbon dioxide content. A mouse provided with air and fed solely on glucose (a type of sugar) and water can function normally for weeks. This evidence supports the idea that animals use respiration for their energy.

STUDENT ACTIVITIES

Creating

Construct a timeline to **demonstrate** the main stages in the discovery of photosynthesis. Include major areas of recent research on your timeline. N

Investigating

Antoine-Laurent Lavoisier achieved much in both biology and chemistry. He was also a dreaded taxman and was beheaded. **Investigate** your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find details about Lavoisier, his life and achievements.

Present your work in one of the following ways:

- an interview
- a written biography.

Debating

Do you think it is right or moral to use animals for experiments like that of Lavoisier's? **Investigate** your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find out about animal rights and how animals are currently used in scientific research.

Present your findings in one of the following forms:

- an animal rights banner
- a sensationalist article for a newspaper or current affairs TV show
- a magazine article or segment for a TV science show explaining why the practice happens
- an interview with a professor who believes that scientists should be allowed to continue the practice.

Unit 3.3 Leaves

context

Leaves are a plant's chemical factory and its lungs. Photosynthesis occurs mainly in the leaves, as does respiration. A range of chemicals is produced in them and gas exchange happens there. These gases need ways of entering and exiting, and plant leaves have developed special structures to allow them to do so. As photosynthesis is powered by sunlight, the leaves must be arranged so that all can get as much light as possible. The cells in each leaf must also be arranged so that they can absorb its energy.

Fig 3.3.1 Leaves are the main sites of photosynthesis and respiration in plants.

Science Clip

Rainforest photosynthesis

Rainforest plants need to cope with the gloom of the forest floor and so, generally, have huge leaves to catch as much light as possible. They also need to cope with huge amounts of rain, and so their leaves have channels that empty the water off them.

Leaf structure

Photosynthesis takes place mainly in a plant's leaves. Most leaves are broad and flat and are positioned so that their surface is roughly horizontal. This allows maximum exposure to any sunlight that falls on them.

The structure of a leaf contains special features that help them carry out photosynthesis and to minimise water loss.

Prac 1 p. 91

Fig 3.3.2 A coloured electron microscope image of a slice through a leaf

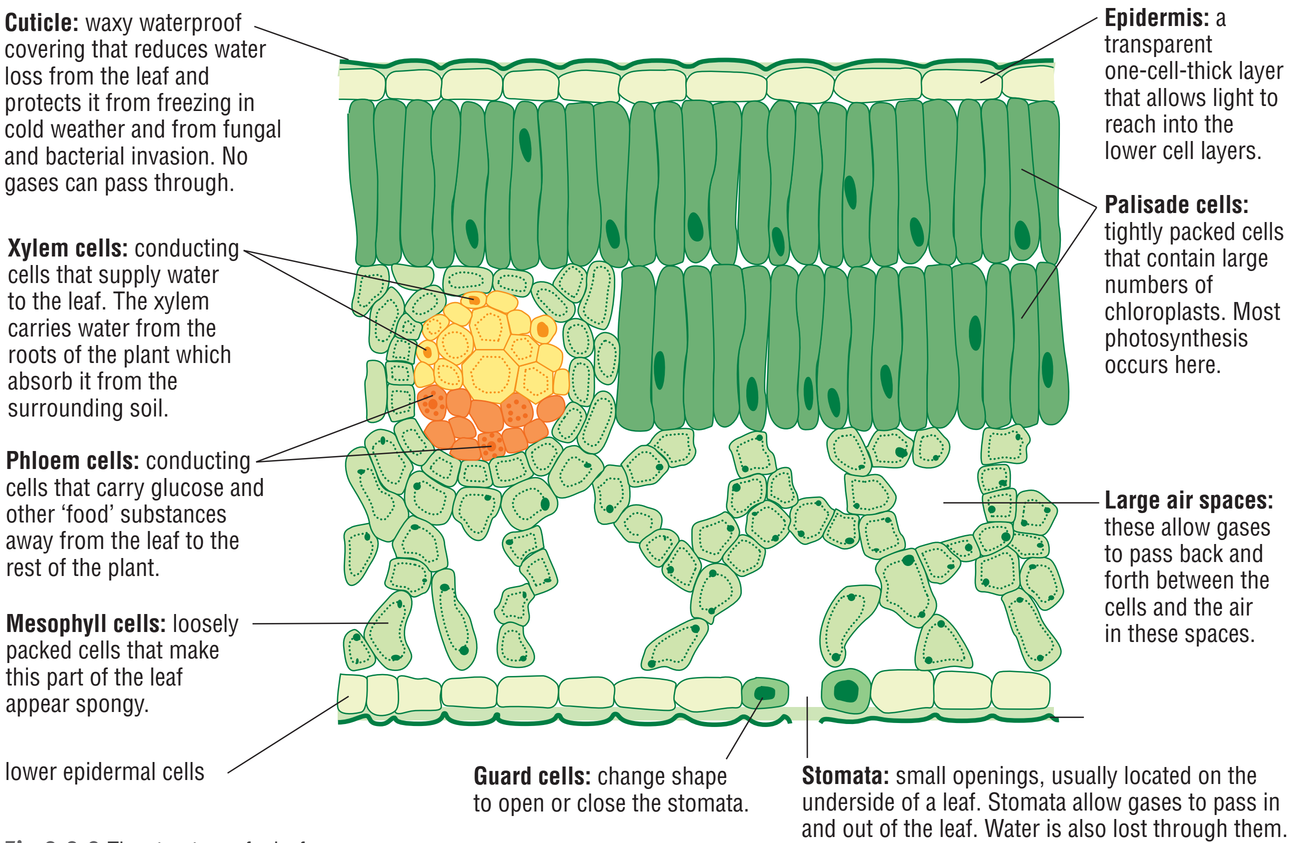


Fig 3.3.3 The structure of a leaf

PP Drag-and-drop

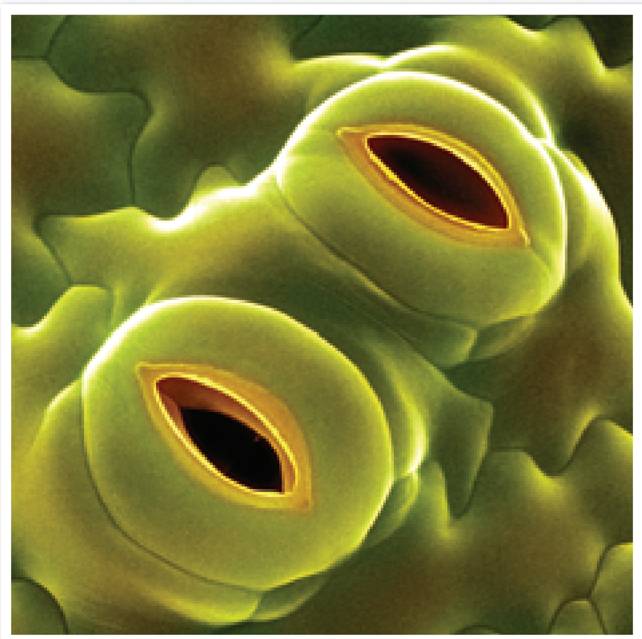


Fig 3.3.4 An open stoma (i.e. a single stomata) with its red guard cells. When open, gases can pass through, allowing photosynthesis to occur. Plants also lose water through them.

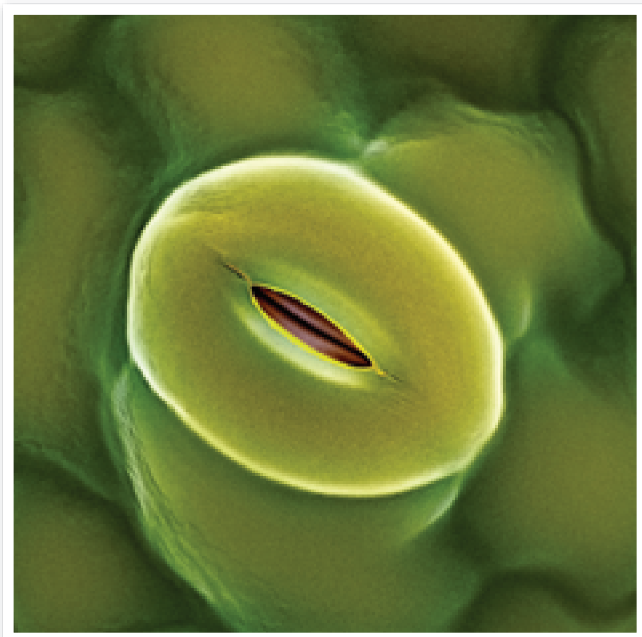


Fig 3.3.5 A closed stoma. When closed, water is not lost from the leaf. This is crucial in times of low water supply. It also blocks the entry and exit of gases. Photosynthesis stops or slows considerably.

Prac 2 p. 92

Leaf pigments

Autumn leaves

Chlorophyll strongly absorbs red, blue and violet light and absorbs some yellow and orange. It doesn't absorb green, reflecting it instead. This makes plants appear green.

Some plants contain pigments other than chlorophyll. These are known as **accessory pigments**, examples being yellow xanthophylls and orange carotenes. In autumn, the plant breaks down its green chlorophyll and stores some of its components, leaving the red, orange or yellow accessory pigments behind.

Marine plants

Water absorbs light and so most aquatic plants are found in the surface layers, where light is more available. Some seaweeds and algae have additional pigments that allow them to absorb more light. Red light is strongly absorbed by water, and so green algae that use this red light are commonly found near the surface. In shallow waters, brown algae absorb blue, green and yellow light. At deeper levels, red algae absorb mainly blue and green light.

Worksheet 3.4 Leaves

Science Clip

Desert photosynthesis

Leaves usually hang roughly horizontally to maximise the amount of sunlight that falls on them. In hot, dry countries, this would cause them to lose too much water, and so plants there have developed methods to preserve their water. For example, the leaves of Australian gum trees hang vertically, exposing only their edges to the sun, thus minimising water loss. The folds in the stem of a cactus act as its leaves, but have far fewer stomata than that found in leafy plants. The spikes on a cactus provide shade for the stem, protection from desert animals and help channel dew down to the plant's roots. Many Australian plants, such as wattles and grevilleas, have spiky leaves for the same reason.

Fig 3.3.6 The vibrant colours of autumn leaves are due to accessory pigments becoming obvious after chlorophyll has been broken down for storage.

Fig 3.3.7 Seaweeds are usually found close to the surface, where it is brightest and photosynthesis will work the best.

Case study: Aboriginal plant classification and use

Aboriginal plant classification is based mainly on use.

There are two main groups:

- *maranhu* (food)
- *mirritjin* (chemicals).

The first and largest main group, *maranhu*, has two separate divisions:

- *ngatha*—vegetable foods and honey
- *gonyil*—meat foods and eggs.

Ngatha is then divided further into:

- *ngatha*—all root foods, nuts and the growth centres of palms
- *borum*—fruit
- *guku*—honey.

Any plant considered unsuitable to eat may be referred to as *nhangining*, which simply means 'useless food'.

The name of the second main group, *mirritjin*, has developed from the English word 'medicine'. Within this group there are a number of subcategories that relate to the type of medicinal or chemical properties involved. These include dyes, glues and resins, poisons and medicines.

Dyes

Dyes are made from roots of many plants and are used to colour the fibres of baskets and mats. The two main dyes are red, which come from bulbous *Mulubirtdi* roots, and yellow, from corkwood tree roots (*Gumurduk*).

Glues and resins

The sap from the grass tree is used as a resin, generally to secure prongs and points to fishing spears, and fish hooks to lines. The sap can be removed from the base of the leaves by beating them. It is sometimes found as a hardened knob on the northern side of a tree, where it has seeped out due to the heat of the Sun.

Poisons

The bark and leaves of various plants were used as 'fish poisons' to stun fish in waterholes, making them float to the surface and easy to catch. Some examples are acacia (i.e. wattle) species rich in tannin, which is the active agent.

Medicines

Some plants yield medicines for many purposes. Common hop bush is an important medicinal plant among Aboriginal people. The leaves are chewed for toothache and used as a dressing for stonefish and stingray wounds. Soaked in water the leaves are used as a sponge to relieve fever. A liquid made from soaking the roots is used for open cuts and sores. The crushed leaves of clematis (headache vine) can be used to relieve headaches.

Fig 3.3.8 The fruits, nuts and seeds from plants are used as food and medicine by Aboriginal people.

3.3 QUESTIONS

Remembering

1 **State** whether the following statements are true or false:
   a Plant leaves are the main site of photosynthesis.
   b The epidermis is at the centre of a leaf.
   c Small openings in a leaf are called stomata.
   d Guard cells keep stomata closed.

2 **Recall** leaf structures by matching each structure to its function:

Structure	Function
a epidermis	i control the size of openings in the leaf
b cuticle	ii specialised water-conducting cells
c stomata	iii waxy, waterproof covering of the leaf
d guard cells	iv loosely packed cells with air spaces between them
e mesophyll cells	v outer layer of cells of the leaf
f palisade cells	vi allow gases to enter and exit the leaf
g xylem cells	vii tightly packed cells containing large numbers of chloroplasts

3 **Name** the plant tissue in which photosynthesis occurs.

4 **Name** two pigments other than chlorophyll that are found in some plants.

5 Figure 3.3.9 shows a section through a plant leaf exposed to sunlight. Use the following list to **name** the leaf structures labelled **a** to **h**:
chloroplast, epidermal cell, stomata, cuticle, air space, xylem vessel, palisade cell, mesophyll cell, guard cell

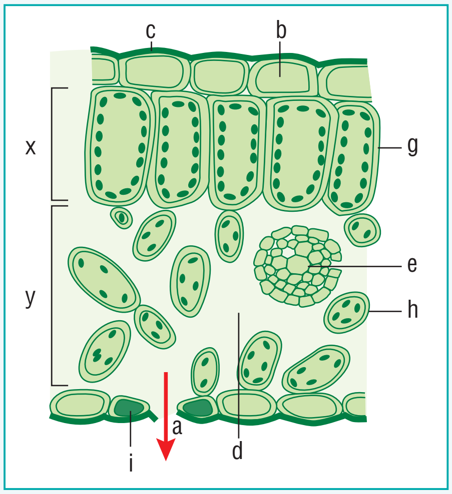


Fig 3.3.9

Understanding

6 **Outline**:
   a how each of the raw materials for photosynthesis enters the leaf
   b how each of the products of photosynthesis leave the leaf.

7 a **Name** the structures through which water exits a leaf.
   b **Outline** how plants minimise their water loss on hot days.

8 Leaves are generally broad and flat. **Explain** how this assists photosynthesis.

9 The leaves of most plants have a waxy cuticle covering their outer surface. **Outline**:
   a advantages of this cuticle
   b one disadvantage of this cuticle.

10 a **Name** the colour of light not absorbed by chlorophyll.
   b **Explain** how we know this colour is not absorbed.
   c **Name** the colours of light most strongly absorbed by chlorophyll.

11 **Explain** why red, yellow and orange are typical colours of autumn leaves.

12 Water is able to absorb light. **Outline** two adaptations to overcome this.

13 **Explain** why some algae have light-trapping pigments in addition to chlorophyll.

Applying

14 **Use** the packing of cells to **explain** why mesophyll tissue is so spongy.

15 Refer to the leaf shown in Figure 3.3.9.
   a **Identify** in which section (i.e. **x** or **y**) most glucose would be produced.
   b Over a day, a particular gas moves in the direction of the red arrow. **Identify** which gas it is and **explain** your answer.

Analysing

16 **Analyse** these plant adaptations and **explain** how each adaptation is a benefit to a plant in its own environment.
   a Australian native plants often have very small leaves or sharp needles as leaves.
   b Plants in tropical rainforests are large and have deep grooves in them.

>>

c The leaves of some Australian native plants are silver-grey-green in colour.

d Australian native plants are often a duller green than those in North America.

e Deciduous trees are native to cold climates and not hot ones.

Evaluating

17 **Propose** what would happen to a plant if all its leaves:

a were smeared with petroleum jelly, blocking all their stomata

b were taped so that they were turned upside down

c had their cuticle scraped off.

3.3 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Find out how the opening and closing of leaf stomata is controlled.

a Use a diagram to describe how the opening and closing of leaf stomata is controlled.

b Use diagrams to contrast the structure of leaves of a desert plant with that of leaves of a rainforest plant.

c Account for any differences in structure.

2 a Research why, how and when different trees lose their leaves.

b Explain how this loss of leaves affects plant growth.

3.3 PRACTICAL ACTIVITIES

1 Leaf classification

Aim

To classify leaves according to different characteristics

Equipment

- a collection of living samples of different leaves
- butcher's paper or A3 paper
- Texta

Method

1 Collect living samples of different leaves. Inspect each leaf, taking note of the following:

- Is the leaf broad and flat or long and narrow like a grass? Is it a needle (like that found on a pine tree or some grevilleas) or is it 'slime' from a pond?
- Does the leaf lie flat or does it naturally curl?
- Is the leaf bright green, olive, silver or some other colour?
- Is the top of the leaf the same colour as the bottom of the leaf?
- Describe the texture of the top and bottom of the leaf. Look particularly for 'waxy' polished tops.

2 After inspection stick the leaves onto A3 paper or cardboard in groups that show some similarity.

2 Stomata and chloroplasts

Aim

To examine stomata and chloroplasts in leaves

Equipment

- compound microscope
- microscope slides and cover slips
- dropper
- tweezers
- razor blade
- stain (e.g. methylene blue or iodine)
- leaves from various plants (e.g. rhubarb and agapanthus)
- elodea (a water plant)

Method

Part A: Stomata

1. Set up the microscope.
2. Peel the lower epidermis (i.e. outer layer) from the bottom of a leaf. Using tweezers may help.
3. Place the epidermis flat on the microscope slide.
4. Add a drop of water and carefully lower the cover slip on top. Be careful not to trap any air bubbles under the slip.
5. Add a drop of stain at one edge of the cover slip and hold a piece of paper towel at the opposite edge to draw the stain under the cover slip and across the leaf sample.
6. View the slide under the microscope. Identify and draw the stomata.
7. Try looking at the stomata of other plant leaves in the same way.
8. Choose another leaf and try to find stomata on the upper epidermis.

Part B: Chloroplasts

1. Take a leaf of elodea.
2. Use a razor blade to cut a very thin slice off the leaf. Your teacher may do this for you.
3. Place the leaf slice on a microscope slide and add a drop of water and a cover slip.
4. View the slide under the microscope. Identify and draw the cells containing green chloroplasts.

Questions

1. **Outline** the purpose of stomata.
2. Stomata are found mainly on the underside of leaves. **Explain** why.
3. **Outline** the function of a guard cell.
4. **Describe** the role of chloroplasts.

CHAPTER REVIEW

Remembering

1 **Name** the part of a plant that provides:
   a pressure to push nutrients up the stalk or trunk
   b support to prevent a plant collapsing too easily.

2 **State** what each of the following stands for:
   a CO_2 b H_2O c O_2

3 **Name** the cells that:
   a transport water in the plant
   b transport glucose in the plant
   c result in growth rings in a tree
   d open and shut stomata.

4 **Recall** the following processes by writing their word equations:
   a photosynthesis
   b aerobic respiration
   c anaerobic respiration in animals.

5 **Recall** leaf structure by matching the parts described below with the structures **i** to **vii** in Figure 3.4.1.
   a Controls the size of openings in the leaf.
   b Specialised water-conducting cells.
   c Waxy, waterproof covering of the leaf.
   d Loosely packed cells with air spaces between them.
   e Outer layer of cells of the leaf.
   f Allow gases to enter and exit the leaf.
   g Tightly packed cells containing large numbers of chloroplasts.

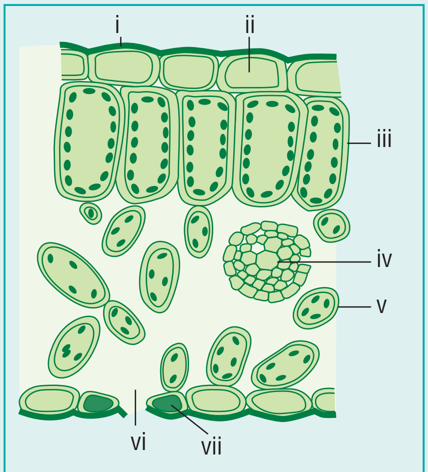


Fig 3.4.1

6 **Recall** basic definitions by matching the following terms with the description that summarises them best:

a photosynthesis	**i** waxy covering
b chlorophyll	**ii** warm blooded
c enzyme	**iii** no oxygen needed
d ATP	**iv** biological catalyst
e cuticle	**v** muscle soreness
f stomata	**vi** stored in liver
g anaerobic respiration	**vii** energy transfer molecule
h endothermic	**viii** makes glucose
i lactic acid	**ix** green pigment
j glycogen	**x** holes in a leaf

Understanding

7 **Modify** the statement below so that it correctly describes photosynthesis.

   Photosynthesis is the process by which plants make their own food, using energy from glucose and chlorophyll to convert carbon dioxide and sunlight into oxygen and water.

8 **Explain** how glucose is stored in a:
   a lettuce
   b potato.

9 a **List** three factors that affect the rate of photosynthesis.
   b **Explain** how each of these factors affects the rate.
   c **Clarify** the importance of photosynthesis to living things.

10 **Explain** why autumn leaves are so colourful.

11 **Outline** how starch can be detected in a substance.

12 *The chemical equation for photosynthesis is the reverse of that for respiration.* **Explain** why it is incorrect to say that photosynthesis is simply the reverse of respiration.

13 A student incorrectly wrote: 'Plants photosynthesise during the day and respire at night'. **Modify** the sentence to make it correct.

Applying

14 **Identify** the chemical formulae for:
   a glucose
   b water
   c lactic acid
   d oxygen gas.

>>

Analysing

15 **Compare** the following by listing their similarities and differences:

- **a** xylem and phloem tissue
- **b** photosynthesis and respiration
- **c** the stomata of leaves found on tropical plants with those in desert regions.

16 An experiment was conducted using three potted plants. Each plant was exposed to continuous light of the same intensity but of different colours. Plants and colours used were: plant A, green light; plant B, yellow light; and plant C, red light.

- **a** **List** three factors that must be kept constant for all plants in this experiment.
- **b** **Identify** which plant (i.e. A to C) would most likely produce more glucose than the others.
- **c** **Justify** your answer.

17 An experiment was conducted using the flasks shown in Figure 3.4.2. All flasks contained water, were at the same temperature and were in sunlight. After 2 hours the carbon dioxide and oxygen levels in each flask were measured.

- **a** **Identify** the flask or flasks in which photosynthesis would occur.
- **b** **Identify** the flask or flasks in which respiration would occur.
- **c** **Predict** which flask would have the highest carbon dioxide level after the 2 hours.
- **d** **Predict** which flask would have the highest oxygen level after the 2 hours.

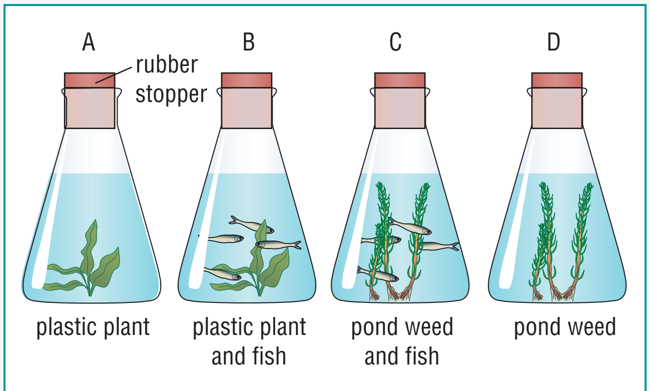


Fig 3.4.2

Creating

18 **Construct** a table to **compare** photosynthesis and respiration. Your table should include reactants, products, conditions and energy changes.

19 **Construct** a mind map of the main concepts and ideas presented in this chapter. Include the following words in your mind map:

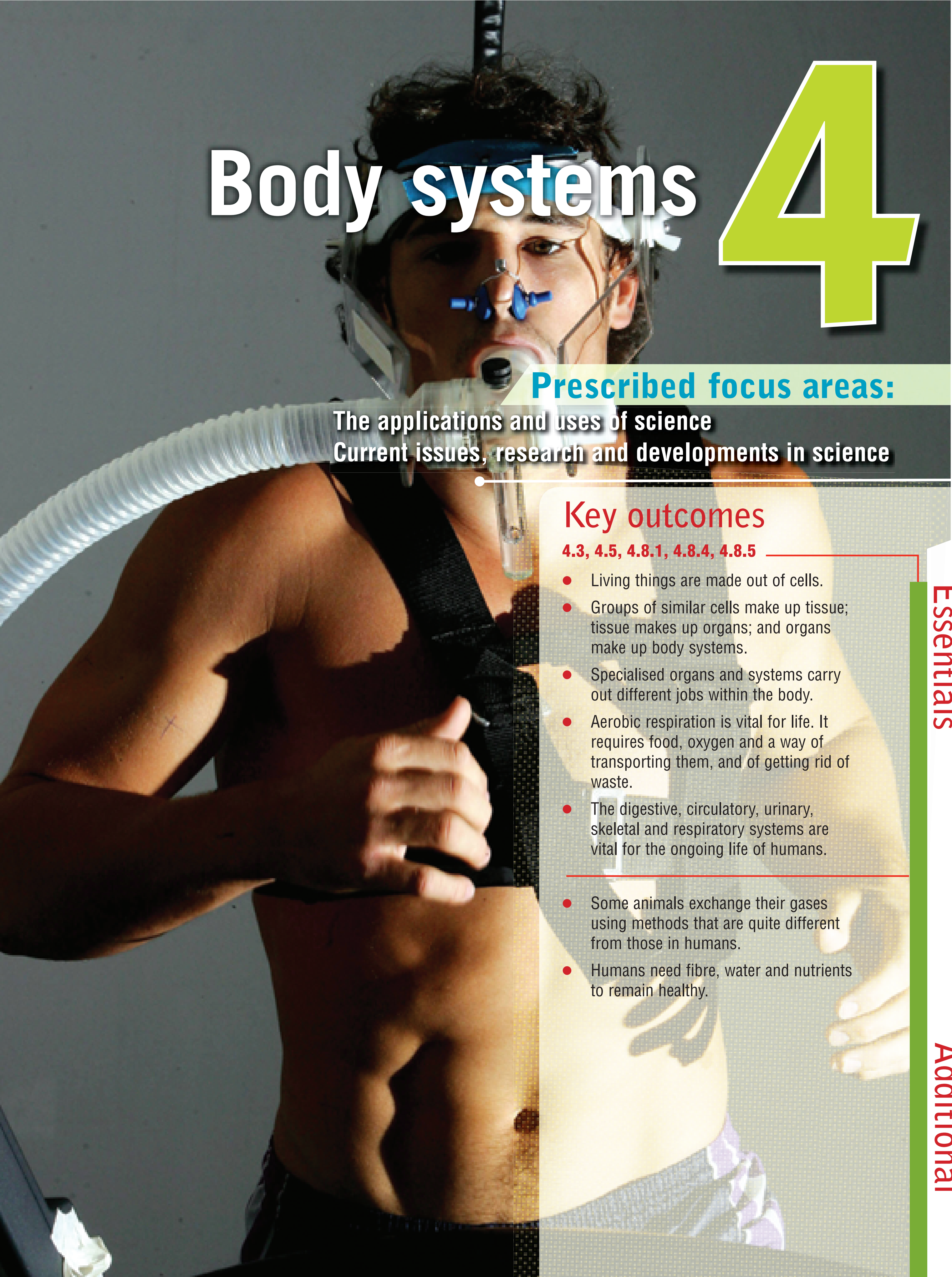
photosynthesis
respiration
chlorophyll
chloroplasts
glucose
oxygen
carbon dioxide
water
xylem tubes
phloem tubes
stomata
guard cells.

Worksheet 3.5 Crossword

Worksheet 3.6 Sci-words

PP Chapter Review Questions

PP Interactive



Body systems 4

Prescribed focus areas:

The applications and uses of science

Current issues, research and developments in science

Key outcomes

4.3, 4.5, 4.8.1, 4.8.4, 4.8.5

Essentials

- Living things are made out of cells.
- Groups of similar cells make up tissue; tissue makes up organs; and organs make up body systems.
- Specialised organs and systems carry out different jobs within the body.
- Aerobic respiration is vital for life. It requires food, oxygen and a way of transporting them, and of getting rid of waste.
- The digestive, circulatory, urinary, skeletal and respiratory systems are vital for the ongoing life of humans.

Additional

- Some animals exchange their gases using methods that are quite different from those in humans.
- Humans need fibre, water and nutrients to remain healthy.

Unit 4.1 Cells to systems

context

All living things are made up of cells. Not all cells are the same, however. Some are skin cells and some are liver cells. Others are blood cells, cheek cells, muscle cells, sperm cells, egg cells, brain cells… Each part of your body has cells that are specialised to carry out a specific job.

Specialised cells

Quick Quiz

Groups of similar cells make up **tissue**. Skin tissue is made from skin cells, liver tissue is made from liver cells and heart tissue is made from heart cells. Tissue groups together to form organs. Kidney tissue makes up the kidneys, brain tissue makes up the brain and heart tissue makes up the heart.

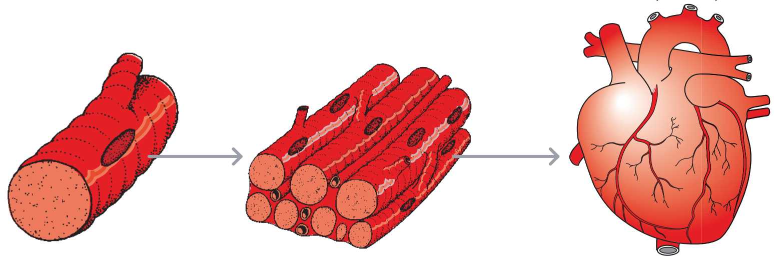


Fig 4.1.1 Cells make up tissue and tissue makes up organs.

Go to Science Focus 1, Unit 5.3

Body systems

A group of organs working together to do a particular job in the body is called a **body system**. For example, the skeletal system is a relatively lightweight structure that holds the body upright and protects the body's internal organs. The skull, for example, protects the brain and the spinal column protects the spinal cord. Another body system, the muscular system, attaches to it. Together they provide us with the ability to move.

Typical body systems include the nervous system, and the male and female reproductive systems.

Aerobic respiration

Cells need energy to stay alive and to carry out their specialised jobs. If cells die then the tissue made from them also dies. Organs and body systems soon fail and the body dies. To make the energy they need, cells need a constant supply of oxygen (O_2) and glucose ($C_6H_{12}O_6$). Glucose is a type of sugar and is one of the main products of digestion—the processing of food in the digestive system.

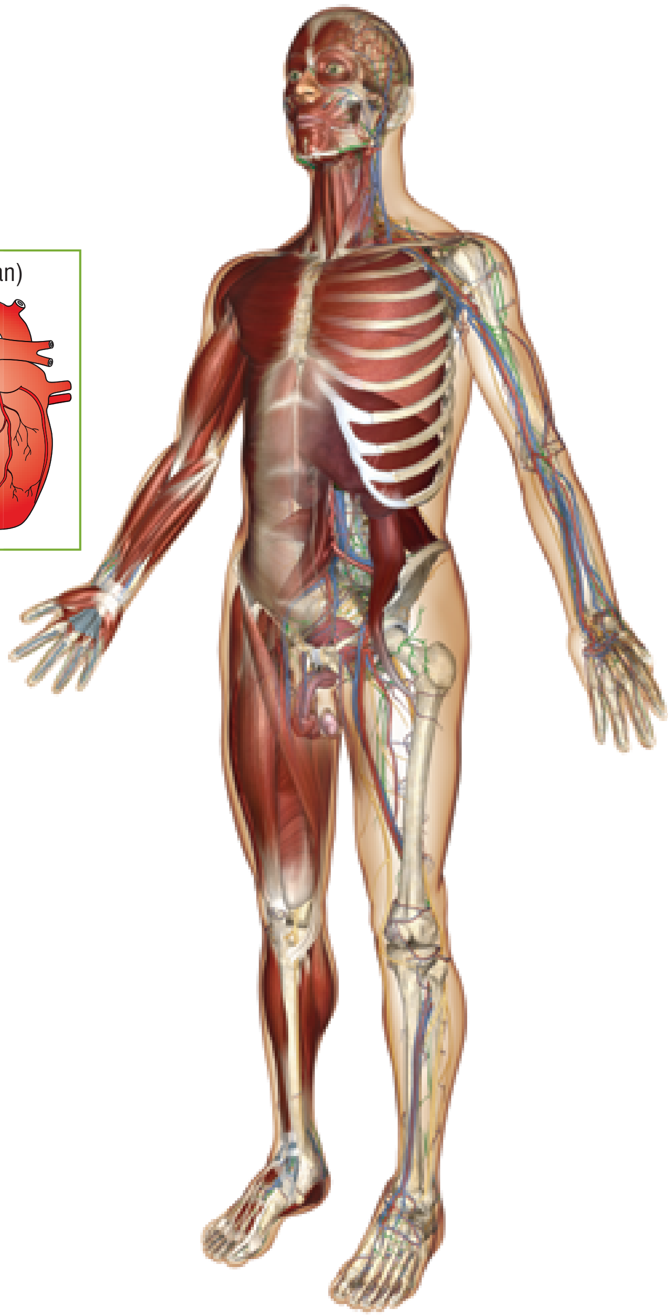


Fig 4.1.2 The human body is made from many different systems.

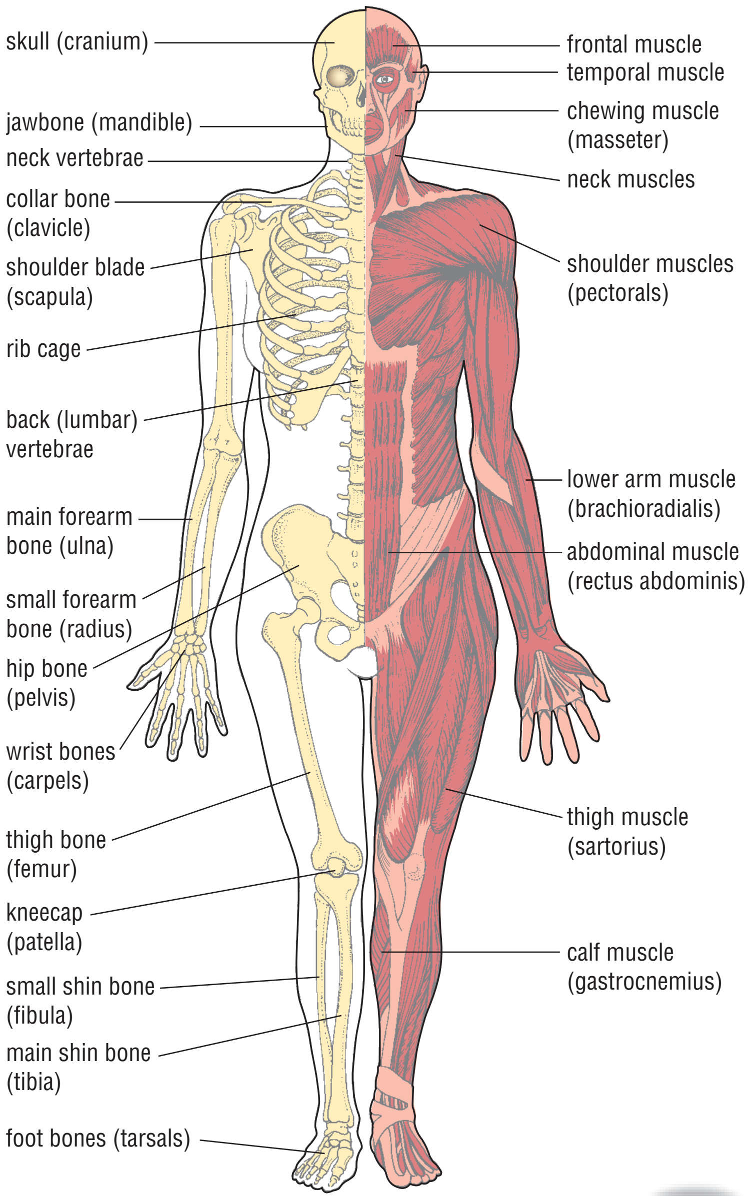


Fig 4.1.3 The skeletal and muscular systems

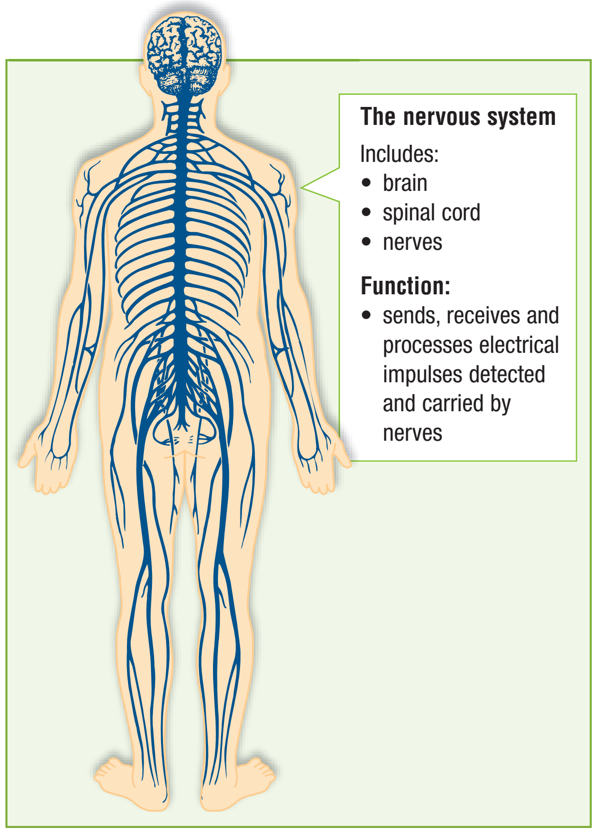


Fig 4.1.4 The nervous system

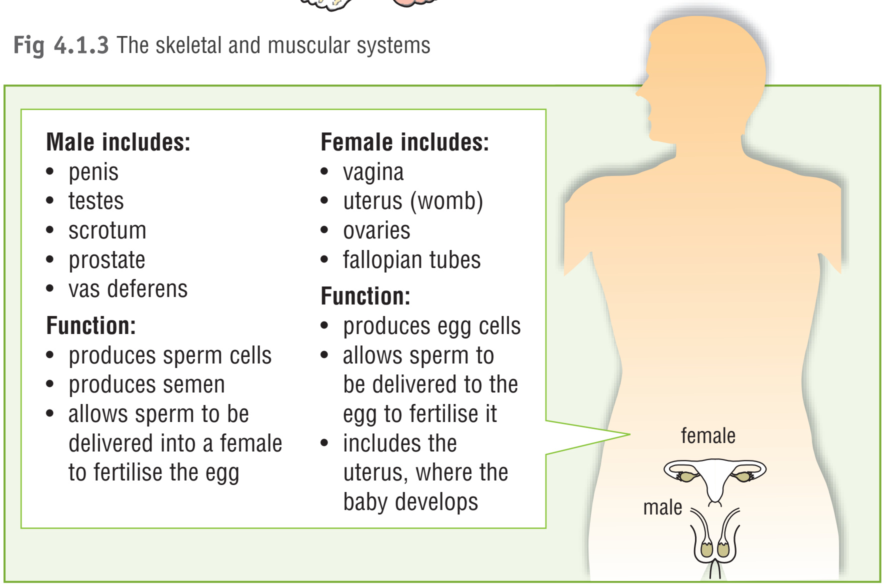


Fig 4.1.5 The reproductive system

Science Clip

Sore muscles

Normally the cells get all the energy they need from aerobic respiration. However, when the body is exercising hard, the cells often do not get enough oxygen to provide the increased energy they now need. This is when cells begin anaerobic respiration, a reaction that still provides energy but needs no oxygen. One of its products is lactic acid. Muscle soreness after exercise is normally blamed on a build-up of lactic acid in the muscles, although recent research indicates that it might be due to tiny tears in the muscles instead.

The cells carry out a chemical reaction called **aerobic respiration**. This reaction can be written as a word equation:

glucose + oxygen ⟶ carbon dioxide + water + energy

Chemists usually write the equation for aerobic respiration as a balanced chemical equation:

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$ + energy

The products of aerobic respiration are carbon dioxide (CO_2), water (H_2O) and the energy the cells need.

Staying alive

Four body systems are vital in keeping cells alive:

- the **digestive system**—supplies the blood with glucose and other nutrients that the cells need
- the **circulatory system**—blood supplies everything the cells need (including glucose and oxygen) and gets rid of whatever waste the cells produce (e.g. carbon dioxide and water)
- the **respiratory system**—supplies the blood with oxygen and removes carbon dioxide from it
- the **urinary system**—reactions in the cells produce wastes that will poison them if allowed to build up. Although the circulatory system removes these wastes from the cells, the blood itself will soon be poisoned unless they are filtered out and removed from the body. This is the role of the kidneys and the urinary system.

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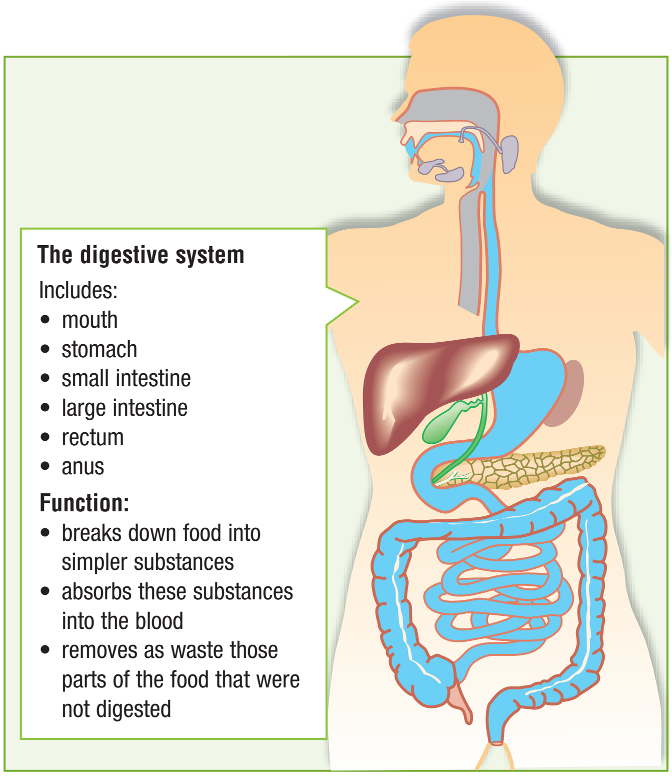


Fig 4.1.6 The digestive system

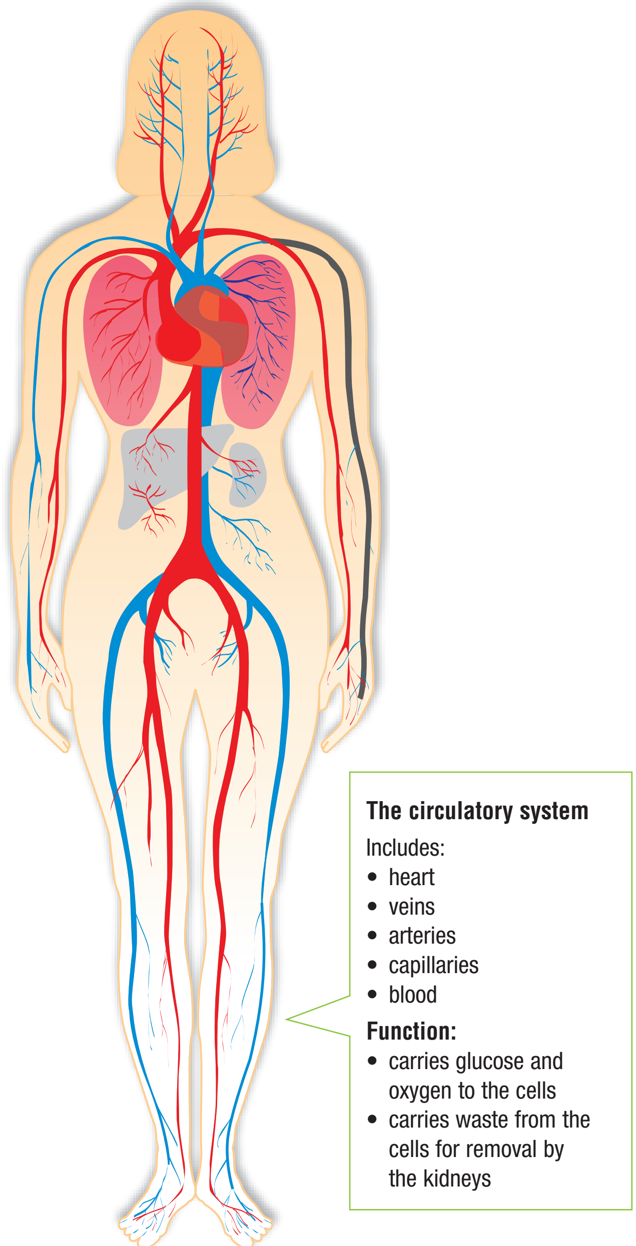


Fig 4.1.7 The circulatory system

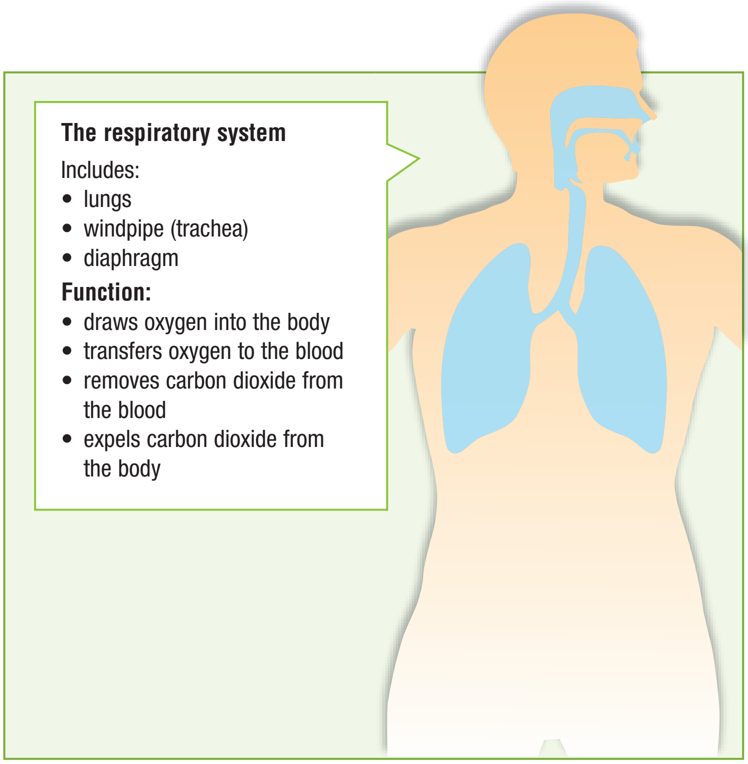


Fig 4.1.8 The respiratory system

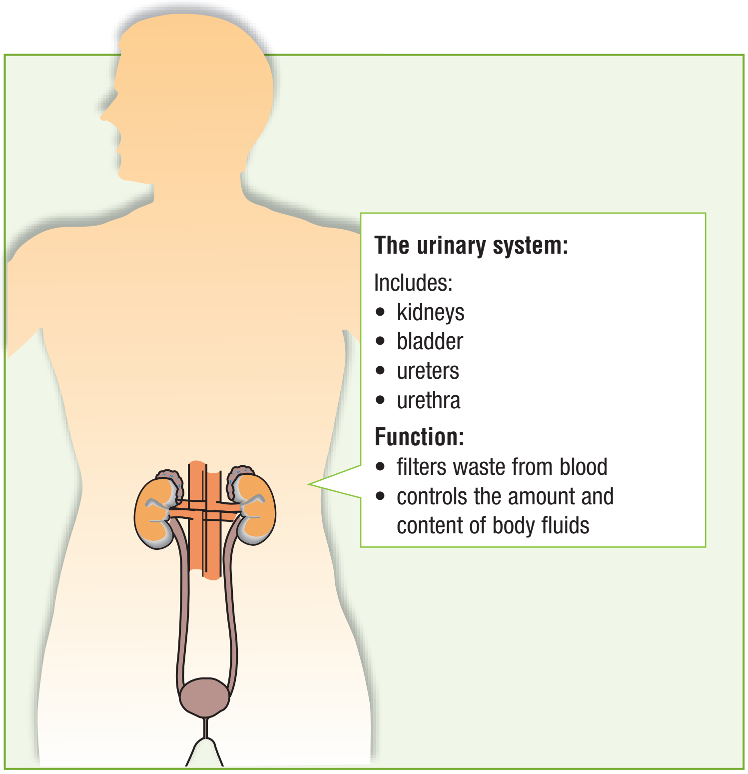


Fig 4.1.9 The urinary system

Science Clip

What is the speed of a sneeze?

Some scientists estimate the speed of a sneeze is around 150 kilometres per hour (42 metres per second), whereas others believe that the speed may be as fast as 85 per cent of the speed of sound or 1045 kilometres per hour! What *is* known is that about 40 000 droplets are produced by a single sneeze and that you can't sneeze while you're asleep.

Science Clip

What colour should urine be?

If you're well-hydrated and drinking enough water then your urine should be transparent and pale yellow (similar to apple juice) in colour. Clear urine indicates that you're over-hydrated, whereas dark yellow usually indicates that you're dehydrated and that you need to increase your water intake. Cloudy urine may indicate a bacterial infection. The smell of urine can be affected by the foods you eat. For example, eating asparagus adds a strong odour to human urine. This is due to the body's breakdown of asparagusic acid. Other foods that contribute to odour include curry, alcohol, coffee, turkey and onion.

Science Clip

Myth: Treat a jellyfish sting with urine

The tiny barbs on most jellyfish inject a base that can be neutralised with acid. That's why surf lifesaving clubs often have a bucket of vinegar ready—vinegar is an acid. Many people believe that a jellyfish sting can be treated with urine but urine is not acidic enough to neutralise the venom. Bluebottle jellyfish stings cannot be soothed with vinegar or urine because the chemical they inject is not a base.

4.1 QUESTIONS

Remembering

1 **List** the following in order from smallest to largest: tissue, system, organ, cell

2 **Name** two organs or major parts in six body systems.

3 **Recall** different body systems by completing the following:

   a mouth + stomach + intestines = _______ system

   b spine + skull + pelvis + bones = _______ system

   c kidney + _______ = urinary system.

Understanding

4 **a** **Recall** aerobic respiration by writing its word equation.

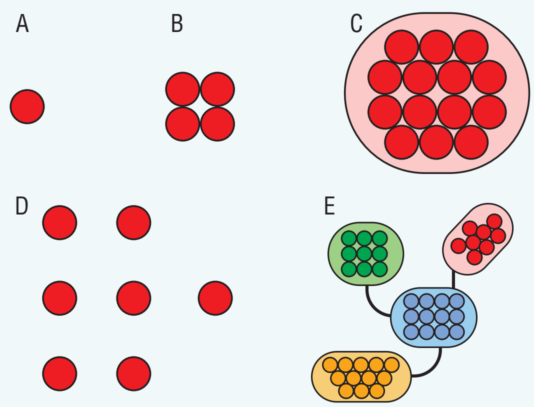
   b **Explain** why cells need to carry out aerobic respiration.

5 **Predict** what the 'locomotion system' refers to.

Applying

6 **Identify** which of the diagrams below best represents:

   a a cell **b** tissue **c** an organ **d** a body system.



7 **Identify** which body system is the main one involved in each situation.

   a The face of a runner goes red after a sprint.

   b The leg jerks upwards after being tapped on the knee.

   c Someone feels the urge to go to the toilet for a wee.

   d A person feels full after a meal.

   e A gasp of air is taken after swimming underwater.

8 **Identify** the system in which females and males have different organs.

Analysing

9 Machines have systems just like the human body. They have electrical systems, fuel systems, control systems, systems to take in and release gases, and systems that hold them together and allow them to move. Choose a machine and one of its systems. Whatever machine and system you choose:

- **Explain** what the machine does.
- **Explain** what the system does for the machine.
- **List** the parts or 'organs' it includes.
- **State** what is needed to keep it functioning properly.
- **Explain** one of the 'diseases' that affects the system, its 'symptoms' and 'cures'.
- **Construct** a diagram, flow chart, concept or mind map showing its related parts.

Evaluating

10 Review the different body systems outlined in this unit and **propose** which one you think to be the most important. **Explain** your choice.

4.1 PRACTICAL ACTIVITY

1 Body plot

Aim

To predict the location and size of the main organs in the human body

Equipment

- butcher's paper
- felt pens

Method

1 Arrange into groups and get one student to lie down on butcher's paper.

2 The other group members can then trace around them with a felt pen.

3 Predict where the main organs, such as the heart, lungs, liver, stomach and intestines, should go and what size each should be.

4 Cut out the predicted shapes from coloured paper and paste them in position.

Unit 4.2 The digestive system

context

Without food, the body dies. Food supplies the body with the energy and the nutrients it needs for growth and for keeping it in good health. Digestion breaks down food as it passes through the digestive system, allowing its nutrients to pass into the bloodstream for use where they are needed in the body.

Digestion: Food for life

Aerobic respiration is the process that cells normally use to get the energy they need to function. One of the reactants needed in this reaction is glucose ($C_6H_{12}O_6$), a type of sugar. Glucose reacts with oxygen (O_2), which is provided by the respiratory system, to form carbon dioxide (CO_2), water (H_2O) and the all-important energy. The equation for this reaction is:

glucose + oxygen ⟶ carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

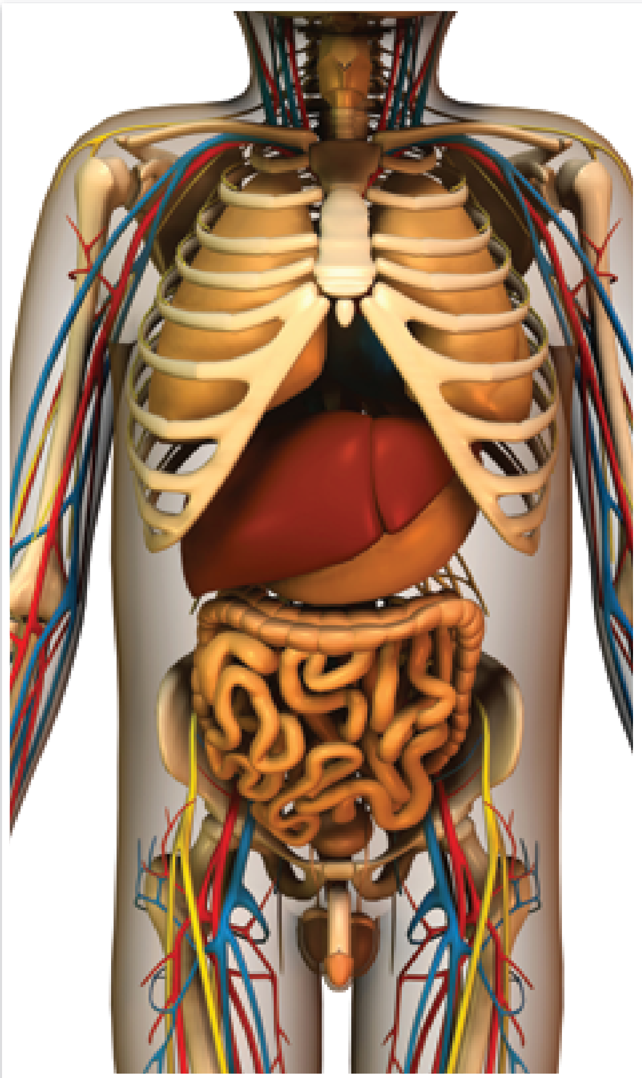


Fig 4.2.1 Artwork of the digestive system, showing how it fits in with other body systems.

Without glucose, cells die. **Digestion** is the process in which food is broken into smaller and simpler substances, such as the glucose the cells need. Once small enough, these nutrients pass into the bloodstream to be transported to the parts of your body that need them. There they pass into the cells of the tissues and organs that need them. Digestion provides the body with necessary carbohydrates, sugars, proteins, fats, vitamins, minerals, fibre and water.

Prac 1 p. 110

The digestive system

The digestive system consists of:

- a six to seven metre-long tube known as either the **digestive tract**, **alimentary canal**, or simply the gut. This is the tube along which food travels and in which food is processed and broken down into smaller components.
- several organs, such as the pancreas, that branch off from the digestive tract. These organs secrete special chemicals known as enzymes, which assist in processing particular types of food. Roughly eight litres of enzymes are produced each day.

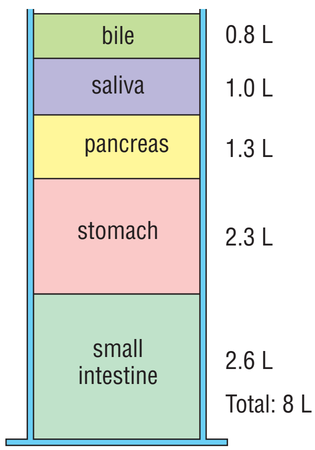


Fig 4.2.2 The amount of digestive juices you produce each day.

Digestion starts when food is placed into the mouth and ends when waste is released from the anus. The whole trip normally takes about 24 hours. The time food spends in each part of the digestive system is shown in the table below.

Part of digestive system	Approximate time spent there
Mouth	1 minute
Oesophagus	3 seconds
Stomach	2 to 4 hours
Small intestine	1 to 4 hours
Large intestine	10 hours to several days

The process of digestion

Eating

You physically break down your food when you eat, mashing it into smaller pieces. This is known as **mechanical digestion**. Another form of digestion, **chemical digestion**, also starts in the mouth. Saliva contains enzymes, which chemically break down the food it mixes with. About one litre of saliva (which is made up of water, mucus and the enzyme **amylase**) is produced every day. Amylase begins breaking down starch into glucose. Food and saliva form a smooth lump called a **bolus**. Water and mucus help make the bolus slippery so that it is easily swallowed.

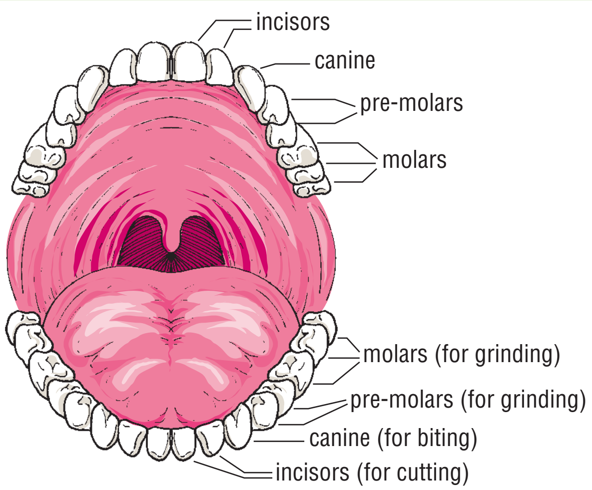


Fig 4.2.3 Different teeth help with different tasks.

Science Clip

No-chew food

Spiders cannot chew their food because they have no teeth, apart from their fangs. Instead, spiders inject enzymes into their prey, dissolving their **innards** (internal organs of the body), which the spider then sucks up. Crocodiles can't chew either. They use their teeth to rip their food into smaller bits.

Swallowing

When you swallow, circular muscles around your oesophagus contract and relax. They form a wave-like movement known as **peristalsis** that pushes the bolus along the oesophagus and towards the stomach. Peristalsis pushes so hard that it allows you to swallow food and drink when lying flat or even upside down.

Churning and mixing

Muscles in the stomach churn food, helping it mix with **gastric juice**. About two litres of gastric juice are produced every day. It contains:

- the enzyme **pepsin**, which helps break down large protein molecules and fats
- **hydrochloric acid** (HCl), which helps the pepsin and kills harmful bacteria.

The entrance and exit of the stomach are controlled by rings of muscles called **sphincters**. A sphincter at the top of the stomach stops acid and partly digested food from rising up into the oesophagus. Another sphincter at the bottom of the stomach protects the lower digestive tract from acid. Every minute or so it lets partly digested, semi-liquid food, called **chyme**, to pass through into the duodenum.

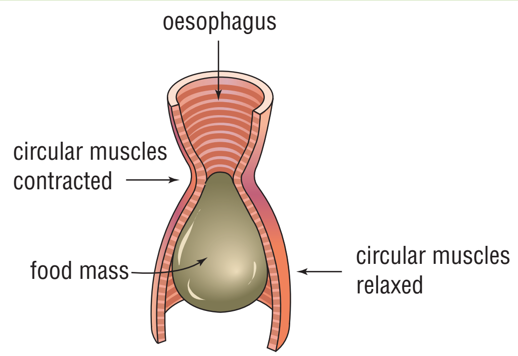


Fig 4.2.4 Peristalsis is like squeezing a marble through a section of rubber tube that normally is slightly narrower than the marble.

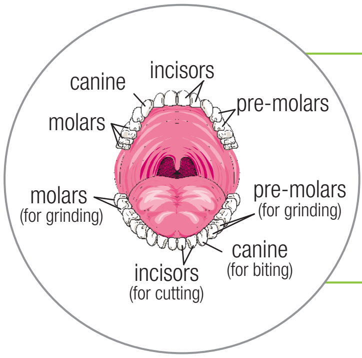
PP Drag-and-drop

Science Clip

Beware the smiling monkey!

Sharks and crocodiles lose teeth when hunting. Sharks have up to 12 000 teeth organised in multiple rows ready to move forward to replace lost ones. Crocodiles simply grow new ones. The front teeth of mice and rats grow constantly because they are constantly wearing away. A hippopotamus has 40 teeth, whereas the narwhal has only one, in the form of a long horn protruding from its forehead. Get out of the way if a monkey bares its teeth when 'smiling'…it is ready to attack! It won't smile at all if friendly, but will smack its lips together at you.

Worksheet 4.1 The digestive system

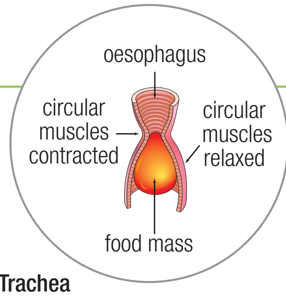


Mouth

Digestion begins in the mouth, where teeth bite, cut and grind food into smaller pieces.

Epiglottis

The epiglottis is a flap that folds over the entrance to the trachea when food or drink are swallowed. This stops food and liquids from entering the lungs.

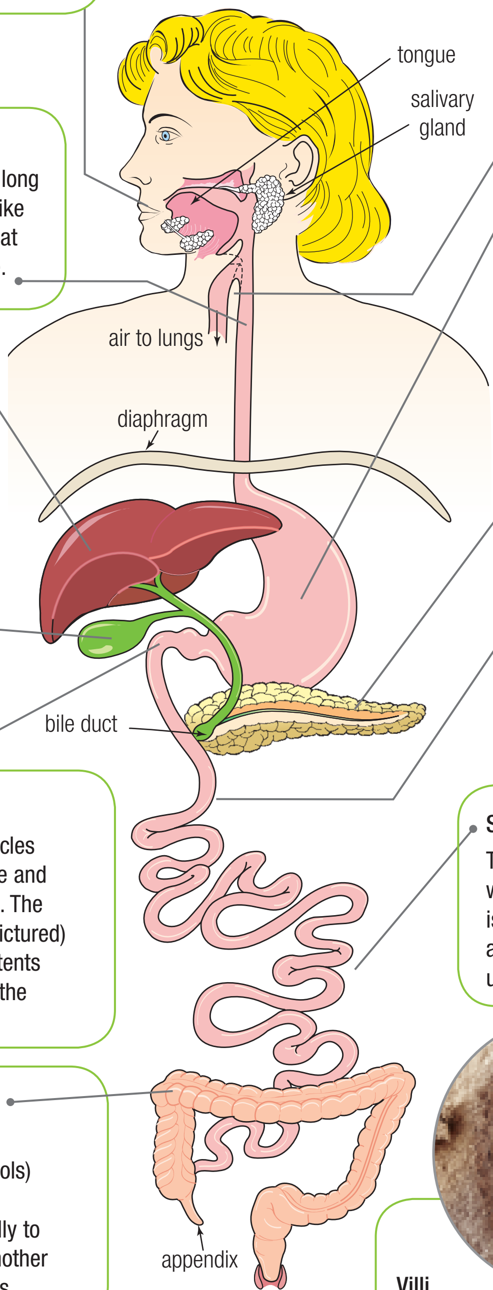


Trachea

The trachea, or windpipe, branches off the oesophagus and leads to the lungs.

Oesophagus

Peristalsis moves the bolus down the 25 cm long tube known as the oesophagus, or gullet—like squeezing a marble through a rubber tube that normally is slightly narrower than the marble.



Stomach

The stomach is a J-shaped organ with a capacity of about 2 L. Muscles in the stomach walls churn food and mix it with **gastric juice**.

Liver

At 1.5 kg, the liver is the body's largest internal organ. The liver is a chemical 'factory', producing chemicals essential in over 500 processes in the body.

Pancreas

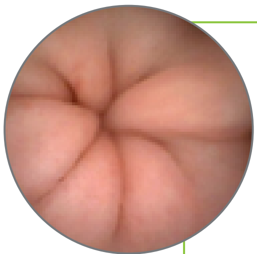
This 15 cm long multipurpose 'side attachment' to the digestive tract produces about 1.3 L of pancreatic juice every day.

Gall bladder

The gall bladder is an 8 cm long muscular sack that stores up to 50 mL of bile produced by the liver.

Duodenum

Here, at the start of the small intestine, tubes from the pancreas, liver and gall bladder join the digestive tract, allowing bile and enzymes to enter.

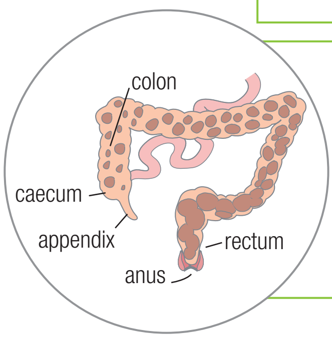


Sphincters

These rings of muscles control the entrance and exit of the stomach. The pyloric sphincter (pictured) stops stomach contents from rising up into the oesophagus.

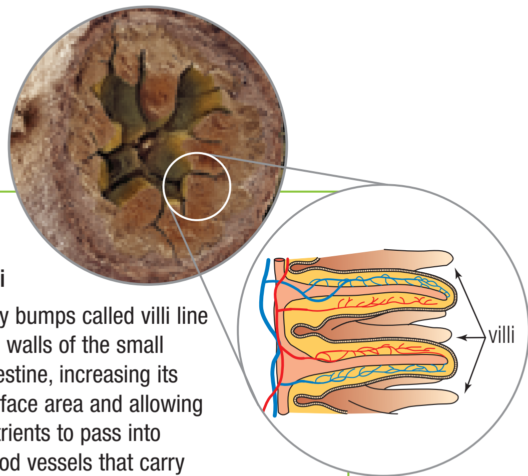
Small intestine

The small intestine is only 3 to 4 cm wide—hence its name. At 4 to 6 m in length, it is the longest part of the digestive tract. Water and a few minerals are absorbed from undigested waste material passing through it.



Large intestine

Lumps of faeces (referred to as stools) form in the large intestine, eventually to be expelled via another sphincter, the anus.



Villi

Tiny bumps called villi line the walls of the small intestine, increasing its surface area and allowing nutrients to pass into blood vessels that carry them away to the body.

Anus

A sphincter (a ring-like muscle) here is normally contracted but relaxes and opens when faeces need to be expelled.

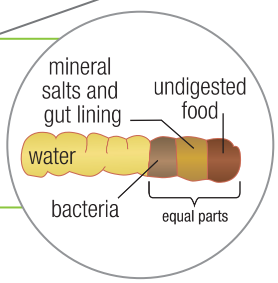


Fig 4.2.5 The human digestive system

Add more enzymes

The **duodenum** is the start of the small intestine and is where tubes from the pancreas, liver and gall bladder secrete pancreatic juice and bile into the small intestine.

Pancreatic juice is produced by the pancreas. It contains:

- more enzymes that help digest carbohydrates, fats and proteins
- a liquid alkali that neutralises the acid in the chyme leaving the stomach.

Fig 4.2.6 Special cells lining the stomach release mucus, which protects it from gastric juice. Otherwise the stomach would digest itself.

Fig 4.2.7 At the base of the stomach is the pyloric sphincter. This sphincter opens only every now and then. In this way, it controls the movement of food through your stomach, keeping it there long enough so that it can be digested properly.

The pancreas also produces the hormone **insulin**, which is a chemical that controls the amount of sugar in the blood and how cells use energy.

Diabetes is a disease that occurs when the pancreas does not produce enough insulin. Diabetics must carefully monitor blood sugar levels and the sugar content of the foods they eat.

With a mass of about 1.5 kilograms, the **liver** is the body's largest internal organ. Its rich red-brown colour is due to its extensive blood supply. The liver is a chemical 'factory' that:

- converts excess glucose into **glycogen** for storage in the liver and muscles. It is then converted back into glucose when needed
- stores vitamins and minerals, including iron, which is needed for the production of red blood cells in bone marrow
- helps in the production of a blood-clotting chemical
- breaks down poisons, such as alcohol
- produces around 700 to 1000 millilitres per day of **bile**, a green liquid that helps break down fats
- produces heat, which is then transferred around the body by the blood.

Prac 2 p. 110

Science Clip

Beaumont's window

On 6 June 1822, a French Canadian soldier named Alexis St Martin was shot in the stomach. His wound was dressed, but when it healed it left a hole through to the inside of his stomach. United States Army surgeon William Beaumont studied digestion by dangling bits of food tied on a silk thread into St Martin's stomach-hole. Beaumont studied digestion times and stomach contractions and also identified hydrochloric acid in gastric juice.

Absorbing the nutrients

More churning and more enzymes are added to the partly digested food once it enters the small intestine. Muscles in the walls mix it up and different enzymes are added to continue the digestion of carbohydrates, proteins, and fats and oils (i.e. lipids). By the time food has reached the small intestine, it is usually broken down enough to pass through the intestinal walls, into the bloodstream and away to the body.

Science Clip

It takes time!

The liver can break down only about 10 grams of alcohol per hour. This is the equivalent of one standard alcoholic drink. Many drivers are not aware of this and have been caught by police the day after drinking alcohol for being over the legal blood alcohol limit.

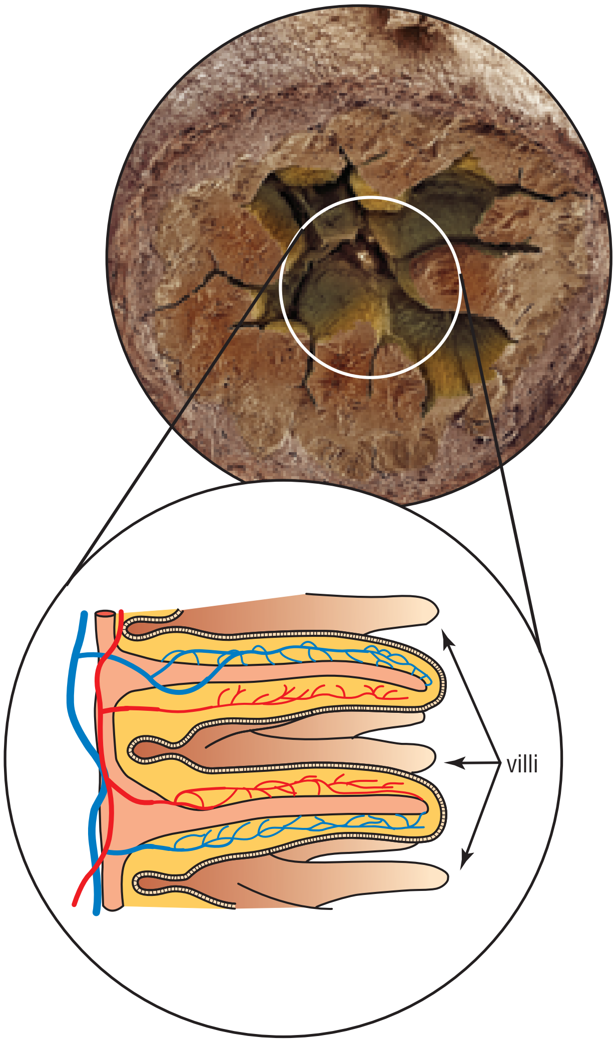


Fig 4.2.8 Tiny bumps called **villi** line the walls of the small intestine. Villi increase the surface area of the small intestine, allowing more nutrients to pass into the bloodstream. Villi contain tiny blood vessels that carry nutrients away to the body. **Lymph vessels** carry away digested fat.

Re-absorbing water

Undigested waste material then passes into the **large intestine**. By now, your food has had a lot of juices added to it while it has passed through the digestive system. All these juices contain valuable water and it is the function of the large intestine to re-absorb it back into the body. A few minerals are also absorbed here.

Getting rid of waste

Lumps of faeces (referred to as stools) form in the large intestine, eventually to be expelled by another sphincter muscle, the anus.

Prac 3 p. 111

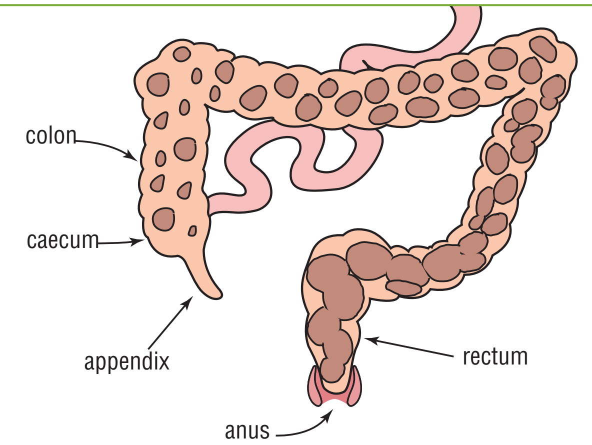


Fig 4.2.9 The large intestine has five parts—the **caecum**, **appendix**, **colon**, **rectum** and **anus**.

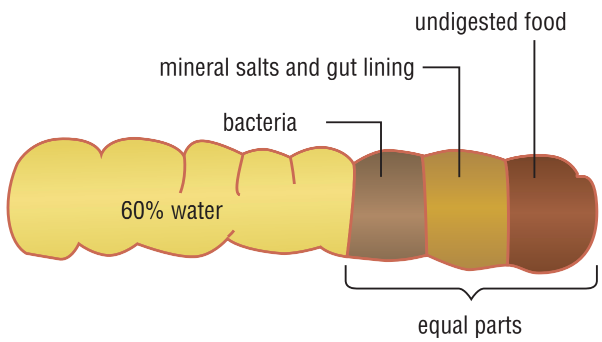


Fig 4.2.10 About 60 per cent of faeces is water. Another 20 per cent is made up of intestinal bacteria that helped break down fibre further up the gut. They also reduce the amount of faeces expelled and contribute to its smell.

Problems of the digestive system

Tooth decay

Tooth decay is caused by **plaque**—a thin film of food, saliva and bacteria that builds up on teeth. The bacteria transform sugar into acid that seeps into the enamel, causing weak spots. These weak spots collect even more sugar and decay until they form cavities that require cleaning, drilling and filling. Regular flossing and brushing with toothpaste after each meal removes much of this plaque and drastically reduces the chances of tooth decay.

If not treated, decay will enter the pulp, where there are nerves. Bacteria from the cavity can cause a painful infection or toothache, which may require root canal work. This involves removing the pulp and disinfecting the pulp chamber, which is then filled with a rubber-like material to prevent bacteria re-entering the tooth.

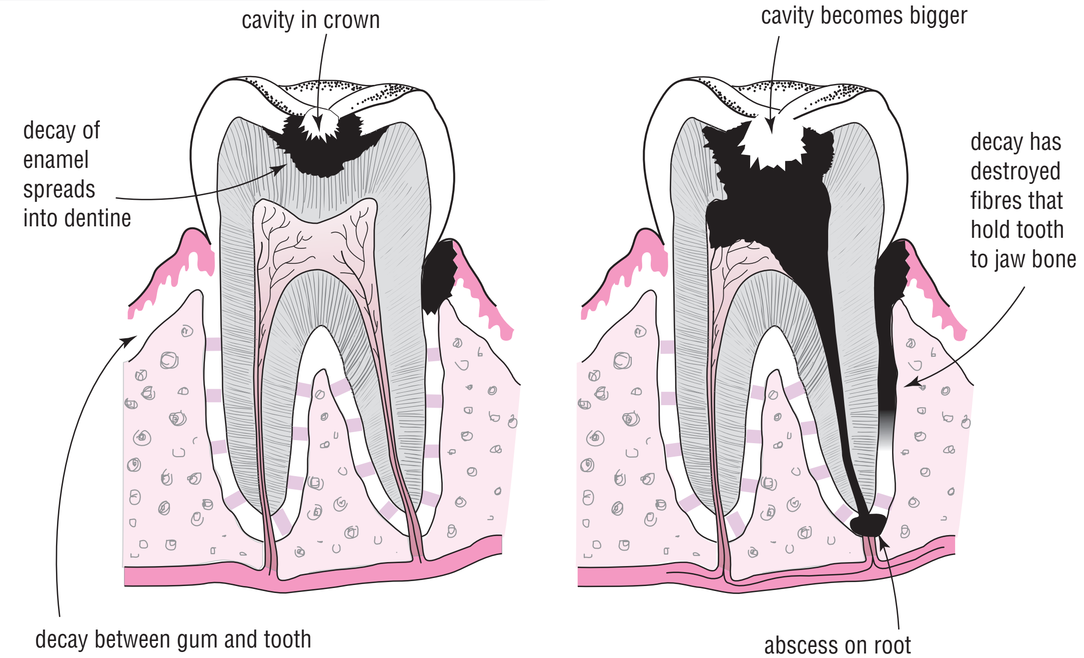


Fig 4.2.11 The progression of tooth decay.

> **Science Clip**
>
> **Beanz meanz fartz**
>
> The amount of flatus a person normally produces per day is about 1500 millilitres, in bursts of 30 to 150 millilitres—enough to inflate a party balloon! Bacteria love baked beans and cause even more flatus. Beans cause food and gas to move quickly through the intestines, leaving little time for the gas to be absorbed into the bloodstream. This leaves more gas exiting as a fart.

Farts and burps

A little air is swallowed whenever food is eaten and burps release some of this air. Bacteria in the intestines feed on undigested food, breaking it down to produce useful vitamins and less useful gases—sulfur dioxide (a smelly and choking gas, SO_2) and methane (CH_4). Acid in the stomach produces odourless hydrogen gas (H_2). Luckily, sphincters stop these gases moving upwards. They are released at the other end instead, through the anus. Gas released this way is called **flatus**. Gas in the intestinal tract is called **flatulence**. Although antisocial, flatulence is a sign of a properly functioning digestive system and a by-product of a healthy diet.

Diarrhoea

Dirty water and poorly prepared food are two ways in which unwanted bacteria can enter the digestive system. To rid itself of these bacteria, the body moves food and faeces more quickly through the digestive tract, resulting in diarrhoea. Diarrhoea leaves little time for the large intestine to remove water from the faeces, increasing water loss from the body and putting it at risk of dehydration. To reduce this risk, lost water, minerals and salts need to be replaced. Gastrolyte is one of many water additives available from the chemist that will do this. A doctor is the best person to consult when experiencing serious or prolonged diarrhoea.

> **Science Clip**
>
> **Faeces transplants**
>
> A Sydney doctor treated over 60 patients who suffered irritable bowel syndrome by recolonising their bowels with 'good' bacteria. This was done by giving them a 'faeces transplant', using faeces from family members not affected by the syndrome.

Heartburn

Sometimes excess acid is produced in the stomach, and occasionally it will escape into the oesophagus to cause a burning sensation commonly called heartburn. Heartburn can be caused by certain foods or by eating too quickly. Another cause may be a faulty sphincter that does not seal the top of the stomach properly. Antacid medicines and tablets partly neutralise stomach acid and usually relieve symptoms. Medical advice should always be sought if heartburn persists, as damage to the oesophagus may result from regular attacks.

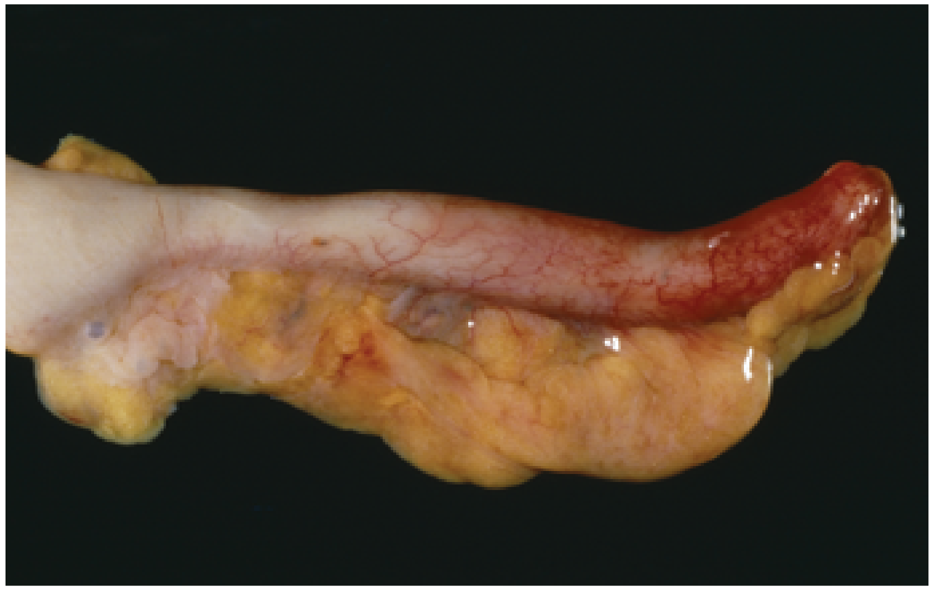


Fig 4.2.12 An inflamed appendix after removal in an appendectomy. The appendix appears to serve no purpose outside childhood, and so it can be removed without harming the future health of the patient. Often, blood supply to the appendix can be blocked off, causing it to 'die' or rupture.

Vomiting

Reverse peristalsis or vomiting can be triggered by infections, extreme pain or stress. Contractions in the stomach wall force food up and out. Vomit usually consists of partly digested food mixed with bile, acid and enzymes. Babies that begin to choke on milk or food may use a vomiting reflex action to clear blockages.

> **Science Clip**
>
> **Intestinal area**
>
> If the inner surface of a typical human intestinal tract were flattened out, it would cover an area equal to that of a tennis court!

Appendicitis

A blockage or ulcers may cause the appendix to become inflamed, causing severe pain, nausea, vomiting and loss of appetite. Although the appendix is thought to play some role in the development of the immune system of babies and young children, it appears to have no useful role later in life. It can therefore be safely removed in an operation called an **appendectomy**.

Eating disorders

Magazines, advertising, television and films tend to promote unrealistically thin bodies as the ideal body shape for women and promote overly muscular and athletic bodies as the ideal for men. Unfortunately, this places unnecessary pressure on young men and women to try to be like this, too. There is a wide range of healthy body shapes—it just might not be the thin or muscular one seen on TV.

Eating disorders can be dangerous

- **Anorexia nervosa**—sufferers unrealistically perceive that they need to lose weight and diet to the point of starving themselves, often to death. An estimated 0.5 per cent of Australians are thought to be anorexic, most of them females aged between 12 and 24 years.
- **Bulimia**—binge eating followed by purging (i.e. removing recently eaten food by vomiting or using laxatives). One per cent of Australians are thought to be bulimic. Like anorexia, more women suffer from bulimia than men.
- **Compulsive eating**—eating huge amounts when not hungry. Between three and seven per cent of Australians are thought to be compulsive eaters, with roughly equal numbers of men and women.
- **Obesity**—when a person is more than 25 per cent overweight. Obesity is most often caused by overeating and a lack of exercise. Just over 12 per cent of Australians and an estimated five per cent of children and adolescents are obese.

All eating disorders can be effectively treated by appropriate medical advice.

4.2 QUESTIONS

Remembering

1 **Name** the chemical that is used by cells to make energy.

2 **List** the main types of teeth, **specifying** what each type does.

3 **Name** three gases that may be present in the digestive system.

4 **Name** the flap of skin that stops food going down 'the wrong way'.

5 **List** possible causes of reverse peristalsis.

6 **Name** the part of the digestive system that:

a is the longest

b holds food for the longest period of time

c is like a cement mixer.

7 **Name** the part of the digestive system in which the following occurs:

a water is absorbed

b physical digestion crushes food

c nutrients pass into the bloodstream.

Understanding

8 You are lying on the couch eating an apple. Gravity won't get it to the stomach, so **describe** how it gets there.

9 **Describe** the function of enzymes.

10 **Account** for the fact that although the gall bladder can store only 50 millilitres of bile, a total of 700 millilitres of bile is produced each day.

11 When someone has food poisoning, they will probably vomit and have diarrhoea. **Account** for this fact.

12 **Predict** what would happen if:

a the gall bladder was removed

b almost all of the small intestine was lost in an accident

c the small intestine was smooth, rather than covered with villi

d the sphincter at the top of the stomach failed

e the mucous lining of your stomach had an ulcer or hole in it

f the anal sphincter failed.

13 **Outline** the steps in tooth decay.

14 **Describe** what burps would be like if they contained sulfur dioxide (SO_2) and methane (CH_4).

15 **Explain** why diarrhoea is so wet.

16 **Explain** what the production of hard, dry faeces would suggest:

a the amount of water being absorbed from the faeces

b the speed at which these faeces move through the large intestine.

Applying

17 Sections of the large intestine are sometimes named the ascending (i.e. going up) colon, descending (i.e. going down) colon and transverse (i.e. across) colon. **Use** this information to sketch a large intestine, and **identify** each section.

Analysing

18 The water supply of NSW and the toothpaste you use both have fluoride added, a chemical that has been shown to help prevent tooth decay. Despite this, tooth decay in children has increased dramatically over recent years. Some people believe that:

- Fluoride should not be added to water supplies.
- The long-term effects of fluoride in the body is still largely unknown.
- The increase in child tooth decay is due to increased sugar content in foods.
- The increase in child tooth decay is due to increased consumption of bottled water, which contains no fluoride.

a **Analyse** the issue of fluoridation, using the questions below as a starting point.

i Should all tap water have added fluoride or should you have a choice?

ii Does public health have more or less priority than individual choice?

iii Is the drinking of bottled water healthy for children's teeth?

iv Do foods have too much added sugar?

b **Summarise** your viewpoint.

Evaluating

19 **Propose** reasons why:

a adults have 32 teeth (16 in each jaw), whereas young children have only around 20

b chewing food for longer saves digestive time in the long run

c vomit often has a green colour and burns the mouth

d heartburn is felt around the heart, despite it not being a heart condition.

Creating

20 Diarrhoea is one of the most difficult words to spell in the English language. **Construct** a mnemonic to help you remember how to spell it.

21 **Construct** a scaled timeline for the minimum times that food spends in each part of the digestive tract.

>>

22 Doctors can now gain information regarding their patient's digestive tract by getting them to swallow a 'pill' camera that contains a miniature video camera, light source and radio transmitter. This pill may eliminate the need for surgery or the insertion of tubes to obtain a diagnosis. Imagine you are the doctor receiving video and sound from the pill inside your patient. **Describe** what you are going to see and hear from the pill as it passes through your patient over the next 24 hours by **constructing**:

- a series of cartoons
- a series of clay or plasticine models of important parts of the journey
- a PowerPoint presentation
- a role play, during which you are the pill camera and your classmates are the parts of the digestive tracts
- an imaginative written essay or Word document.

Fig 4.2.13 Once science-fiction, the pill camera is now reality. Many problems of the digestive tract are now analysed using this pill.

4.2 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Research the digestive systems of other animals (e.g. worms, sheep, cows). Compare and contrast them with that of humans.

2 Research other digestive diseases/disorders, such as tapeworms, salmonella, listeriosis, dysentery, typhoid, cholera, hernias, gallstones, Crohn's disease, irritable bowel syndrome, cancer and giardia.

a Outline the cause, signs, symptoms and treatments/cures of the disease/disorder.

b Write a journal of your day as if you had contracted this disease, describing how you feel at different times, what you have to do during the day to cope and how it affects your life. (L)

3 Research the names and effects of some digestive enzymes and summarise your information in a table. Enzymes investigated should include proteases, which break down proteins; lipases, which break down fats; and amylases, which break down carbohydrates. (L)

e-xploring

PP Web Destination

Find out more about eating disorders and how they can be treated by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Present your findings in one of the following ways:

- a doctor or food nutritionist discussing an eating disorder with a patient
- a page for a magazine like *Dolly* or *Ralph*.
- a script for a TV medical series like *All Saints*
- a video for a TV program on health like *Body Work* or *You Are What You Eat*.

4.2 PRACTICAL ACTIVITIES

1 Energy in a biscuit

Aim

To determine the chemical potential energy stored in a dry biscuit

Equipment

- dry biscuit (e.g. Clix cracker)
- cork
- pin
- test tube
- bench mat
- retort stand
- bosshead and clamp
- 10 mL measuring cylinder
- thermometer
- tongs
- matches or lit Bunsen burner
- access to electronic scales

Method

1. Assemble the apparatus, as shown in Figure 4.2.14, and measure the temperature of the 10 mL of water.
2. Find the mass of the dry biscuit.
3. Use the tongs to hold the biscuit and light it, using matches or a Bunsen burner.
4. When the biscuit is burning constantly, hold it directly under the test tube so that it heats the water.
5. When the biscuit is completely burnt, measure the temperature of the water again.

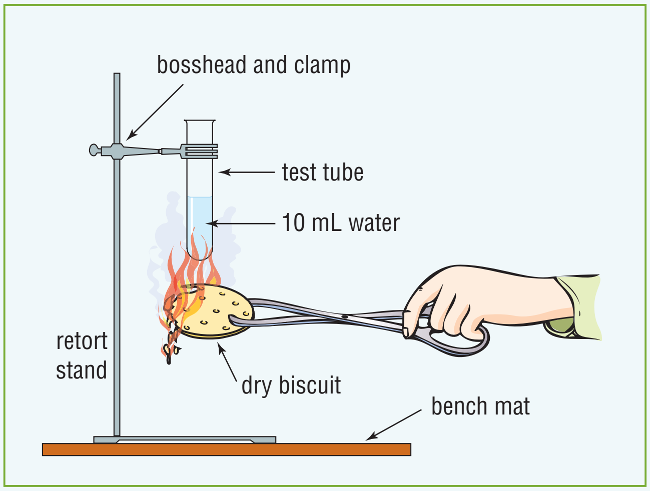


Fig 4.2.14

Questions

1. **Calculate** the rise in temperature of the water in the test tube. N
2. It takes 42 joules of energy to raise the temperature of 10 mL of water by 1°C. Multiply your answer to Question 1 by 42. The answer tells you how many joules of energy were transferred from the biscuit to the water. **Calculate** how much heat was required to give the observed rise in temperature (as calculated in Question 1). N
3. **Predict** whether the biscuit actually contains more or less energy than that calculated in Question 2. **Explain** your prediction.
4. According to your results, **calculate** how much energy is in each gram of biscuit.
5. **Propose** ways in which this experiment could be made more accurate.

2 A model intestine

Aim

To investigate how the small intestine works

Equipment

- two 500 mL beakers
- two 20 cm lengths of dialysis tubing
- starch solution
- glucose solution
- iodine solution
- Testape

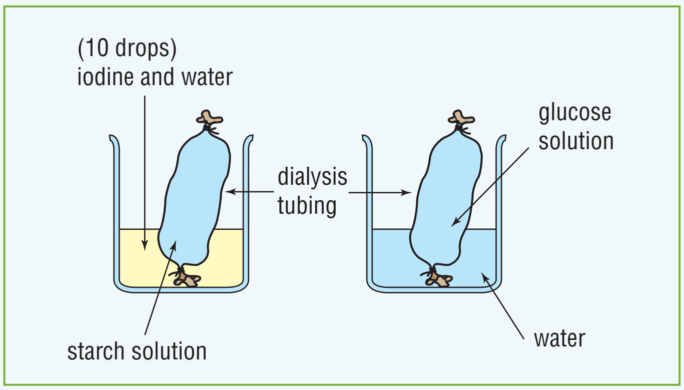


Fig 4.2.15

>>

Method

1 Soak both sections of dialysis tubing in a beaker of water for a few minutes.

2 Tie a knot in one end of each section and rub the other ends to separate them.

3 Fill one tube with starch solution, tie the open end and rinse with water. Place this tube in a beaker containing water and iodine solution, as shown in Figure 4.2.15.

4 Fill the other tube with glucose solution, tie the open end and rinse with water. Place this tube in a beaker containing only water. Test the water with a piece of Testape.

5 After 15 minutes, observe beaker A, and test the water in beaker B with Testape.

6 Write down any important observations.

Questions

1 **Explain** how you know when starch or glucose is present in a solution.

2 **Describe** the directions in which starch and glucose molecules were able to move and **explain** why this was the case.

3 **Compare** dialysis tubing with the small intestine.

3 Enzyme action

Aim

To observe the action of enzymes on food

Equipment

- plain unsalted cracker biscuit
- crushed junket tablet (rennin) in solution
- three test tubes
- test-tube rack
- three 500 mL beakers
- bench mat
- tripod
- gauze mat
- Bunsen burner
- thermometer

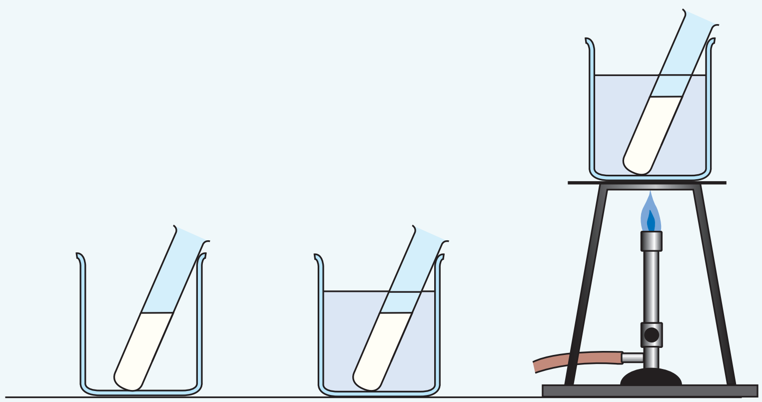


Fig 4.2.16

Method

Part A: Biscuit munching

A plain cracker biscuit is a good source of starch.

1 Chew a piece of plain dry biscuit for several minutes without swallowing.

2 Note any change to the taste of the chewed biscuit.

Part B: Curdling milk

Rennin is an enzyme that occurs in our stomachs. In this experiment it is obtained from a junket tablet.

1 Half-fill three test tubes with cold milk. Place one in an empty beaker.

2 Place another of the test tubes of milk in hot water and allow it to reach about 38°C.

3 Heat a third test tube of milk in a beaker of water until the temperature reaches about 80°C.

4 Add one-third of your rennin solution to each test tube and observe.

Questions

1 **Describe** the taste detected after chewing the cracker for several minutes.

2 **Account** for the change in taste of the cracker.

3 **Recall** the name of the substance in your mouth that contains the enzyme that breaks down starch.

4 **Account** for the temperature at which the enzyme rennin worked best.

5 **Propose** an advantage of milk curdling in your stomach.

Science Focus Analysing food

Prescribed Focus Area:
Current issues, research and developments in science

Fig 4.2.17 Carbohydrates, starches, sugars, and fats and oils are all vital to your diet. Too much, however, and they will be stored as fat.

Food is the fuel that your body needs to operate. It provides energy for movement and the production of heat. Your body is a little like a car. A car needs petrol, but it also requires oil, brake fluid and water for it to operate at its peak performance. Your body needs vitamins, minerals and other substances to maintain health, and for making new cells to allow growth and repair of body tissue.

To maintain a healthy diet, you need water, fibre and nutrients.

Water

Water is an important part of your body cells and makes up about two-thirds of your body. Water is required to dissolve other chemicals, so that they can be transported easily around the body by blood, which is itself almost all water (90%). Lack of water (**dehydration**) can cause low blood pressure and become life threatening.

Fibre

Fibre (sometimes called roughage) is found in the cell walls of plants such as cereals, vegetables, fruit, nuts and seeds. Fibre is not fully broken down during digestion and its bulk speeds the movement of matter through your intestines. Without fibre, undigested food would spend too much time in the large intestine, and too much water would be removed, resulting in harder, drier faeces and **constipation** (i.e. difficulty passing faeces). Fibre also soaks up some poisonous wastes for removal from our bodies. A lack of fibre in the diet increases the risk of diseases such as bowel cancer. Processing of foods often removes fibre, which is found in the bran surrounding grains like wheat and brown rice. Brown bread has lots of fibre because it is made from wholemeal grains that have not had their bran removed.

> **Science Clip**
>
> **Six elephants**
>
> During a lifetime, a human being will consume around 30 tonnes of food—that's about as much as the mass of six elephants!

Nutrients

There are five main **nutrients**. These are:

- carbohydrates (including starches and sugars)
- lipids (i.e. fats and oils)
- proteins
- vitamins
- minerals.

> **Science Clip**
>
> **Sweet!**
>
> Saccharine is an artificial sweetener that is 500 times sweeter than sugar. It was discovered by accident in 1879 by American scientist Constantin Fahlberg when he licked his fingers after working all day with coal tar! To remain safe, don't follow Fahlberg's example by licking your fingers after an experiment!

Carbohydrates

Your body converts most of the carbohydrates it consumes into glucose, the sugar the cells use for energy. In this way, carbohydrates, starches and sugars provide us with our main source of energy. Excess glucose is converted into glycogen and stored in the liver, or into body fat, which is then stored around the body. Sugar, pasta, rice, potatoes, bread, cake and biscuits all contain lots of carbohydrates.

Lipids (fats and oils)

Lipids are a rich source of energy and contain twice the energy of carbohydrates. Fat is stored under the skin as an energy reserve, and to provide insulation against loss of body heat. Fats contain important vitamins, and are used for making cell membranes and nerve cells. Cooking oil is an obvious source of lipids, as is anything that is fried in it, such as potato chips. Other sources are spreads, such as margarine, and dairy products, such as milk, cream, cheese and butter.

Proteins

Proteins provide the raw materials required for the growth and repair of damaged or worn-out tissues. They are needed to heal cuts and wounds and for building muscle. Proteins provide only 10 per cent of your body's energy. Meat, chicken, fish, eggs and cheese are good sources of protein.

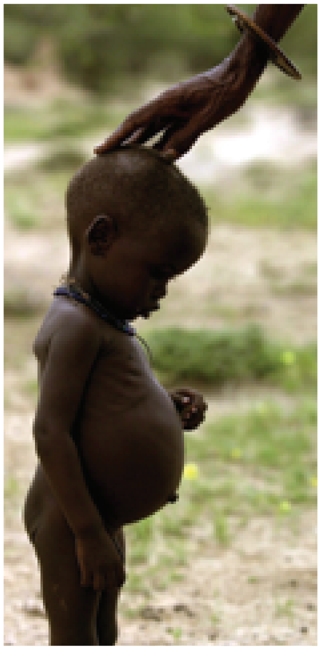


Fig 4.2.18 A lack of protein can lead to **kwashiorkor**, a disease that most generally affects children aged between 1 and 3 years. In severe cases, muscles waste away and body fluids accumulate in the skin, causing swelling. This is why starving children in poor nations often appear thin, but with swollen stomachs.

Vitamins

Although **vitamins** provide no energy, small amounts are needed to speed up various chemical reactions in your body and to maintain good health. Lack of vitamins or other nutrients can result in what are known as **deficiency diseases**. Excess vitamin intake can also cause problems. Some of the more important vitamins are shown in the table below.

Fig 4.2.19 Most fruit and vegetables are excellent sources of vitamins, especially vitamins A, B12 and C.

Minerals

Elements known as minerals are also required for healthy growth and to avoid deficiency diseases. Minerals that are needed in larger amounts are called **major elements**, whereas those needed in smaller amounts are called **trace elements**. As with vitamins, health problems can be caused by too little or too much of some minerals. Some of the more important minerals are shown in the table below.

Science Clip

Blimey limeys!

During long voyages, English sailors with the Royal Navy were given rations of citrus fruits to protect them from scurvy caused by lack of vitamin C. Limes were commonly used, and so 'limeys' became a nickname for the English.

Nutrient	Males	Females
Protein	51 grams	50 grams
Vitamin C	30 milligrams	30 milligrams
Calcium	1200 milligrams	1000 milligrams
Iron	12 milligrams	12 milligrams
Sodium	920–2300 milligrams	920–2300 milligrams

Vitamin	Some sources	Important for	Deficiency may cause
A	Milk, dairy products, eggs, carrots, oranges, butter, margarine, green vegetables, fish liver oil, liver	Healthy skin, eyes, bones and teeth; lining of digestive and respiratory systems; pregnancy and foetal development	Poor vision in dim light; retarded growth; infections
B12	Meat, fish, liver, milk, eggs, cheese, green vegetables	Formation of red and white blood cells; healthy nerves, skin, hair	Loss of appetite; headache; nausea; diarrhoea; fatigue; confusion; loss of memory; depression
C	Oranges, lemons, grapefruit, green peppers, blackcurrants, strawberries, tomatoes, potatoes, green vegetables	Healthy bones, teeth and tissues; wound healing	Scurvy (symptoms include bleeding gums and internal organs, easy bruising, depression)

A balanced diet

Everyone has their favourite foods and it is tempting to eat only those. Your body, however, needs a range of foods and the many different nutrients they provide.

A diet of French fries will not provide that range of nutrients, and neither will a diet of strawberries, lollies or meat pies. The approximate recommended daily intakes of selected nutrients for those aged 12 to 15 years are shown in the table below.

Science Clip

No-fat water

Water contains no fat nor any other food type, and so contributes zero kilojoules to your diet. Water is, however, used by the body in many ways, so try to drink at least one litre (i.e. four glasses) a day.

	Mineral	Some sources	Important for	Deficiency may cause
Major elements	Calcium	Milk, cheese, dairy products, tinned salmon, peanuts, tofu	Healthy bones and teeth; muscle contractions; heart; nervous system; blood clotting	Nerve and bone disorders; osteoporosis; rickets; insomnia
	Sodium and chlorine	Table salt (sodium chloride), green vegetables	Water balance in the body; muscle contractions; transmission of nerve impulses; production of stomach acid	Deficiency is rare (excess more likely); apathy; loss of appetite; vomiting; muscle cramps
Trace elements	Iron	Red meat, liver, cereals, green vegetables	Energy; oxygen transport in blood; storage in muscles	Fatigue; reduced resistance to infection; anaemia
	Zinc	Meat, green vegetables	Energy; detoxification of chemicals such as alcohol; healthy brain, bones, teeth and skin; reproductive and immune systems	Skin problems; reproductive defects; loss of eye function; osteoporosis

Energy in food

You need food for energy but your body will store it as fat if you take in more energy than you use. The energy content of foods is measured in **kilojoules** (kJ).

The recommended energy intake according to age is shown in the table below. A megajoule equals 1000 kilojoules or one million joules.

	Average daily energy requirements (megajoules)	
Age (years)	Male	Female
10	8.6	7.8
11	9.3	8.2
12	9.5	8.6
13	10.4	9.0
14	11.2	9.2
15	11.8	9.3
16	12.5	9.4
17	12.8	9.4

Sample menus

The following table gives the nutritional and energy content of a single serving of selected foods.

Food	Energy (kJ)	Carbohydrates (g)	Protein (g)	Fats (g)	Vitamin C (mg)	Calcium (mg)	Iron (mg)
Milk (250 mL)	630	11	8	8.2	2.3	91	0.1
Bread (1 slice)	294	13	3	1	0	18	0.9
Jam (1 teaspoon)	58	3	0	0	3	1	0.05
Margarine (1 tsp)	143	0	0	3.8	0	0	0
Soft drink (375 mL)	668	40	0.1	0.1	0	11	0.1
Hamburger	1300	40	15	35	3	35	3.0
French fries (1 serve)	950	24	2.6	13	10	10	0.5
Peas (½ cup)	281	13	4.3	0.2	11	22	1.2
Fruit salad (1 cup)	235	15	0.6	0	3	10	0.3

Using energy

The following table shows the approximate energy expenditure for an adult doing various activities.

Worksheet 4.2 Analyse this!

Prac 4 p. 117

Activity	Energy expended per hour (kJ)
Sleeping	250
Sitting	370
Walking	1000
Jogging	1380
Running fast	1680

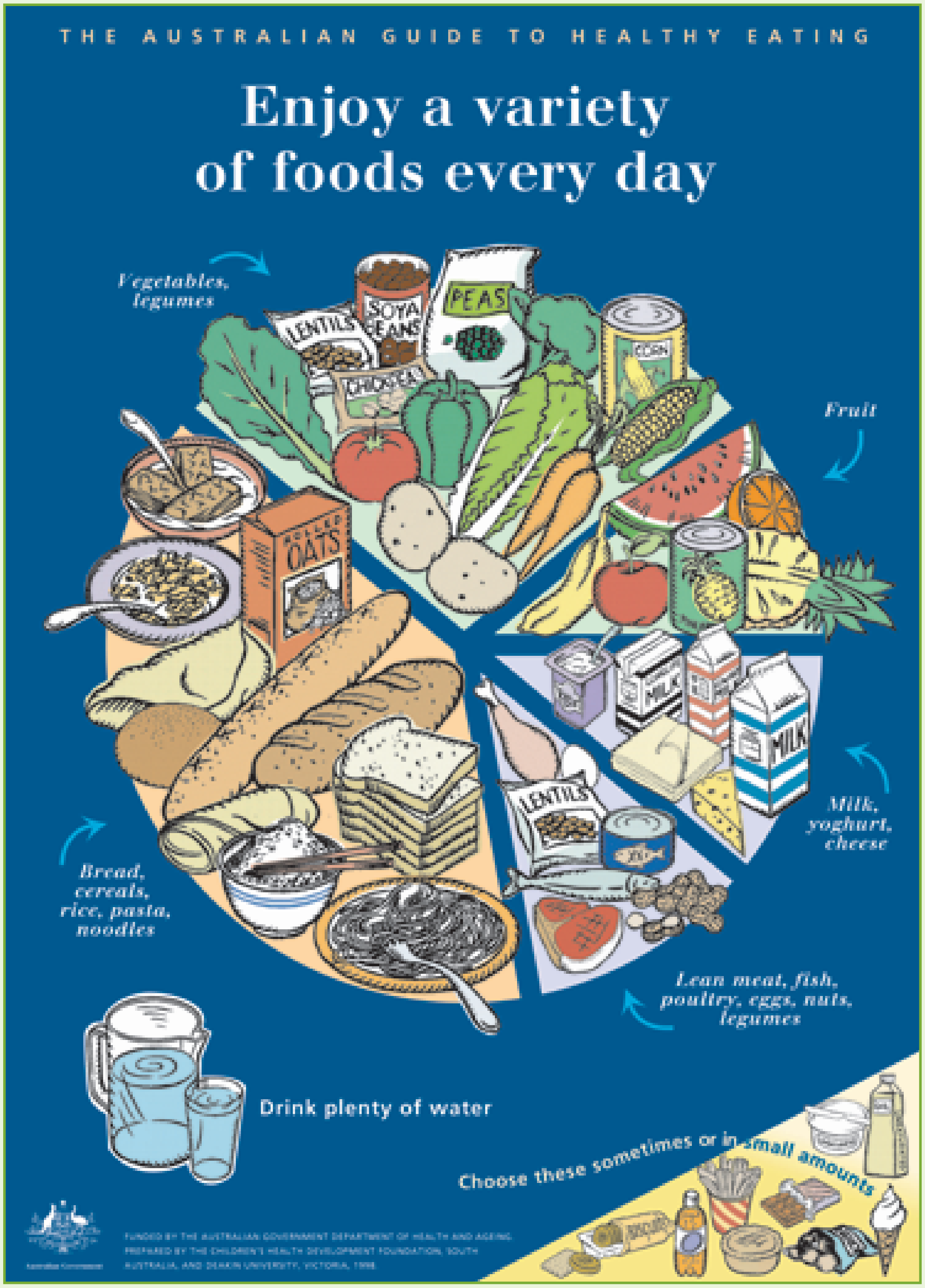


Fig 4.2.20 *The Australian Guide to Healthy Eating* helps Australians to choose a healthy diet.

STUDENT ACTIVITIES

1 **Name** four foods that are good sources of:
  a carbohydrates b lipids c protein.

2 **Name** three foods that are good sources of the vitamins:
  a A b B12 c C.

3 **Name** two foods that are good sources of the minerals:
  a iron b calcium c sodium and chlorine.

4 **Describe** what a deficiency in the vitamins and minerals listed in questions 2 and 3 causes.

5 **Name** a food that has lots of fibre.

6 **Explain** the importance of water in your diet.

7 **Describe** what the nutrients listed in Question 1 are used for in the body.

8 **Predict** what would happen if your diet contained insufficient fibre.

9 a **State** the suggested daily energy requirement for your age group and gender.
  b It is recommended that a good diet should contain 55 to 60 per cent of your daily energy as carbohydrates and less than 30 per cent of daily energy as fat. **Calculate** what these energy amounts would be for you.

10 **Use** the information on energy to complete the following:
  a **Explain** why energy is still used even when you are sleeping.
  b **Explain** why the energy expenditure amounts can be approximate only.
  c **Identify** factors that might affect the amount of energy used.

11 **List** everything that you ate and drank last night for dinner and before you went to bed.

12 **Calculate** an estimate of how much of that energy you used between dinner and your arrival at school this morning. Ⓝ

13 Use Excel or the percentage graph circle on a Mathomat to accurately **construct** a pie graph showing the composition of the following foods: Ⓝ
  a meat: 13% fat, 18% protein, 69% water and other substances
  b potato: 2% protein, 21% carbohydrates, 77% water and other substances
  c baked beans: 0.5% fat, 5% protein, 7% fibre, 10.5% carbohydrates, 77% water and other substances.

14 Use Excel or graph paper to **construct** a column graph showing the approximate daily requirements of proteins, vitamin C, calcium, iron and sodium for 13-year-olds. Ⓝ

15 **Construct** a line graph by plotting the daily energy requirements for both males and females between the ages of 10 and 17 years. Ⓝ
  a **Propose** reasons why dietary requirements are different for females and males.
  b **Predict** what effect pregnancy would have on a woman's energy requirements. **Explain** your answer.

INVESTIGATING

1 a Keep a diary of the food you eat over a week and use a table of food composition from a library or other source to calculate the amount of energy and selected nutrients you consumed each day. Ⓝ
  b Compare and contrast your diet with that suggested by recommended dietary allowances in food composition tables. Ⓝ

2 Compare and contrast the amounts of energy, carbohydrates, protein, fat, sugar and dietary fibre in various breakfast cereals. Ⓝ

3 Collect three samples (e.g. photos from magazines, video clips) showing how the media portray an 'ideal' body shape for men or women. Contrast this with magazine pictures showing other body types.

PRACTICAL ACTIVITY

4 Basic food tests

DYO

Aim

To test for the presence of starch, glucose, lipids and protein in food

Equipment

- starch
- iodine solution
- a white tile
- glucose solution
- Testape
- watch-glass
- margarine
- vegetable oil
- brown paper
- protein solution
- Albustix paper
- vitamin C solution
- DCPIP solution
- test tube
- eye dropper
- spatula

Method

Part A: Basic food tests

1 The presence in food of starch, glucose, lipids (fats and oils), protein and vitamin C can be determined easily using the following simple tests. Perform each test as shown in Figure 4.2.21, and carefully record your observations.

Part B: Testing various foods

1 Use the methods from part A to test different samples of foodstuffs (e.g. apple, cheese, milk, egg white, butter, a lolly, flour, meat, orange juice, lemon, potato, biscuit, bread).

2 Present your results in a table, showing what each food contained.

Questions

1 **Outline** how you tested a particular food for the presence of:

  a starch

  b glucose

  c lipids

  d protein

  e vitamin C.

2 **Construct** a table to show what nutrients each food contained.

3 Does a negative test result mean there is none of that particular nutrient in that food? **Explain** your answer.

4 **Assess** which food(s) contained the most nutrients.

5 **Design** an experiment to **compare** the concentration of vitamin C in particular foods.

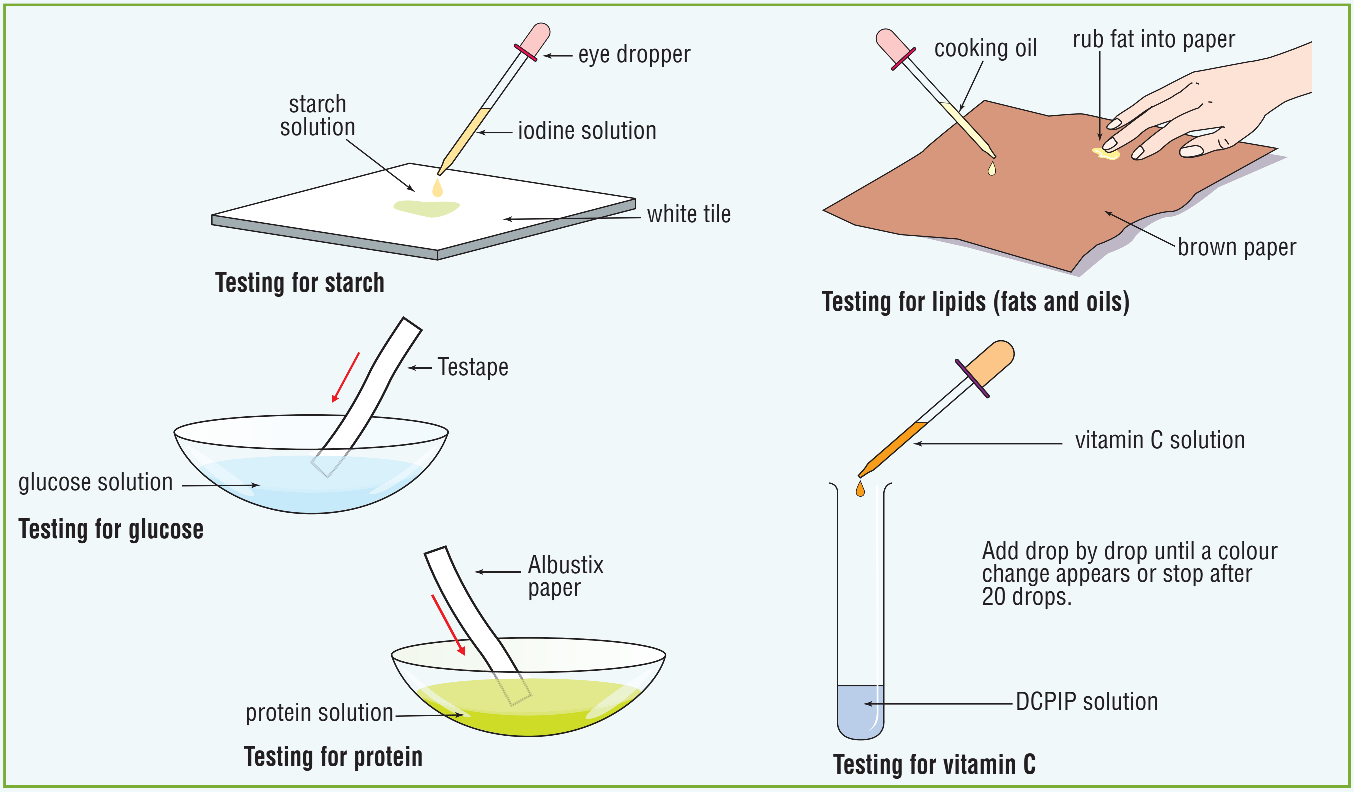


Fig 4.2.21

Unit 4.3 Blood and circulation

context

Blood is the river of life. It transports oxygen and nutrients to the cells and takes carbon dioxide and waste away from them for removal. Also, blood transports heat around your body and helps you fight disease. The heart pumps blood around a network of tubing 150 000 kilometres long. This is known as the circulatory system.

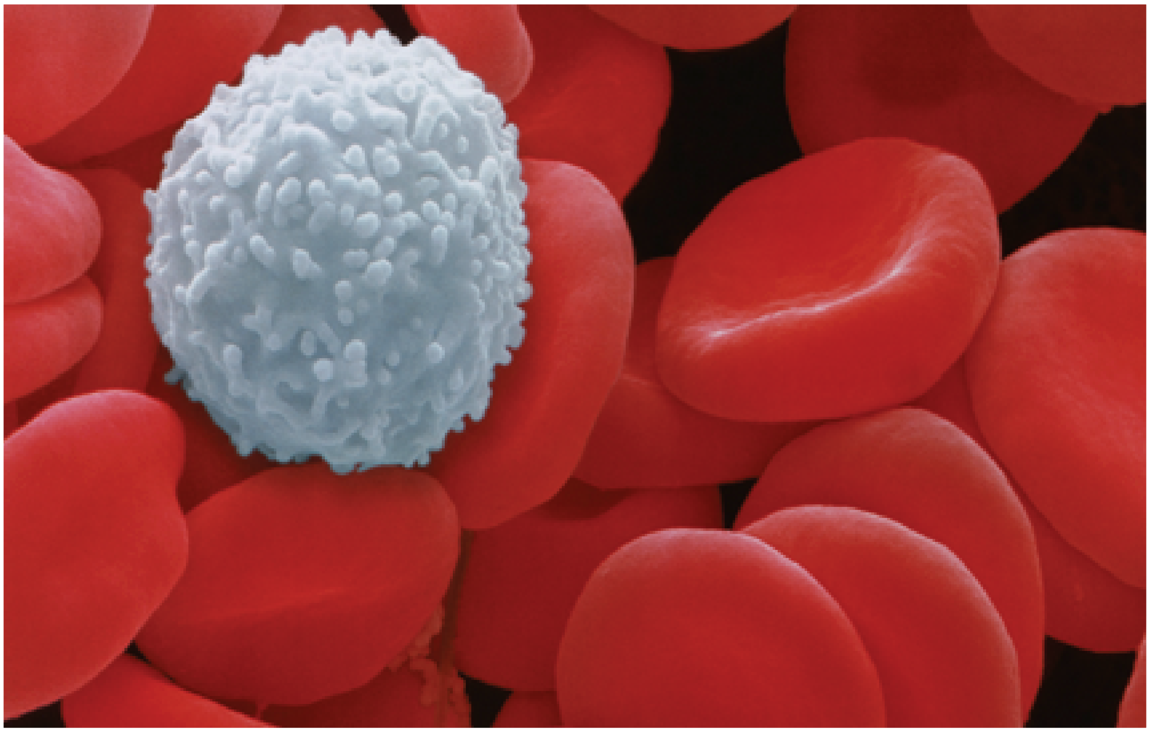


Fig 4.3.1 Red blood cells and a single white blood cell

Blood

Your **blood** has three main jobs:

- It carries oxygen, glucose, water and nutrients from the respiratory and digestive systems to the cells.
- It removes waste material and carbon dioxide from the cells.
- It maintains body temperature by delivering heat produced in the liver.

The human body contains about 5.5 litres of blood, which is made up of red and white blood cells, platelets and plasma.

Prac 1 p. 126

The heart

Your heart is about the same size as your clenched fist. Its position and orientation is given roughly by placing your right fist in the centre of your chest and letting it hang.

The heart pumps blood around the body, beating at around 90 to 120 beats per minute for children and 70 beats per minute for adults. Super-fit athletes may have heart rates below 30! Nerve impulses generated within the heart trigger each beat.

The heart is made of a strong type of muscle called **cardiac muscle**. In adults, the heart pumps up to 5 litres of blood every minute and up to 40 litres when beating rapidly during exercise or stress.

The heart is really two pumps joined together that push the blood out to different places in the body.

Prac 2 p. 126

Science Clip

Blue blooded!

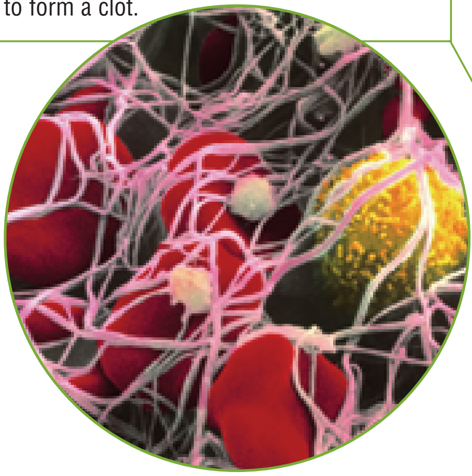
Not all creatures have red blood. A lobster has blue-green blood due to the copper chemicals in it. A starfish has clear, watery blood.

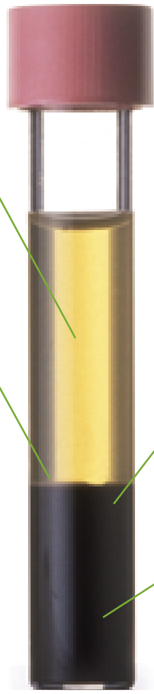
Plasma

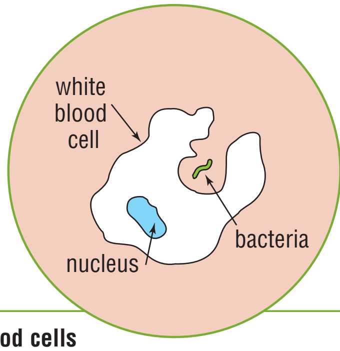
Plasma is a clear, yellow liquid, 90% of which is water. In the body, white and red blood cells and platelets are suspended in plasma and are transported with it.

Platelets

Platelets are broken-up blood cells. They trigger the formation of fibrin strands, shown here trapping red blood cells, a single white blood cell and smaller platelets, to form a clot.







White blood cells

White blood cells help rid the body of bacteria and viruses by surrounding and destroying them, or by producing chemicals to kill them. Here, a white blood cell engulfs bacteria.

Red blood cells

Red blood cells carry an iron-containing substance called haemoglobin. Haemoglobin carries oxygen and is what gives blood its red colour.

Fig 4.3.2 Blood settles readily into its different parts—55% plasma and 45% red cells, with small amounts of white blood cells and platelets.

Go to Science Focus 1, Unit 5.3

Science Fact File

Blood types

Blood transfusions can be deadly if blood is not matched between the donor and the recipient.

There are several types of human blood. Blood can be classified in two ways:

- **blood type**—Blood contains no more than two types of **antigen** (i.e. antigens A or B). Type A blood contains antigen A, type B blood contains antigen B, type AB blood contains both, and type O blood contains neither antigen A nor B. The most common type of blood is type O.
- **Rhesus factor**—Rhesus is another type of antigen. Blood that contains the Rhesus antigen is classified as Rhesus positive (Rh+). Blood without the Rhesus antigen is classified as Rhesus negative (Rh–).

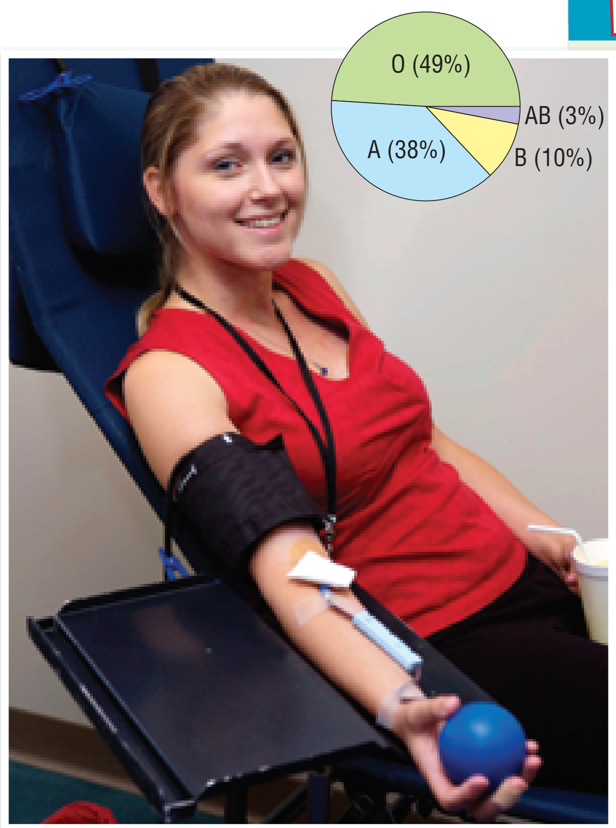
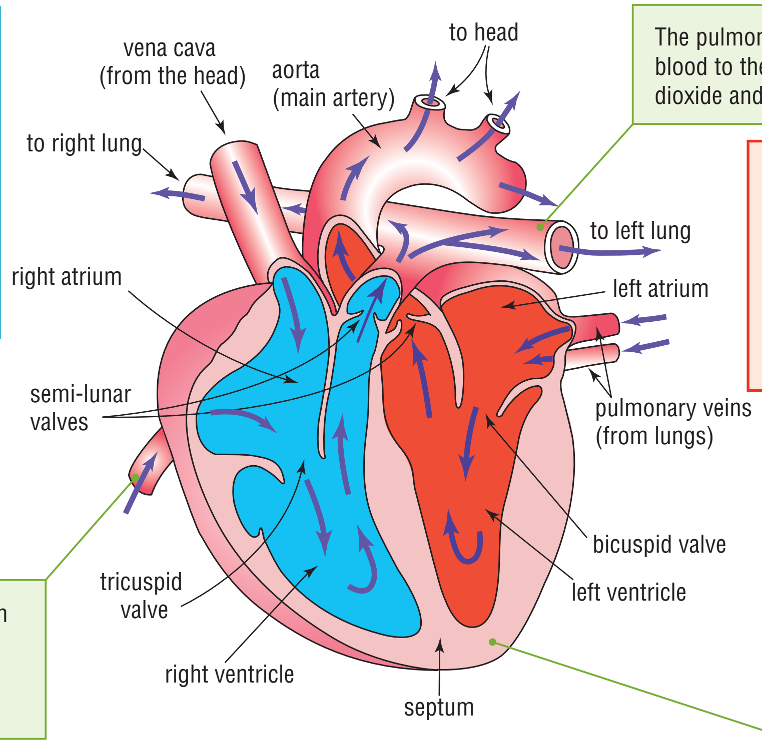


Fig 4.3.3 For a blood transfusion to be safe, the donor blood must not contain any antigens that are not already in the recipient's blood. Otherwise blood cells are likely to clump together and form deadly blockages. **Inset:** This pie chart shows the percentages of each blood type in the Australian population.

The 'right' pump draws blood from the body and sends it to the lungs to pick up oxygen. Blood that has had most of its oxygen removed is said to be deoxygenated. Deoxygenated blood is a dull red-blue colour.

The pulmonary artery carries deoxygenated blood to the lungs for removal of carbon dioxide and to receive a new load of oxygen.

The 'left' pump receives the oxygen-rich blood from the lungs and then pushes it out to the head and the body. Blood that is rich in oxygen is said to be oxygenated. Oxygenated blood is bright red.



The walls of the left side of the heart are thicker than those on the right side as they must withstand greater pressure. For the same reason, the walls of each ventricle are thicker than those of the corresponding atrium.

The vena cava is the main vein from the body, carrying deoxygenated blood back to the heart.

Key

direction of blood flow | oxygenated blood | deoxygenated blood

Fig 4.3.4 A cross-section of the human heart. Imagine placing the heart inside the chest of its owner. Although the 'left' and 'right' labels seem opposite to you, they make sense to the owner.

Science Clip

Super pump

Your heart is really a super pump—it could fill a petrol tanker in one day!

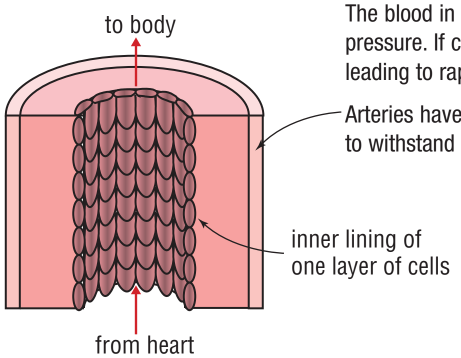
Drag-and-drop

Worksheet 4.3 The heart

Prac 3
p. 127

Blood vessels

Blood travels along tubes called **blood vessels**, and the adult body contains over 150 000 kilometres of them. There are three types of blood vessels—**arteries**, **capillaries** and **veins**.



The blood in arteries is at high pressure. If cut they may spurt, leading to rapid blood loss.

Arteries have thick elastic walls to withstand high pressure.

Fig 4.3.5 Arteries carry oxygenated blood away from the heart to the organs and tissues. A regular surge, or 'pulse', can be felt at several pressure points around the body where blood passes through arteries close to bones.

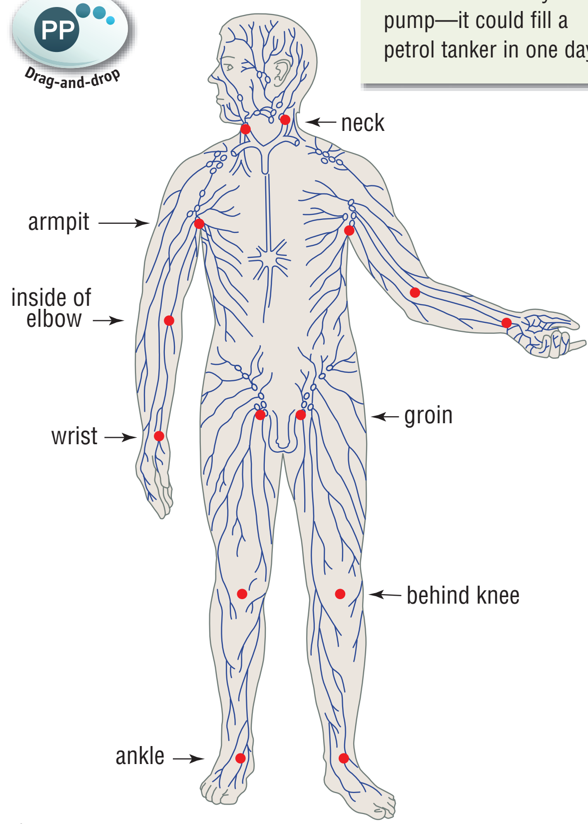


Fig 4.3.6 Pulse pressure points

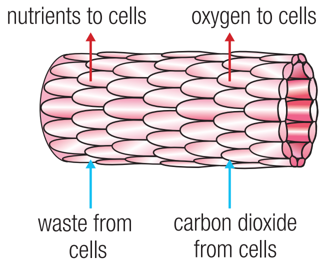


Fig 4.3.7 Capillaries service virtually every tissue in the body, making them the most common type of blood vessels.

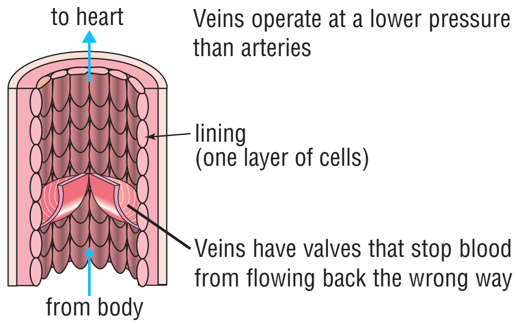


Fig 4.3.8 Veins return deoxygenated blood from the body to the heart.

> **Science Clip**
>
> **Red eye**
>
> Flash photography often results in photographs of people with red eyes due to light reflecting from blood-filled capillaries at the back of the eye.

The circulatory system

The heart, arteries, veins and capillaries all combine to form the circulatory system that transports oxygen, carbon dioxide, digested food, chemicals and heat around your body.

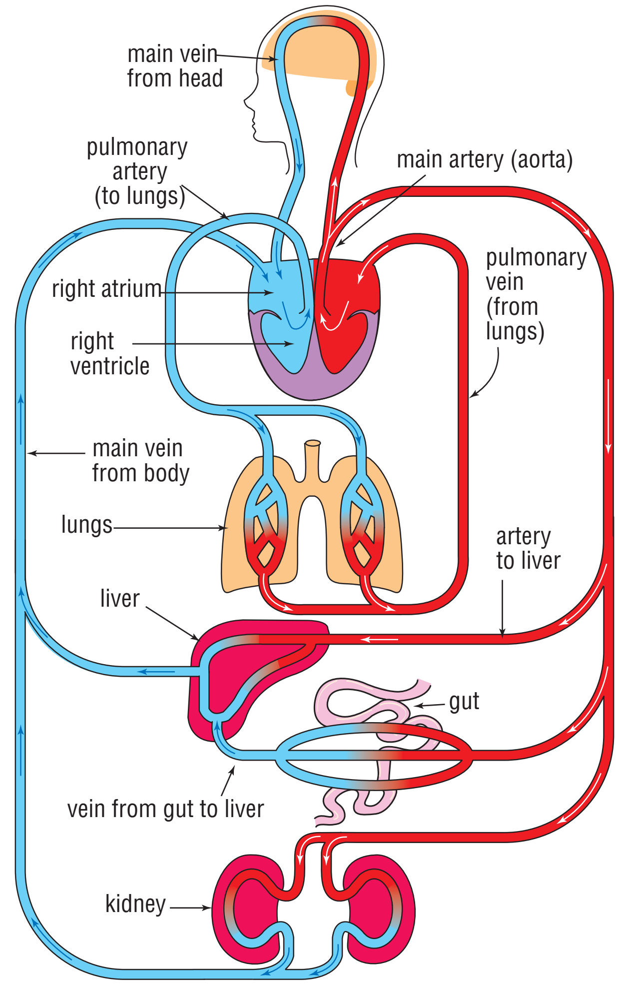


Fig 4.3.9 A simplified diagram of the circulatory system

Problems of the circulatory system

Bruises

A bruise is caused by ruptured (broken) blood vessels that allow blood to leak out. The haemoglobin in this blood quickly loses its load of oxygen and changes from bright red to purple or blue. The haemoglobin itself is then broken down into chemicals that will eventually be filtered out by the kidneys and passed in urine. The main chemical it is broken down into is yellow in colour. Therefore, a bruise gradually fades from blue-purple to green (since blue and yellow make green) to yellow to nothing as the haemoglobin is broken down and the leaked blood is eventually cleared away.

High blood pressure

Blood pressure has two readings. One reading is taken when the heart contracts (**systolic** blood pressure) and the other when the heart relaxes (**diastolic** blood pressure). A typical reading for healthy adults is around ‘120 over 80’ (which means systolic reading = 120 mmHg, diastolic reading = 80 mmHg).

High blood pressure, or **hypertension**, increases the risk of heart attack and can be caused by stress, alcohol consumption or from narrowed and hardened arteries caused by poor diet or high salt intake.

> **Science Clip**
>
> **Why are veins blue?**
>
> Look carefully at your arms and you will see the ‘blue’ veins that return de-oxygenated blood to the heart. These veins contain purple-red blood that needs to reach the lungs before it can load up with oxygen and become bright red again. If you accidentally cut yourself, though, the red-blue blood immediately grabs oxygen from the air, turning it bright red.

Angina

Coronary arteries branch off the aorta and supply the heart muscle with blood. A build-up of fat and **cholesterol** can narrow them and reduce the flow of blood, glucose and oxygen to the heart muscle. If blood flow reduces significantly, then the heart muscle will start to fail. This causes a pressure-like pain in the chest or shoulders, a condition known as **angina**. Angina can also be triggered by exertion or emotional stress.

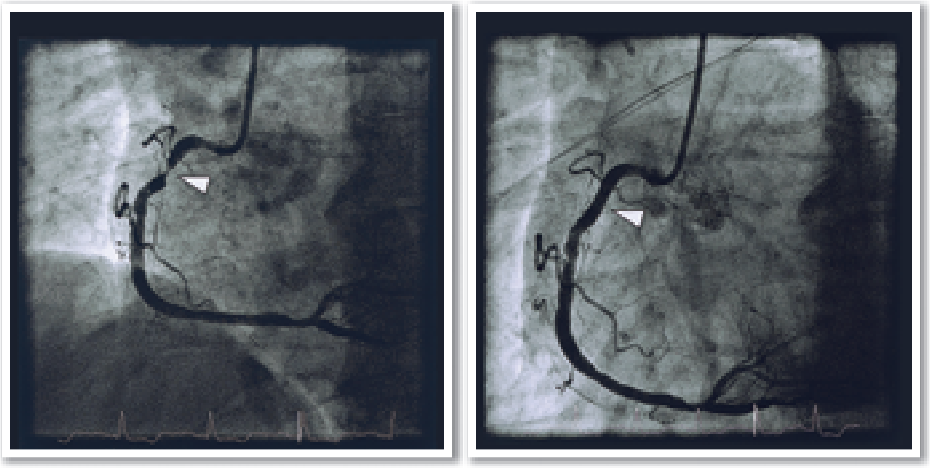


Fig 4.3.10 (left) This nearly blocked coronary artery was causing angina pains. **(right)** This is the same artery after a stent was inserted.

Heart attacks

If a coronary artery blocks completely, the heart muscle it supplies dies—this is a **heart attack**. The severity of a heart attack depends on the size of the area of muscle affected and the condition of the other arteries.

Heart technology

Fixing blockages

The risk of heart attack due to dangerously narrowed arteries may be reduced by various medical procedures:

- The artery can be widened by inflating a special tiny balloon in the affected area.
- A special titanium alloy 'sleeve' (called a **stent**) can be inserted to keep the artery walls apart.
- The blockage can be destroyed with a laser beam.
- The blockage can be bypassed by connecting a section of vein taken from the leg.

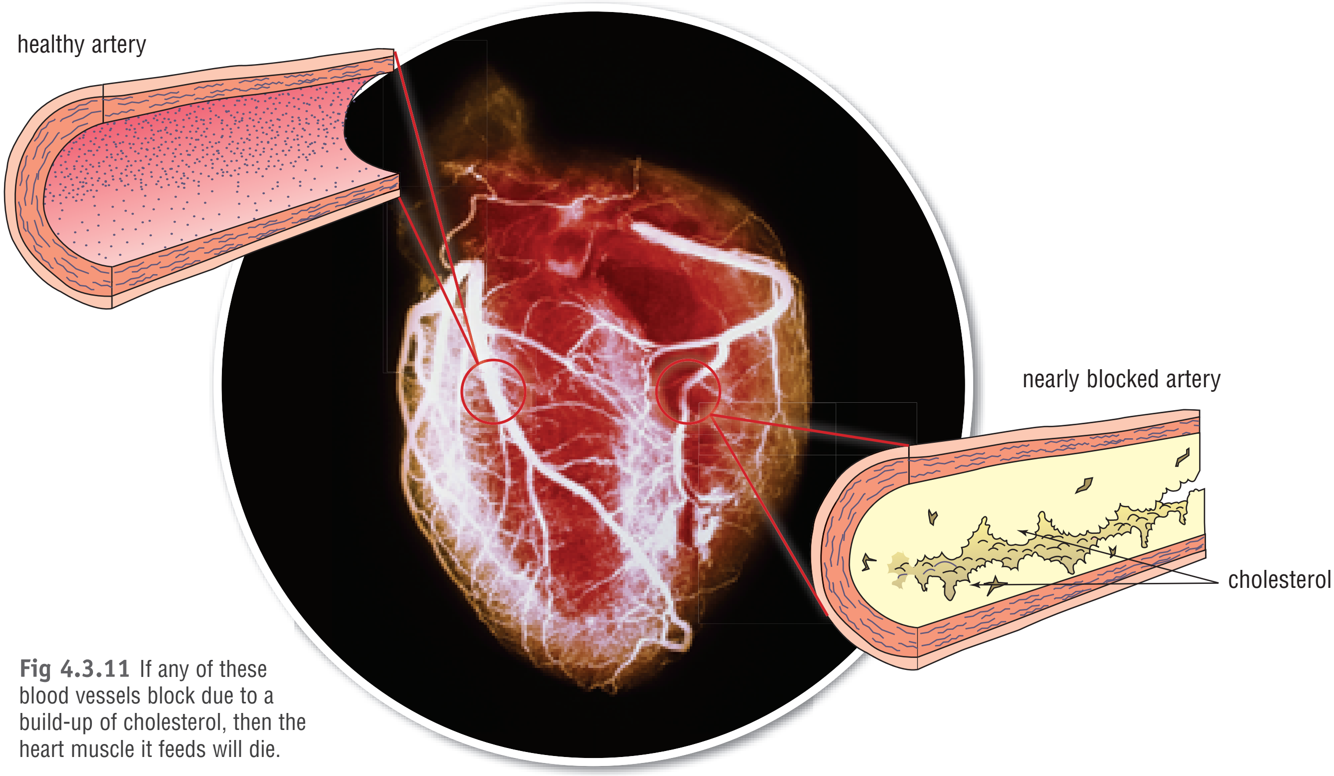


Fig 4.3.11 If any of these blood vessels block due to a build-up of cholesterol, then the heart muscle it feeds will die.

Heart valves

All four valves of the heart must be operating properly for the heart to function normally. A heart valve may become defective and not allow enough blood to flow when open, or it may allow blood to leak back the wrong way when shut. A doctor would hear this as a **heart murmur**. Faulty valves can be replaced by artificial ones or ones taken from a deceased human donor or a pig. Artificial valves tend to cause blood clots and patients need to take anti-clotting drugs.

Pacemakers

The heartbeat originates from special **pacemaker cells** at the top of the heart in the wall of the right atrium. These cells produce electrical impulses that trigger the contractions in the heart muscle that pumps the blood. These electrical impulses can be displayed as an **electrocardiogram** (i.e. **ECG**).

Heart disease, stress and medication can cause the heart to beat too slow, too fast or erratically. An irregular heartbeat may be treated by implanting an artificial pacemaker, which sends its own impulses to make the heart beat properly.

Worksheet 4.4 The circulatory system

Worksheet 4.5 Blood flow rates

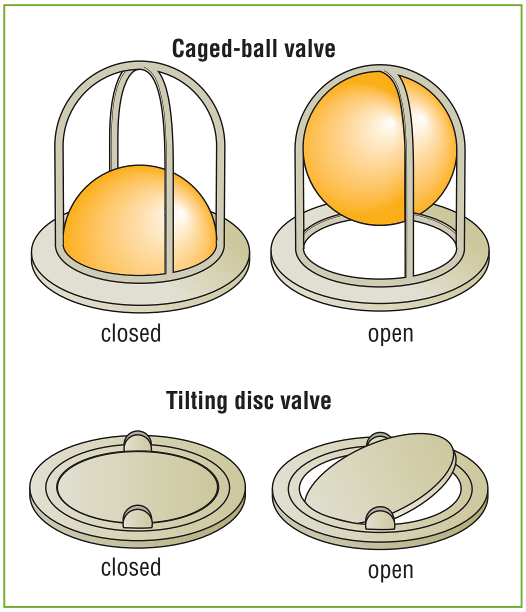


Fig 4.3.12 Two types of artificial heart valve

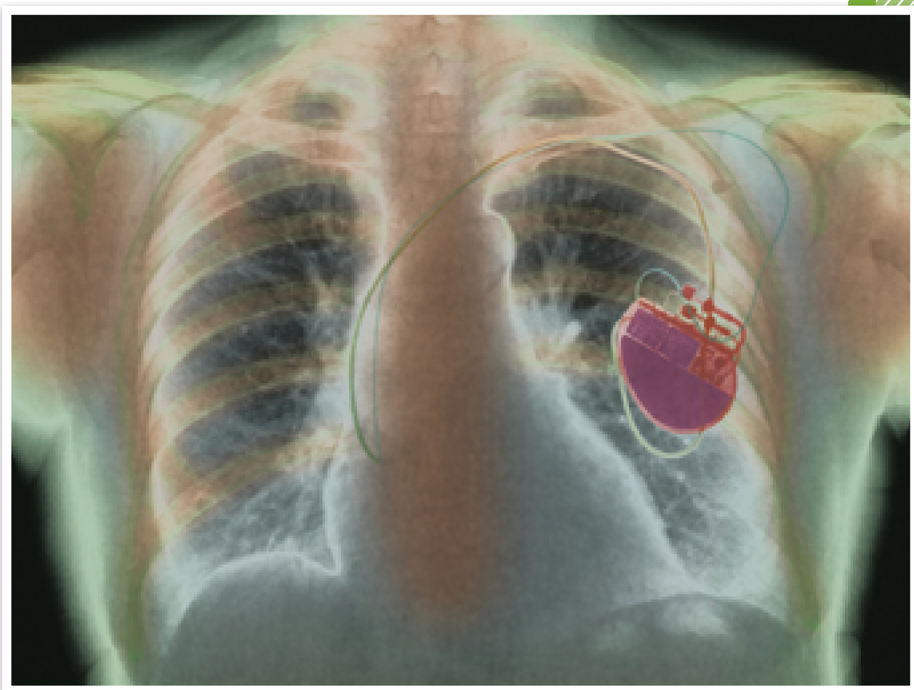


Fig 4.3.14 An artificial heart pacemaker fitted inside the chest

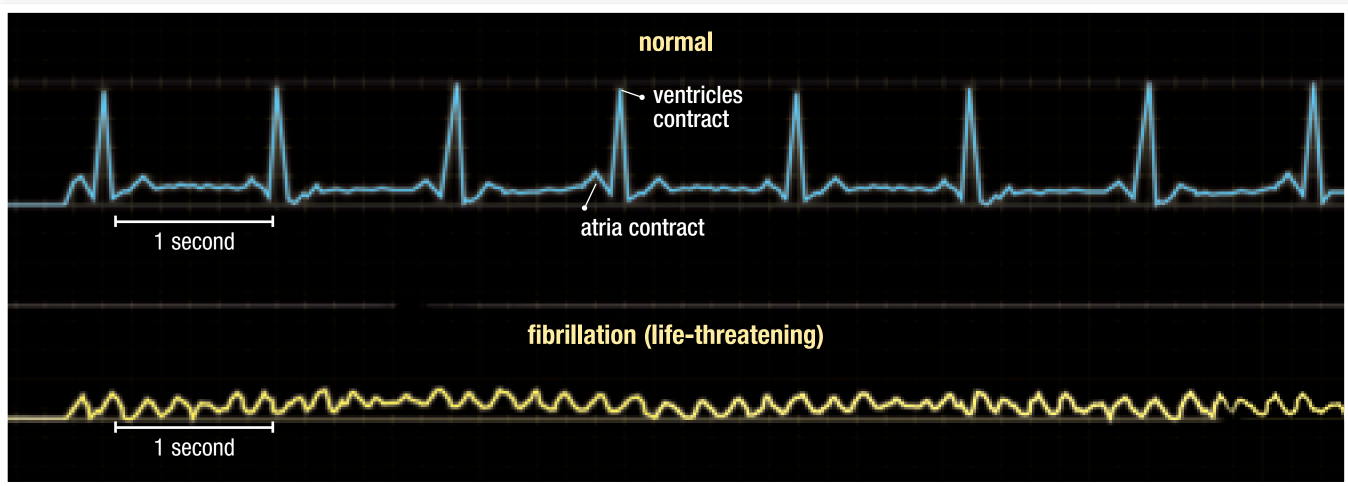


Fig 4.3.13 Good and bad electrocardiograms (ECGs)

4.3 QUESTIONS

Remembering

1 **State** whether the following are true or false:

- **a** Blood is either Rh positive or ABO.
- **b** Blood type AB contains both A and B antigens.
- **c** Blood having no Rhesus antigen is type O.

2 **State** which of the three types of blood vessels:

- **a** carry blood away from the heart
- **b** have walls one cell thick
- **c** have the thickest walls
- **d** show a pulse
- **e** have valves
- **f** have elastic walls
- **g** are the most common.

3 **List**:

- **a** six organs fed by the circulatory system
- **b** four methods of fixing a blockage in a coronary artery
- **c** three types of heart implant.

Understanding

4 **Describe** what tasks the following perform:

- **a** red blood cells
- **b** white blood cells
- **c** plasma
- **d** platelets.

5 **Describe** what happens in:

- **a** the aorta
- **b** the pulmonary vein
- **c** the right ventricle
- **d** the left atrium.

6 **Explain** why there are two blood pressure readings.

7 **Explain** what cholesterol is and what it does.

8 **Outline** what happens in a heart attack.

9 **Account** for the following:

- **a** The pulmonary artery splits in two and there are two pulmonary veins.
- **b** Your heart beats faster when you are running, feel threatened or get a fright.

10 **Predict** what would happen if you had insufficient:

- **a** red blood cells
- **b** white blood cells
- **c** platelets.

Applying

11 **Identify** which blood vessels most likely have been cut if:

- **a** you scratch your leg
- **b** blood loss is rapid.

12 **Use** Figure 4.3.2 to estimate how much of blood is made up of red cells. Is it: N

- **A** less than five per cent
- **B** a little under 50 per cent
- **C** a little over 50 per cent
- **D** about 95 per cent?

Analysing

13 **Calculate** how much blood an adult heart would pump in: N

- **a** an hour
- **b** a day
- **c** a week
- **d** a year
- **e** an average lifetime.

Evaluating

14 **Predict** which blood types may be donated to which patients by completing the table below.

	Donor's blood			
Patient's blood	**A**	**B**	**AB**	**O**
A	Yes	No		Yes
B				
AB		Yes		
O				

15 **Propose** reasons why some people donate their blood to a blood bank:

- **a** for other people to use
- **b** to use later for themselves.

>>

16 People over 50 kilograms may donate a maximum of 0.5 kilograms of their blood (about 0.5 litres) at one time to a blood bank.

a **Calculate** what percentage of their weight this represents. N

b **Propose** reasons why people lighter than 50 kilograms may not donate their blood legally.

Creating

17 Imagine you are a nutrient that has just been absorbed into blood vessels surrounding the small intestine. **Construct** a short story, recounting your journey to the big toe. L

18 **Construct** a board game based on the circulatory system.

4.3 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Find out more about blood, the heart, blood vessels and the circulatory system.

a In particular, research:

- how paramedics try to restart a heart
- why athletes are required to have blood tests at sporting events
- varicose veins
- what a sphygmomanometer measures
- other heart or blood disorders, such as leukaemia, haemophilia, angina and heart attack.

b Present your work in one of the following ways:

- a poster for a doctor's waiting room
- a pamphlet for patients or sportspeople who are about to undergo an operation or drug test.

2 Research some heart or blood disorders. Possibilities include leukaemia, haemophilia, angina and heart attack. Summarise your information as a webpage that would inform people with these diseases about their condition. L

3 Research animals that act as vampires, drinking the blood of other animals. Select one of these animals and find out:

- its drinking habits (i.e. where, when and what does it attack? How much blood is drunk etc.?)
- where the animal and its prey lives
- what other food or liquid, if any, it eats or drinks
- how it stops the blood of its victim from clotting
- if it injects other chemicals that irritate or poison
- how it spends the rest of its day.

Present your work in one of the following ways: L

- a horror short-story
- a cartoon strip
- a newspaper article about an attack
- a documentary for TV or a magazine article.

e-xploring

PP Web Destination

Explore the discovery of human blood groups by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Read the article and then play the Blood Typing game.

Science Clip

Animal vampires!

Although human-like vampires are the stuff of fiction, animal vampires do exist. Mosquitoes and fleas could be considered vampires because both bite and suck up blood from their victims. The Asian vampire moth drinks the blood of cows—its fangs being strong and long enough to pierce through their thick hides!

4.3 PRACTICAL ACTIVITIES

1 Blood cells under a microscope

Aim

To examine a prepared slide of a blood sample

Equipment

- a pre-prepared microscope slide containing a blood sample
- microscope
- lamp

Method

1. Place the slide on the microscope stage, and adjust the microscope so it is just above the slide.
2. Adjust the light source.
3. Focus the microscope while looking through it until a clear image is obtained. Remember to always move the microscope up and away from the slide.
4. Sketch the field of view, using the lowest magnification. Record the magnification in your sketch.
5. Repeat, using higher magnifications.
6. Sketch what you see.

Questions

1. On your sketches, attempt to **identify** and label the different types of blood cells. For example, is the cell a red or white blood cell?
2. It is illegal to allow students to make up microscope slides using their own blood. **Propose** reasons why.

2 Heart rate

Aim

To examine the effect of activity on heart rate

Equipment

- a watch or timer
- graph paper or graphing software

Method

1. Find your resting pulse rate (pulses per minute), while standing, by counting the number of pulses in 15 seconds and multiplying the result by 4. Do this three or more times and average your results. Write down your average resting pulse rate.
2. Repeat step 1 while:

   a lying down **b** sitting.
3. Gently jog or run on the spot for 3 minutes. (Don't overdo it!) Stop and immediately measure your pulse rate.
4. Keep resting and each minute measure your pulse rate until it doesn't get any lower. Record all your results in a table like the one below.

Time after end of jog (minute)	0	1	2	3	4	5	6	7	8	9
Pulse rate (per minute)										

Fig 4.3.15 How to measure pulse rate

Questions

1. **Construct** a bar graph of your results for steps 1 and 2 above.
2. **Construct** a line graph for the results in your table for steps 3 and 4.
3. **State** how long your pulse rate took to return to normal.
4. **Compare** your results with those of classmates.
5. **Account** for any differences in results.

3 Heart dissection

Aim

To dissect a heart and examine its structure

Equipment

- a sheep or bullock's heart
- disposable gloves
- dissection board
- scissors and scalpel

Method

1 Sketch the heart before any cuts are made.

2 Cut a 2 cm thick disc from the 'pointy end' of the heart, as shown in Figure 4.3.16.

3 Continue cutting layers from the heart until the heart is fully divided into 2 cm 'layers'.

4 Sketch a selection of layers into your workbook.

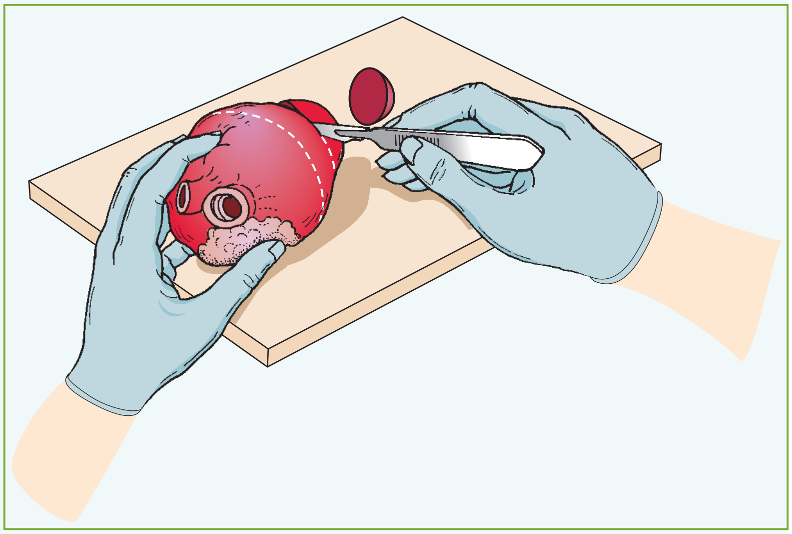


Fig 4.3.16

Questions

1 **Describe** any differences in the thickness of the outer wall on either side of the heart. If so, **identify** which was thicker.

2 **State** how many chambers you counted.

3 You may have observed white 'strings' in the heart. **Propose** what they might be for.

4 Your heart may already have been sliced open or spiked before you dissected it. **Propose** reasons why.

Unit 4.4 The respiratory system

context The cells in the human body carry out aerobic respiration to obtain the energy they need. Aerobic respiration uses oxygen and produces carbon dioxide. Hence, staying alive depends on a constant supply of oxygen and a way of removing the waste, carbon dioxide. This is the function of the respiratory system.

Fig 4.4.1 The tree-like airways that feed the lungs

Prac 1 p. 134

Breathing

Breathing allows your body to take in the oxygen that its cells need and to expel the carbon dioxide the cells produce as waste. When breathing in (i.e. inhaling), your ribs move up and out. This occurs due to the action of muscles in the chest (known as the **intercostals**) and the **diaphragm**. The diaphragm is a sheet of muscular tissue that separates your chest from your abdomen. The larger space in the chest causes the pressure inside to decrease, causing air to rush into the lungs. When breathing out (i.e. exhaling), your chest returns to its normal size and the air inside is forced out.

The percentage composition of inhaled and exhaled air varies because gases are exchanged between the lungs and the bloodstream.

Gas	Percentage in inhaled air	Percentage in exhaled air
Nitrogen	79.0	79.5
Oxygen	21.0	14.0
Carbon dioxide	0.04	5.6
Water vapour	Varies with location	100 (i.e. fully saturated)

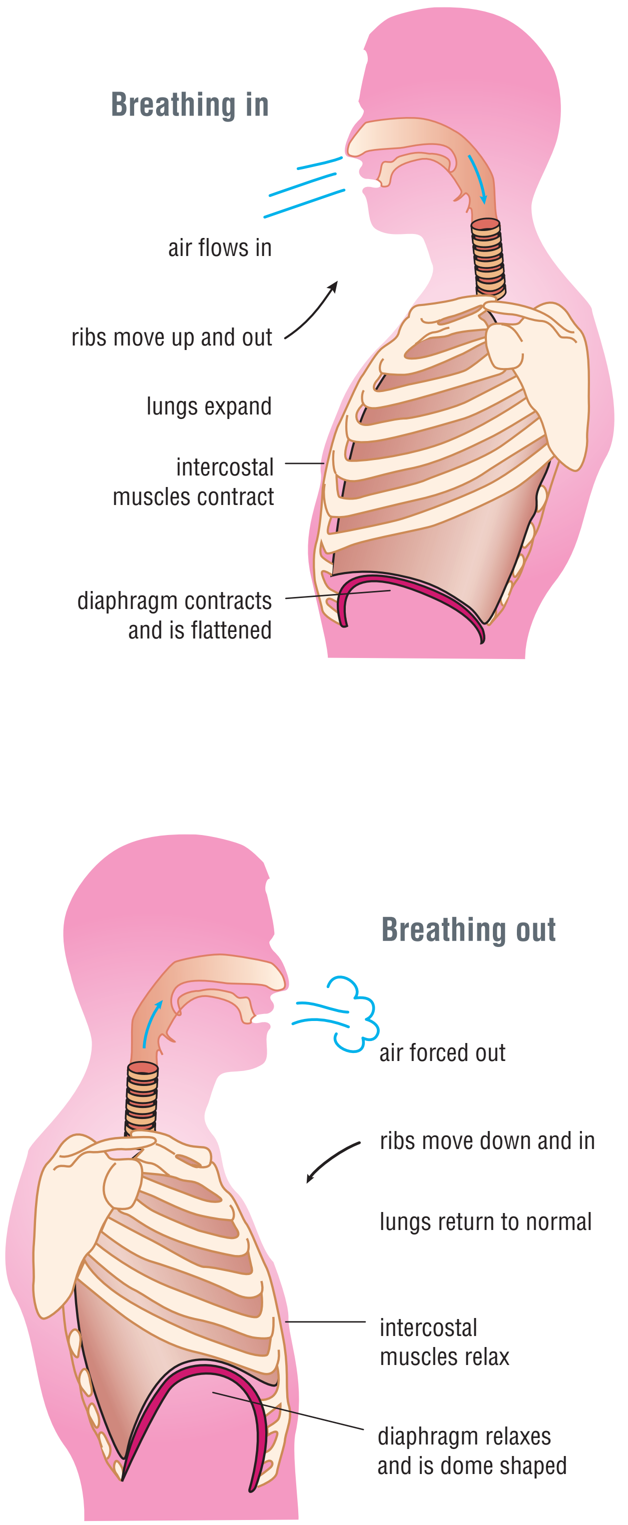


Fig 4.4.2 How the body breathes

Science Clip

Bubbles in the blood

Around 78 per cent of air is nitrogen gas. Normally it does no harm—you breathe it in but you breathe it straight back out. However, during deep-sea diving the increased pressure causes some of this nitrogen to dissolve in the blood. If the diver returns to the surface too quickly, the reduced pressure causes the dissolved nitrogen to form bubbles in the blood. This is similar to the way bubbles form when the lid is taken off a soft drink bottle. The bubbles rupture tissues, block blood vessels and cause extreme pains in the joints, known as the 'bends'. The condition is relieved by returning the diver to high pressure and then slowly lowering the pressure. This breaks up the bubbles so that the nitrogen can then be removed by the lungs.

Breathing rate varies with age, physical activity and mood. Each breath exchanges around 500 millilitres of air. The vital capacity of the lungs is the maximum amount of air than can be exhaled after taking a deep breath. Vital capacity is normally around 4500 millilitres, but may be as high as 6500 millilitres in a well-trained athlete.

Prac 2 p. 134
Prac 3 p. 134

The human respiratory system

Most inhaled air enters via your nose. Here it is warmed, moistened and filtered. Nostril hairs filter out larger dust particles while tiny hair-like **cilia** trap finer particles. Even more particles get stuck in sticky mucus produced by mucous glands that line the inside of the nose. The mucus and trapped particles move to the back of the nose, into the **pharynx** and are eventually swallowed. You swallow around 600 millilitres of this mucus per day without being aware of it!

The inhaled air then passes into the **trachea** or windpipe. Parallel to it is the **oesophagus** (foodpipe), which sends food to the stomach. Nearby lies a flap of tissue called the **epiglottis**, which closes over the trachea, making sure that food and drink does not go down it and into the lungs. The vocal cords of the **larynx** provide some protection for the trachea, as do the reflex reactions of coughing and sneezing. You might also cough because of dust. Cilia line the entire respiratory system, constantly beating upwards and sending any dust that gets in back to the pharynx, to be coughed out or swallowed.

The trachea divides into two branches called **bronchi**, which in turn divide into smaller and smaller branches. These smallest branches are known as **bronchioles**, off which sprout clusters of tiny sacs called **alveoli**.

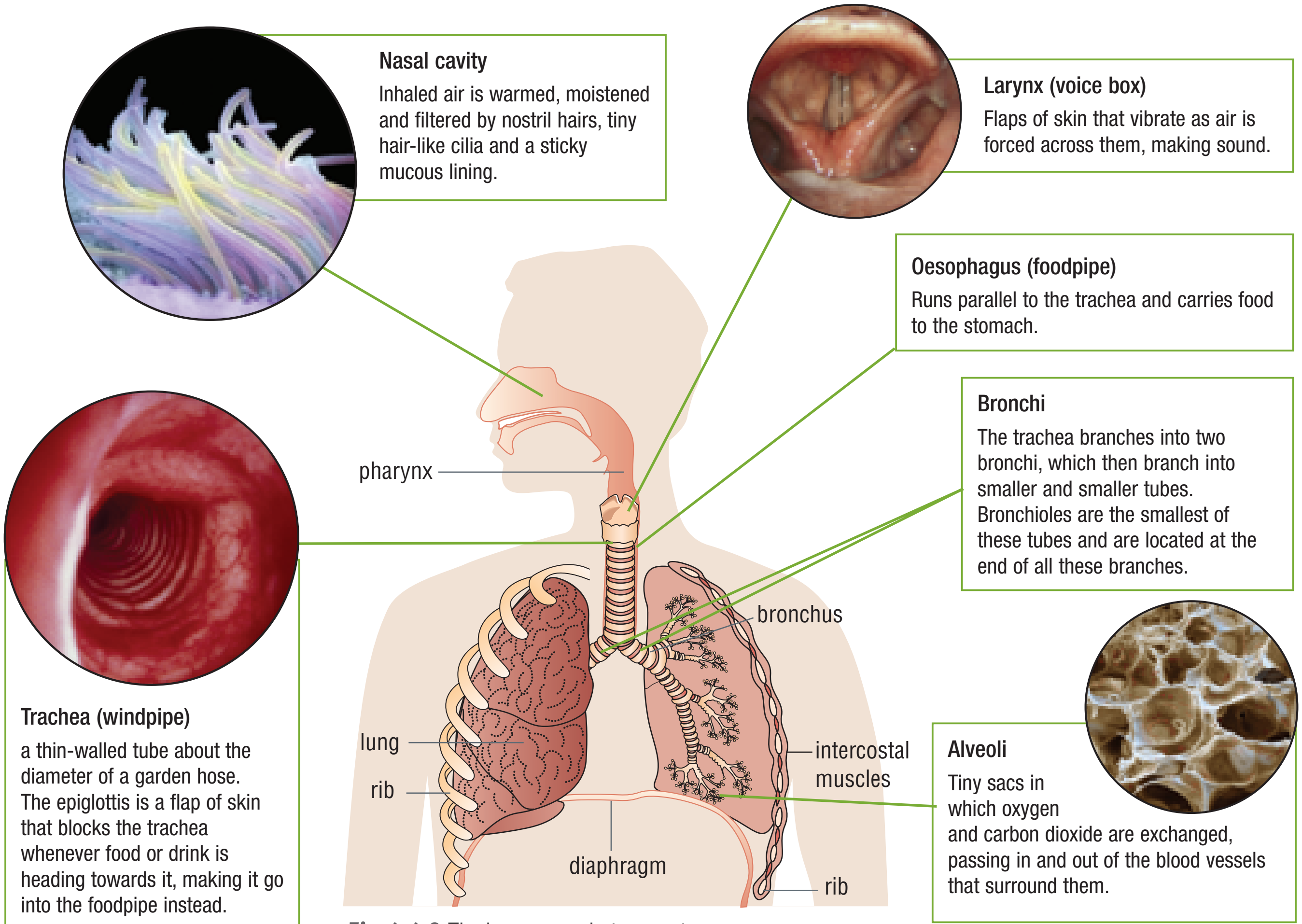


Fig 4.4.3 The human respiratory system

Gas exchange in the alveoli

Gas exchange occurs in the alveoli. The oxygen that you breathe in passes into the bloodstream through the alveoli, as does the carbon dioxide that you breathe out. There are around 500 million alveoli in the lungs, giving a total surface of about 80 square metres.

The walls of alveoli are only one cell thick. Each alveolus lies close to the wall of a capillary. **Capillaries** are the smallest blood vessels of all. Their walls are only one cell thick and are so thin that gases pass easily through them from the lungs and the bloodstream. Gases cross between the alveoli and the capillaries by **diffusion**, a process during which substances naturally move from areas of high concentration to areas of lower concentration. Oxygen is more concentrated in the alveoli than in the blood of the capillaries, and so it diffuses from the alveoli into the blood. Carbon dioxide diffuses from the blood (high concentration) into the alveoli (low concentration).

Worksheet 4.6 Asthma

Science Clip

Smoking

Tobacco smoke immediately inhibits the action of the cilia that remove mucus, allowing it to accumulate and making infection more likely. Tobacco smoke also coats the alveoli in tar, leading to shortness of breath.

PP Drag-and-drop

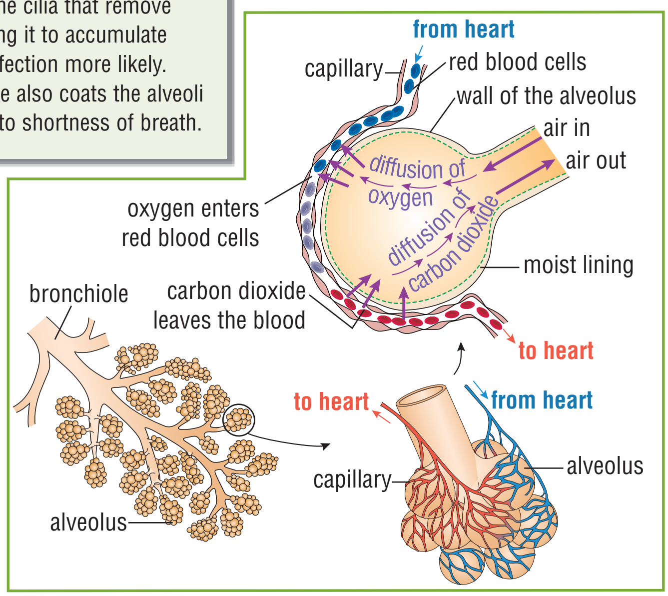


Fig 4.4.4 The airways branch and branch, ending in the alveoli, where gas exchange takes place.

Case study Respiratory systems in other animals

Not all animals and organisms have lungs as we do. Different animals often have very different ways to obtain the oxygen for respiration and to get rid of the carbon dioxide they produce.

- Frogs have lungs but also use their skin for additional gas exchange. (Human skin also 'breathes' but accounts for only 0.06 per cent of our total gas exchange between air and blood.)
- Fish use gills.
- Flattened, worm-like animals often use their body surface for gas exchange.
- Insects do not have lungs or blood vessels, but use a system of air-filled tubes for gas exchange.
- Single-celled (unicellular) organisms can exchange gases directly with their watery surroundings through their cell walls or membranes.

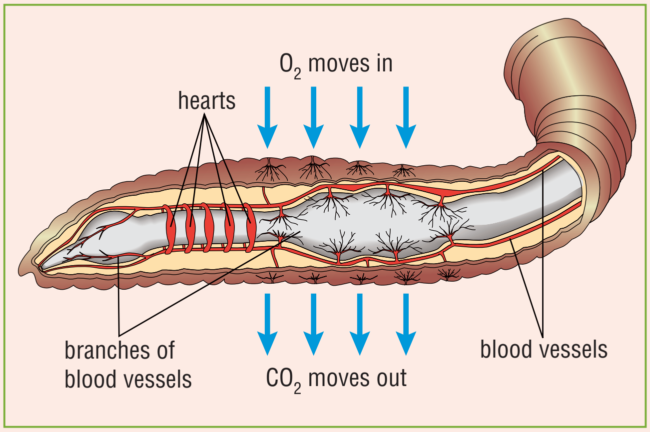


Fig 4.4.5 An earthworm exchanges gases through its skin.

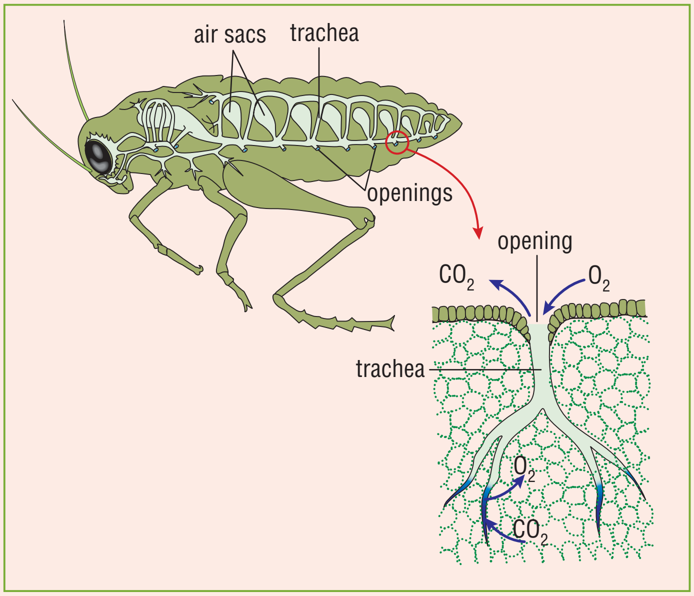


Fig 4.4.6 Insects use a system of air-filled tubes to exchange gases.

Go to Science Focus 1, Unit 4.4

PP Drag-and-drop

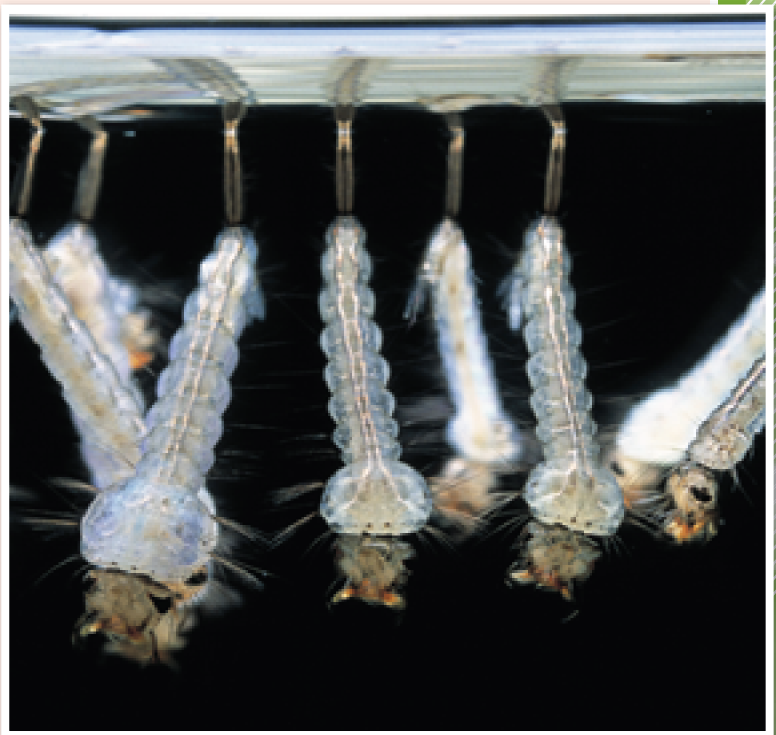


Fig 4.4.7 Mosquito larvae use a tube that connects to the water's surface to exchange their gases.

4.4 QUESTIONS

Remembering

1 **Name** parts **a** to **h** in Figure 4.4.8.

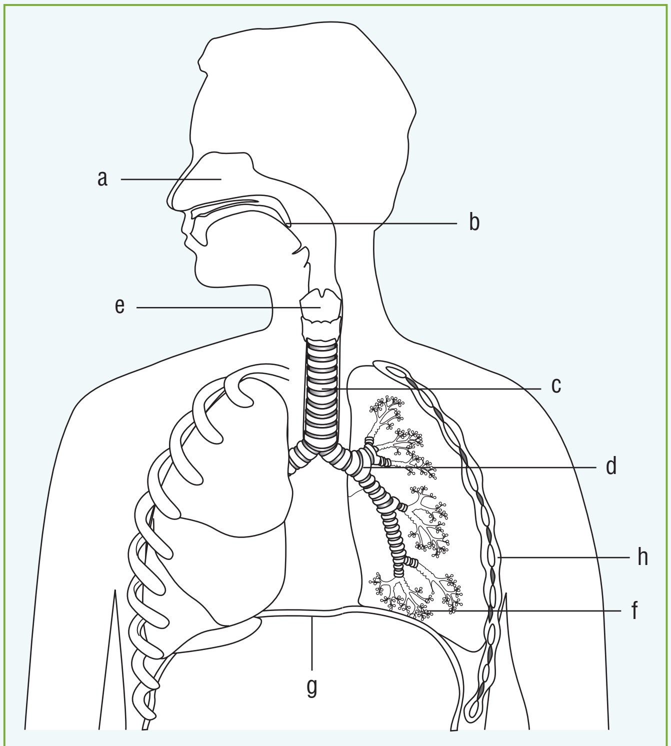


Fig 4.4.8

2 **Recall** the respiratory system by matching each structure to the function it performs.

Structure	**Function**
Trachea	Filters, warms and humidifies air
Epiglottis	Removes foreign particles from the lungs
Nose	The site of gas exchange
Cilia	Carries air to and from the lungs
Alveolus	Prevents food from entering the trachea

3 **List** from thickest to thinnest:

alveoli, trachea, bronchi, trachea, bronchiole

Understanding

4 **a Name** two structures that prevent food from entering the trachea.

b Describe what happens if some food accidentally finds its way into the trachea.

5 **a Name** the structures that enable your lungs to have a very large surface area.

b Explain why a large surface area is important in the lungs.

6 **Explain** what smoking does to the alveoli and your ability to breathe.

7 Smoking is a known cause of lung cancer. It is also a main cause of cancer of the mouth and larynx, sometimes requiring surgery to remove the tongue or voicebox. **Explain** why smoking would affect those three areas of the body.

Applying

8 From the two choices given, **explain** what happens to each of the following when a breath is taken in.

a diaphragm—does it contract or relax?

b chest cavity—does it enlarge or become smaller?

c ribs—are they raised or lowered?

d intercostal muscles—do they contract or relax?

e pressure in the chest cavity—does it increase or decrease?

9 **Use** the table on page 128 to determine whether the proportion of each gas in exhaled air is greater than, less than or about the same as the proportion in inhaled air.

a nitrogen

b oxygen

c carbon dioxide

d water vapour.

10 Figure 4.4.9 shows part of the human respiratory system. **Identify** the structures **x** and **y** and explain what each does.

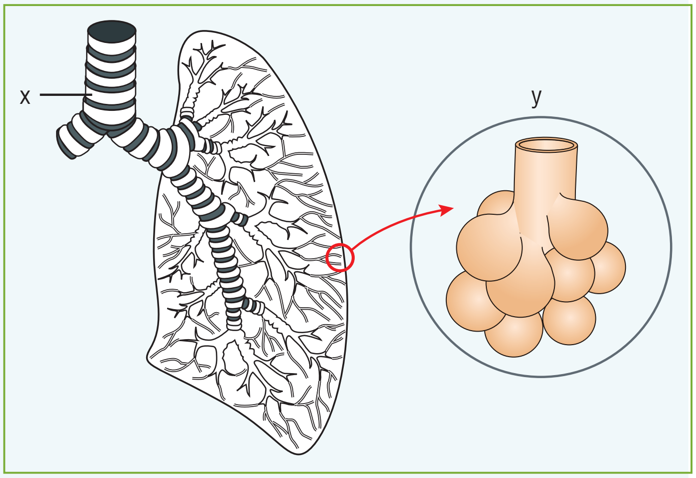


Fig 4.4.9

>>

Analysing

11 The apparatus shown in Figure 4.4.10 is sometimes used as a model to show what happens when breathing.

a **Compare** the respiratory system with this apparatus and **specify** which part of the apparatus represents which body part:

Apparatus	**Body part**
Plastic tube	Chest
Balloons	Trachea
Bell jar	Diaphragm
Rubber floor	Lungs

b **Explain** why the balloons inflate when the rubber floor is pulled down.

c **State** one way in which this model does not match the way you breathe.

12 Figure 4.4.11 shows an alveolus and a capillary.

a **Analyse** the movement of gases as represented by the arrows and **identify** which gases move:

i from **a** to **b**

ii from **b** to **a**.

b **State** whether the following are true or false:

i The concentration of CO_2 at **x** would be higher than at **y**.

ii The concentration of O_2 at **x** would be higher than at **y**.

Evaluating

13 It is better to breathe through the nose than through the mouth. **Propose** two reasons why.

14 **Outline** what part of the respiratory system is affected by the medical condition bronchitis.

15 **Propose** reasons why a person breathes faster when:

a they are running **b** they are frightened.

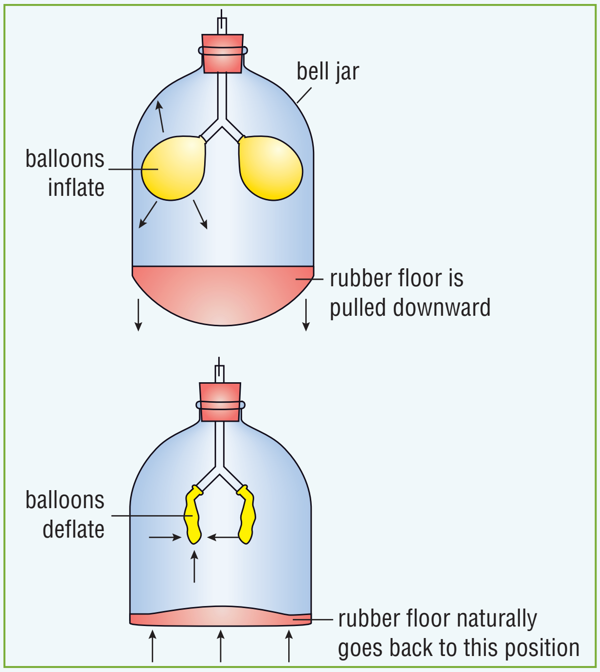


Fig 4.4.10

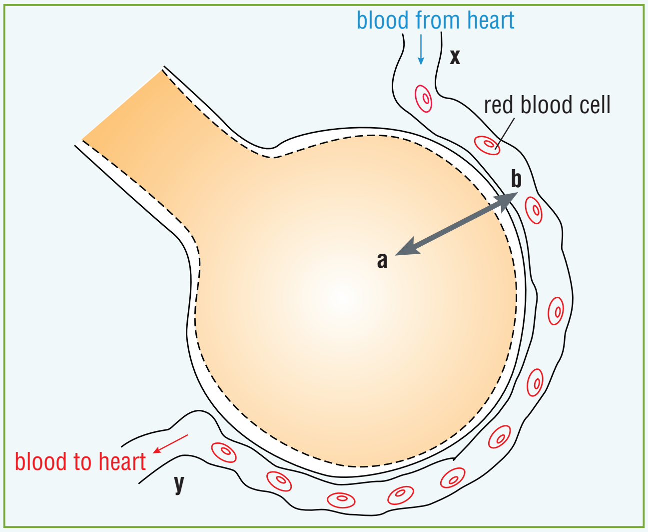


Fig 4.4.11

4.4 INVESTIGATING

Investigate available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1. Outline the special features that marine mammals have to enable them to spend long periods underwater without breathing. Construct a segment for *Sesame Street* or another children's program to teach any baby marine mammal watching what to do.
2. Research how your breathing is controlled, and how your body adjusts its breathing during and after exercise. Produce a poster that includes a graph.
3. Gather information about 'altitude sickness', its symptoms, its cause, the height at which it starts, treatment (if any) and how highly trained mountain climbers can reach heights of over 6000 metres without experiencing this sickness. Produce an advice pamphlet for mountaineers or for those travelling to mountainous countries.
4. Research the respiratory system of either a fish, a frog or a bird. Produce an information sheet for vets working with these animals.

4.4 PRACTICAL ACTIVITIES

1 Inhaled and exhaled air

Aim

To investigate the gases that are in inhaled and exhaled air

Equipment

- flasks and glassware, as shown in Figure 4.4.12
- limewater
- Note: Use a disposable straw as the mouthpiece if the equipment is to be used by more than one person.

Method

1 Set up the apparatus as shown in Figure 4.4.12. Be sure to check that your set-up matches the diagram exactly. Note that only one of the tubes connected to the mouthpiece extends below the level of the limewater.

2 Inhale and exhale continuously for several minutes without removing your lips from the mouthpiece.

3 Record any changes in the colour of the limewater in flasks A and B.

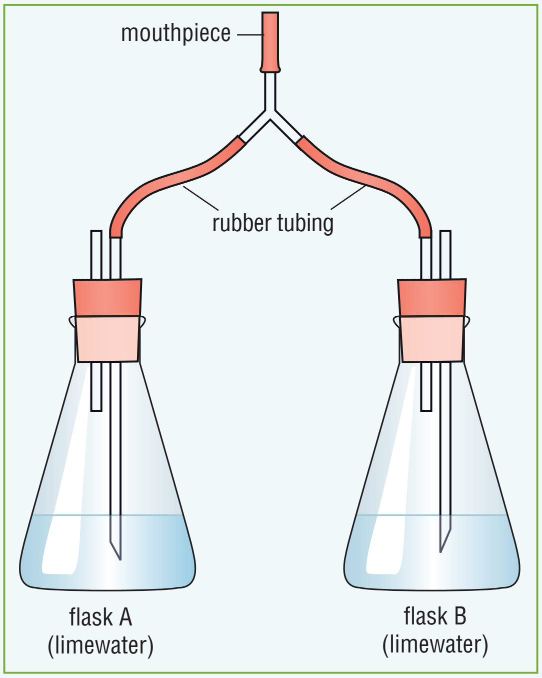


Fig 4.4.12

Questions

1 **Explain** any changes in flask A.

2 **Explain** any changes in flask B.

2 Exercise and breathing

DYO

Aim

To determine the effect of exercise on carbon dioxide production

Method

Design your own experiment to investigate the effect of exercise on the production of carbon dioxide. An indicator, such as alkaline bromothymol blue, may be used to test for carbon dioxide. This indicator solution is normally pale blue, but turns yellow in the presence of carbon dioxide. You might time how long it takes to change the colour of the indicator before and after exercising.

3 Lung capacity

DYO

Aim

To measure the size of one breath

Method

Design your own method for measuring the volume of air expelled in one breath. Present your work as a practical report. Include all the normal features, such as aim, materials, method, results and conclusion.

Questions

1 **Compare** the volume obtained in this experiment with the 'average' adult lung capacity.

2 Is the volume measured here the same as vital capacity? **Explain** your answer.

Unit 4.5 The urinary system

context

Your body produces solid, liquid and gaseous waste materials while doing its many jobs. If the body did not get rid of all these materials, they would poison it and make you very ill.

Fig 4.5.1 Your cells produce wastes. The urinary system filters out some of them.

Excretion

Any build-up of waste in the body can be harmful. Undigested solid waste, for example, needs to be eliminated from your digestive tract and is expelled through the anus as faeces.

Your body cells also produce wastes that must be got rid of for them to continue to function properly. **Excretion** is the removal of these wastes. This waste can be:

- **gaseous**—Your body cells obtain their energy by burning glucose in a process known as respiration. This reaction releases dissolved carbon dioxide (CO_2) and water (H_2O) into the bloodstream. Carbon dioxide then travels to the lungs. It changes from dissolved to gaseous form and is then breathed out. Some water vapour is also exhaled (i.e. breathed out).
- **liquid**—Urine is waste made of **urea**, assorted waste products and excess water. Urea is produced by the liver after protein has been digested in the cells. Protein is needed for growth and repair, but any excess is broken down into simpler substances, the main one being urea. Urea passes into the bloodstream, where it travels to the kidneys to be filtered out with excess water and other waste products.

The kidneys

Kidneys are red-brown, bean-shaped organs that filter an amazing 1.3 litres of blood every minute (about one-quarter of the blood pumped by the heart).

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Kidney cortex (renal cortex)
located here are tiny filtration units called nephrons. Each kidney contains over a million nephrons.

Kidney pelvis (renal pelvis)
the pale-cream core of the kidney. The pelvis acts as a funnel that drains urine from the medulla to the ureter and bladder.

Medulla
darker areas of the kidney. The medulla contains cone-shaped funnels that drain urine from the nephrons to the pelvis.

Fig 4.5.2 A dissected kidney

Science Clip

An 80 km long filter!

If the tiny tubes of all **nephrons** were stretched end-to-end, they would stretch an incredible 80 km!

Urine

Of every litre of blood processed, the kidneys filter out about one millilitre of waste liquid, or **urine**. Urine is produced at the rate of one drop per minute, or one to two litres per day. Urine consists of approximately:

- 95 per cent water
- five per cent urea
- small amounts of salts and other substances
- a small amount of bile (which gives urine its yellow colour).

Science Clip

A wee bit of information

About 47 per cent of a human's water output is in urine, 31 per cent in sweat, 16 per cent breathed out and six per cent in faeces.

Although camels need to drink water only occasionally, they drink in large quantities when they do. One way they conserve water between drinks is to produce sticky urine with the consistency of honey. The kangaroo rat is able to extract all the water it needs from the food it eats, and does not need to drink water. As a result, its urine is super-concentrated.

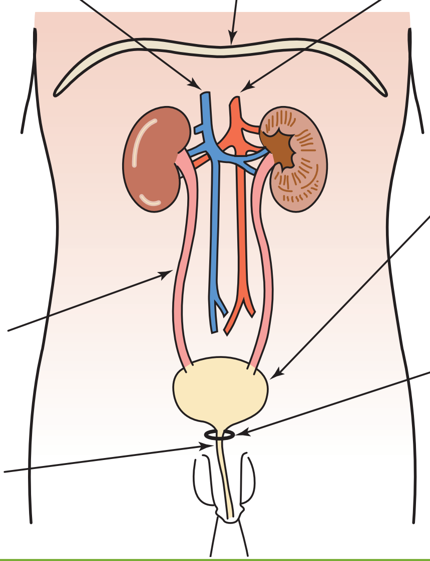

Fig 4.5.3 The urinary system

PP Drag-and-drop

Kidney problems

Kidney stones

Sometimes concentrated substances in urine crystallise into small, solid particles called **kidney stones**. Kidneys stones form within the kidneys, ureters or bladder and can cause extreme pain. If they are small enough, kidney stones may pass out of the body in urine, but if they are too large, they may need to be shattered first. This is done in a procedure called a **lithotripsy**, during which a focused beam of ultrasound blasts them into pieces small enough to pass through the urinary tract.

Fig 4.5.4 One way to reduce the risk of kidney stones is to drink at least one litre of water every day.

Kidney failure

The body can function normally on a single kidney. If both kidneys fail, however, the situation becomes life threatening due to the build-up of poisonous wastes in the blood. The only options for survival are:

- **dialysis**—The blood is redirected into machines that filter it artificially. Dialysis must be performed regularly (e.g. three times per week for up to 8 hours each).
- **kidney transplant**—The donor kidney could come from a deceased or live donor. The transplant is most likely to be successful if it comes from a close relative.

Worksheet 4.7 The urinary system

4.5 QUESTIONS

Remembering

1 **Name** a waste that is:
   a solid
   b liquid
   c gas.

2 **Recall** the urinary system by matching each body part to its function.

Body parts	Functions
Circulatory system	Filter blood
Kidneys	Allow urine to reach storage area
Ureters	Tube which allows urine to leave the body
Bladder	Urine storage
Urethra	Transports wastes and nutrients

3 **Specify** how much blood kidneys can filter in an hour.

4 **Name** the chemical that gives urine its yellow colour.

Understanding

5 **Define** the term *excretion*. L

6 **Describe** what a nephron is and what it does.

7 **Describe** how waste products get to the lungs and kidneys.

8 **Explain** why kidney stones often need to be blasted into smaller pieces.

9 **Explain** why drinking lots of water should reduce the risk of developing a kidney stone.

10 If someone donates a kidney to someone with kidney failure, both are left with one healthy kidney. **Explain** whether they both can live normal lives.

Applying

11 Many animals that live in the desert produce thick sticky urine with little water. **Identify** the advantage this gives them.

Analysing

12 People who have suffered kidney failure need to undergo dialysis. **Calculate** how many hours this takes: N
   a every week
   b in one year.

Evaluating

13 **Propose** reasons why:
   a People tend to urinate more in cold weather.
   b Pregnant women tend to urinate more frequently.
   c Foods such as red beetroot, asparagus and multivitamin pills change the colour and/or smell of urine.

14 **Propose** why kidney transplants are generally more successful if the donor kidney comes from a close relative.

Creating

15 **Use** Excel or the percentage circle on a Mathomat to **construct** an accurate pie chart that shows the composition of urine.

4.5 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Research how the kidney works in detail (e.g. explain what a Bowman's capsule is).

2 Find out more about dialysis and describe how it works.

3 Outline the causes of incontinence.

4.5 PRACTICAL ACTIVITY

1 Kidney dissection

Aim

To dissect a kidney and observe its structure

Equipment

- newspaper
- a sheep or bullock kidney
- dissecting board
- scalpel
- disposable gloves

Method

1. Find the ureter in the middle of the kidney, and cut lengthwise, as shown in Figure 4.5.5.
2. Sketch the inner structure of the kidney.

Questions

1. **Explain** the purpose of fat around the kidney.
2. **Compare** this sheep's kidney with the structure of a human kidney.

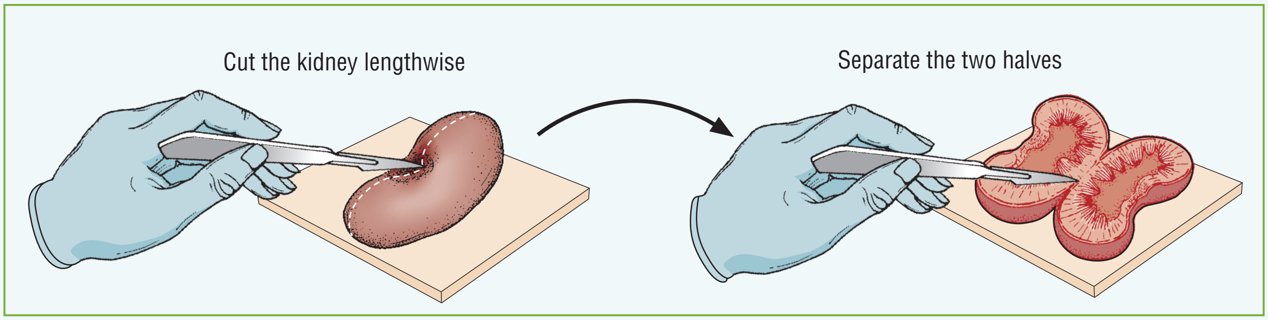

Fig 4.5.5

Science Focus: Spare parts

Prescribed Focus Area:

Current issues, research and developments in science

The body is very complicated and sometimes things go wrong or stop working. Many major medical conditions can now be overcome by removing the faulty body part and transplanting a replacement part. Unfortunately, the number of patients needing transplants is far greater than the supply of organs from human donors. To overcome this problem, scientists are developing new technologies and materials they can use. This means that replacement body parts can now come from sources other than humans.

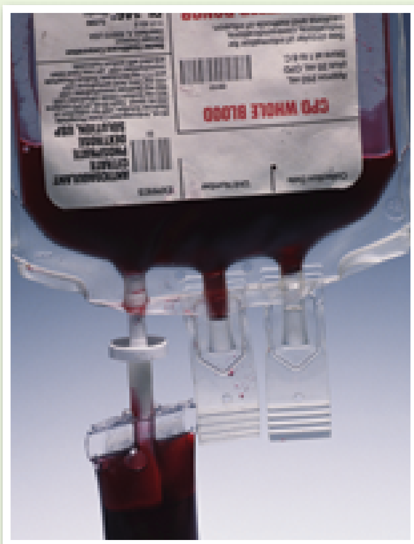

Fig 4.5.6 Blood transfusions are common and can be considered to be spare parts. The United States army is currently trialling artificial blood called Polyheme.

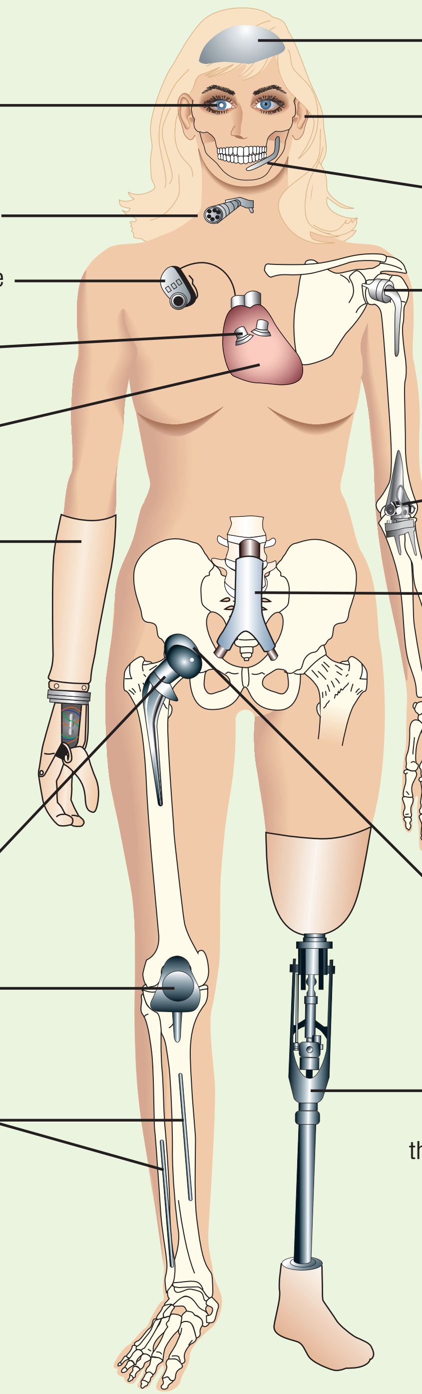

Fig 4.5.7 Commonly-used artificial body parts

Rejection of spare parts

The immune system helps to protect the body from disease and removes foreign objects that get inside it, including any transplanted parts. Because of this, many transplanted parts are **rejected** by the body. There are a number of ways to minimise rejection:

- The spare parts can be made from materials that the immune system does not respond to.
- The spare parts can be made so similar to the recipient's cells that the immune system does not recognise them as being foreign.
- Patients can be given regular doses of anti-rejection drugs.

Living transplants

Allotransplants

Allotransplants are human-to-human transplants—an organ from living or dead donors is placed into the recipient's body. Transplanted organs are often rejected by the immune system and patients need to take anti-rejection drugs after the operation.

Many people want to donate their organs after death to help ill patients recover and lead normal lives. Hearts, lungs, livers, kidneys, the cornea of the eye and the pancreas have all been successfully donated this way.

Transplants can come from a live donor. The body can function well on only one kidney or with 90 per cent of your liver removed. Sometimes people donate a kidney or part of their liver to patients who need them. The organs are less likely to be rejected if the donor is closely related to the patient.

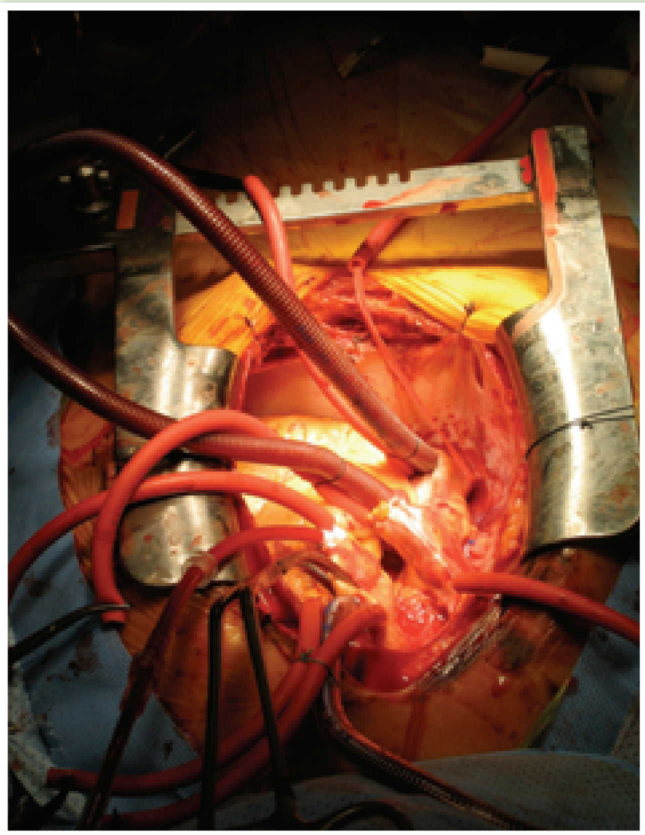

Fig 4.5.8 Heart transplants have a high rate of success.

Xenotransplants

Xenotransplants are transplants from animals, such as pigs or sheep, to humans. Animals are bred and have their cells changed to be more like human cells. This means that the body is less likely to attack the implanted organ. Xenotransplant techniques are still being developed and have many hurdles to overcome.

Many people strongly believe it is wrong to put animal organs in a human. Others believe breeding and killing animals for their organs is wrong. There is also fear that a virus could be transferred between animals and humans, causing new diseases.

Science Clip

Face transplants

The world's first partial face transplant was carried out successfully in 2005 in France on a woman whose dog had savagely attacked her while she was asleep. In 2008, two full face transplants were successfully carried out—one in France and the other in the United States.

Tissue culturing

Tissue culturing involves growing cells outside a living human. Tissue culturing has already been used successfully to grow skin for burns patients. The big advantage here is that the skin is grown from the patient's own cells, meaning it is not rejected by the body.

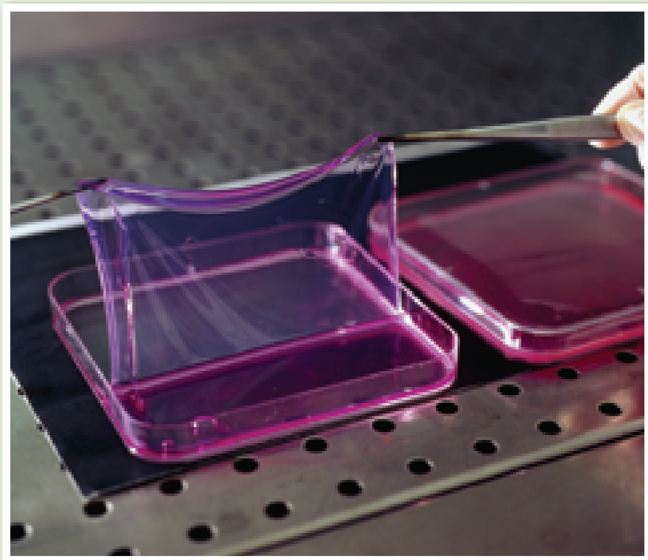

Fig 4.5.9 This artificially grown human skin is ready for transplant onto a burns patient.

Scaffolding

Other techniques involve growing whole new organs. This requires a **scaffold** onto which the cells grow.

Fig 4.5.10 In 2007, Australian performance artist Stelarc used a scaffold to grow an ear on his arm. One of the early successes of scaffolding was to grow a human ear on the back of a mouse.

Stem cells

New organs may be able to be grown from **stem cells**. Stem cells are special cells that have the potential to grow into many different types of specialised cells. They are found in the body and in embryos. Cells could be taken from the body, grown into a new organ using a scaffold, and the organ could be placed back into the body.

Artificial transplants

Many materials, such as titanium and surgical stainless steel, can replace solid parts of the body, such as bones and joints. Worn hip sockets and knees are commonly replaced this way. Whole organs, such as an artificial heart, have also been developed. Because of the design of these materials, they are not rejected by the body and last a very long time.

Australian inventions

The cochlear implant was developed in Australia and has become a worldwide success. It allows many hearing-impaired people, particularly children, to hear for the first time. This bionic ear involves a microprocessor, electronics, sensors and connections that are attached into the cochlear inside the inner ear.

Fig 4.5.11 The cochlear implant was developed in Australia. The external part shown includes the microphone and transmitter.

STUDENT ACTIVITIES

1 **List** three ways in which rejection can be minimised.

2 **Explain** the difference between an allotransplant and a xenotransplant.

3 **Identify** four parts of the body that might be replaced using an artificial transplant and the materials these transplants are commonly made from.

4 **Propose** reasons why:

   a People agree to donate their organs when they die.

   b Families often refuse the use of the organs of a recently deceased relative.

   c People sometimes donate their own blood in the months before they undergo an operation.

5 Few people have ethical concerns regarding tissue culturing. **Account** for this fact.

6 **Propose** reasons why a human ear was first grown on the back of a mouse and not a person.

INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet, newspapers etc.) to:

1 Gather information on stem cell research. Use this information to decide whether you think stem cell research is ethical and present your opinion in a letter.

2 Research the history of transplants. Your research might start with an Internet search on Victor Chang, Fiona Coote, Fiona Wood or Christian Barnard.

3 **Investigate** blood transfusions. Who can donate and who can't? What rules are there about blood types? How are blood supplies made safe?

Surveying

Construct a pamphlet that describes the different transplant techniques (i.e. allotransplants, xenotransplants, tissue culture techniques and artificial body parts). Propose a maximum of 10 questions that will gather the views of the public regarding the techniques, including the following:

- Which technique do people consider might be the best?
- Which technique do people think should *not* be used and why?
- How do people rate each technique and towards which technique do they think research money should go?
- Would people have a transplant from an animal if their life depended on it?

Summarise your results and write a conclusion of what you found out.

Debating

People are living older than ever before. As they pass into old age, they may need transplants and spare parts to remain healthy and active. Since they are near the end of their lives, is this worth the cost? Split into groups and prepare a debate either for the affirmative (i.e. yes, it is worth the cost), or the negative (i.e. no, it is not worth the cost).

CHAPTER REVIEW

Remembering

1 **Recall** the word equation used for aerobic respiration.

2 **Name** two enzymes, and **state** where each may be found.

3 **Name** the digestive disorder that might involve:

a damage to the stomach lining

b inflammation of a small offshoot of the large intestine

c scar tissue forming in the liver.

4 **Name** the eating disorder that involves binge eating followed by purging.

5 **Recall** the digestive system by matching each part of the digestive system with its function.

Part of system	Function
a Mouth	i Produces enzymes including insulin
b Oesophagus	ii Start of small intestine
c Stomach	iii Makes saliva
d Pancreas	iv Where most absorption of nutrients occurs
e Liver	v Exit for faeces
f Duodenum	vi The body's chemical factory
g Small intestine	vii Like a cement-mixer for food and gastric juices
h Large intestine	viii Where water is re-absorbed.
i Anus	ix Connects mouth to stomach

6 **Name** the parts of the heart represented by **a** to **m** in Figure 4.6.1.

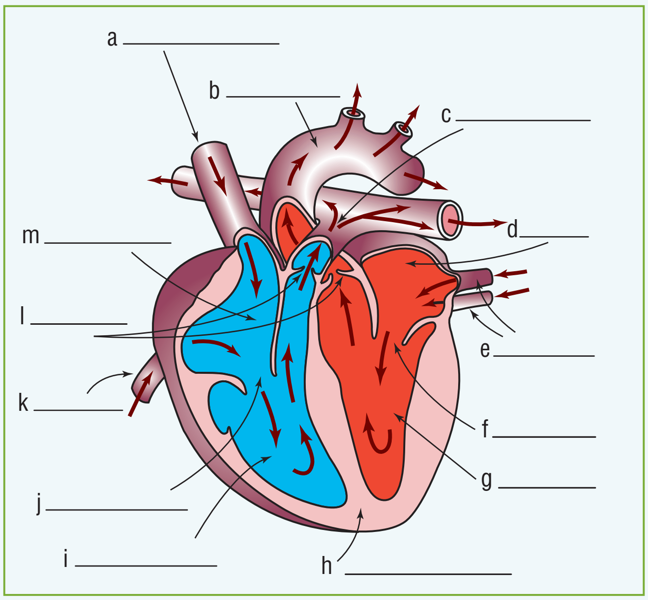

Fig 4.6.1

7 **Recall** the circulatory system by matching each blood vessel type to its description.

Vessels	Descriptions
Vein	High pressure
Artery	Fine tubes near cells
Capillary	Return blood to heart

8 **Specify** what ECG stands for.

9 **Name** the substance that often clogs arteries.

10 **State** three differences between the air you inhale and the air you exhale.

11 **Recall** the respiratory system by matching the functions described in **a** to **f** to structures **i** to **vi** on the diagram of the human respiratory system in Figure 4.6.2.

a Filters, warms and humidifies air

b Contracts and flattens during inspiration

c The site of gas exchange

d Carries air to and from the lungs

e Prevents food from entering the trachea

f Passage of air through this creates sounds

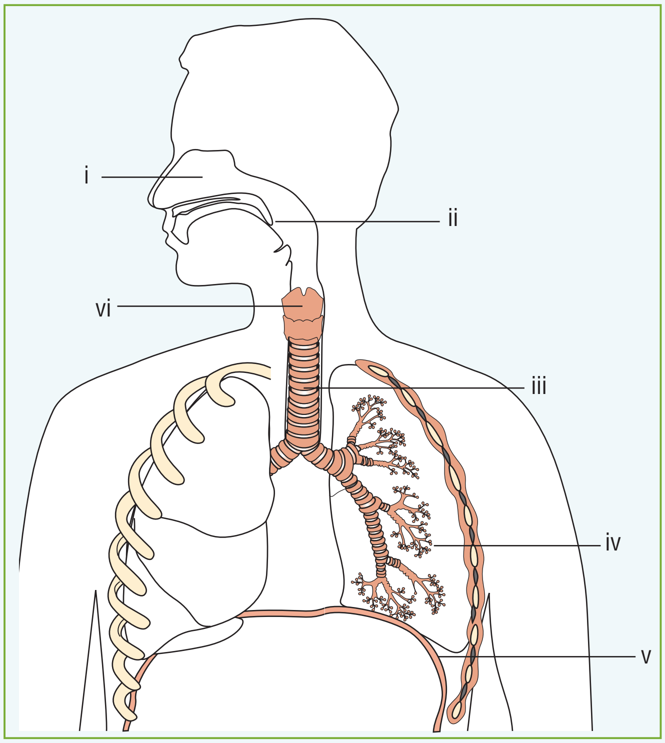

Fig 4.6.2

>>

12 **State** whether the following are true or false:

- **a** Your kidneys are about the size of your eyeballs.
- **b** Urine travels down tubes called urethras to the bladder, which has a capacity of about five litres.
- **c** It is possible to live normally with only one kidney.

Understanding

13 **Explain** the importance of aerobic respiration to the body.

14 In the blood, **describe** the role of:

- **a** platelets
- **b** red blood cells
- **c** plasma
- **d** white blood cells.

15 **Describe** how the following wastes are produced:

- **a** carbon dioxide
- **b** urea.

16 **Explain** how you are excreting waste even as you read this question.

Applying

17 **Identify** the body system that is most likely to be involved in:

- **a** puberty
- **b** a cut and bleeding finger
- **c** asthma
- **d** constipation.

18 **Identify** where the urethra exits from the male body.

Analysing

19 **Contrast**:

- **a** starch and glycogen
- **b** a sphincter and peristalsis
- **c** angina and a heart attack.

20 **Compare**:

- **a** the energy contained in fats with that in carbohydrates
- **b** the amount of urine the bladder can hold with the amount that makes you want to urinate.

21 **Assess** whether a person with type B blood will be allowed to donate blood to a patient with:

- **a** type A blood
- **b** type AB blood
- **c** type O blood
- **d** type B blood.

Evaluating

22 In a building, an atrium is where people enter. In the heart, an atrium is where blood enters. **Propose** a meaning for the word *atrium*.

23 **Propose** what would happen if:

- **a** the air to the lungs was not first filtered
- **b** the heart and diaphragm were voluntary muscles (i.e. muscles that require conscious thought to get them moving).

24 Look over the various problems of the digestive, circulatory, respiratory and urinary systems and **list** them in order from those you consider to be the most dangerous to those you consider to be just mildly annoying. **Justify** your choice.

Worksheet 4.8 Crossword

Worksheet 4.9 Sci-words

PP Chapter Review Questions

5 Microbes

Prescribed focus area:

The implications of science for society and the environment

Key outcomes

4.4, 4.8.3

- Microorganisms (also known as microbes) are usually made up of only one cell, making most of them invisible to the naked eye.
- Some types of microbes cause a range of diseases and infections.
- Some types of microbes, especially fungi, are used directly as food or in the production of food and drinks.
- Microbes reproduce via a variety of different means.
- Bacteria and protists reproduce by cell division, producing two identical daughter cells.

Essentials

Unit 5.1 What are microbes?

context

To most people, germs are something incredibly small that can make you sick. Scientists know germs by another name, microorganisms, which is often shortened to simply microbes. Microbes are living things—they need food and somewhere to live, they reproduce and eventually die. Although many types of microbes can make you seriously ill, others are vital in the production of foods and in breaking down waste.

Fig 5.1.1 A scanning electron microscope (SEM) image of the worn bristle of a toothbrush. The muck on it is a build-up of microscopic plaque and bacteria. A fomite is any non-living object that can carry disease-causing microbes. This bristle is a fomite, as is the tissue you blow your nose into and the toilet paper with which you wipe your bum.

Microbes

PP Quick Quiz

Microorganisms (also known as **microbes**) are living organisms, usually made up of just a single cell. This makes most of them far too small to be seen with the naked eye, so a microscope is usually needed to see them.

Microbes come in many types, shapes and forms. Scientists classify them into five groups:

- bacteria
- fungi
- protists (protozoa)
- algae
- viruses.

Fig 5.1.2 Whereas other microbes need a microscope to be seen, fungi (e.g. mushrooms, toadstools, yeasts and moulds) are large enough to be seen with the naked eye.

Prac 1 p. 153

Science Clip

That stinks!

You have more microbes in and on you than you have body cells! Your intestines contain more bacteria than the total number of people who have ever lived! Each gram of faeces you produce contains 100 000 000 000 microbes. This means that human adults excrete their own weight in bacteria each year!

Observing microbes

Microbiologists are the scientists who study microorganisms. As these organisms are usually invisible and can cause serious illness, the work of microbiologists involves using different types of microscopes and simple but specialised techniques that will keep themselves safe.

Fig 5.1.3 Microbiologists commonly use Petri dishes. Petri dishes are used to grow or culture microbes for study and experimentation. This microbiologist is inspecting the bacteria grown in a Petri dish.

Exactly how big are microbes?

Normal length units, such as the metre and even the millimetre, are far too big to measure the size of most microbes. Other smaller units are used instead. These units are based on the metre, the prefix showing what fraction or how many metres it represents. A kilometre, for example, is abbreviated as km. The prefix is kilo or k, representing 1000 metres. This means that 1 km = 1000 m.

Metric conversions

Protozoa, for example, range from one to about 300 micrometres (μm) long. This makes them a tiny one-thousandth to one-tenth of a millimetre long! Viruses are smaller still—a typical virus being only 100 nanometres (100 nm) long. This is a ridiculously tiny 0.000 000 1 m or one hundred-billionths of a metre long!

Comparing microbes

Object	Size	Able to be seen by
Kelp	1 metre (m)	Human eye
Red algae	10 centimetres (cm)	Human eye
Fungal spore	1 millimetre (mm)	Human eye
Protozoa	100 micrometres (μm)	Light microscope
Bacteria	1 micrometre (μm)	Light microscope
Virus	100 nanometres (nm)	Electron microscope
Large molecules	1 nanometre (nm)	Electron microscope

Microscopes used in microbiology

PP Drag-and-drop

Prac 2 p. 154

Although many fungi, such as mushrooms, are big enough to be seen with the naked eye, most microbes need some form of microscope to see them. Bacteria and protists are big enough to be seen with compound light microscopes. Viruses are smaller again and can be seen only with much more powerful electron microscopes.

Metric unit	Meaning of prefix	Equivalent length in metres
1 metre (m)	No prefix needed	The standard unit of length
1 centimetre (cm)	c = centi = 1/100	0.01 m
1 millimetre (mm)	m = milli = 1/1000	0.001 m
1 micrometre (μm)	μ = micro = 1/1000 000	0.000 001 m
1 nanometre (nm)	n = nano = 1/1 000 000 000	0.000 000 001 m

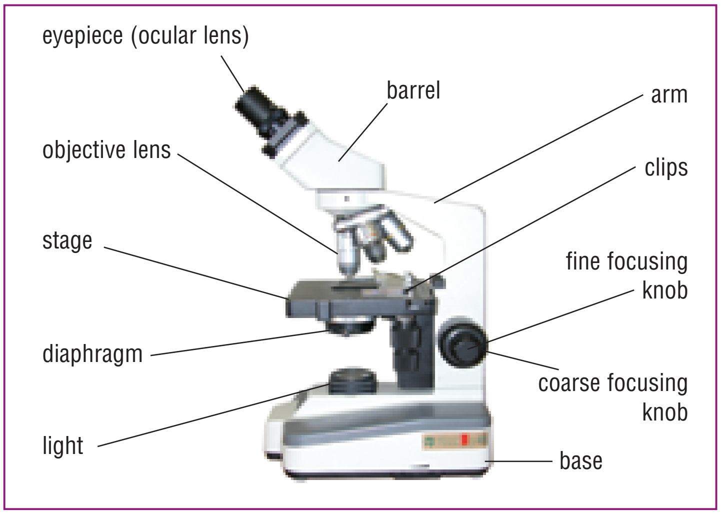

Fig 5.1.4 A typical light microscope that is capable of magnifying 40 times using low power or 400 times using high power.

PP Drag-and-drop

Electron microscopes magnify objects between 10 000 and 100 000 times, making them the only way of viewing objects that are smaller than 0.2 mm. This includes viruses and the internal parts (i.e. organelles) of plants and animal cells. They cannot be used to view live specimens. Although the images produced are black and white, they can be false-coloured to highlight their different features.

Go to Science Focus 1, Unit 5.1

Fig 5.1.5 A microbiologist using an electron microscope. Only electron microscopes are powerful enough to make viruses visible.

Fungi

Fungi are the biggest of all the microbes. Some are seen easily, whereas others are visible only using a microscope. Fungi can be classified as:

- **mushrooms** and **toadstools**—These are probably the best-known fungi, coming in many colours, shapes and sizes. Some are edible whereas others are highly poisonous.
- **moulds**—These grow on decaying food, damp surfaces (e.g. bathroom walls) and between your toes.
- **yeasts**—These are used to make bread, buns and cakes and alcoholic drinks (e.g. wine and beer).

Fig 5.1.6 Fungi come in many different forms. Mushrooms and toadstools are forms of fungi, as is the tinea that forms between your toes and the mould that grows on fruit.

Although many fungi look like plants, they gain their energy in a very different way. Plants use a process known as **photosynthesis** to make a sugar called glucose, which is then used as their 'food' and energy source. Fungi do not contain the chemicals needed for photosynthesis, and so cannot gain their energy in this way. Instead, they 'feed' on dead material, helping it to decay and return its nutrients to the environment.

Prac 3 p. 154

Protists

Protists (sometimes called **protozoa**) are single-celled organisms that live in water and areas of high moisture. Protists can be classified as:

- **flagellates**—These move about rapidly by flicking their whip-like tails.

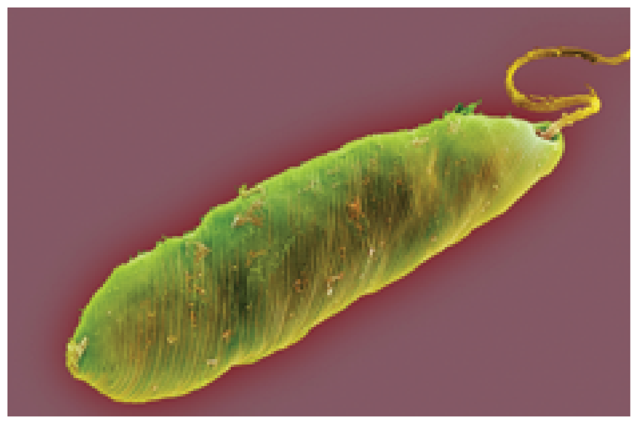

Fig 5.1.7 An SEM image of a euglena, which is a flagellate. Euglena is a plant-like protist because it contains the green pigment chlorophyll and uses photosynthesis to make its own food.

- **ciliates**—These move about by beating tiny hair-like cilia, which cover their exterior.
- **amoeba**—These have no definite shape and flow rather than swim. An amoeba extends a part of its cell body in the direction that it wants to move. This outwards extension is called a false foot or **pseudopod**, and the contents of the cell flow into it as it forms.
- **sporozoans**—These can't move about on their own but need to hitch a ride in other cells. Malaria is caused by a sporozoan that is carried by the blood cells of infected people. Mosquitoes pass on a little blood every time they bite and are capable of passing along a few sporozoans with it.

Giardia and cryptosporidium are two protists that can cause diarrhoea, vomiting and severe illness. They are commonly tested for in drinking water, the results being recorded as the number of microorganisms found in each 100 litres of water. Chlorine kills these protists and the amount of chlorine added to drinking water is increased if these microbes are discovered.

Fig 5.1.8 An SEM image of two ciliates known as paramecium. Paramecium is animal-like in that it catches and consumes food from the water in which they swim.

Fig 5.1.9 An SEM image of a group of amoebas. Amoebas are animal-like because they surround and consume other microbes that are in the water with them.

Prac 4
p. 154

Bacteria

A single bacterial cell (more properly called a **bacterium**) is made up of a cell wall, cell membrane and cytoplasm. Unlike plant and animal cells, bacteria do not have a nucleus. The three basic shapes of bacteria are **cocci** (spherical), **bacillus** (rod-shaped) and **spirilla** (spiral).

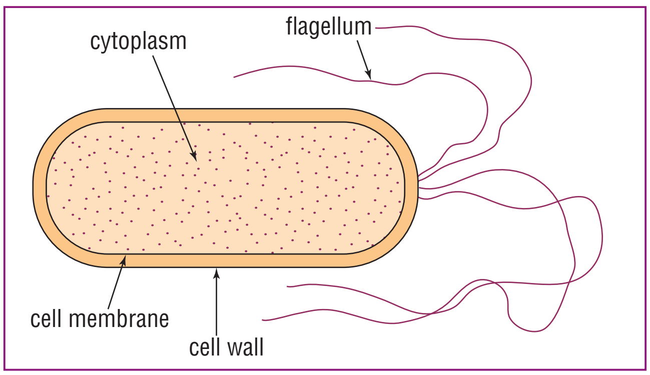

Fig 5.1.10 Bacterial cells are unusual in that they do not have a nucleus. Some bacteria have tails (i.e. **flagella**), which are whipped back and forth, allowing the cell to move about on its own.

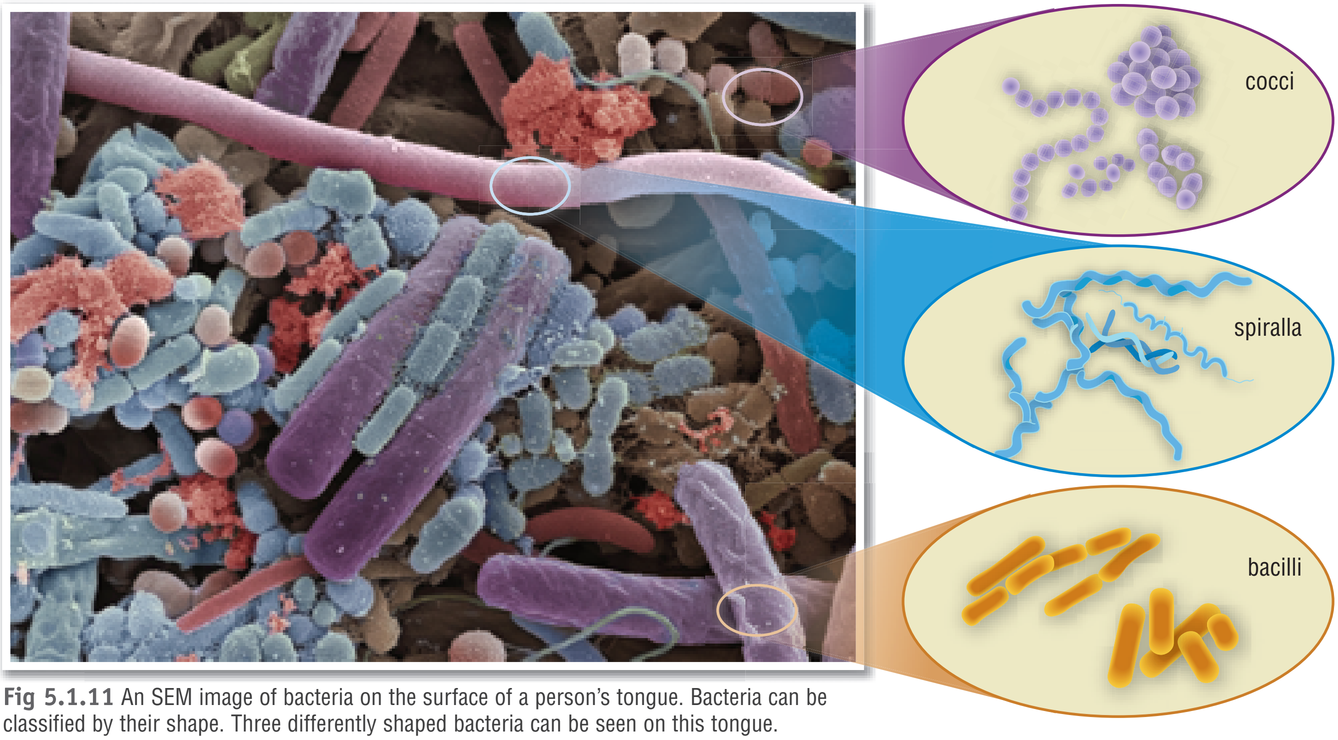

Fig 5.1.11 An SEM image of bacteria on the surface of a person's tongue. Bacteria can be classified by their shape. Three differently shaped bacteria can be seen on this tongue.

The human body is home to millions and millions of bacteria of many different types. They live everywhere in and on you—on your skin, in your nose, in your blood and in your intestines. Some bacteria are harmful or annoying to you, for example, those under your arms cause body odour, those on your skin cause the pus in pimples and those in your mouth cause bad breath. Other bacteria do not cause you any harm at all and, instead, help you stay healthy. These bacteria are sometimes called probiotics and are found in yoghurts and drinks like Yakult. They work by taking up all the available space, leaving no room for harmful bacteria that are trying to invade your body.

Science Clip

Zits!

Staphylococcus aureus bacteria normally live on the skin and in the nose, throat and large intestine. But if these bacteria build up in a blocked skin pore, pus forms and the result is a zit!

Science Clip

Belches and farts!

Depending on the microbes involved, the result of digestion may be waste gas. Methanogens are bacteria that live in the intestines and which produce carbon dioxide, hydrogen and methane gas. These microbes can produce up to two litres of gas each day, which then exits the body in some unpleasant way!

Fig 5.1.12 Gangrene is dead tissue infected with bacteria. Gangrene has set into the toes of this heavy smoker and will need to be amputated to stop the bacteria from spreading. Smoking is known to increase your risk of gangrene.

Viruses

Viruses are much smaller than other microbes and can be viewed only using an electron microscope. Viruses cause many illnesses (*virus* is the Latin word for poison) and do not feed, die and reproduce like other organisms. At the centre of a virus is a chemical that contains all the instructions for building a new virus particle. This chemical is either DNA or RNA and is surrounded by a coat of protein. Different viruses can have differently shaped protein coats, although many take on a similar polyhedral shape.

Fig 5.1.13 Herpes simplex is a common virus that bursts out as blisters, better known as cold sores.

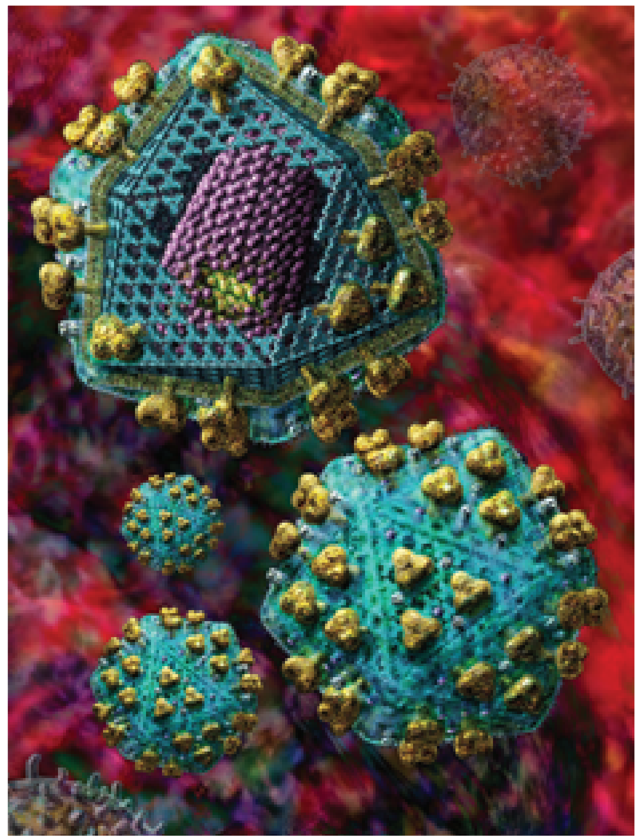

Fig 5.1.14 A model of the HIV virus that causes AIDS. Its polyhedral shape can be seen.

Worksheet 5.1 Microbes

5.1 QUESTIONS

Remembering

1 **State** a more scientific word for germs.

2 **Name** five different types of microbes, and produce an example of each.

3 **State** whether the following statements are true or false:

  a All microbes cause disease.

  b Most microbes are too small to be seen with the naked eye.

  c Bacteria cannot survive long outside a living thing.

  d Viruses are dangerous because they reproduce quickly on the surfaces of non-living objects.

4 **List** the types of microbes that can be seen with:

  a the naked eye

  b a 'normal' light microscope

  c an electron microscope.

5 **State** four ways in which protists move.

6 **Name** the three basic shapes of bacteria.

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7 **Name** the parts of the microscope labelled in Figure 5.1.15.

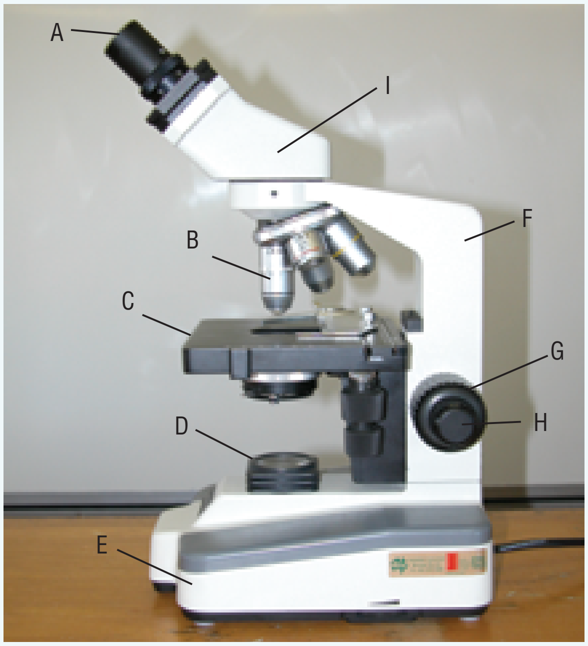

Fig 5.1.15

Understanding

8 **Explain** the terms:

a microbe **b** fomite **c** protist.

9 **Specify** the prefix used in the unit kilometre (km) and **explain** what it means.

10 **Explain** why:

a A euglena is considered to be a plant-like protist.

b A paramecium is considered to be an animal-like protist.

11 **Classify** whether an amoeba is plant- or animal-like. **Explain** your choice.

12 **Clarify** why a fungus cannot be considered to be a plant.

13 **Outline** how fungi obtain their nutrients.

14 **Describe** four ways in which protists use to move about.

Applying

15 Prefixes are used throughout the metric system and not just for units of length. For the units nm and µm:

a **Identify** the name of the unit.

b **Identify** the prefix in each.

c **Explain** what the prefix means.

16 **Identify** the missing units. Ⓝ

a 1 mm = 0.001 ___

b 1 ___ = 0.000 000 001 m

c 1000 m = 1 ___

Analysing

17 **Contrast** the characteristics of a bacterium and a protist.

18 **Identify** the missing units. Ⓝ

a 100 cm = 1 ___

b 1 000 000 µm = 1 ___

c 1 000 000 000 ___ = 1 m

19 **Calculate** the numbers that are missing in these unit conversions. Ⓝ

a 0.01 m = ___ m

b 1000 mm = _____ µm

c ____ µm = 1 nm.

20 Three different surfaces in a classroom were wiped with sterilised damp cotton buds. The cotton buds were then wiped over agar jelly in Petri dishes. Figure 5.1.16 shows the results after the Petri dishes were incubated for three days.

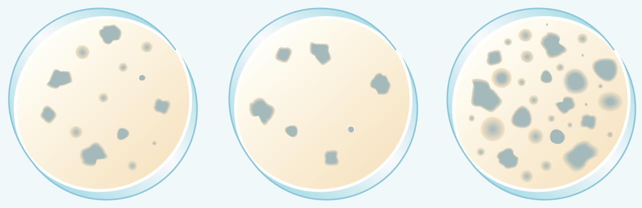

Fig 5.1.16

a **Compare** the three sets of results.

b **Analyse** the results and write a conclusion for the experiment.

Evaluating

21 **Propose** a set of precautions that should be taken when collecting water while camping in the bush.

22 It is difficult to classify viruses as living organisms. **Propose** reasons why they:

a could be classified as living

b cannot be thought of as living.

23 Viruses can survive only in living bodies or living body fluids. **Explain** why.

24 **Propose** reasons for each of the following:

a Everyone (especially food workers) should wash their hands after going to the toilet.

b A mobile phone, computer keyboard and computer mouse often have far more bacteria than the toilet bowl at home.

c Wet clothes start to smell after a few days.

d Tinea can be picked up easily from the floor of the shower.

5.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 **a** Research the development of the microscope and electron microscope.

b Apply the information you find to construct an illustrated and scaled timeline that shows the main events in the discovery of the microscope and electron microscope. N

c Outline the impact of each discovery on the understanding of microbes.

2 Construct a poster using diagrams to explain how a light microscope magnifies.

3 **Investigate** your available resources (e.g. textbooks, encyclopaedias, Internet etc.) and select one example of each type of microbe (i.e. bacteria, fungi, virus and protist). Summarise the information about each, covering the details below. Then combine your information sheets to construct a class reference booklet:

a scientific and common names

b labelled diagram

c preferred environment

d advantages or disadvantages of the microbe to its environment and humans.

5.1 PRACTICAL ACTIVITIES

Safety

Check with all students whether any have allergies to products used or produced by the experiments in this chapter. Remind students not to breathe in any products produced and to wash their hands thoroughly with antibacterial soap after each prac.

1 Fun with fomites

Aim

Observe microbes found on everyday objects.

Equipment

- sterile Petri dishes containing nutrient agar
- electrical tape
- permanent markers
- cotton buds
- antibacterial soap

Safety

1 Do not take samples from a toilet, your mouth, other body parts or unhygienic places, as this could lead to growing dangerous bacteria that can cause serious illness.

2 Lids must not be removed from agar plates. Make all observations through the lid.

Method

1 Discuss and select a range of appropriate fomite samples. Use only everyday objects (e.g. pens, door knobs, seats, desk tops or hand rails).

2 Expose agar plates to a variety of everyday objects. This may be done by leaving the lid off for a period of time; wiping a cotton bud on an object and then onto the agar; or pressing an object, such as a leaf, onto the agar.

3 Place the lid on the agar and seal with electrical tape immediately.

4 Write your name, the fomite tested and the date on a label on the underside of the plate.

5 Incubate samples overnight, upside down at 35°C.

6 Observe samples without opening plates.

7 Record your results in a table that includes labelled diagrams.

Questions

1 **Compare** and **contrast** results for the range of non-living objects sampled.

2 **Assess** whether non-living objects are 'germ' free.

2 Observing bacteria and moulds

Aim

To observe bacteria and moulds using a microscope

Equipment

- mouldy bread
- agar plates from Prac 1
- stereo microscope
- microscope lamp (if needed)
- forceps

Method

1 Set up a microscope to focus at low power.

2 Use forceps to place a small piece of mould on a glass slide.

Safety

1 Do not breathe in any of the mould spores.

2 Lids must not be removed from agar plates.

3 Observe the mould under the microscope and draw your observations. Record on your diagram the magnification used.

4 Observe the agar plates from Prac 1 under the microscope.

Questions

1 **Distinguish** bacterial from fungal specimens on the agar plates.

2 **Compare** your observations of bread mould and any fungus on the agar plates.

3 Observing fungi

Aim

To observe a variety of fungi

Equipment

- various types of fungi (e.g. mushrooms, food mould, yeast solution)
- monocular microscope
- microscope slides
- stereo microscope
- hand lens

Method

1 Mushrooms and mould can be viewed using stereo microscopes and hand lenses.

2 Yeast can be viewed on a microscope slide using a microscope.

3 Draw diagrams of all specimens observed and label any features you can identify.

Questions

1 **Contrast** each of the different types of fungus observed.

2 **Describe** the structural features of mould.

4 Pond life

Aim

To observe and identify some protists present in pond water

Equipment

- pond water
- droppers
- monocular microscope
- microscope slides
- gelatin (3 g in 100 mL of water)
- neutral red or methylene blue stain
- probes
- cover slips

Method

1 Place a drop of pond water on a slide and lower the cover slip, using a probe.

2 Observe protists at a low microscopic power.

3 Record your observations, using labelled diagrams.

4 To aid observation a drop of gelatin solution can be added to the slide to slow down the movement of the protists. To enhance the visibility of structures a drop of neutral red or methylene blue stain can be placed on a slide, left to dry, and then a drop of pond water added.

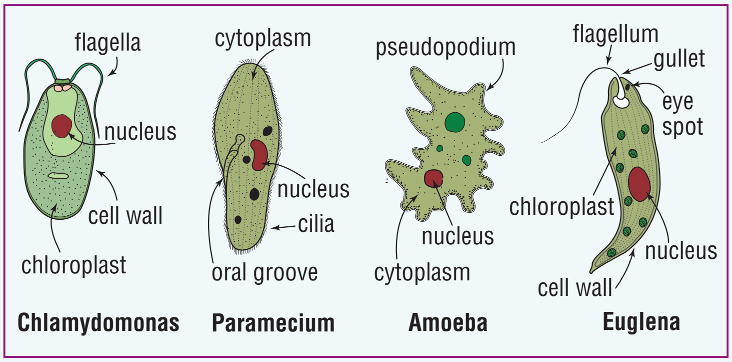

Fig 5.1.17 Some common protists that you may see in pond water

Questions

1 **Describe** any features you observe that help the protists to move.

PP Drag-and-drop

2 Given the observations made of the pond water when viewed under a microscope, **assess** the suitability of pond water for human consumption.

3 **Propose** a method for measuring the size of the protists observed in the experiment.

Unit 5.2 Reproduction of microbes

context Microbes can reproduce at an amazing rate, especially in the warm and moist environment of the human body. Diseases occur because microbes start reproducing as soon as they enter the body, quickly building into millions. The more microbes there are, the sicker you get. You start off feeling fine but soon feel terrible.

Fig 5.2.1 We all have a fungus known as thrush in our mouths, but it is kept under control by our immune system. If the system is not functioning properly, then thrush can reproduce uncontrollably. This is what has happened to this person.

Microbes reproduce without sex

Whereas animals and plants need a male and a female to reproduce, microbes do not use sex or a male and female to reproduce. Different microbes reproduce in different ways. This may be by:

- bits breaking off and growing (some types of fungi)
- releasing spores (some types of fungi)
- splitting in two (bacteria, protists and some types of fungi)
- invasion (viruses).

Breaking off

Fungi (e.g. mushrooms, toadstools and moulds) produce furry, thread-like structures known as **hyphae**. Although the hyphae in moulds are quite visible, these threads grow underneath mushrooms and toadstools and so usually cannot be seen. Hyphae grow into the food source to which the fungus has attached itself, digesting nutrients for further growth. A new fungus can grow from bits of hyphae that have broken off.

PP Drag-and-drop

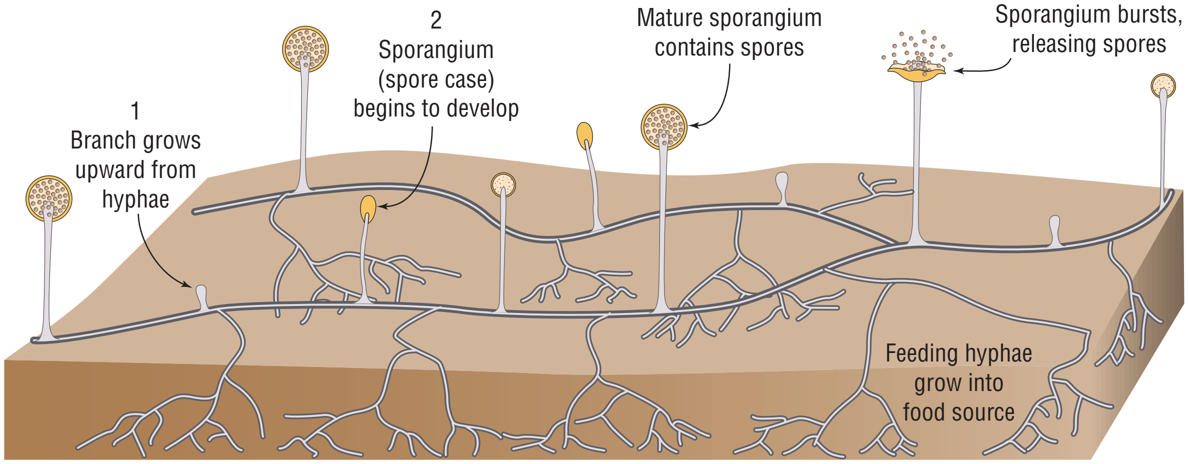

Fig 5.2.2 Fungi reproduce using spores that grow from hyphae or by bits of hyphae breaking off.

Releasing spores

Fungi can also reproduce by **spores**. Spores form in a capsule called a **sporangium** that grows upwards from the hyphae. The sporangium bursts open when mature, releasing its spores into the air. Spores are able to survive for long periods of time until they find the right place to grow. They act much like the seeds of a plant, although they lack the food supply that a seed carries with it.

The part of the mushroom that is eaten is really just a big sporangium, preparing its spores to release into the air.

Fig 5.2.3 An SEM image of the spores of slime mould. Changes in humidity cause the grey threads to flick the red spores away to a site where they can start anew.

Science Clip

Killer teddy bears!

New Zealand scientists have discovered that the toys in doctors' waiting rooms are often heavily contaminated with disease-causing bacteria. These toys are rarely cleaned and have been dribbled and sneezed on by sick children visiting the surgery. The toys are acting as **fomites**, non-living things on which bacteria can live and reproduce.

Science Clip

Bad breath

The stink of morning breath occurs due to bacteria building up during the night at the back of the tongue. These bacteria are able to reproduce more easily as less saliva is produced during sleep. The recommended cures are morning mouthwash or a good brush! But it also helps to floss and brush, including your tongue, before going to bed the night before.

Splitting in two

Budding

Yeasts are fungi, too, but they reproduce in a very different way—yeasts reproduce by **budding**. A yeast cell (known as the **parent cell**) forms a **bud** on its outer surface. A copy of everything in the parent cell is moved into it, including the instructions for growth and further reproduction. A cell wall then forms between the bud and the parent cell and the bud breaks away. The bud then grows into a full-sized cell.

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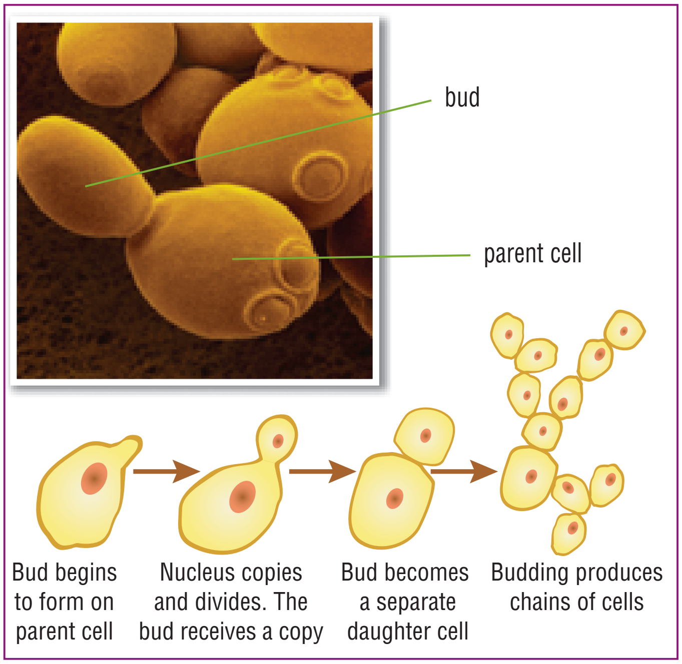

Fig 5.2.4 (top) This SEM image clearly shows the parent cells, buds forming and bud scars left after they break away. **(bottom)** Yeast cells reproduce by budding.

Binary fission

Like yeast, protists and bacteria reproduce by cells splitting in two. When yeast cells split, they form an immature bud cell that needs to grow. When the **parent cells** of protists and bacteria split, they form identical and full-sized cells. These fully grown, new cells are known as **daughter cells**. The process of division is known as **binary fission**.

Although most bacteria take between one and three hours to reproduce, some bacteria can undergo binary fission in as little as 20 minutes. The daughter cells divide just as quickly. At this rate, a new 'generation' of bacteria is being formed and the total population is doubling every 20 minutes. From a single bacterium, a colony of over one million would be formed in seven hours. This is going to make you very sick!

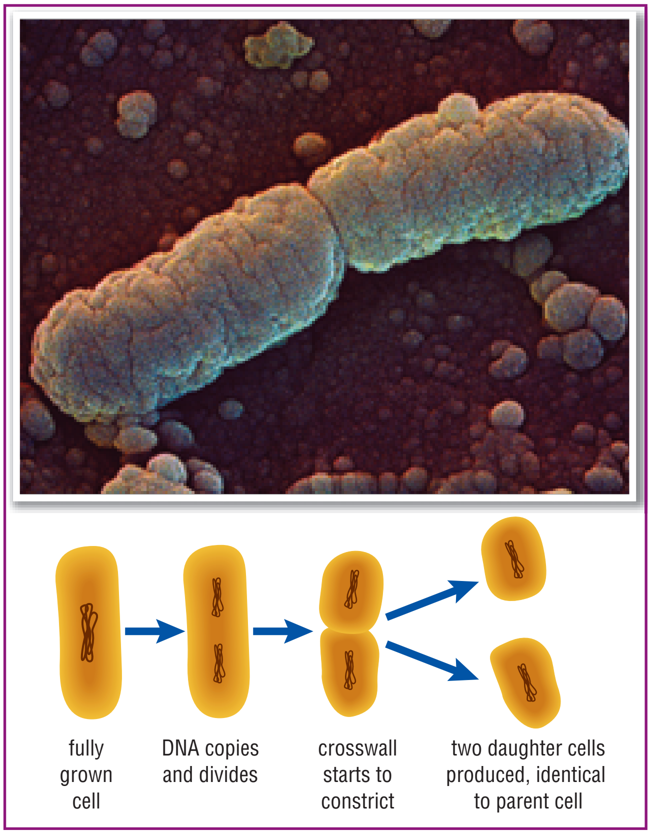

Fig 5.2.5 A single bacterium parent cell in the process of splitting into two identical daughter cells. This process is known as binary fission.

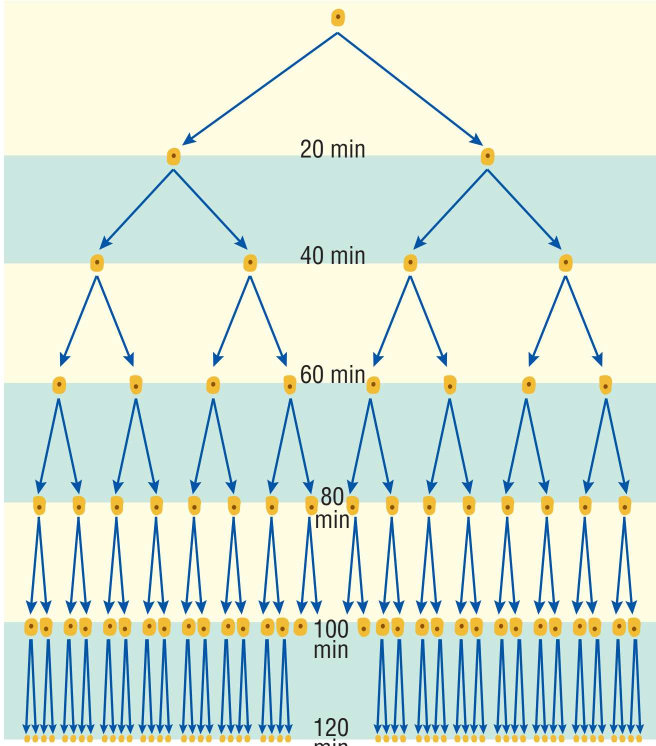

Fig 5.2.6 The total number of bacteria increases very rapidly under the right conditions.

Bacteria need the right conditions to grow and reproduce. All bacteria need moist and warm environments and the human body provides the ideal conditions for many of them—it is moist, has lots of food and a core temperature of 37°C. These simple conditions allow bacteria to be grown easily in the laboratory for our own use and testing. Microbiologists need to supply them with only a warm, moist environment with a supply of their preferred food source. All that is needed to breed large colonies of bacteria in the laboratory is a Petri dish with a layer of jelly-like agar and an incubator (i.e. an oven that can be set at a warm but not hot temperature).

Science Clip

Explosive diarrhoea!

Some protists, such as giardia, can produce a protective capsule called a **cyst**. A cyst is like an egg that can survive in tough conditions. It hatches only when conditions are right for growth. This makes it difficult to remove protists in drinking water because cysts can survive even after water has been disinfected. Symptoms of infection by giardia are stomach cramps, vomiting, explosive diarrhoea and the production of huge amounts of gas that smells like sulfur.

Fig 5.2.7 Bacteria are commonly grown in Petri dishes on layers of high-nutrient jelly called agar.

Antibiotics

Your body has ways to fight bacteria and overcome infection. If an infection is severe, then extra help may be needed. This is when you need to take antibiotics. **Antibiotics** are drugs that kill bacteria, usually by destroying their cell walls. Nonetheless, any bacteria that survive are likely to be resistant to the antibiotic. They will then start to breed and the infection will continue. The antibiotic is then not effective anymore and a new drug-resistant, stronger strain of bacteria will have developed.

Fig 5.2.8 Antibiotics work against only some types of bacteria. They do not work against viruses, fungi or protists.

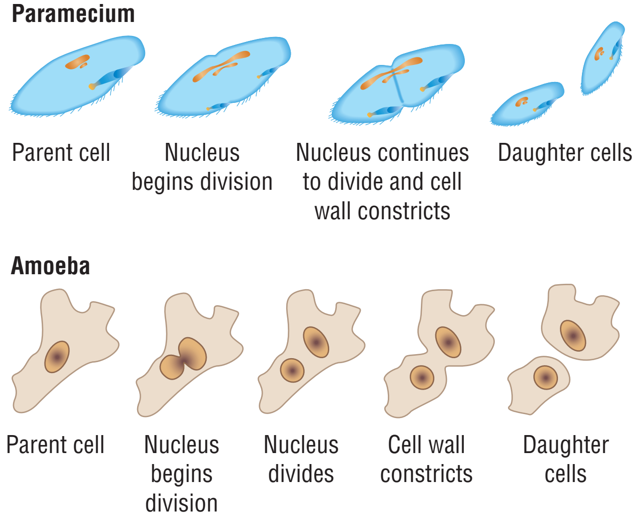

Fig 5.2.9 Like bacteria, protists such as paramecium and amoeba reproduce by binary fission.

Invasion

A virus cannot reproduce by itself but needs a **host cell**. A host cell is any cell that the virus invades and takes over. When a virus comes into contact with a host cell, it hijacks the cell and forces it to become a virus factory.

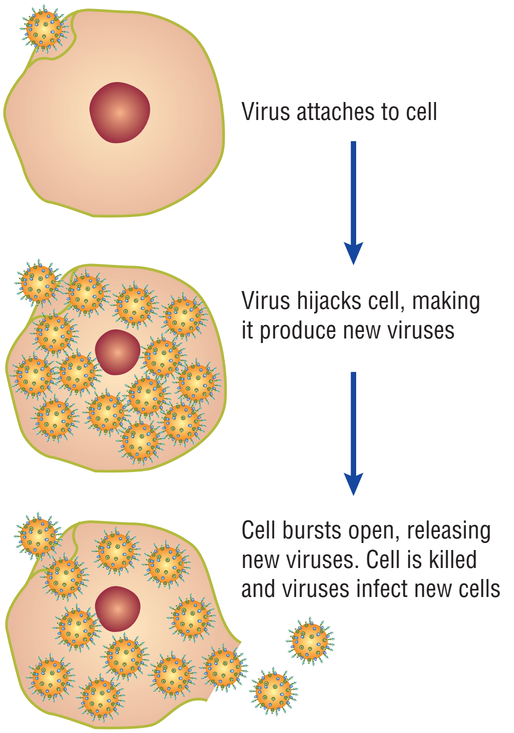

Fig 5.2.10 A virus reproduces by hijacking a cell and forcing it to make copies of the virus. The cell then bursts open, spreading the virus to other cells.

The cell bursts open when full of new viruses, releasing them into the body so that they can infect more cells. If no host cells are available, viruses can lie dormant (i.e. asleep) for many years, waiting for a suitable host cell to come along.

Antibodies

Antibiotics only kill bacteria and do not work against viruses. Instead, your body has an **immune system** that builds **antibodies** to destroy invading virus and bacteria. When you are young, you have very few of these antibodies, and so you get sick with all sorts of viruses, such as colds, chicken pox, measles and mumps. Your body builds a new set of antibodies to fight every time a new virus enters. This takes time, however. In the meantime you get sick. Eventually, the antibodies kill all the virus particles and you feel well again. These antibodies remain in your body, although in decreasing numbers as you age. Their presence means that you are unlikely to ever get ill with that particular virus again. The antibodies are there and are ready to fight at the first sign of invasion.

Each virus has its own specific antibodies. The chicken pox virus triggers the immune system to build antibodies to fight it. Unfortunately, these antibodies have no effect on other viruses, such as measles or influenza (i.e. the flu).

Sometimes the virus itself **mutates** (i.e. changes), making a slightly different version of the same virus. Unfortunately, the antibodies made for one version cannot fight a different version of the same virus. The cold virus mutates very quickly. This means that although you are probably safe from last year's version of the cold, you will probably catch this year's 'new improved' version.

Science Clip

The life of a virus?

Normally living things can move, feed, excrete waste, produce energy, grow and respond to things around them. The only one of these things that a virus can do is reproduce, and it needs to take over a living cell to do it! Because of this, some scientists argue that viruses are not living, whereas others argue that they are.

Vaccinations

Vaccinations 'infect' you with something very similar to a virus. This could be a modified virus or a harmless virus that is very similar in shape to one that is nasty. This 'fake' virus then 'bluffs' your body into making antibodies that can then protect you from the real disease.

Worksheet 5.2 Bacterial growth

Fig 5.2.11 When you are vaccinated you may be injected with a harmless version of a virus that makes your immune system produce antibodies ready to fight the real virus.

5.2 QUESTIONS

Remembering

1 **List** the four basic methods by which microbes reproduce.

2 **State** whether the following statements are true or false:
- a Yeast reproduces using binary fission.
- b Bacteria grow best on moist rather than dry skin.
- c Viruses can reproduce only within a host cell.
- d Antibiotics can kill a virus.

3 **Name** the process by which:
- a two identical daughter cells are produced
- b two cells are produced, one smaller than the other
- c a virus changes slightly to produce a new version
- d you are deliberately 'infected' with a harmless virus.

4 **Name** the special dish used to grow bacteria in the laboratory.

Understanding

5 **Explain** why microbes do not need a male and female or sex to reproduce.

6 **Define** the following terms: (L)
- a parent cell b daughter cell c host cell.

7 **Describe** the conditions needed for bacteria to grow.

8 Fungi reproduce using two very different methods. Both, however, involve the hyphae.
- a **Outline** the role of hyphae in both methods of reproduction.
- b Apart from their role in reproduction, **describe** what else hyphae do for fungi.

9 **Outline** the stages of budding in yeast.

10 **Modify** these statements so that they become true.
- a Protists reproduce by a process known as budding.
- b Cysts kill protists.
- c Water that contains giardia is safe to drink.

11 **Explain**:
- a why you probably won't get measles if you've already had it
- b how vaccination can protect you from getting ill from a virus.

12 **Explain** how you can catch a cold each year, despite having the antibodies from past colds.

>>

Applying

13 **Identify** two benefits that binary fission give bacteria and their reproduction.

14 Tinea is a fungus that lives off damp, warm human flesh. **Use** this information to:

- **a** **Explain** why you should always wipe between your toes after a shower.
- **b** **Identify** where else on the body tinea could grow easily.

Analysing

15 **Compare** the reproduction of bacteria and yeasts by making a **list** of their similarities and differences.

16 The mouth is full of the bacteria that give rise to bad breath. The amount of bacteria in saliva samples before and after using various mouthwashes was determined by collecting saliva and growing colonies on agar plates. The plates were incubated for 48 hours at 37°C and the results are shown in the table.

	Colonies counted before using mouthwash	Colonies counted after using mouthwash
Listerkill	20	10
Sugarystuff	11	15
Bacterbang	60	15
Whammo	30	10

- **a** **State** an aim for the experiment.
- **b** **Identify** which mouthwash was not effective in reducing bacteria.
- **c** **Propose** reasons why this mouthwash *increased* the amount of bacteria in saliva.
- **d** For each of the other mouthwashes, **calculate** the percentage of bacteria killed. Ⓝ
- **e** Rank the mouthwashes in order from least to most effective.
- **f** Draw a conclusion from the data about the most effective mouthwash.

Evaluating

17 **Propose** reasons why:

- **a** Microbes have survived and flourished over billions of years.
- **b** Microbes have not overrun the planet, despite being able to reproduce so rapidly.

18 **Propose** reasons why:

- **a** Raw chicken goes 'off' quicker than cooked chicken.
- **b** Chicken sitting out of the refrigerator for a short time can be safe to eat, but should not be eaten after sitting a few hours on the bench.

19 Public toilets once had cloth towels on which everyone wiped their hands after washing. These have now been replaced by single-use paper towels or air dryers. **Propose** a reason for this change.

Creating

20 For the mouthwashes analysed in Question 16:

- **a** **Construct** a scaled bar graph that **compares** the performance of each mouthwash.
- **b** **Design** a marketing campaign for the most effective mouthwash.

21
- **a** If a single bacterium reproduced every 30 minutes, **calculate** how many there would be after five hours. Ⓝ
- **b** **Construct** a line graph, showing the number of bacteria formed each half hour for five hours. Ⓝ
- **c** **Use** the graph to **explain** why bacteria can make you sick within one day.
- **d** **Use** the graph to **predict** the bacterial population after 10 hours.

5.2 INVESTIGATING

e-xploring

Web Destination

Connect to ***Science Focus 2 Second Edition Student Lounge*** for a list of web detinations to assist with the following:

1 Research a specific microbe (i.e. bacteria or protozoa) that can cause food poisoning in humans as a result of their fast rate of reproduction. Whichever microbe you **investigate**:

  a Describe the conditions that may cause bacteria to grow to levels that cause food poisoning.

  b Outline the main ways that food poisoning occurs and how microbes can be transmitted between people and food.

  c Outline how to handle food in order to avoid food poisoning.

  d Present your information as a brochure to teach people how to avoid food poisoning.

2 Visit the website of your local water supplier, such as Sydney Water. Use the information from their website to identify the measures taken to stop microbes contaminating the water supply.

5.2 PRACTICAL ACTIVITY

1 Budding yeast

Aim

To observe yeast cells reproducing by the process of budding

Equipment

- freshly made yeast/sugar solution
- microscope slides
- cover slips
- probes
- droppers
- tissues
- microscopes

Method

1 Add a drop of yeast/sugar solution to the microscope slide.

2 Gently lower a cover slip onto it using the probe.

3 Draw out excess yeast solution using a tissue.

Safety

Check with all students whether they have any allergies to products used or produced by the experiments in this chapter. Remind students not to breathe in any products produced and to wash their hands thoroughly with antibacterial soap after each experiment.

4 Focus the microscope slide at low power, then increase to high power.

5 Find an area to view and draw five different examples of yeast budding.

Questions

1 Which type of microorganism would you **classify** yeast as?

2 **Explain** why sugar was added to the yeast solution.

3 **Use** your results to **explain** how yeast reproduces.

4 Based upon observations in this experiment, **assess** budding as a means of reproduction.

Unit 5.3 Microbes: Good or bad?

context

Fungi, protists, bacteria and viruses are responsible for many of the diseases that strike humans, animals and plants. Not all microbes are bad, however, as some can help us. For example, some microbes are used to produce food and drinks; some decompose garbage and compost and keep the soil fertile; and others are used to make medicines and life-saving drugs. Scientists are even trying to make viruses that can enter cells and help cure diseases such as cancer!

Fig 5.3.1 Yellowish-white pus and green phlegm are sure signs of a bacterial infection. This one-year-old boy has conjunctivitis, a highly contagious bacterial infection of the eye.

Bacteria

Good bacteria

Decomposition

Compost bins are amazing—all sorts of vegetable food scraps are thrown in and they break down into compost for the garden. Bacteria help to break down matter that was once living or was once part of a living organism. This decomposition occurs everywhere—in the garden, in the soil, in decaying animal remains and in the waste of animals and humans. **Decomposition** is important for two reasons:

- It returns nutrients to the soil that can then be used by plants.
- It rids the Earth of dead plants, animals and their waste.

Imagine the Earth if nothing decomposed! Everything that has ever died would still be here. All their waste would be here too!

Fig 5.3.2 Bacteria and fungi help break down food and garden waste in compost.

Bacteria are used in the treatment of industrial waste and to break down human faeces in sewage. Scientists have found that certain bacteria can break down oil and these have been used to clean up oil spills. They pose no risk to the environment since they die off when they finish consuming the oil.

Food production

Some types of bacteria are used in the production of foods and drinks, such as yoghurt, yoghurt drinks and cheese.

To make **yoghurt**:

- Bacteria are added to milk. These bacteria consume the sugar in the milk, turning the milk sour. Exactly the right type of bacteria must be added to make yoghurt. Although the wrong bacteria may still cause the milk to go sour, the taste will be terrible and may make it unsafe to drink.
- Sometimes sugar or artificial sweeteners and fruit are added to take away the sour taste of the natural yoghurt.

To make **cheese**:

- Rennin (a chemical from a sheep's stomach) is added to milk. This causes the milk to clot and form **curds**, floating in a liquid called **whey**.
- The mixture is filtered, removing the solid curds from the whey.
- Bacteria or fungi are added to the curds. These feed on the curd, ripening it and giving it flavour. The holes in Swiss cheese are caused by bacteria releasing gas as they ripen the cheese.

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Fig 5.3.3 The production of cheese and yoghurt both rely on bacteria.

Medical purposes

Some types of bacteria are used to produce hormones for medical purposes and drugs, such as insulin for people with diabetes.

Bad bacteria

Bacteria often cause disease and infection. They also quickly decompose food left out of the fridge for too long, making it go 'off'. Natural bacteria in the food start to break it down, producing **toxins** (or poisonous chemicals) as they work. If you eat the food, then these toxins will give you a range of symptoms from a grumbling stomach to diarrhoea. They may even make you violently ill. This is known as **food poisoning**.

Fig 5.3.4 Keeping food in the refrigerator slows down the growth of bacteria and reduces the risk of food poisoning.

Science Clip

Pure dog poo soup!

When leather was tanned in the 1800s, the cow hides were soaked in different 'soups'. Bacteria in one 'soup' softened the leather. This soup was made up from dog faeces and chicken faeces, mixed in water and then warmed. At first, collecting dog poo was a job done by elderly women, but when times got hard, men and children collected it, too. The collectors were called 'purefinders' because dog faeces was often called 'pure'.

Science Clip

The friendly peanut

In agriculture, bacteria assist with the supply of nitrogen in the soil. Nitrogen is used by plants for growth and so is very important. **Nitrogen-fixing bacteria** take nitrogen from the air and put it in the soil in a form that plants can use. These bacteria often live in nodules on the roots of plants, such as beans, peanuts and native wattle trees.

Science Clip

The Black Death

The bubonic plague is otherwise known as the Black Death, so-called because of the purplish-black appearance of the skin of its victims. The bubonic plague swept over Europe in the fourteenth century, killing one-quarter of its population. Scientists now know that the plague was caused by bacteria carried in the blood of rats at the time. Fleas sucked up a little infected blood whenever they bit a rat and the bacteria grew rapidly in the flea's stomach. Fleas also bit humans, vomiting a little of their stomach contents into the wound. The bacteria from the stomach were also transferred. A single plague-filled flea bite was a death sentence, turning the victim's skin purple-black before killing them. Antibiotics have almost eradicated many serious bacterial diseases, such as Black Death. There were no antibiotics in the Middle Ages, however. Instead, doctors suggested driving the 'bad air' of the plague away from you by sitting in a sewer, getting the local monk to whip themselves in the town square, eating arsenic or crushed gemstones (emeralds were supposed to be good) or shaving the bottom of a chicken and strapping it to you! No wonder so many died!

Fig 5.3.5 The Black Death (bubonic plague) killed roughly one-quarter of the population of Europe. No-one at the time knew about bacteria and, instead, most thought the disease was caused by 'bad air'. This is what the plague doctors of Marseilles, France, wore in the early eighteenth century to 'protect' themselves from the disease. The bronze beak was filled with aromatic herbs that supposedly cleansed the air.

Fungi

Fungi to eat

There are many fungi that can be eaten safely, the mushroom being the most common. Other edible fungi are shiitaki and enoki (both exotic types of mushrooms), truffles and some strange-looking wood fungi.

Yeast is a useful fungus that is used in the production of bread, wine and beer. Yeasts gain their energy through a process called respiration, during which glucose is used to produce carbon dioxide, water and energy.

If the respiration requires oxygen, then the process is referred to as **aerobic respiration**. It has the equation:

glucose + oxygen → carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

This is what occurs in the yeast that is added when making bread. Bubbles of carbon dioxide are produced,

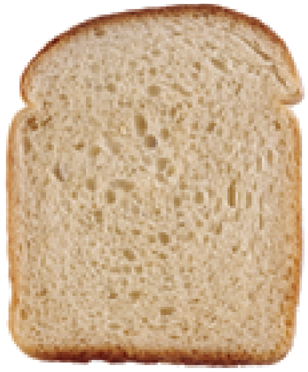

Fig 5.3.6 Bubbles of carbon dioxide make bread take on a honeycomb appearance. If no yeast is added, then the bread ends up flat and dense like pita bread.

causing the bread to rise, making thousands of tiny holes that give bread its sponge-like appearance and texture.

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Anaerobic respiration occurs when there is no oxygen. In the absence of oxygen (or limited supplies of it), yeast will feed on the glucose in fruits, vegetables or cereal grains. The main product of the reaction is a type of alcohol called **ethanol**. The process is more commonly known as **fermentation**. It has the equation:

glucose → alcohol + carbon dioxide + energy

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{energy}$$

Any type of fruit, vegetable or grain can be used, although grapes (producing wine), potatoes (vodka), barley (beer), wheat (whisky) and rice (sake) are most commonly used. Yeast will even work on the glucose in cactus to make tequila. The carbon dioxide produced by the yeast causes the bubbles in beer and champagne. In wine, this gas is allowed to escape before the wine is bottled.

Fig 5.3.7 The bubbles in champagne are caused by the build-up of carbon dioxide gas from the respiration reaction of yeast and the glucose in grapes. In wine, this gas is allowed to escape before bottling.

Science Clip

Tasty truffles

The truffle is the rarest, most expensive and tastiest of all the edible fungi. Truffles grow completely underground among the roots of large old trees and only at certain times of the year. Pigs or dogs are trained to sniff out truffles, which are then dug up. Thin shavings of the truffle are then used in cooking. Although truffles have grown for centuries in Europe, particularly France, they have been found recently in Tasmania, where tree roots were deliberately infected with their spores. Truffles might look like a lump of dirt but they taste fantastic!

Science Clip

The Australian connection

Although Fleming discovered the bacteria-killing properties of penicillin, it took the work of an Australian pathologist, Howard Florey (1898–1968), 10 years later to develop it into an effective antibiotic. Florey was awarded the 1945 Nobel Prize for medicine.

Fungi to heal

Penicillin was the first antibiotic ever discovered and it was found by accident in bread mould, a type of fungus.

In 1928, the Scottish physician and bacteriologist Alexander Fleming (1881–1955) found that mould had contaminated agar plates in which he was growing bacteria. On closer inspection, Fleming noticed that the bacteria around the mould had stopped growing. The mould was the bread mould, *Penicillium notatum*.

Although there are now many other antibiotics, penicillin is still used to treat many bacterial infections. Amoxycillin, for example, is a synthetic penicillin-based antibiotic that is commonly used for heavy bacterial chest infections. Penicillin is not effective against all the different bacterial infections that exist and some people are highly allergic to it.

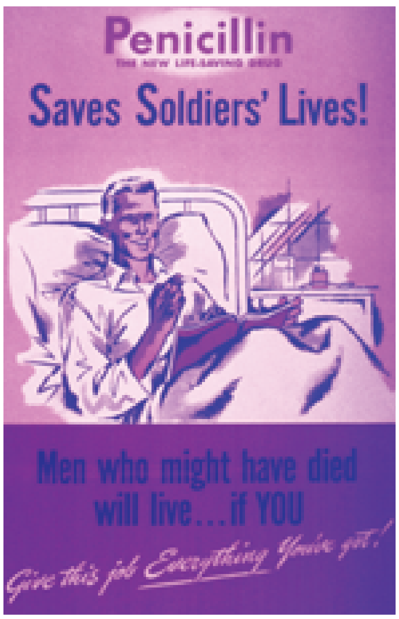


Fig 5.3.8 Although discovered in 1928, penicillin was not mass-produced until 1944, when 2.8 million doses were produced in time for the last months of World War II and the Allied invasion of Europe. Penicillin saved the lives of many Allied soldiers who had severe infections as a result of combat.

For these reasons, many different non-penicillin antibiotics have since been developed.

Before 1928 a minor but infected scratch was often deadly because nothing could stop the infection from spreading. Few now die from bacterial infections because of antibiotics. Antibiotics have almost eradicated many serious bacterial diseases and plagues, such as the Black Death. A disadvantage of antibiotics, however, is that bacteria can become resistant to them, and therefore become even more deadly.

Fungal diseases

Fungi are responsible for a range of fungal diseases, including thrush, tinea (sometimes called athlete's foot) and ringworm. Most fungal diseases can be easily treated with antifungal powders or creams.

Fig 5.3.9 Tinea is caused by a fungus. To minimise your chances of tinea, always dry between your toes.

Viruses

Viruses are usually harmful for any host (whether human, animal, plant or bacteria) that gets infected by them. In humans, viruses cause a range of diseases from an annoying cold, through to measles and chicken pox to deadly diseases, such as HIV/AIDS.

Despite this, some beneficial uses for viruses are now being investigated. Recently, for example, a virus was injected into a brain tumour in a human. The virus killed the cancerous cells, reducing the size of the tumour. The patient survived.

Worksheet 5.3 Preserving foods

Worksheet 5.4 Disease

Science Clip

The self-destructing potato

Geneticists have created a potato that can self-destruct in the face of its fungal enemy. If the fungus attacks, the potato sacrifices itself and takes the fungus with it, preventing it from spreading.

5.3 QUESTIONS

Remembering

1 **State** whether the following statements are true or false:
   - a Bacteria are always harmful.
   - b Decomposing bacteria help break down food waste to form compost.
   - c Nitrogen-fixing bacteria help plants to grow by supplying nutrients to the soil.
   - d Yoghurt is made using bacteria, but cheese is made by a virus.

2 **Name** two symptoms that are commonly associated with bacterial infections.

3 **List**:
   - a four ways in which fungi can be used
   - b three ways in which bacteria can be used.

4 Fermentation is used in the production of alcoholic beverages.
   - a **State** another name for fermentation.
   - b **Recall** the reaction by writing its word equation.
   - c **Specify** the type of alcohol produced.
   - d **List** the fruits and grains commonly used in alcohol production.

5 **Specify** what spread the bacterium that caused the bubonic plague.

Understanding

6 **Describe**:
   - a two ways in which decomposition benefits the Earth
   - b one way in which decomposition can harm us.

7 **Outline** how viruses might be used to actually benefit humans.

8 **Specify** the type of microbe used in each of the following and explain how it works:
   - a making bread
   - b making yoghurt
   - c making wine
   - d treating sewage
   - e composting.

9 Write the word equation that **explains** why bread appears frothy.

10 a **Describe** how the holes in bread are formed.
   - b **Explain** why breads like pita and chapati are 'flat' and are more dense than other breads.

11 Although wine and champagne are both produced by fermenting grapes, champagne has bubbles whereas wine does not. **Explain** why.

12 **Outline** how penicillin was discovered.

Analysing

13 **Compare** aerobic and anaerobic respiration by listing their similarities and differences.

Evaluating

14 Microbes do good and bad. **Assess** their overall contribution to society and decide whether they are our friends or our foes.

15 Cheeses have many different styles and flavours, yet they are all made with bacteria. **Propose** how this might be achieved.

16 Bacteria may be useful in cleaning up oil spills. **Propose** how this might happen.

17 From what you have learnt about the reproduction of viruses, **propose** how a virus injected into a tumour would kill the cancerous cells.

Creating

18 Imagine that all of the world's decomposing microbes have disappeared. Write a short story that **describes** what the world has become. L

5.3 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Research how one particular type of cheese is made using a fungus or bacteria.
   - a Construct a poster explaining the steps in making the cheese.
   - b Outline the role played by the fungus or bacteria in developing that type of cheese.
   - c Explain how the temperature affects the product.
   - d Cheese can be made hard or soft. Propose ways in which this might be accomplished.

2 a Research how yoghurt is made and outline the steps involved.

b The milk used to make yoghurt is chemically changed. Explain the chemical change using equations, and clarify the role and type of bacteria needed to make yoghurt.

3 Select a disease caused by microbes; for example, the flu (i.e. influenza), hepatitis, HIV/AIDS, polio, Ebola, avian flu, gangrene or one of the many sexually transmitted infections (e.g. gonorrhoea). Whatever your choice, you must:

a Identify the microbe responsible.

b Explain how it gets into the body.

c List its symptoms.

d Describe any prevention, cure or ways of treating the disease.

e Describe the likely future for a patient who does not seek treatment.

Present your work in one of the following ways: L

- a PowerPoint presentation
- a poster for a doctor's waiting room
- a health advice page for a magazine
- a video segment for a TV health program.

e-xploring

Web Destination

Travel back in time to the Middle Ages and **investigate** further about the Black Death by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Present a history of the Black Death in one of the following ways:

- a written history
- a video documentary, re-enacting scenes from the time
- a role play, during which you are a doctor of the Middle Ages giving out advice and 'cures' to your patients
- a script or video trailer for a science-fiction movie about a modern scientist or doctor travelling back in time, armed with modern knowledge and antibiotics
- a script or trailer for a thriller movie about a terrorist threatening that a genetically modified Black Death bacteria will soon be spread.

5.3 PRACTICAL ACTIVITIES

Safety

Check with all students whether there are any allergies to products used or produced by the experiments in this chapter. Remind students not to breathe in any products produced and to wash their hands thoroughly with antibacterial soap after each experiment.

1 Getting cheesy

Aim

To model the process of cheese making by making curd cheese

Equipment

- culture of microbes
- rennin
- 500 mL pasteurised milk
- lemon juice
- cotton scissors
- disinfectant
- thermometer
- sieve
- muslin

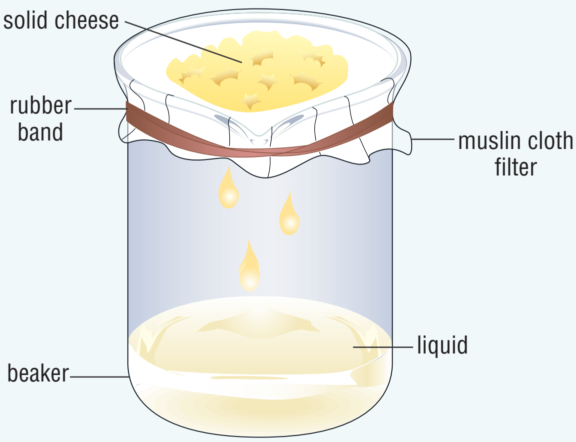


Fig 5.3.10

Safety

Do not taste cheese as contamination is likely under school laboratory conditions.

Method

1 Place the milk in a clean beaker and heat to 40°C.
2 Divide the milk evenly into three 250 mL beakers.
3 Add 15 mL of lemon juice to beaker A and leave for 15 minutes.
4 Add 5 mL of rennin to beaker B and also leave for 15 minutes.
5 Add the cultured microbes to beaker C when it is at 30°C and leave overnight at 30°C. **Disinfect all surfaces in contact with microbes and wash hands.**
6 Strain the contents of beaker A into a 20 cm square of muslin placed in a sieve. Tie the corners of the muslin and hang in refrigerator until next lesson. Alternatively, strain the contents, as shown in Figure 5.3.10.
7 Repeat with beaker B, using a new piece of muslin.
8 Next lesson, strain beaker C through the muslin.
9 Open and compare the three muslin bags containing samples of curd cheese.

Questions

1 **Compare** and **contrast** the three samples of curd cheese.
2 **Propose** reasons why rennin and lemon juice make the cheese curdle.
3 **Identify** ways in which this experiment models real cheese making.

2 Bread making

Aim

To bake mini-loaves of bread and compare the results obtained when the amount of yeast is varied

Equipment

- live yeast
- flour
- measuring spoons
- three clean crucibles
- crucible tongs
- access to oven (depending on the recipe: butter, margarine or oil, salt, sugar)

Method

1 Investigate your available resources to find a recipe for bread.
2 In groups, make up single batches of dough:
   - exactly according to the recipe
   - with more yeast than the recipe calls for
   - with less yeast than the recipe calls for.
3 Split each batch into smaller batches
4 Place a small ball of each type of dough into the crucibles, marking which is which.
5 Bake at the temperature the recipe specifies.
6 Check regularly and use the tongs to remove when they appear cooked.
7 When cool, compare the consistency of each mini-loaf.

Questions

1 **Describe** the appearance of each mini-loaf.
2 **Identify** which mini-loaf was the ‘best’. **Justify** your answer, **listing** the characteristics you used to make your decision.
3 **Explain** the function of yeast in making bread.

CHAPTER REVIEW

Remembering

1 **State** how you can see:
   a fungi
   b bacteria
   c viruses.
2 **Outline** one use for each type of microbe.
3 **State** whether each of the following statements about protists is true or false:
   a Protists can produce cysts that are like eggs.
   b Amoeba have cilia for movement.
   c Drinking water containing protists can cause diarrhoea and vomiting.

4 **Recall** the basic shapes of bacteria by sketching them.

5 **Recall** basic definitions by matching the following terms with the best description:

a antibiotic	**i** only way to see viruses
b binary fission	**ii** breaking down of waste
c budding	**iii** yeast reproduce this way
d decomposition	**iv** non-living thing that bacteria grow on
e fermentation	**v** microbe
f flagella	**vi** bacteria reproduce this way
g fomite	**vii** produces alcohol
h microorganism	**viii** kills some bacteria
i mould	**ix** fuzzy appearance
j electron microscope	**x** tail

Understanding

6 **Modify** the following statements to make them true:

a Protists are many-celled animals found in water.

b Light microscopes are used to study viruses.

c Yeast reproduces by means of binary fission.

7 **Clarify** the term *anaerobic respiration* by writing its word equation and giving an example of how it is used.

8 **Outline** how bacteria are important in 'cleaning up' the environment.

9 Food is more likely to 'go off' on a hot day than on a cold one. **Explain** why.

10 Use mutation to **explain** why people catch colds each year.

11 Copy and complete the following table to **summarise** the benefits and problems to society of each type of microbe. If possible, use specific examples in your summary.

Microbe type	Benefits	Problems and cost to society
Bacteria	Making foods such as yoghurt and cheese	
Fungi		
Protist		
Virus		Cause many diseases and illness that kill many people every year Many people miss work This costs society a lot of money in medical research, sick days and loss of productivity

12 External spa baths and those in gyms are rarely emptied and need to have their chlorine concentrations checked regularly. **Account** for this fact given that most bacteria multiply best at temperatures around 37°C.

Applying

13 **Identify** two microbes that you are likely to find in pond water.

14 **Identify** which microbes:

a can grow from a broken-off piece

b have daughter cells

c reproduce using buds

d reproduce by splitting in two

e invade other cells

f reproduce using spores.

15 **Identify** whether antibiotics and/or vaccinations would be effective in treating these conditions. **Explain** each answer.

a a cold **b** an infected tooth

c vomiting caused by giardia **d** tinea.

Analysing

16 Figure 5.4.1 shows a paramecium. Use the diagram and scale to **calculate** the length of the paramecium in nanometres. N

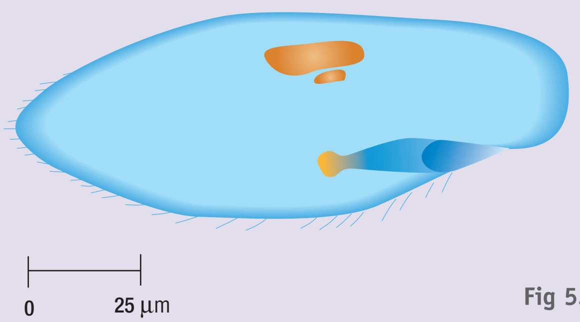


Fig 5.4.1

Evaluating

17 Microbes are studied by growing cultures on agar in Petri dishes. **Propose** three safety precautions required for such experiments.

Creating

18 **Construct** a key to classify each of the four classes of microorganisms.

19 **Construct** a cartoon strip or series of diagrams to show the main steps in the reproduction of:

a yeast **b** moulds **c** bacteria **d** viruses.

PP Interactive

Worksheet 5.5 Crossword

Worksheet 5.6 Sci-words

PP Chapter Review Questions

PP Interactive

6 Ecology

Prescribed focus area:

The implications of science for society and the environment

Key outcomes

4.4, 4.10, 4.11, 4.12

Essentials

- Physical, functional and behavioural adaptations match organisms to their environment.
- Organisms form a series of food chains that, together, form a food web.
- Producers (i.e. plants) make their own food using photosynthesis.
- Consumers eat producers and/or each other.
- Bushfires, flood and drought affect Australian ecosystems regularly.
- Fossil fuels were once living things and are a store of their energy.
- Fossil fuels include petrol, gas, oils, diesel and aviation fuel.
- Fossil fuels are non-renewable forms of energy.
- Renewable sources of energy include solar, wind, tidal, wave and geothermal power.

Additional

- Competition, predators and birth/death rates influence the size of a population.
- Aboriginal and non-Aboriginal people have both changed the environment through different land-management practices and techniques.

Unit 6.1 Ecosystems

context

Humans rely on their environment just like every other living thing on planet Earth. Living things get everything they need for survival from their environment—food and water, shelter and a breeding mate.

In the wild, living things (more properly called **organisms**) are perfectly suited to their environment and live in an ecosystem that is perfectly suited to them. Change it a little and the organism might not survive.

Fig 6.1.1 Every organism relies on their environment.

Science Clip

Failed ecosystem!

Biosphere 2 is a human-made structure covering 1.3 hectares near Oracle, Arizona, USA. Within the massive structure is a small rainforest, savannah grassland, mangrove swamps, a desert and an ocean complete with a coral reef! Between 1991 and 1993, four men and four women lived within this sealed and artificial ecosystem, hoping to live completely self-sufficiently and hoping that it could be used as a model for future settlements in space. Although bananas, sweet potatoes and peanuts grew well, the crew was soon experiencing constant hunger and required 'secret' deliveries of food. Likewise, oxygen levels were far lower than expected and so oxygen was regularly pumped in. After a number of changes in ownership, Biosphere 2 is now a tourist attraction.

Where do you live?

PP Quick Quiz

An **ecosystem** is a specific area in which organisms live. When scientists study an ecosystem, they investigate:

- the **biotic** environment of living organisms (i.e. plant, animal or microbes, such as bacteria and fungi) that live in the area or that are just visiting it. These are referred to as the **community** of the ecosystem.
- how these living organisms interact with each other
- the non-living (i.e. **abiotic**) environment of the area. This comprises the physical factors of the area, such as available light and water, temperature, wind direction and strength, and the types of rock and soil found there.
- how this non-living environment affects the organisms that live there.

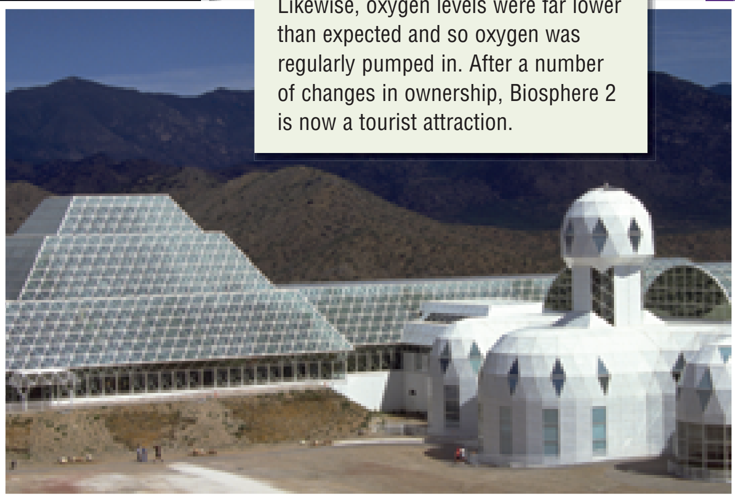


Fig 6.1.2 Biosphere 2 failed dismally in its aim of a self-contained ecosystem that could be replicated as a base on the Moon or Mars.

Ecology is the study of an organism's home. Every home needs an address and scientists have developed a way of specifying where organisms live. Organisms do not have house numbers, street names or suburbs, and so descriptions like habitat and biome are used instead.

Biomes

Similar **biomes** will display similar physical conditions and will sustain similar types of animals and plants, regardless of where they occur on Earth. For example, tropical monsoon rainforests will always be hot, humid and wet. It will always be in heavy shade down by the ground, while the treetops will be bathed in sunlight. Its soil will be rich with nutrients and will support a wide variety of plants and fungi that will, in turn, support a wide variety of animals, birds and insects.

In contrast, deserts will always be dry and bathed in sunlight. Their days will be hot and their nights will often be freezing, particularly in winter. It will support only a limited range of plant life, which will support only a limited range of animals and birds. Very few, if any, animals and plants will be found in the heights of icy and windswept mountains. Likewise, the dark, dry conditions in caves will sustain few plants and even fewer animals. Different biomes obviously display different climates, plants and animals.

Habitats and microhabitats

There will be plenty of different places to live within a biome. These are **habitats**. In a tropical rainforest, for example, there will be trees, rivers and the soil itself. **Microhabitats** are even more defined. In a tree, for example, organisms will live among its leaves, whereas others will live in hollows in its trunk, and still others will live amongst the roots and even under them.

- Equatorial and tropical rainforests
- Tropical monsoon forests
- Mediterranean shrub woodlands
- Temperate forests (evergreen and deciduous)
- Cold temperate coniferous forests
- Tropical savanna grasslands
- Temperate grasslands
- Deserts and semi-desert
- Tundra
- High mountains

PP Interactive

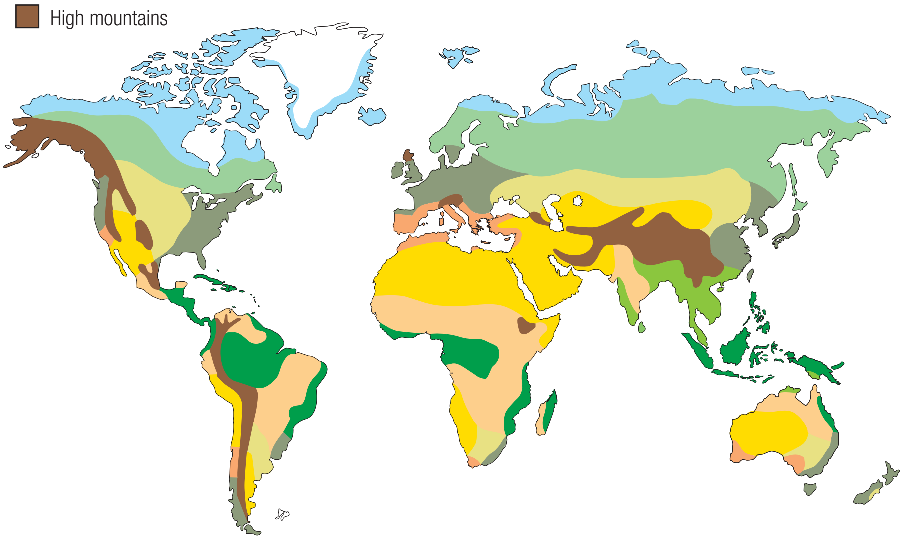
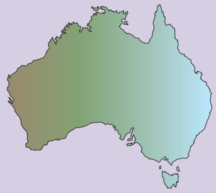


Fig 6.1.3 The same types of biomes are found across the world because they experience similar climates. Different climates cause different biomes to exist.

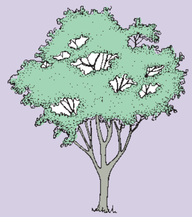
Biosphere
the least specific category in the address. Biosphere refers to the part of Earth in which the living organism is found.

Biogeographical region
each has its own unique plant and animal life, e.g. Australia, North America, Africa and the Antarctic are different biogeographical regions.

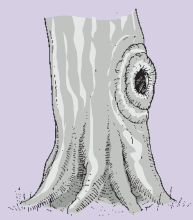


Biome
refers to areas that have similar climatic conditions (such as rainfall, wind conditions, humidity and temperature). Grasslands, deserts, rainforests, the tropics and arctic tundras are different biomes. Organisms living in the same type of biome have similar features even though they may be in very different biogeographical regions.

Habitats
are specific areas in which the organism lives. In a desert biome, for example, there might be sand dunes, clay pans, tussocks of grass, scraggly trees and exposed rocks. All are different habitats within the biome.



Microhabitats
the most specific part in an organism's address. Each microhabitat has different conditions, even though they are in the same overall habitat. In a tropical rainforest, different microhabitats would be found between the roots of trees, others under the bark, under the dirt itself or within a pile of dung.



Organism

Fig 6.1.4 Every organism, animal, plant or microbe, has its own address.

Fig 6.1.5 Camels thrive in the Australian desert biome because it is similar in climate to the desert biome in the Middle East.

Fig 6.1.6 Different habitats can exist in the same biome. The desert biome can have dunes, clay pans and many more habitats.

Science Clip

Different deserts, same animals

The Simpson Desert is a desert biome in Australia. The plants and animals found in this area show characteristics similar to those found in desert biomes in other parts of the world. Camels were imported into Australia from 1866 to assist transport in the desert. Herds of wild camels now graze on the tough grasses of the Simpson Desert.

Prac 1 p. 179
Prac 2 p. 179
Prac 3 p. 179

Science Clip

Eating mum and dad

Salmon begin their lives in a freshwater river biome and then migrate to a saltwater ocean biome to mature. When they are ready to reproduce, they migrate back to their original freshwater home to lay their eggs. Once the eggs are laid, the adult salmon die, their bodies providing food for the fingerlings (i.e. baby salmon).

Case study: The *kowari*

At night the *kowari* hunts in the sand dunes and clay pans for small birds, marsupial mice, lizards and insects. These areas are its habitat. During the extreme heat of the day, the kowari returns to its burrow a few centimetres below the surface. This is its microhabitat. **Microhabitat** is the most specific part of an organism's address.

The *kowari*'s community includes:

- the plants that the kowari uses for shelter or food
- the plants that provide shelter for, or are eaten by, animals that are then eaten by the kowari
- the animals that the kowari eats
- the other kowaris in the area.

The non-living environment includes the soil type of the dunes, the rainfall and the temperature of the desert.

Fig 6.1.7 The *kowari* is a tiny marsupial mouse that lives in a burrow below clumps of spinifex on desert sand dunes.

Science Clip

A different world

Sometimes there is not much separating two very different microhabitats and their inhabitants. Cane toads were introduced into Australia to control the sugar cane beetle. They failed (and continue to fail) because cane beetles live in one microhabitat at the top of the plant whereas the cane toads live in another microhabitat at its base!

Australia's ecosystems

Australia has a variety of different climates and biomes, from deserts to rainforests, beaches to snowfields, and grasslands to caves. Each biome has its own unique habitats and microhabitats. In Australia, these ecosystems have been shaped by bushfires, floods and drought.

Bushfire

Lightning strikes regularly spark bushfires in winter in northern Australia, during spring in southern Queensland and northern New South Wales, and during summer in the southern areas of Australia.

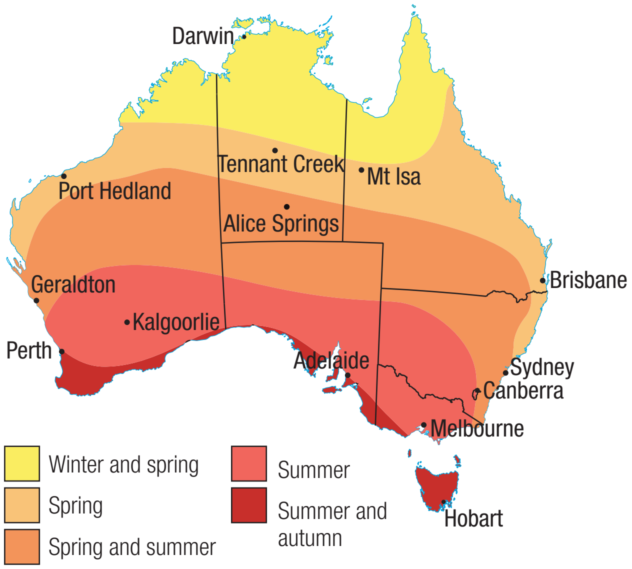


Fig 6.1.8 Bushfires strike different parts of Australia at different times of the year because of the very different climates and seasons experienced in the north and south—summer is wet and humid in the north while it is hot and dry in the south.

The effect of bushfire

Bushfires dramatically affect the ecosystems through which it burns. The effect of bushfire is determined by:

- how often a bushfire occurs—Areas hit frequently by bushfires either do not recover or take a long time to do so. This can change the type of plants living there. For example, frequent bushfires will permanently destroy forests of mountain ash, which is a type of eucalypt or gumtree. Mountain ash produce seeds only after many years. They need time to recover from a fire and will survive only if bushfires are rare. Frequent fires would change the habitat by allowing other trees to dominate. The types of animals that live there would then change, too.
- how intense or hot the fire is—Habitats with lots of ground vegetation experience very hot fires. In spring, vegetation is abundant and so spring bushfires tend to be very intense. Very hot fires scorch the soil and any seed in it, resulting in no new plants growing next season.
- how fast the fire moves through the area—Only surface vegetation would be burnt if the fire is fast, leaving the taller trees untouched. Choking weeds and scrub are burnt off, giving seeds from the trees light, nutrients and room to grow.

Science Clip

The most devastating of all

After 12 years of drought, Victoria was hit with its hottest summer ever with temperatures breaking all previous records. On Saturday 7 February 2009, bushfires swept across much of the State, trapping and killing around 180 people, killing untold wildlife and destroying complete towns. Up to 2000 houses, schools, shops and businesses were burnt down, leaving 8000 or so homeless and many more unemployed. One scientist has estimated that temperatures in the firestorm reached an incredible 1400°C.

Fig 6.1.9 Burnt houses and cars after the firestorm of 7 February 2009.

Fig 6.1.10 Australian ecosystems have been shaped over millions of years by bushfires.

Bushfires, animals and plants

Many native plants and animals have developed specialised ways to survive these unpredictable infernos.

- Highly mobile animals, such as kangaroos and birds, can move to safety and are likely to escape approaching fires.
- Slower animals, such as wombats, echidnas, reptiles and amphibians, may burrow underground or shelter under rocks.
- Banksias, hakeas, some acacias and many eucalypts need the heat generated by a fire to break open their seed pods. These plants usually reproduce rapidly following a bushfire.
- The silver and blackwood wattles, as well as some other plants, regrow from root suckers, even if the plant above the surface was destroyed.
- Treeferns, the narrow-leaf peppermint gum and many other eucalypts, have thick protective bark. These plants regenerate their lost foliage from tiny **epicormic buds** hidden in a layer beneath the bark.

After a fire passes through, the animal population drops initially. Foliage has been destroyed, leaving little food and shelter for the survivors. The habitat slowly begins to regenerate, but what it will look like depends on the type of plants and animals that live there and the rate at which they reproduce. Growing plants also require more water than mature plants. If regeneration is to happen, then good rains need to follow the bushfire.

Worksheet 6.1 Bushfire intensity

Science Clip

Burn outs

It often appears from the media that most bushfires are lit deliberately. Although arson is a major cause of fire, lightning is just as bad. About 26 per cent of bushfires are caused by lightning, 25 per cent by arson, 16 per cent were caused by fire escaping from controlled burning on farms, 10 per cent from campfires, seven per cent from dropped cigarettes, three per cent from machinery sparks, two per cent from escapes from controlled burning in bushland and 12 per cent from unknown causes. In the past, Aboriginal hunters sometimes set fire to the bush deliberately. This reduced tree cover and produced more grazing pasture for kangaroos, which could then be hunted for food.

Flood

Australia is a very flat continent with few established river systems. Tropical cyclones dump up to 1000 millimetres of rainfall within a few days, often causing major flooding, untold soil erosion and most animals in the area to die. Floods can, however, bring later benefits to an ecosystem by:

- replenishing its ground and soil water
- allowing water-dependent species, such as fish and pelicans, to breed
- helping to regenerate long-lived and slow-reproducing trees living in arid biomes.

Generally, the cyclone season (i.e. summer and early autumn) brings floods to northern Australia. In southern Australia, flooding occurs most often during winter and spring.

Although they are a long way from Australia, ocean currents travelling along the Pacific coast of South America influence Australia's weather patterns. During **el Niño** (pronounced 'ninyo') these currents are particularly warm, rainfall in Australia is rare and drought results. During **la Niña** (pronounced 'ninya') the currents are unusually cold, rainfall is high and flooding is likely.

Science Clip

Mega-flood!

Lake Eyre in South Australia is fed by the outback rivers of Queensland. Normally it is empty. In 1973–74, it flooded and covered an area of more than 390 000 square kilometres to a depth of 10 metres. This is equivalent to about half the area of New South Wales!

Fig 6.1.11 Floods cause more large-scale damage than any other natural disaster.

Drought

Although floods and bushfire bring rapid changes to ecosystems, drought creeps up over a number of years. Although farmers are the first affected by times of drought, everyone in the community eventually suffers. Food items become scarce and prices soar, and water restrictions can be introduced. As plants die, erosion increases and dust storms become more frequent. Wildlife has little food and struggles to survive. They may not reproduce or give birth to only small litters.

In a wet country like the United Kingdom, 14 days without any rain is considered a drought. This definition would be ridiculous in a dry continent like Australia. Here, a region is considered to be in drought if it receives 10 per cent less rainfall than the lowest ever recorded.

Science Clip

Drought kills nearly ten million!

A total of 9.5 million people died of starvation in China in the drought of 1877–78.

Causes of drought

Drought is largely due to changes in global temperatures. These are influenced by currents in the ocean and in the gases of the atmosphere, and the melting and movement of masses of ice in the Arctic and Antarctic. Australia experiences below-average rainfalls during years of el Niño and experiences above-average rainfalls in years of la Niña.

Fig 6.1.12 Very little water, food or shelter are available during a drought. Many animals do not survive.

6.1 QUESTIONS

Remembering

1 **List**:
   a five different types of biomes found in Australia
   b four habitats that might be found in a tropical rainforest
   c three biogeographical regions in Australia
   d two microhabitats in a tree.

2 All tropical biomes have similar characteristics. For a tropical biome, **list**:
   a three non-living characteristics
   b two living characteristics.

3 For a desert biome, **name**:
   a three habitats
   b two microhabitats in a tussock of grass.

4 **Recall** the damage caused by bushfires by matching the type with its most likely damage.

fast	few new plants grow
intense/hot	changes type of tree growing
frequent	weeds burnt off, new trees grow.

5 For each of the following, **state** two ways that:
   a animals survive bushfires
   b plants survive bushfires.

>>

6 **State** two benefits and two disadvantages of flooding.

7 **Recall** the causes of drought by matching the term with its correct description.

la Niña	bring drought
el Niño	brings flood.

Understanding

8 **Define** the following terms:
- **a** ecosystem
- **b** community
- **c** biotic
- **d** abiotic.

9 **Explain** how camels can live successfully in the desert of Australia, despite not originating there.

10 **Describe** how bushfire can assist plant species to survive.

11 Drought can be considered the worst of the natural hazards. **Outline** some consequences of drought.

Applying

12 **Identify** which of these terms best matches each of the following places:

Clarence Gorge, NSW	biosphere
Australia	habitat
planet Earth	biome
Clarence River	microhabitat
under a rock in the river	New South Wales.

13 **Identify** each of these levels in your own address. The first level is done for you.

biosphere	planet Earth
biogeographical region	(Hint: Your country)
biome	(Hint: Your city)
habitat	(Hint: Your street)
microhabitat	(Hint: Your house or apartment number).

14 A letter addressed to a kowari might look like that shown in Figure 6.1.13 on the right.

For the kowari, **identify** its:
- **a** microhabitat
- **b** habitat
- **c** biome
- **d** biogeographical region
- **e** biosphere.

15 **Use** the information given below and the map in Figure 6.1.4 to **propose** two other areas in the world in which each of these animals could live comfortably.
- **a** camels (native to the deserts of the Middle East and now wild in Central Australia).
- **b** bears (different varieties of bear are commonly found in cold, temperate coniferous forests).

16 **Use** Figure 6.1.8 to **propose** when bushfire is most likely to occur in:
- **a** outback NSW
- **b** Sydney and the south coast
- **c** the north coast of NSW.

17 **Explain** why different regions in New South Wales have different bushfire 'seasons'.

18 **Identify** which organisms are most likely to survive a flood.

19 It is estimated that flood damage costs Australians over $400 million a year, and is the costliest form of natural disaster. Apart from erosion and animal loss, **describe** other damage caused by floods.

Analysing

20 **Classify** the following as either biotic or abiotic components of the environment:
- **a** flowers
- **b** thunderstorms
- **c** beetles
- **d** northerly winds
- **e** mushrooms.

21 The conditions and water found in oceans, rivers, lakes, dams and a fish tank are all very different. **Compare** and **contrast** these four water environments.

Evaluating

22 **Propose** reasons why organisms living in the same type of biome have similar characteristics.

23 **Propose** ways in which animals, such as the kowari, survive the hot dust storms that often whip across the desert.

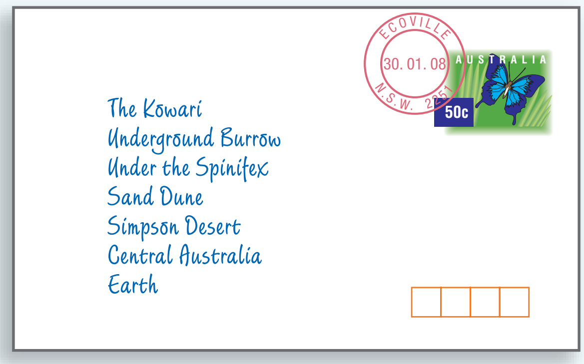


Figure 6.1.13

>>

24 Year 8 students at two high schools, class A in Broken Hill and class N in Newcastle, were asked to record the amount of rainfall that fell from 1 May to 1 October. Class A recorded less than 90 mm of rain, and class N recorded 300 mm of rain. **Assess** whether the vegetation around Broken Hill and Newcastle would be the same or different and **justify** your answer.

25 When adult salmon have laid their eggs, they die. This is essential if the 'fingerlings' are to survive. **Propose** a reason for this.

26 The water in a fish tank must be kept fresh. To ensure its freshness, about 70 per cent of the water must be replaced every few weeks. **Explain** why it needs to be replaced and why 30 per cent of old water is left behind.

Creating

27 Accurately **construct** a pie chart, showing the causes of bushfires in the past 20 years. N

28 Tell the story of 24 hours in the life of a kowari from the kowari's perspective. Ensure you **describe** and **explain**:
- what your is home like
- what you eat
- the other animals with which you come into contact
- any adventures you get up to.

Present your story as a piece of writing, a puppet play or as selected pages from a child's picture book.

6.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Research a particular biome such as Mt Warning, NSW or Carnarvon Gorge, Qld. Find:
- at least one photo of the biome
- what animals, plants and microbes live there
- what different habitats might be found there
- who eats who and what
- what is its non-living environment, such as climate, soil etc.
- where in Australia these biomes exist
- where similar biomes exist elsewhere in the world.

Present your findings as a Word document with hyperlinks to websites, a PowerPoint presentation or as a poster. L

2 Find out about a major flood, bushfire or drought that hit Australia in the past 30 years. Research:
- when and why it happened
- how the plants and animals in the area were affected
- what it did to people's homes, farms, businesses and lives
- any evacuation that took place
- how long it took the area to recover
- any factors that changed the way the disaster proceeded.

Present your findings as a map with attached comments and labels.

3 Research burn treatments, such as spray-on skin, which was first used successfully on victims of the Bali terrorist bombings in 2002. The Australian Red Cross Blood Service and Queensland University of Technology (QUT) are investigating this method as a possible treatment for bushfire burn victims. Find:
- how the treatment is carried out
- the benefits for the victim
- any problems associated with it.

Present your work as a poster or a web page for the Red Cross or QUT. L

6.1 PRACTICAL ACTIVITIES

1 Your local ecosystems

Aim

To investigate a local ecosystem

Equipment

- digital camera

Method

1. Carefully inspect a section of your own backyard, school grounds or park.
2. Write down:
   a. what plants and animals live there
   b. what their water requirements are
   c. the availability of water (i.e. how can they get water)
   d. what the soil they live in or on looks like (i.e. sandy, clay etc.)
   e. how the plants there interact with each other.
3. Use the digital camera to record any features of the ecosystem that you find interesting.

2 Mould ecosystems

Aim

To grow mould in a 'mini-ecosystem'

Equipment

- six slices of bread (or cut slices into six pieces)
- six resealable plastic bags or cling-wrap

Method

1. Dampen three slices of bread by sprinkling a little water on them.
2. Seal the slices, wrapping each individually in cling-wrap or placing one slice in each resealable plastic bag.
3. Place one in sunlight, another in a dark cupboard and another in the refrigerator.
4. Wrap up or seal three dry pieces of bread. As before, place one in sunlight, another in a dark cupboard and the third in the fridge.
5. Inspect each bag each day over the next week.
6. Record your observations in an appropriately designed results table.

Questions

1. **Identify** which slice(s) grew mould.
2. **List** them in order from the one that grew none or only limited amounts of mould to the one that grew the most.
3. Is mould an organism? **Justify** your answer.
4. Each bag represents an ecosystem.
   a. **List** the biotic factors in the ecosystem.
   b. **List** the abiotic factors.

3 Constructing a mini-biome

Aim

To build a model of a biome

Equipment

- PET bottle or aquarium
- variety of plants
- soil, worms etc.

Method

1. **Design** your own mini-biome that can be placed in an aquarium or a PET bottle. Select a variety of organisms (e.g. mosses, small plants, mushrooms or fungi, earthworms etc.). Ensure that air can enter the mini-biome.
2. Construct your mini-biome and make observations over a number of weeks.

DYO

Unit 6.2 Being suited to your ecosystem

context Organisms have certain features, or **adaptations**, that fit them into their ecosystem perfectly. These adaptations allow them to cope with the environment found there, allow them to find sufficient food and to avoid being eaten. This gives them the best chance to survive, mature and reproduce. Adaptations also allow organisms to cope with daily and seasonal changes in the ecosystem, changes caused by other organisms as they migrate in and out, and random but dramatic changes caused by bushfires, flood or drought.

Fig 6.2.1 Day becomes night and summer becomes autumn—organisms must be able to survive changes in their ecosystem.

The effect of the environment

The type of organisms that inhabit an ecosystem depends on the **environment** found there. 'Environment' refers to everything that surrounds an organism. It can be categorised as either a land (**terrestrial**) environment or a water (**aquatic**) environment. Whatever the environment, its ability to sustain life depends on certain factors that can be classified as either non-living (**abiotic**) or living (**biotic**).

The non-living environment

The type of animals that inhabit an ecosystem depends on the plants found there. Plants are very sensitive to soil conditions and the quality of available water and air. The type of plants found in an ecosystem and the animals they support depends on a variety of non-living or abiotic factors.

How hot is it?

Biological processes, such as photosynthesis, respiration and reproduction, need the right temperature in which to happen. When living things get too hot or too cold, they do not function properly.

Science Clip

Hot night life

Daytime temperatures can reach 50°C in the Australian desert. It's too hot for most animals and so they spend their days sleeping in a cool shelter, making the daytime desert look deserted. These animals come out only in the cool of the night to feed, play and mate. Some humans living in hot climates do something similar—the Spanish, Portuguese and Mexicans traditionally have a siesta during the hot afternoons, rising again in the cool evenings.

How bright is it?

Light allows plants to carry out **photosynthesis**, the process by which plants make their own food. On land, light is readily available. In a water environment, however, most of the light is reflected at the surface. Only a small percentage of light (i.e. the green and blue colours of the spectrum) penetrates to any depth. This is called the **photic** zone and is where seaweeds, kelp and coral grow and where most fish live. No plants are found on the deep, dark ocean floor. This is also the reason why plants are generally not found in caves on land.

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How damp is it?

Humidity is the amount of water vapour that is in the air. The amount of water lost from an organism depends on the humidity. The air is very humid in tropical biomes and so plants and animals lose little water to the environment. In contrast, the dry air of desert biomes causes its organisms to lose a lot of water. Any plants or animals living there must have features that will help them retain as much water as possible.

How much oxygen is there?

The amount of oxygen in the air decreases when climbing a mountain, as well as when going deeper and deeper underwater. Fast-moving water has more oxygen than still water. Under the soil, oxygen content depends on the size of soil particles and the spaces between them.

Fig 6.2.2 Seaweeds are usually found only in the photic zone, near the surface. Here it is bright and photosynthesis will work best.

Fig 6.2.3 The fast-flowing water in creeks and rivers has higher oxygen content than stagnant water in swamps.

How acidic is it?

Plants have a preferred soil **acidity** in which they like to live, as do organisms that live in water. Some plants prefer acidic soil (e.g. azaleas, rhododendrons, cabbages, beans, peas and silverbeet), whereas some prefer a more alkaline soil (e.g. most annual flowers like pansies). Acidity is measured using the **pH scale**.

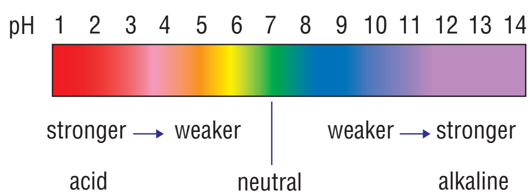

Fig 6.2.4 The pH scale measures acidity—pH 7 is neutral.

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Science Clip

A wee lemon tree

Most citrus plants like an acidic soil and one way of making it acidic is to wee on it! Lots of wee and the tree will probably produce lots of lemons. Wee on its leaves and the acid will burn them.

Fig 6.2.5 The albatross is a bird that lives near the sea. It has special salt glands that are situated on its head above its eyes. They are connected to the nostrils and remove any excess salt the bird consumes. The salt runs out of the nostrils and down grooves in the side of the beak, finally dripping off the tip.

How salty is it?

Salinity measures the saltiness of a landscape. Organisms in freshwater are very different in the way their bodies function compared with those living in a marine environment. On land, the salinity of the soil or the ground water beneath the surface will decide which plants will survive.

Is it nutritious?

Plants require **nutrients** in the form of minerals and trace elements. Carnivorous plants live in areas that lack nutrients, getting them instead from the bugs they trap and dissolve.

Fig 6.2.6 The pitcher plant, sundews and the Venus fly trap get their nutrients from the bugs they catch and dissolve.

Is it sea or land?

The intertidal area is the space that lies between high and low tides. It is exposed to air at low tide and is completely submerged at high tide. Whatever lives here must be able to survive both conditions.

Are there currents?

Plants in areas buffeted by strong wind or water currents must have strong root systems to support them.

Fig 6.2.7 Waves and strong currents and tides would easily cause shellfish, such as oysters and mussels, to wash off their rocks if they could not 'grip' them so tightly.

The living environment

Where an organism lives is influenced by a variety of biotic factors. These factors include all the other plants and animals with which the organism has either direct or indirect contact. This interaction might be beneficial for the organism. Sometimes it isn't—it might get eaten!

Is there any competition?

Animals living in the same area might have the same food or nesting requirements and will then need to compete for them. Plants must compete with each other for light, moisture and soil nutrients.

How will seeds spread?

Although animals are free to move about an ecosystem, plants rely on the wind, insects or animals to **disperse** them, allowing them to reproduce. Their flowers and seeds are often shaped to help them with this process.

Fig 6.2.8 A bee collects pollen and transfers it from one plant to another, assisting the plant to reproduce.

Fig 6.2.9 A coconut is a big seed that can float a long way because of its size and buoyancy. Wind and currents can blow coconuts to new continents and islands.

Eat or be eaten?

Predation is when one animal eats another. **Predators** hunt other animals for food. Their **prey** will be eaten.

Are humans involved?

Human intervention is one of the most influential factors on the environment. Land clearing, crops, plantations, cities, roads, and soil, air and water pollution all dramatically affect ecosystems.

Adaptations

Living organisms face different life-threatening situations every day. Those that cope best will survive the longest and will be more likely to reproduce, ensuring the survival of the species. This is often known as 'survival of the fittest'. Characteristics that allow an organism to survive are called **adaptations**. Adaptations can be classified as physical, functional or behavioural.

An organism will thrive in its own ecosystem because of its adaptations. King penguins, for example, are perfectly adapted for the pack-ice on which they live in Antarctica and in the freezing waters that surround it. Oily feathers and a good layer of blubber protect them from the cold and they huddle together in huge flocks to conserve warmth in the depths of winter.

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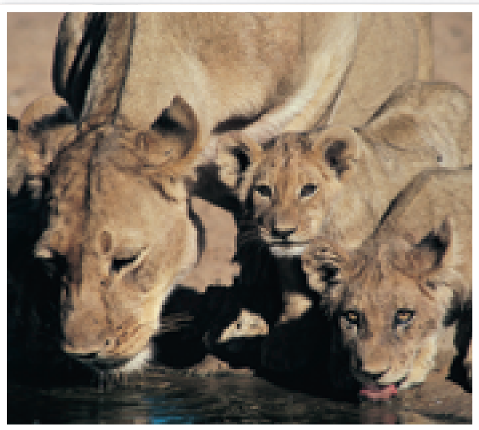
Fig 6.2.10 Some flowers are used in the perfume industry because of their wonderful scents. The *rafflesia* is not one of them… it has a scent of rotting meat!

Science Clip

Stinky flowers

Most flowers smell sweetly to attract bees and honey-eating birds. The giant *rafflesia*, however, has huge flowers, weighing up to seven kilograms, which emit the fragrance of rotting meat to attract the flies necessary for its pollination. It is a parasitic plant that lives on other climbing plants in the forests of South-East Asia.

Fig 6.2.11 Predators eat prey.



Behavioural adaptations

Behaviours can be instinctive or learnt. Animals and people instinctively curl up against each other when it's cold and seek shade when it's hot. Lion cubs learn hunting by watching their mother stalk and catch prey.

Functional adaptations

The internal workings of an organism must suit the ecosystem and environment it lives in. For example, the enzymes in an animal's digestive tract must suit its food source. Vultures have enzymes specialised for the rotten meat they scavenge.

Physical adaptations

The colour, shape, size and structure of an animal's body could mean survival or not. The echidna has feet perfect for burrowing and spines to deter predators.

Fig 6.2.12 Physical, functional and behavioural adaptations

Flipper-shaped wings allow them to move easily through the water and enzymes in their bellies allow them to digest the fish they catch. The dark colouring on their back makes it difficult for predator birds to see them from the air. Likewise, their white bellies make it difficult for sea lions to see them from below when swimming.

Take these penguins to a rainforest and they will soon die—their adaptations will cause them to overheat and to starve. Here, however, lives another flightless bird, the cassowary. Its adaptations (i.e. colouring, long legs, beak shape etc.) perfectly suit it to the rainforest and its diet (i.e. fallen seeds, shoots, roots, fungi and ground insects) but not to the Antarctic.

Worksheet 6.2 Whodunnit?

PP Drag-and-drop

Science Clip

Why have national parks?

The Royal National Park south of Sydney is the second oldest national park in the world. Only Yellowstone National Park in the United States is older. Nowadays, we think of national parks as a way of protecting fragile ecosystems. In 1886, however, the Royal National Park was thought of as a 'metropolitan pleasure ground' where 'experienced picnickers could forget the labours and worries of town' and 'take their leisure and recuperate with intellectual activities, such as sketching, photography and botany'.

Fig 6.2.13 Penguins are perfectly adapted to their Antarctic ecosystem, just as cassowaries are perfectly adapted to their tropical rainforest ecosystem. Swap their ecosystems and they will soon die, their adaptations working against them.

6.2 QUESTIONS

Remembering

1 **Recall** basic definitions by matching the word with its best description.

a aquatic	**i** where light gets to
b terrestrial	**ii** water vapour in the air
c abiotic	**iii** measures acidity
d biotic	**iv** carried out by green plants
e photosynthesis	**v** between high and low tides
f photic zone	**vi** gets eaten
g humidity	**vii** water-based
h pH	**viii** living factor
i salinity	**ix** kills to eat
j intertidal	**x** land-based
k predator	**xi** amount of salt
l prey	**xii** non-living factor

2 **State** whether the following statements are true or false:

a The colour of the background on which an organism lives (e.g. a rock face) is an example of an abiotic factor.

b The amount of nutrient in the soil is an abiotic factor.

c A parasitic worm is responsible for a condition known as elephantiasis in humans. The human being is part of the parasite's biotic environment.

d Koalas and magpies living in the same tree are competitors.

3 As a human, you are affected by many factors of the ecosystem in which you live. **List** three:

a abiotic factors that affect you

b biotic factors that affect you.

Understanding

4 Copy each of the following statements, and **modify** any that are incorrect:

a The non-living factors that influence where an organism can live are called biotic factors.

b The more saturated the air is with water, the less humid it is.

c On land, the percentage of oxygen in the air increases with altitude.

d Water that flows quickly has less oxygen than water that is still.

5 **Explain** why it is important for an organism to reach maturity.

6 African finches and Australian finches have similarly shaped beaks. Australian finches eat a variety of seeds.

a **Predict** the type of food you would then expect African finches to eat.

b **Describe** their habitat.

7 Rivers drain into the sea. **Explain** why fish living in the sea cannot be found in the rivers.

Applying

8 **Identify** a physical adaptation that allows the following animals to survive in their environment:

a echidna

b honeyeater

c penguin

d tiger

e dolphin.

9 The gut of an animal must be suited to the food they eat. **Identify** the type of food that these animals would need to be able to process in their gut.

a vultures

b cows

c kangaroos

d sharks

e dingoes.

10 **Identify** abiotic factors that would influence the following organisms:

a an orca (killer whale)

b a red-back spider

c a mushroom on a forest floor

d your family pet.

11 Mangroves grow in intertidal areas (i.e. areas that are exposed to the air at low tide, but are covered in sea water at high tide). **Identify** abiotic factors that will affect them.

Analysing

12 **Use** the pH scale in Figure 6.2.4 to **specify** what pH the following numbers represent:

a 7

b 6

c 2

d 9

>>

13 Use examples to **contrast**:

- **a** behavioural adaptation with a physical adaptation.
- **b** an instinctive with a learnt adaptation.

14 King penguins have many adaptations that allow them to survive in Antarctica. **Classify** them as physical, functional or behavioural:

- **a** Large numbers of penguins huddle together in winter.
- **b** Their webbed feet allow for faster swimming.
- **c** They have rounded bodies to conserve heat.
- **d** Chicks have soft, fluffy feathers.
- **e** Males incubate the egg under a fold of fat between their legs.
- **f** Stomach enzymes allow them to digest fish.

15 **Classify** the following as a physical, functional or behavioural adaptation:

- **a** Animals often spread out on a hot day.
- **b** Koalas have sharp claws.
- **c** Echidnas roll into a ball when threatened.
- **d** Camels have nostrils that can close.
- **e** Small prairie dogs only emerge in groups.

Evaluating

16 Elephants have very large, thin ears.

- **a** **Classify** this as a physical, functional or behavioural adaptation.
- **b** **Propose** the advantages that very large thin ears gives elephants in their ecosystem.
- **c** **Predict** what would happen if these elephants had small, thick ears.

17 **a** **Propose** reasons why farmers often alternate the growing of legume crops, such as peas or clover, with other crops.

- **b** **Justify** your answer.

18 Both desert cacti and alpine pine trees have long, needle-shaped leaves. This is an adaptation to limited water availability. Considering the high snowfall of many alpine regions, **propose** reasons for pine trees having such a characteristic.

19 The ‘tree line’ is an imaginary line at a certain altitude on a mountain beyond which no trees are found. **Propose** reasons for trees not growing beyond this point.

Creating

20 **Construct** diagrams showing the likely beak shape of the following birds:

- **a** South American humming birds sip on the honey at the base of long tropical flowers.
- **b** The little penguin (fairy penguin) rips apart the fish it catches.
- **c** The pelican can store the fish it catches for later consumption.
- **d** Spoonbills shovel up mud, sifting it for food and then spit the dirt out.

21 Imagine that you are a scientist who has developed a way to genetically engineer a ‘new’ animal—one that has a combination of different characteristics from a variety of animals. **List** the features of other animals that you would like to see in your ‘new’ animal. **Construct** your animal, as a model, diagram or collage of photos, or the **outline** of a story in which the animal you have engineered runs amok.

22 Bushwalkers tend to think that humans should not interfere with the environment. Instead, land developers say that it is important to use the land to provide homes and recreational facilities for people to enjoy. Those in the mining and timber industries insist that the land should provide the raw materials to meet the needs of technological progress. What is your opinion? **Construct** a written argument, **justifying** your position. L

6.2 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Research the life cycle of a frog and present your information as a poster aimed at people visiting a national park who want to learn more about its wildlife. On your poster: L

- **a** Describe the biotic and abiotic factors that influence the water phase of the life cycle
- **b** Describe how these factors change when the frog moves onto a land environment

>>

c Outline the characteristics that adult frogs display that enable them to move from water to land

d Explain whether the adult frog is able to leave its watery environment completely.

2 Research a national park or a major zoo. Find:
- a map showing its location
- a map of the zoo or park
- the animals that are there
- any special feature of the zoo or park (e.g. endangered species, special breeding program etc.)
- how the zoo or national park has changed over the years.

Present your information either as a debate about whether zoos are cruel or whether national parks should be wilderness, locked up so that people cannot enter; a pamphlet or website for the zoo or national park; or a story called 'If I could set up my own zoo'. L

3 Compare one of the following groups of animals:
- hoofed mammals. Are all hooves the same? How are differences in an animal's environment reflected in the type of hoof it has?
- big cat carnivores. How are the differences in the food they eat reflected in the size and shape of their bodies?
- ocean-going mammals. How are the differences in the food they eat reflected in the type of teeth they have?
- flightless birds. How are the differences in their environments reflected in the size and shape of their bodies?

Present your findings as a Word document. You must include a table comparing some of their features. L

e-xploring

Find out more about Australian ecosystems by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

PP Web Destination

a Select an Australian ecosystem and outline the abiotic features that exist in this ecosystem.

b Outline the biotic features of this ecosystem.

c Design a diagram or model of an animal to demonstrate its adaptations to surviving perfectly in this environment.

d Construct a key that outlines the main adaptations of your animal.

6.2 PRACTICAL ACTIVITIES

1 The effect of an abiotic factor on plant growth

Aim

To determine the effect of the amount of light on plant growth

Equipment

- six individually potted seedlings (These must be of the same species and at the same stage of development.)
- two covers—one should be **translucent** (i.e. allowing a small percentage of light through), whereas the other should be completely **opaque** (i.e. allowing no light through)

Method

1 Set aside two of the seedlings as control plants. Place these in a sunlit position.

2 Place two of the other seedlings under the translucent cover. Place the last two seedlings under the opaque cover.

3 Monitor the plants for at least one week. During this time, each seedling should be watered at the same time with a specific amount of water. (Be careful not to overwater the plants.)

4 Record your findings at the end of the specified time period.

Questions

1 **Justify** the use of more seedlings than required.

2 **Justify** why it is important that the seedlings should be of the same species and at the same stage of development.

3 **Explain** why the two seedlings that were set aside and given sunlight were needed.

4 **Design** an experiment to investigate other abiotic factors, such as the soil type, humidity, water availability and temperature.

2 Testing for soil acidity around the schoolyard

Aim

To test the acidity of the soil at various locations around the schoolyard

Equipment

- three or four test tubes
- distilled water
- three or four beakers
- glass stirring rod
- litmus paper
- filter paper (e.g. coffee filter paper)

Method

1. Collect samples of soil (each enough to fill a large test tube) from three or four different areas around the schoolyard. Label your test tubes sample 1, sample 2 etc. You could collect your samples from:
   - **a** under a pine or eucalypt tree
   - **b** from the middle of the playing field
   - **c** near a rubbish bin
   - **d** by the bicycle racks.
2. Place each sample into a beaker (label your beakers sample 1, sample 2 etc.), and add approximately 100 mL of distilled water.
3. Stir the sample for some time, until everything is well mixed. Allow the sample to settle.
4. Separate the water from the soil using a filter paper.
5. Test the acidity of the water using both red and blue litmus paper. (Note: Red litmus paper turns blue in the presence of basic substances.)
6. Record the results you obtained in a table. For example:

Sample number	pH value
Sample 1	6
Sample 2	

Questions

1. **Identify** a suitable control for this experiment.
2. **Explain** why distilled water was used rather than tap water.
3. **Use** the table in Figure 6.2.3 to **identify** the pH of each sample and **explain** whether it is acidic or basic.
4. **Account** for the results you obtained from your samples.

3 Instinctive or learnt?

Aim

To observe and classify behaviours

Method

1. Casually observe a pet over one week. The pet could be your own, your neighbour's or a classmate's.
2. Record 10 behaviours that they exhibit over the week.
3. Classify each behaviour as instinctive or learnt, justifying each choice.

Unit 6.3 Food chains and food webs

context

Plants are the only food source for herbivorous animals, such as kangaroos and emus, zebras and giraffes, rabbits and field mice. These, in turn, are the only food source for carnivorous animals, such as dingoes and foxes, lions and tigers, owls and kookaburras. Most of us humans are omnivorous, eating plants directly as salads, vegetables or fruit, or eating the meat, milk or eggs from herbivorous animals, such as cattle, sheep, pigs and chickens. In this way, plants are an essential part of every food chain for every creature on Earth.

Where energy starts

The Sun produces enormous amounts of energy, and some of it travels 150 million kilometres to reach Earth. Its energy arrives as:

- visible light, seen as the brightness of daylight
- heat (infra-red (IR) radiation), felt as warmth
- ultraviolet (UV) radiation that causes skin cancer
- gamma radiation, X-rays, microwaves and radio waves.

Fig 6.3.1 All animals eventually rely on plants for their food.

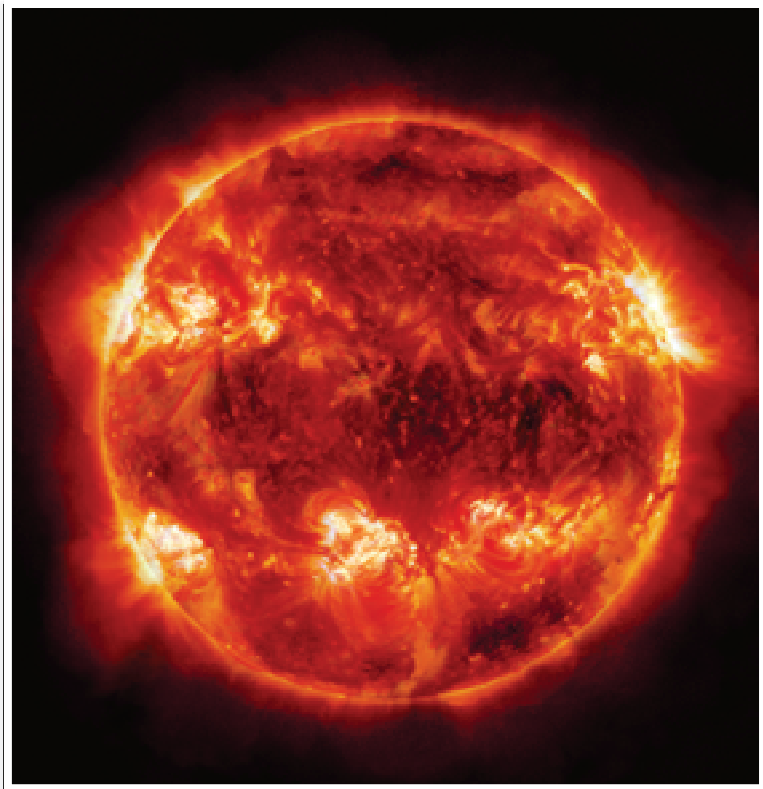


Fig 6.3.2 The Sun is the source of all food energy on Earth.

How plants get their energy

The energy in sunlight drives a process called **photosynthesis**. Photosynthesis occurs in plants, green algae and some microbes, converting light energy into a form that they can use for living. Photosynthesis combines carbon dioxide (CO_2) and water (H_2O) to make a type of sugar, called glucose ($C_6H_{12}O_6$), and oxygen gas (O_2). This process is best shown as a chemical equation:

carbon dioxide + water + energy → glucose + oxygen

$$6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Plants are referred to as **producers** (or **autotrophs**) because they produce their own food—glucose. Plants are then used as food by other organisms in the ecosystem. Plants also supply the ecosystem with vital oxygen.

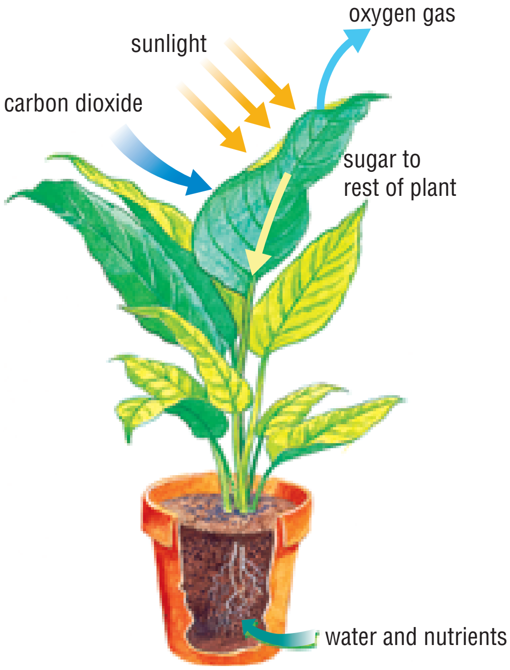


Fig 6.3.3 Chlorophyll makes a leaf look green. Sunlight is absorbed by the chlorophyll in a leaf, providing the energy required to convert the carbon dioxide (taken in through the leaves) and water (taken in through the roots) into glucose and oxygen gas.

How animals get their energy

Animals and some microbes can't make their own food. These organisms are called **consumers** or **heterotrophs**. Animals that only eat plants are called **herbivores** or **primary consumers**. Animals that eat other animals that eat plants are called **carnivores** or **secondary consumers**. Some eat plants and animals and are known as **omnivores**. Really large animals might eat other carnivores. These are known as **tertiary consumers**.

Fig 6.3.4 A herbivore (the gazelle) has become food for a carnivore (the crocodile).

Food chains and food webs

A food chain shows what a set of organisms in an ecosystem eat, with each organism acting as a link in the chain. Each link is called a **trophic level**. Food chains rarely have more than six links or trophic levels. Arrows connect each level and point in the direction in which the food is going.

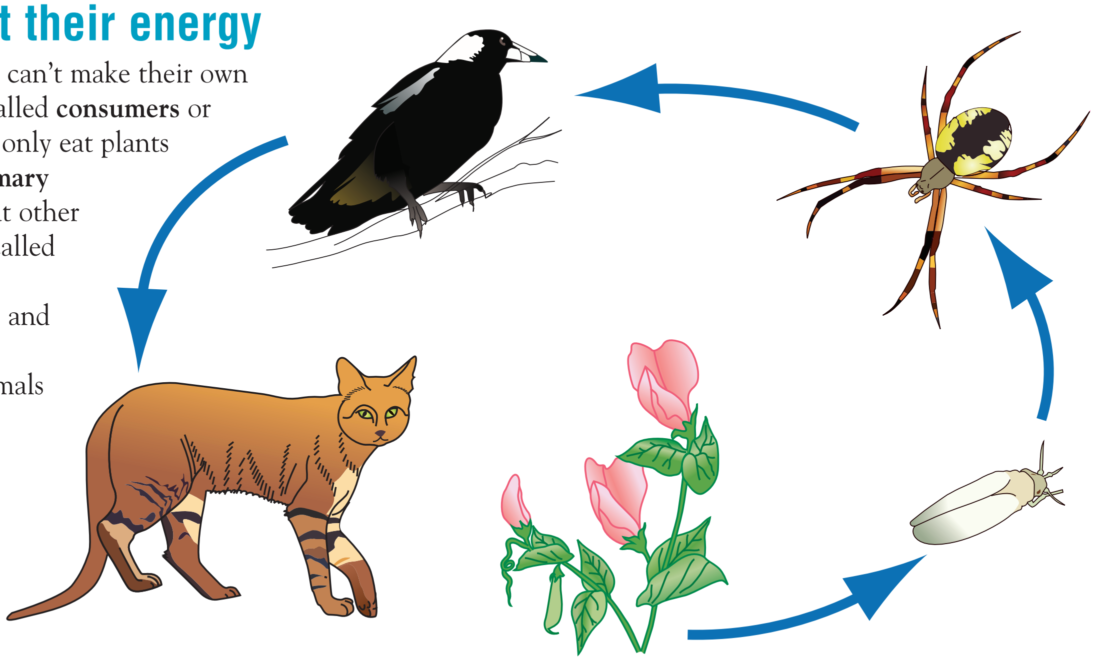


Fig 6.3.5 A simple food chain. Herbivores eat producers (i.e. plants) and carnivores eat herbivores or other carnivores.

Fig 6.3.6 Animals are more likely to survive a downturn in conditions if they have more than one source of food.

Animals usually eat more than one type of food and so there are usually multiple, tangled food chains in any ecosystem. For example, kowaris eat a variety of small mammals, reptiles, insects and plant material. Kowaris themselves are eaten by hawks, owls and even domestic cats. The interaction of several food chains is known as a **food web**.

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The flow of energy

Energy flows through an ecosystem from plants (producers) to herbivores (primary consumers) to carnivores (secondary consumers). Plants use only a small amount (approximately 0.2 per cent) of the Sun's energy that shines on them and only five to 20 per cent is transferred to the herbivores in the next level in the food chain. Hence, the number of plants in any ecosystem is always greater than the number of herbivores, which is always less than the number of carnivores. This is best represented in a food pyramid.

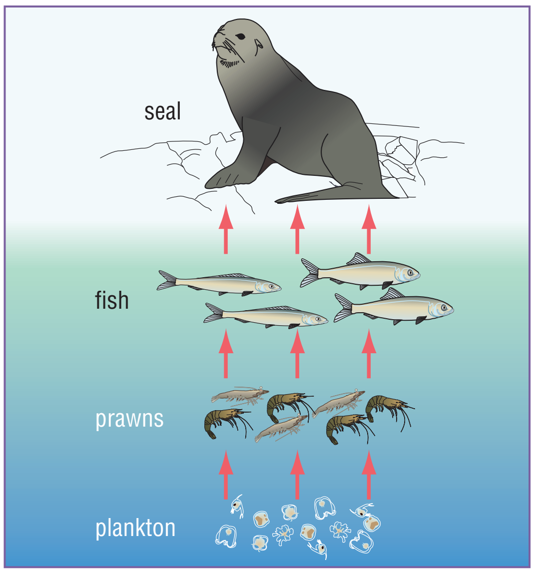

Fig 6.3.7 Hundreds of tiny plankton might be needed to feed just six prawns, which would be just enough to feed three fish, which would be just enough food for one seal.

Decomposers and detritivores

Organic matter comes from living organisms. It could be the organism themselves, their waste or their remains after death. Organic matter always contains the element carbon, C. **Decomposers** break down the dead bodies of plants and animals, recycling them and making their nutrients available once more for plants. Bacteria and fungi (e.g. mushrooms and moulds) are examples of decomposers.

Detritivores are animals that eat **detritus**, which is dead organic material in soil. Earthworms and dung beetles are detritivores.

Fig 6.3.8 Without decomposers like fungi, dead material would never break down.

Fig 6.3.9 Dung beetles eat poo!

Fig 6.3.10 High biodiversity means that many different plants and animals are living together in an ecosystem.

Biodiversity

Biodiversity refers to the number of different species present in a community.

Communities with high biodiversity survive environmental change well. If something destroys one of the organisms in the food chain. then the other organisms simply switch to other food sources. Communities with low biodiversity have little or no ability to switch to other food sources and may die off as a result.

If the herbivorous animals in a community eat only one particular plant species, then they will be wiped out if that plant species is wiped out by a disease or some other disaster. The carnivores that eat the herbivores would, in turn, be wiped out, too. If the herbivores had a variety of plants to choose from, however, they would probably survive the loss of one particular species.

Fig 6.3.11 Low biodiversity means that only a few different plants and animals live in an ecosystem.

Humans have reduced the biodiversity of many ecosystems. Natural vegetation has been removed and replaced by crops or forests of only one plant species. As a result, many species are now endangered or extinct. Pine plantations and fields of wheat and sugar cane, for example, have very low biodiversity.

Relationships between organisms

Organisms do not live on their own but interact with the other organisms in the ecosystem. Some interactions benefit both organisms, whereas other interactions benefit one organism while harming the other.

Science Clip

Better than a toothbrush

It was previously thought that sharks had to keep swimming in order to breathe. Recently, however, scientists have observed sharks resting on the ocean floor, with their mouths open. Why? They are having their teeth cleaned by lots of little 'cleaner fish'. Now that's a trusting relationship!

Benefiting both organisms

Mutualism (or **symbiosis**) is when both organisms benefit from their relationship with each other. For example, some sharks have their mouths nibbled by small fish. The fish get an easy meal and the sharks get their teeth scrubbed clean. Bees collect pollen for their hive, but they also spread it to other plants, allowing their reproduction.

Fig 6.3.12 Both the sea anemone and the clownfish benefit from their mutual relationship. Although the anemone has stinging tentacles that it uses to stun prey, the clownfish's slime coating prevents it from being stung and allows it to live among these poisonous tentacles, protecting it from predators, and feeding on the anemone's leftovers. In return, the anemone is cleaned of parasites by the clownfish.

Benefiting one organism

Commensalism is when one species benefits while the other species is unaffected. Remora are a tropical fish that attach themselves to faster-swimming fish, such as sharks. The sharks are not harmed by their presence, but do not benefit from it either. The remora benefit in two ways—they get a free ride and they consume any of the shark's 'leftovers'.

Harming one organism

Amensalism is when one species is harmed while the other species is unaffected. Trails throughout feeding areas left by cows and sheep may not affect the animals, but the plants they walk on are destroyed.

No benefit at all

Competition is when animals compete for food, water or nesting materials. Plants compete for nutrients, water and light. Weeds in the garden often crowd out other plants. They grow so quickly that other plants suffer and die.

Benefiting one organism, harming another

Exploitation is when one species benefits from the interaction while the other is harmed. This type of interaction could be:

- **Predation**, which is when one animal kills another for food. A seal catching a fish or a perentie lizard snatching a wallaby are examples of predation.

Fig 6.3.13 Sometimes juvenile fish hide among the tentacles of a jellyfish. Although the jellyfish does not benefit nor get hurt by the relationship, the fish gain protection from predators. This is an example of commensalism.

Science Clip

Hitching a ride

Sea anemones sometimes hitch a ride on the back of hermit crabs. The hermit crab is camouflaged and protected by the anemone, and the anemone gains mobility. Both benefit from the relationship.

Fig 6.3.14 Predators must kill to survive. This rock wallaby has just become food for the perentie lizard.

- **Herbivory**, which is when a herbivore eats a plant, reducing it in size but not killing it. This happens when kangaroos graze on grass, possums eat bottlebrushes or when dugongs feed on sea grasses.
- **Parasitism**, which is when one organism (the **parasite**) lives on or in another (the **host**). The host is usually not killed but is robbed of its nutrients, making it ill. Tapeworms are parasites that live in the gut of animals. Dogs and cats often have tapeworms if not treated. Humans sometimes have parasites, such as head lice and threadworms.

Worksheet 6.3 Energy in the community

PP Drag-and-drop

Science Clip

Eating from the inside out

Parasitoids are parasites that kill their hosts. An example of a parasitoid is the braconid fly, which lays its eggs inside the cabbage white caterpillar. When the eggs hatch, the fly grubs eat the caterpillar from the inside out!

Science Clip

Cooperative hunting

Humpback whales sometimes use a 'bubble net' to catch fish. Initially swimming below a school of fish, they begin to slowly spiral upwards, exhaling air as they ascend. This air forms columns of bubbles that surround the fish and keep them in a close-knit group, making it easier for the whales to feed.

Fig 6.3.15 Elephantiasis is caused by the filaria worm parasite *Wuchereria bancrofti*, a parasite of tropical countries.

6.3 QUESTIONS

Remembering

1 **State** what the abbreviations 'UV' and 'IR' mean.

2 **Name** the process represented by the word equation:

carbon dioxide + water + energy ⟶ glucose + oxygen

3 **Name** the simple sugar that is made by plants as food.

4 **Recall** food chains by matching these terms with their correct descriptions.

a herbivore	**i** makes its own energy
b producer	**ii** eats animals only
c carnivore	**iii** eats plants only
d omnivore	**iv** eats both plants and animals

5 **Name** a predator and its prey.

Understanding

6 **Describe** how people outside detect energy from the Sun.

7 **Explain** why green plants are referred to as producers.

8 **Explain** why food chains rarely have more than six links.

9 **Describe** how biodiversity can help a community to survive.

10 **Use** an example to **explain** the meaning of the following terms:

a mutualism

b commensalism

c amensalism

d competition

e exploitation.

>>

11 **Describe** a world without decomposers.

12 **Account** for the fact that the number of plants in an ecosystem is greater than the number of herbivores and carnivores.

Analysing

13 **Classify** each of these relationships as an example of parasitism, mutualism or commensalism:

- **a** tapeworm in the gut of a dog
- **b** the fungus that causes tinea between the toes
- **c** honey possums feeding on the pollen, spreading it as they move from tree to tree.

14 **Classify** the following as showing either high or low biodiversity:

- **a** the Daintree rainforest
- **b** a sugar cane plantation
- **c** a soccer field
- **d** the Great Barrier Reef.

15 **Compare** predation, herbivory and parasitism by listing their similarities and differences.

16 **Classify** the relationship between a dog and its fleas.

Evaluating

17 A scientist was determining the number of food chains present in several different areas. In area A, she found 10 different food chains. In area B, she found 50 different food chains. In which area would you expect to find the greatest biodiversity? **Justify** your answer.

18 **Propose** ways in which cooperative hunting can benefit a carnivorous species.

19 Two organisms of exactly the same species might require different quantities of food. **Propose** reasons why.

20 Are humans herbivores, carnivores or omnivores? **Justify** your answer.

Creating

21 **Construct** a likely food pyramid for the great white shark (i.e. white pointer).

22 **Construct** a simple food chain for a set of organisms that you might find in your own backyard.

23 **Construct** the likely food chain for the organisms shown in Figure 6.3.16.

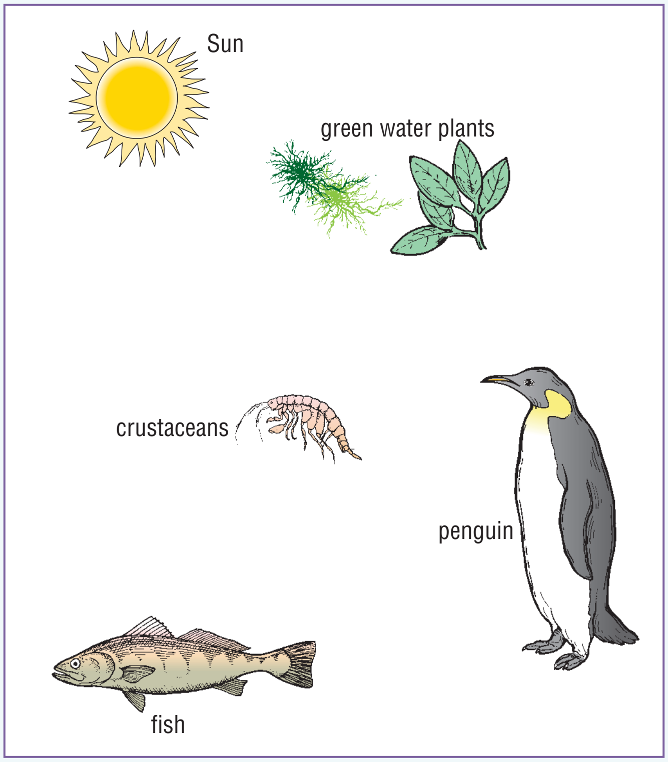

Fig 6.3.16

6.3 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 **a** Research an organism that uses a unique strategy to catch prey, such as the angler fish, which uses a 'lure' to entice its prey into striking distance. Other organisms, such as the praying mantis, are the same colour as their surroundings (i.e. they are camouflaged). Some, such as the killer whale and the hyena, work in a cooperative group.

b Summarise the information in the form of a magazine article of 1000 words with illustrations. L

2 **a** Research the many different biomes that dingoes occupy and the food chains they are a part of. They can, for example, thrive in the wet and dry tropics of Queensland; the arid and semi-arid region of Central Australia; the cool, coastal, mountainous region of south-east Australia; and the humid coastal mountains of eastern Australia. The food chain is different for each different biome.

b Summarise the information in the form of a film documentary or produce a series of food webs for each biome.

>>

3 a Find out about camouflage. Research:
- how camouflage is used as a survival tool and as a tool for hunting
- three organisms that use camouflage effectively to help them survive or succeed in hunting
- how humans camouflage
- the different types of camouflage used by the Defence Forces and the environments and situations in which they are used.

b Present your findings in one of the following forms:
- a poster
- a fashion page for *Defence News Weekly* (L)
- a front page story for a newspaper that is read by insects (L)
- a catwalk fashion show of camouflage used by the defence forces
- a video or series of photos that show how camouflage works in different environments.

e-xploring

Construct some examples of food webs by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

6.3 PRACTICAL ACTIVITY

1 A model food web

Aim

To construct an alien food web

Equipment

- different-coloured plasticine and/or playdough and modelling tools or different coloured pencils/Textas
- string or line

Method

1. Imagine you have just landed on an alien planet, on which there are plants and lots of different animals.
2. Construct or draw a food chain for the planet. It should include a plant, herbivore and various carnivores of different sizes and viciousness.
3. Connect the different organisms you have invented with string, indicating who eats what or who.
4. Squash or 'rub out' one of the organisms and determine what effect it has on the other organisms in the web.

   OPTION: Instead of simply constructing them, you might 'act out' each food web with your models, perhaps even filming it as a claymation.

Questions

1. **Define** the terms *producer*, *primary consumer*, *secondary consumer* and *tertiary consumer*. (L)
2. For each of your organisms, **identify** their trophic level in the food chain.
3. **Explain** why communities with a high biodiversity have a better chance of long-term survival than communities with a low biodiversity.

Unit 6.4 Energy crisis

context

Humans are just like all other animals—we need the energy from food to stay alive, to function in our environment and to reproduce. For these basics, we have about the same personal energy requirements as other mammals of about the same size.

Unlike other animals, however, humans expect much more out of life than just survival. These expectations have a cost. They need energy—huge quantities of energy.

Fig 6.4.1 The life we lead in Australia is a good one, but also one that uses a lot of energy.

More energy please

In Australia and other Western countries, people have come to expect all kinds of luxuries. We want heating and cooling, computers, TVs and iPods, and we want to be able to travel by car, plane, ship and train. These inventions make our lives more pleasant but they are not really essential. A lot of energy is used in their initial production and they use a lot of energy to run. These non-essentials have caused an energy crisis.

Energy can be categorised as coming from two main sources—**non-renewable** and **renewable**.

Non-renewable energy sources

The energy sources that cannot be replaced are referred to as non-renewable energy. Two important sources of non-renewable energy are:

- fossil fuels, such as coal, gas, crude oil and its products (petrol, diesel, kerosene and aviation fuel etc.)
- uranium and other nuclear fuels, which are used in nuclear power plants.

Fossil fuels

Fossil fuels are formed from dead organic matter, but not all dead matter forms fossil fuels. Very special conditions and millions of years are required.

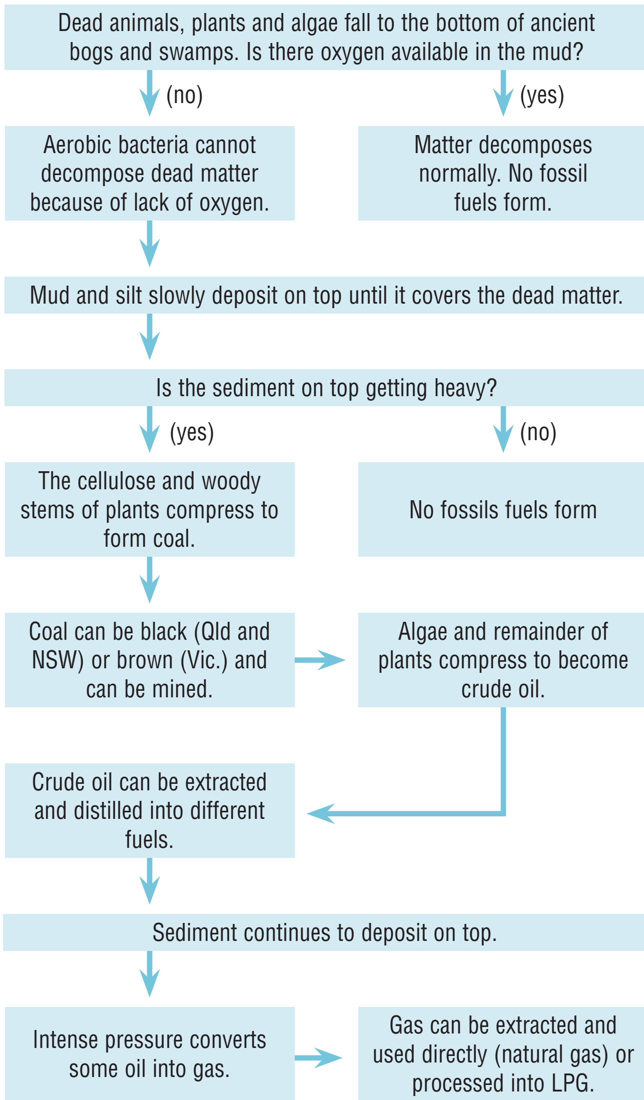

Fig 6.4.2 The conditions required to form coal, oil and gas are very specific and rare.

Fig 6.4.3 Most power stations in New South Wales are powered by black coal, one of the fossil fuels.

Fossil fuels have clear advantages over many other energy sources:

- They provide large amounts of energy when burned.
- They are relatively cheap.
- Coal is plentiful in Australia, is easily mined and provides export income.
- Oil is transported easily.
- Natural gas is an efficient source of heat.

Fossil fuels also bring with them some serious disadvantages:

- Burning them releases large quantities of pollutants, particularly the greenhouse gas, carbon dioxide (CO_2).
- They are non-renewable. Once used, they cannot be used again.
- There are limited world supplies of natural gas and oil. Australia has very limited supplies, making us very dependent on other nations.

Nuclear fission

Although still unable to be seen by the naked eye, uranium atoms are huge compared with most other atoms. In the centre of the uranium atom is a nucleus that contains protons and neutrons. When bombarded with other neutrons, these uranium nuclei split, forming a **fissure**. Enormous amounts of energy are released, far more than could ever be obtained from wood, gas or petrol. More neutrons are also released, which then go on to bombard other uranium nuclei, releasing even more neutrons and more energy. A **chain reaction** is under way. The process is referred to as **nuclear fission**.

The advantages of using nuclear fission to generate power are:

- Uranium provides massive amounts of energy that can be used to generate electricity.
- No greenhouse gases are emitted.
- Australia has large reserves of uranium ore, providing export income.
- Historically, there has been a low accident rate in nuclear power plants.

There are, however, serious disadvantages in using nuclear fission:

- Uranium is non-renewable. There are limited deposits and it will run out, although not for a long time.
- Nuclear fission produces wastes that remain radioactive for many thousands of years.

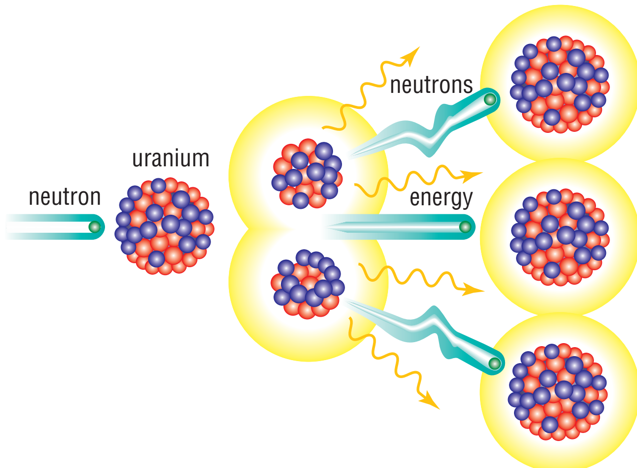

Fig 6.4.4 A chain reaction must be managed and regulated carefully, otherwise the power plant will suffer **meltdown** due to the immense heat released. During meltdown, the concrete and steel of the reactor and the Earth beneath the reactor begin to melt, releasing radioactivity into the air, soil and underground water table.

Science Clip

When things go REALLY bad

In 1979, steam caused a bubble to form in cooling pipes at the Three Mile Island nuclear reactor in the United States. Radioactivity was released into the air and the reactor suffered a near meltdown. In 1986, the roof of a nuclear reactor at Chernobyl, in the Ukraine, was blown off by a steam explosion. Winds dumped the radioactivity across north-western Europe. Much of the area around Chernobyl will be uninhabitable because of radioactive contamination for hundreds, possibly thousands, of years. People contaminated by the radioactivity will be affected for generations to come because of increased rates of cancers and birth defects.

- All methods developed for storing radioactive wastes have failed after only a few decades.
- Accidents pose a high risk of meltdown and the release of radioactive gases and water. Accidents involving uranium have the potential to be far more dangerous than those involving fossil fuels.
- Nuclear power plants pose a security and terrorist risk.

Nuclear fusion

Fission splits big atoms like uranium. **Fusion** is the opposite—it joins or fuses two hydrogen atoms together to make a bigger helium atom. Fusion needs huge amounts of energy to get it started, but it produces far larger amounts of energy when it happens.

There are advantages to using nuclear fusion to generate electricity:

- No toxic wastes are produced. There is no radioactive waste and no greenhouse gases are released.
- There is so much hydrogen on Earth that its supply is almost limitless. Four litres of sea water would supply enough hydrogen atoms to power the United States (the world's most energy greedy nation) with all its needs for one day!

Science Clip

A- and H-bombs

Atomic bombs, like the ones that destroyed the Japanese cities of Hiroshima and Nagasaki in 1945, use heavy fuels, like uranium or plutonium, and use nuclear fission to create their energy. H-bombs use nuclear fusion and release far more energy than an atomic bomb.

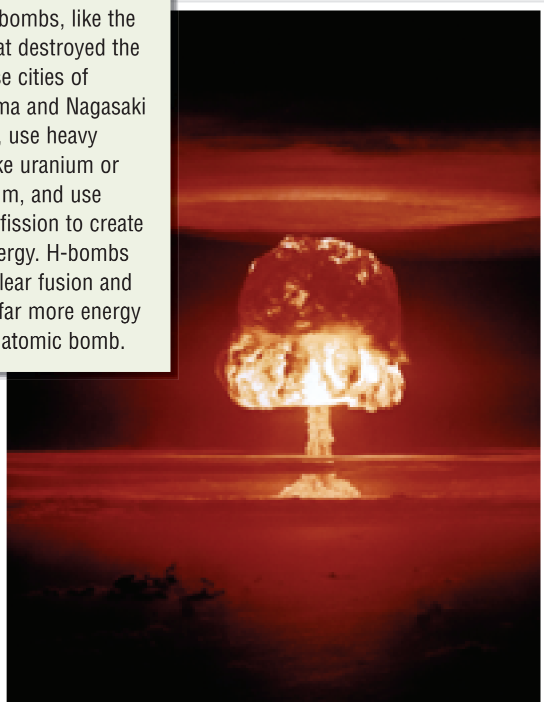

Fig 6.4.5 Hydrogen bombs have been tested many times but have never been used in war.

However, some serious hurdles stand in our way:

- Current technology cannot control fusion reactions. At this stage, fusion cannot be used to generate power safely.
- Uncontrolled fusion is the basis for the hydrogen or H-bomb.

Renewable energy sources

If the problems of global warming and depleted resources are to be averted, then alternative, practical and renewable sources of energy need to be found quickly. **Renewable energy** is energy that comes from sources that can be used over and over again, with minimal impact on the environment.

The main renewable energy sources are:

- energy from the Sun
- energy from the heat stored within the Earth
- energy from wind
- energy from water
- 'green energy'; i.e. energy derived from a variety of organic sources called biomass.

Solar energy

Green plants use the light energy from sunlight to carry out photosynthesis and stay alive. Reptiles bask in the sunlight, absorbing its precious heat. It seems silly, then, that solar energy is rarely used by humans. Although free and non-polluting, it is used only occasionally as a heat source or as a source of electricity.

There are many advantages to using solar power:

- Sunlight is free.
- The supply of sunlight is never-ending.
- Sunlight is plentiful in much of the world, particularly in Australia and in developing countries that lie near the equator.
- Solar energy is non-polluting.
- There are many different ways that solar energy can be used.

There are, however, some disadvantages:

- The actual manufacture of solar cells uses a lot of energy and releases toxic pollutants.
- The power produced is very weather dependent.
- Some countries would not be able to rely on solar power because of their position on the globe.

Science Clip

Oz... a great dump!

The geology of Australia is extremely stable. We suffer few earthquakes and some scientists have suggested that this makes us the ideal location for the storage of nuclear waste. Some have considered 'injecting' radioactive waste deep underground into stable beds of a rock called shale, effectively trapping it far beneath the Earth's surface. Another scientist suggested that nuclear waste be buried deep in Uluru!

- Large collectors are needed, which take up large expanses of land.

There are numerous ways in which the Sun's energy can be utilised.

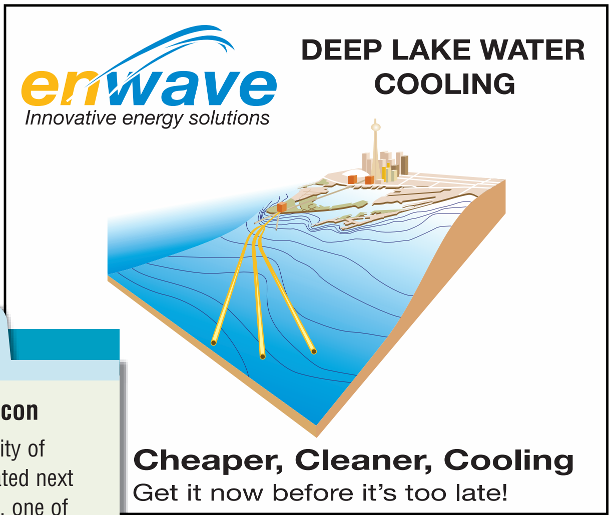

Fig 6.4.6 An energy-efficient way of cooling buildings

> **Science Clip**
>
> **Freezing air con**
>
> The Canadian city of Toronto is situated next to Lake Ontario, one of the Great Lakes of North America. Toronto has freezing winters and, although huge, the lake freezes over regularly. This incredibly cold water is being used to air condition many office buildings in downtown Toronto during their very hot summers. Pipes draw near-freezing water from deep in the lake and pump it through skyscrapers to cool them.

Passive solar use

Homes and offices can be built to be heated by sunlight. Windows, heat-absorbing materials and bodies of water can be placed strategically to trap and retain heat from sunlight.

Active solar use

Solar collectors can actively gather heat from the Sun, distributing it to where it is needed (such as hot-water systems or pool heaters) or by converting it into electrical energy.

Solar ponds

In a shallow pond, sunlight passes through the water to be absorbed by its base and sides. These gradually warm, as does the water in contact with them.

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Warm water rises and cool water drops, causing **convection currents** throughout the pond. These continue until the temperature of the pond is uniform throughout.

If salt is added, however, warm water will not rise. It stays at the bottom of the pond, leaving the top cold. Water pipes can be laid along the bottom of the pond and can be used to heat freshwater passed along them. The temperatures at the bottom of solar ponds can be as high as 107°C. This is hot enough to generate steam to turn turbines that generate electricity.

The Dead Sea is very deep, extremely salty and constantly bathed in sunlight. These conditions make it the ideal solar pond and Israel uses it to generate part of its electrical needs.

Solar cells

Solar cells, or **photovoltaic cells**, convert light energy into electrical energy. Solar cells have no moving parts to service and require no fuel. Solar cells now commonly power telephones, water pumps and lights in the outback, the snow and along country freeways. Solar cells are also used to power satellites and space probes—the original purpose for which NASA first developed them.

Fig 6.4.7 Solar cells are extremely useful in remote areas where it is too difficult or too expensive to install power lines.

Around the home, solar cells are sometimes used to power electronic toys, calculators, telephones, radios, solar hot-water heaters and garden lights. Unfortunately, the manufacture of solar cells is very inefficient. It uses a lot of energy and also produces toxic wastes. Solar cells are also very poor in storing the electricity produced.

On a larger scale, their use is limited by the number needed to generate the electricity requirements for even a small town—large areas of land would need to be covered to 'catch' sufficient sunlight.

Solar concentrators

The Winston tube concentrates light to intensities similar to that of the Sun's surface, enabling the generation of enormous quantities of cheap, non-polluting energy without the need for huge panels.

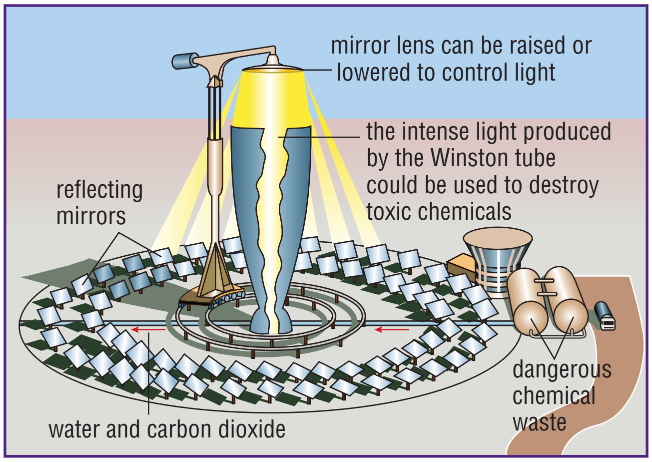

Fig 6.4.8 By 2010, it is hoped that the Winston tube will be in widespread use in countries where light is plentiful.

Fig 6.4.9 Computerised mirrors track the Sun and focus its heat and light onto the same point on the Winston tube.

Geothermal energy

A region of hot magma and molten rock lies below the Earth's crust. In most places, the crust is thick enough to insulate the surface from the intense heat below. At some points, however, the crust is very thin and hot magma is very close to the surface. New Zealand and Iceland, for example, lie on weaknesses called **fault lines**. Here, the crust is so thin that water often seeps down and becomes superheated. Full of steam, it then bursts from the surface as a geyser, hot springs or mud-pool.

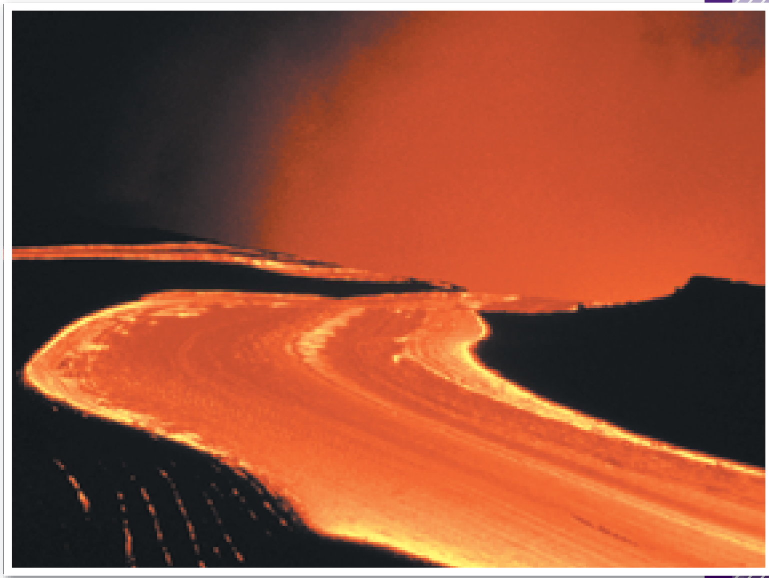

Fig 6.4.10 Geothermal energy is only practical in areas that lie on fault lines. It is here that the magma of the mantle is closest to the surface.

This natural geothermal energy can be tapped by pumping water deep underground. The steam released is then channelled into a turbine to produce electrical power.

Australia has few major fault lines and so only limited use can be made of geothermal energy. In South Australia, the Mulka cattle station has used it since 1987 and the Garden East Apartments have been using it since 1994. Funding has also been provided for a pilot plant in the Hunter Valley, NSW. Some regions of New Zealand produce up to 75 per cent of their energy needs from geothermal sources. Other countries that produce some power from geothermal energy production are the United States, the Philippines, Iceland, Russia, Mexico, Italy and Japan.

The advantages of using geothermal power are:

- immense amounts of energy are available
- geothermal energy never runs out.

Science Clip

Steamboat explodes!

The tallest geyser in the world is the Steamboat Geyser in Yellowstone National Park, USA, blasting water into the sky to an incredible height of 115 metres!

Nonetheless, there are disadvantages:

- Only a few countries (such as New Zealand, Japan, Iceland etc.) have fault lines where there is easy access to magma beneath the surface.
- Underground pressures change when water is extracted from or is pumped into rocks, making earthquakes more likely.
- Geothermal energy produces a number of gaseous pollutants, particularly carbon dioxide (CO_2), hydrogen sulfide (H_2S) , sulfur dioxide (SO_2) and methane (CH_4).

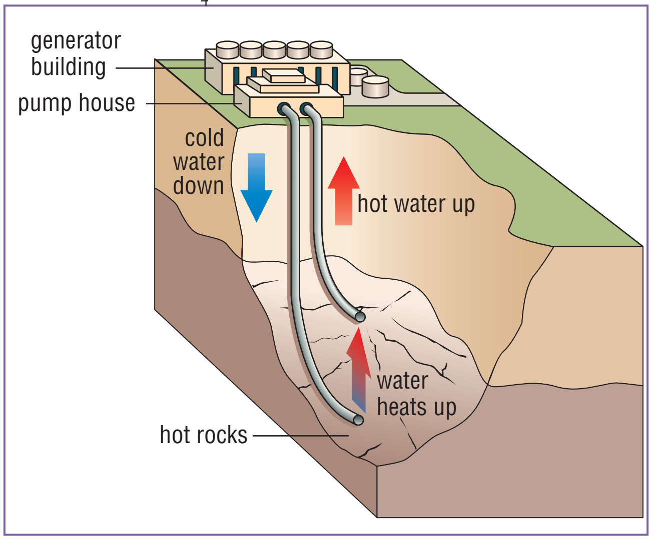

Fig 6.4.11 Geothermal energy uses the heat from the mantle to boil water to turn turbines that produce electricity.

Wind energy

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Global winds result when hot air rises from regions around the equator. Cooler air from the Poles rushes in to fill the gap left behind. These movements of air form global or trade winds.

Sailing boats and windmills have used the wind to power them for thousands of years. Wind turbines are the new generation of windmills. They convert the kinetic energy of moving wind into electrical energy, which is then used directly to run machines, is fed directly into the electricity grid or can be stored in batteries for later use.

The advantages of using wind are:

- The more wind, then the more energy produced. (As wind speed doubles, energy produced increases eightfold.)
- Wind energy is completely non-polluting.

Disadvantages are that:

- Wind needs to blow consistently and strongly for it to be of practical use.

Fig 6.4.12 Wind farms are already becoming a common sight along Australia's coastline.

- Each turbine is incredibly large and groups of them are needed to make them practical. The natural scenery is destroyed.
- Their blades are noisy as they cut through the air.
- The spinning blades can kill birds as they fly through. The coast is generally windy and therefore suitable for wind turbines, putting migratory sea birds at great risk.

Currently, New South Wales has four operating wind farms: Australia's first at Crookwell; another west of Bathurst at Blayney; Kooragang Island off Newcastle; and Hampton, near the Blue Mountains.

Energy from water

Energy can be produced using waves, currents, tides, falling water, and differences in salt content.

Hydroelectricity

Gravity pulls water downhill until it reaches the sea. As it falls, its **gravitational potential energy** can be harnessed by passing it through turbines that generate electricity. Electricity produced this way is referred to as **hydroelectricity**.

One way of producing hydroelectricity is to make a small volume of water fall from a great height. The Alps in Europe and the Rocky Mountains in the United States are ideal because they are so high. Although much lower, the Snowy Mountain Scheme in New

South Wales also generates power this way. This scheme consists of 16 dams, 145 kilometres of tunnels and seven power stations. It provides 50 per cent of Australia's hydropower. Another 30 per cent comes from the mountains in Tasmania.

Another way to generate hydroelectricity is to make a large volume of water fall from a much smaller height. Dams built on the Amazon River (Brazil), the Nile (Egypt and Sudan) and the Yangtze River (China) use this method.

Fig 6.4.13 Hydroelectric dams are a good source of renewable energy.

Hydroelectricity has many advantages. It is:

- a highly renewable source of energy
- pollution free
- able to respond quickly to demand during peaks of energy consumption
- relatively cheap.

There are disadvantages, however:

- Dam walls and the water they hold back result in large losses of useful farmland or natural bush and the habitats they contain.
- The water is no longer flowing and so the oxygen content in the water drops. Eventually, it drops to levels that are so low that normal fish populations cannot be sustained.
- Much of Australia is being hit with more frequent droughts, making rainfall less reliable and causing water flow from dams to be restricted.

Energy from the ocean

There are four methods currently available to produce electrical energy from sea water.

Ocean thermal energy conversion (OTEC)

Warm ocean water is pumped through a pipeline and is used to heat freshwater to boiling point. The steam produced then generates electricity. Although very suitable to the tropics, it is very expensive.

Osmotic pressure

Osmosis is the movement of water from a low salt solution (such as freshwater) to a stronger salt solution (such as sea water) through a semi-permeable membrane. This membrane allows water molecules to pass through it, but prevents the movement of salt particles. Japanese scientists have used osmotic pressure to generate large quantities of pollution-free energy. This method works only where there is a significant difference in salt concentration, such as a freshwater river flowing into the sea.

Wave generators

Waves are forced into a narrow gully, causing the air above them to rise and fall. This movement of air passes through a turbine to produce electricity. This method relies on the power station being situated on rocky cliffs, and therefore it has had limited usage.

Another method is to use floating wave generators. Various designs are currently being developed around the world, including one in Port Kembla, NSW.

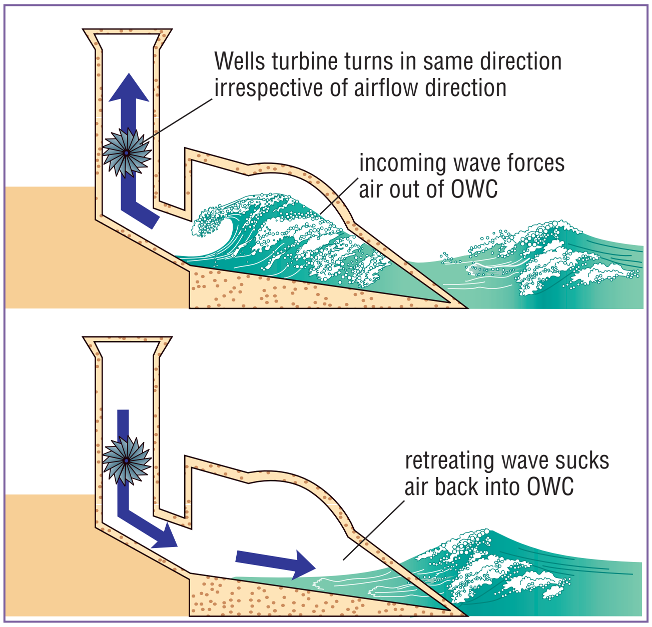


Fig 6.4.14 An oscillating wave column (OWC) generates energy using waves. Waves push air past a turbine, causing it to spin.

Tides

The daily movement of the tides is the only known renewable resource that is totally predictable.

A dam is built across a bay's entrance so that the incoming tide turns a turbine to produce electricity. At high tide, the water is trapped behind the barrier. At low tide the water is released, flowing once again through the turbine. The amount of energy generated is related to the size of the tides. Only a few countries, such as France, have tides that are large enough to currently use this technology. The northern coast of Western Australia near Broome would be ideal for this technology, although there is little need because of its low local population.

Science Clip

Curl up in compost

It's long been known that the insides of haystacks and composts are warm. Both are examples of biomass that release large amounts of heat energy as they decompose.

Biomass

Biomass is the term used to describe organic material, such as plants and animals, living or dead, or their wastes. It includes everything from wood from fallen trees or industrial processes to the faeces from humans and animals. The energy that is stored in biomass is referred to as **bio energy**.

Timber and crops

Timber is a renewable resource that can be burnt for heating and cooking, but it also takes time to grow. Many countries are now planting fast-growing trees that are suitable for coppicing. Coppicing harvests only the tree canopy and does not kill the tree. Every few years, the shoots that have sprouted from the stump can be harvested again. The roots of the trees also help to keep the soil together to reduce erosion.

Agricultural crops and their waste (e.g. sugar cane, corn, rice and wheat, and oil-bearing crops, such as sunflowers) can be converted into fuels like ethanol and bio-diesel. In Brazil, most cars run on ethanol processed from its huge sugar cane crops. In Australia, biofuel producers are receiving $37 million in subsidies to help reach the Federal Government's goal of producing 350 megalitres (i.e. 350 million litres) of renewable fuel production by 2010. However, there are those who do not agree that land and energy should be used to grow crops to fuel our cars rather than for food. Also, as less suitable land is then available for producing food crops, less food is produced, causing food prices to rise.

Waste products

For centuries people have used the manure from cows and camels as an energy source. In developing countries, they still do. Manure is first shaped into 'pancakes' or 'bricks'. They are then dried, stored and burnt when needed to provide heat for cooking.

In the developed world, more processed food is being consumed than ever before. The waste from this processing includes peelings, pulp, filter sludges, fibrous wastes and the water from the washing and blanching of food products. When combined with anaerobic bacteria, these wastes have the potential to produce the fuel ethanol.

Household waste can be burnt or placed in landfill. Anaerobic bacteria can then decompose the waste to generate **biogas** (e.g. methane (CH_4) and carbon dioxide (CO_2)), which is then collected and processed by special landfill gas plants.

Science Clip

Waste, nuts and poo

More than 80 per cent of collected household wastes each day is biomass (i.e. food scraps, garden waste, paper and plastic materials). A power plant in Queensland is producing electricity by using waste macadamia nut shells. This saves roughly 9500 tonnes of greenhouse gases being emitted!

On farms, pigs use only 50 per cent of the food they eat. The other 50 per cent is waste pig poo. At a pig farm near Ballarat, Victoria, this waste is being used to generate electricity.

Conservation

If everyone uses less energy, then less energy needs to be produced. The advantages of energy conservation are less pollution and less greenhouse gases being emitted. Our resources will also last longer.

Energy conservation is based on the three Rs:

1 Reduce

- Don't buy things that are not needed.
- Buy things unwrapped instead of wrapped.
- Reduce shower time. This saves energy AND water!
- Switch off electrical appliances and lights when not using them.

2 Reuse

- Switch to reusable bags for grocery shopping or reuse plastic bags.
- Think of another way of using things that would otherwise be thrown out.

3 Recycle

- Donate unwanted items to opportunity/charity shops or pass them on directly to someone who may be able to use them.
- Use council recycling programs.
- Put all vegetable and fruit scraps into a compost bin.

6.4 QUESTIONS

Remembering

1 **List**:
- **a** two non-renewable energy resources
- **b** four renewable energy resources
- **c** six different fossil fuels and their uses.

2 **List** three things that are required for organic material to become coal.

3 **Specify** what type of energy a solar cell produces.

4 **List** three countries that could use geothermal energy.

5 **List** agricultural crops that can be used to produce fuel.

6 **Name** the fuel produced from them.

7 **List** the three Rs of conservation and give an example of each.

Understanding

8 **Explain** why humans have greater energy requirements than a mammal of about the same size.

9 **Describe** what *meltdown* is and why and where might it occur.

10 **Explain** why the burning of fossil fuels is often associated with global warming.

11 A classmate cannot understand why coal and gas are called *fossil fuels*. **Explain** to him/her why they are.

12 Humans have used biomass as a fuel for many centuries. **Describe** how.

Applying

13 All of the following use water to generate electricity. **Identify** which method each is referring to:
- **a** OWC
- **b** differences in saltiness
- **c** warm ocean water
- **d** OTEC
- **e** water falling down a mountain.

14 **Identify** whether fission or fusion is involved in the following:
- **a** nuclear power plants
- **b** the atomic or A-bomb
- **c** the hydrogen or H-bomb.

Analysing

15 **Distinguish**:
- **a** nuclear fission from nuclear fusion
- **b** passive solar use from active solar use
- **c** wave energy from tidal energy
- **d** biomass from biofuel.

Evaluating

16 **Propose** reasons why:
- **a** petrol is used as the main energy source in cars
- **b** solar cells are more useful in Far North Queensland than Tasmania
- **c** the sides of solar ponds are painted black.

17 **Propose** some of the advantages of having house windows face north in Australia.

18 The oil fields of the Middle East lie under hot dry deserts. In prehistoric times, would you expect these areas to be the deserts they are now, or warm and wet swamps and shallow lakes? **Justify** your reasoning.

19 **Propose** sites in New South Wales that probably would be good for:
- **a** black coal power generation
- **b** tidal power
- **c** wave power
- **d** wind power.

20 Rank all the energy sources discussed in this unit from those most likely to be successful in New South Wales to those that are least likely to be successful and used in the State. **Justify** your ranking.

Creating

21 **Construct** a table that shows the advantages and disadvantages of any five sources of energy.

22 **Design** an energy poster. You might decide to include a number of different methods of energy production or, alternatively, to look at one specific method in more detail. **Outline**:
- **a** whether this is a renewable or non-renewable resource
- **b** the advantages and disadvantages of this type of energy source
- **c** the requirements for this type of energy source
- **d** which countries can use this method of energy production
- **e** whether it has already been employed as an energy source and its success.

>>

23 a Construct a list of the energy wastage in your home. Are lights left on in empty rooms? Is the water left running while you are cleaning your teeth? Do taps drip? Do you recycle paper, PET plastics and glass? Does your home have a compost bin? Is your home adequately insulated? How can you improve the energy usage in your home?

b Design a plan of attack on energy wastage, including at least 10 points that can be improved upon.

6.4 INVESTIGATING

1 Visit your local council and examine what is being done in your community to conserve resources. Does it have 'green waste', glass, PET plastic and paper collection? What happens to them after they are picked up?

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to complete questions 2 and 3.

2 Research more about the work being done by Australian company Energy Developments in utilising energy from landfill sites.

3 Find the dates of significant energy events and inventions, such as the:
- invention of the motor car
- first 'freeway' or 'motorway' to open
- invention of the airplane
- approximate start of the Industrial Revolution
- first railroad to be opened
- first town to be supplied with electricity
- first nuclear explosion on Earth
- first nuclear power plant to be commissioned.

Present your work as a scale timeline. Some dates that you must include are:
- 1859: The first oil well drilled by Col. Edwin Drake in Titusville, Pennsylvania, USA.
- 1879: Thomas Edison invents the light bulb.
- 1942: The world's first nuclear reactor. Dr Enrico Fermi designed the structure at the University of Chicago, Illinois, USA.

e-xploring

Web Destination

Complete the following activities by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.
- Examine how to save water, and study environmentally friendly designs for a home.
- Design an environmentally friendly house using the information provided. Create an architectural plan of the house, including the environmentally friendly features.

6.4 PRACTICAL ACTIVITIES

1 Checking out osmosis

Aim

To observe the movement of water across a semi-permeable membrane

Equipment

- three 10 cm lengths of dialysis tubing
- three large beakers
- distilled water
- salt water (two different concentrations)
- stopwatch

Method

1 Tie a knot in the bottom of each length of dialysis tubing.

2 Label each tube A, B and C.

>>

3 Fill tube A to three-quarters full with distilled water, and tie off the top with a rubber band. Leave about 3 centimetres of space at the top of the tubing.

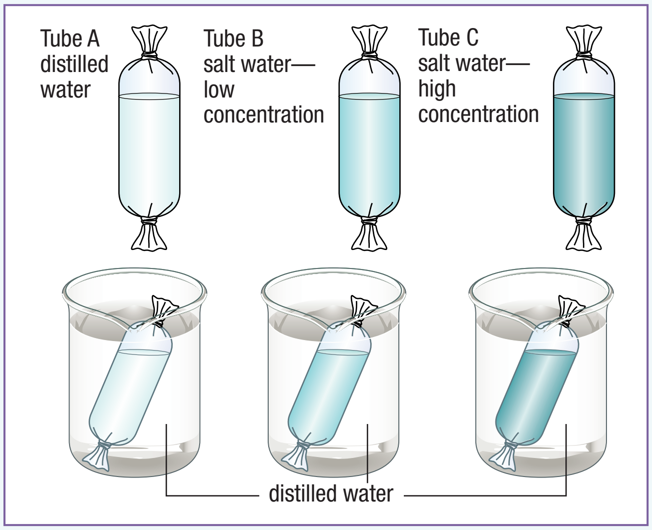


Fig 6.4.15

4 Fill tube B to three-quarters full with the lowest concentration of salt water, and tie off the top as before.

5 Place each tube into a beaker of distilled water—the tube should be almost completely immersed.

6 You will find that the volume of liquid in tube B will increase as the water moves into the tube to try and balance the salinity. Using a stopwatch, time how long this process takes.

7 As you did with tubes A and B, fill tube C to three-quarters full with the highest concentration of salt water.

8 Place tube C into a beaker of distilled water and time how long it takes for the tube to become full.

9 In your notebook, record your results in a table similar to the one below.

	Tube A	Tube B	Tube C
Tick to indicate a movement of water			
Time taken for water to fill tube			

Questions

1 **Construct** a diagram of the experiment, labelling all parts.

2 **Describe** how the appearance of the dialysis tubing has changed. Have all tubes changed in the same way?

3 What molecules have moved across the tubing membrane—the water molecules or the salt particles? **Justify** your answer.

4 On your diagram, **identify** the movement of molecules.

5 **Assess** what this tells you about the dialysis tubing.

6 **Identify** the term for the movement of water molecules across this type of membrane.

7 Was there any difference in the time it took for the water to move into tubes B and C? **Predict** why.

2 Constructing windmills

DYO

Aim

To build a model of a windmill

Equipment

- junk materials
- access to an electric fan

Method

Design your own windmill and build it using simple materials, such as cardboard, paper and pins. Try a variety of blade shapes and sizes. Use an electric fan to produce different wind speeds.

Questions

1 **Identify** at which speed the windmill worked best.

2 **Identify** which blade shape and size worked best.

CHAPTER REVIEW

Remembering

1 **State** whether the following are true or false:

a All living things require energy.

b The carbon dioxide used by autotrophs is obtained through the soil.

c Chlorophyll is the green pigment found in the leaves of plants.

d Humans are examples of omnivores.

e The number of different plants in an ecosystem is referred to as biodiversity.

2 **List** six different biomes.

3 **List** three abiotic and three biotic factors that might logically affect bushwalkers.

4 **State** what type of organism is the start of every food chain.

5 **State** what the arrows in a food chain represent.

6 **Name** a place in New South Wales where you will find hydroelectric power plants.

Understanding

7 **Produce** an example to help you **define** each of the following:

a producer

b herbivore

c carnivore

d omnivore

e primary consumer

f secondary consumer

g tertiary consumer.

8 **Discuss** the statement:
The more specialised the habitat, the more vulnerable the species is to any change.

9 **Explain** why good rain following a bushfire helps regeneration of the bush.

10 **Explain** how the Sun's energy ends up on the dinner plate.

11 **Describe** the role that worms play in the ecosystem.

Applying

12 **Identify** the word in each set of brackets that best describes each level in the following address:

15 Elizabeth Street	(biosphere, biome, habitat, microhabitat)
Broken Hill	(biogeographical region, biome, habitat)
New South Wales	(biosphere, biogeographical region, biome)
Australia	(biosphere, biogeographical region, biome)
Earth	(biosphere, biogeographical region, biome).

Analysing

13 **Distinguish**:

a biotic from abiotic factors in an ecosystem

b a grassland from a swamp

c renewable from non-renewable energies.

14 **Analyse** the map in Figure 6.1.3 and:

a **State** what you notice about those biomes that lie along the equator.

b **Predict** whether plant life in these areas would be similar.

c **Explain** why similar types of animals are found there.

15 The ghost orchid lives in the dark woods of Europe. It contains no chlorophyll. A fungus grows on its roots. If it is removed, the orchid soon dies. **Analyse** what is happening here and:

a **Describe** the role the fungus is playing.

b **Identify** the type of relationship being displayed here.

16 **Discuss** advantages and disadvantages of using fossil fuels and uranium as energy sources.

Evaluating

17 **Propose** reasons why:

a Biomes with plenty of water and light tend to have high biodiversity.

b The leaves of the water lily float on the surface of the water instead of being submerged under water.

c Plants on the forest floor have more chlorophyll in their leaves than plants in more open aspects.

18 Many carnivores exhibit a range of behaviours that assist them in catching their prey. **Propose** a reason for this behaviour.

19 In the zoo environment, not all of the animals are fed the same amount of food. Is this reasonable? **Justify** your answer.

20 The greater bilby lives in the desert area of Central Australia. It has an omnivorous diet (i.e. it eats both plant and animal matter). **Justify** whether this provides the bilby with an ecological advantage compared with other animals that eat only plants or only animals.

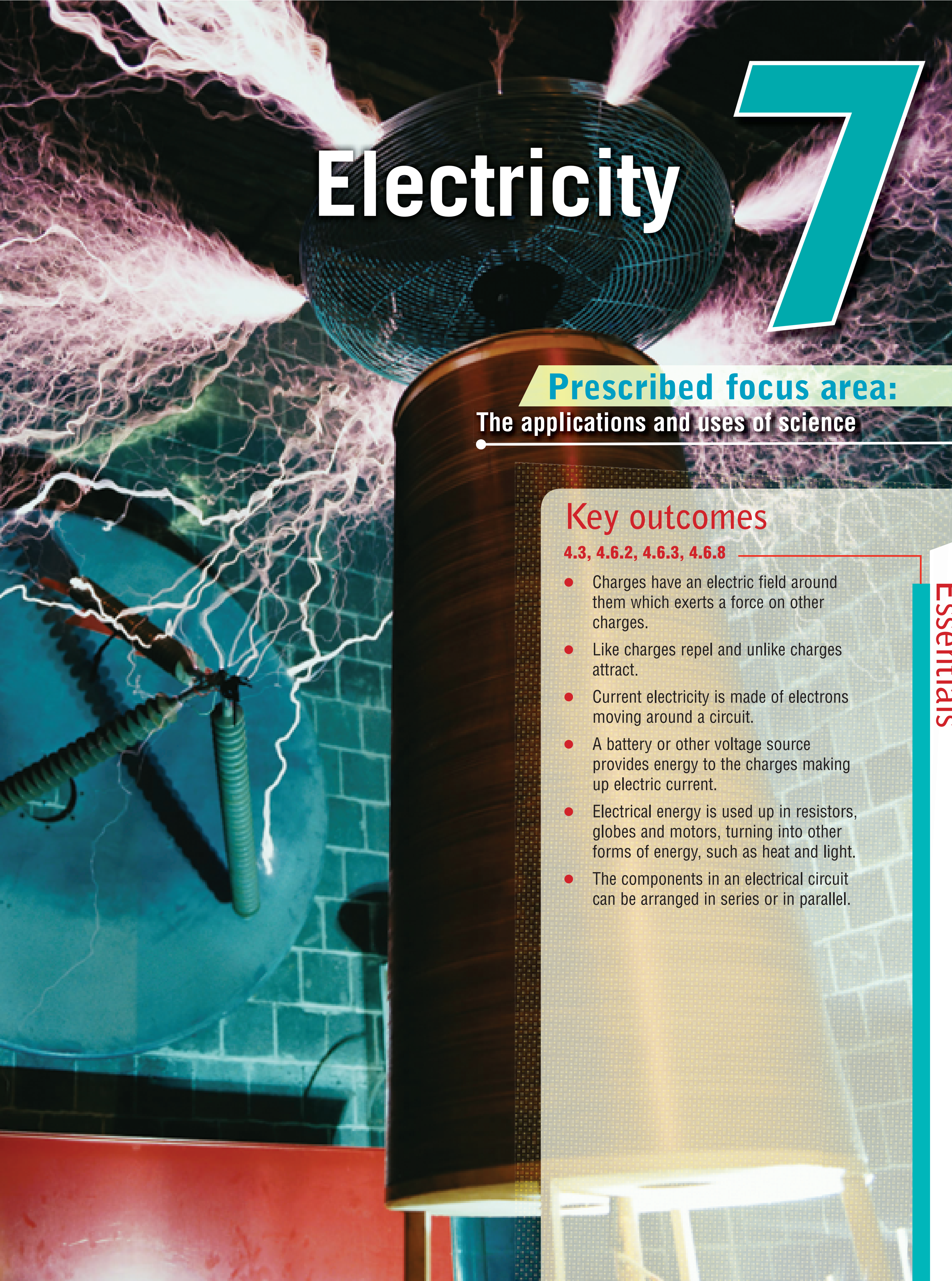
Creating

21 **Use** the food web drawings in Figure 6.3.6 to **construct** three food chains.

22 **Construct** a food chain that you might find in your local area. **Identify** and label each of the organisms as either a producer or consumer, and their 'order' in the chain (i.e. which ones are first-order consumers, second-order etc.)

Worksheet 6.4 Crossword **Worksheet 6.5** Sci-words

PP Chapter Review Questions



7 Electricity

Prescribed focus area:

The applications and uses of science

Key outcomes

4.3, 4.6.2, 4.6.3, 4.6.8

- Charges have an electric field around them which exerts a force on other charges.
- Like charges repel and unlike charges attract.
- Current electricity is made of electrons moving around a circuit.
- A battery or other voltage source provides energy to the charges making up electric current.
- Electrical energy is used up in resistors, globes and motors, turning into other forms of energy, such as heat and light.
- The components in an electrical circuit can be arranged in series or in parallel.

Unit 7.1 Static electricity

context

You can be easily 'shocked' after touching someone who has just slid down a plastic slide. Likewise, a crackling sensation often can be felt when you remove your jumper over your head or when you remove clothes from the tumble dryer. These phenomena are caused by a form of electricity known as **static electricity**.

Fig 7.1.1 Static electricity is all about charge. It often appears as sparks, sometimes as lightning.

Quick Quiz

Positive, negative or neutral?

Most objects are **neutral**—that is, they have no overall electric charge. Objects can become charged, however, if they rub against other objects or materials. To understand how this happens, it is necessary to look at what is happening to the atoms that make up the objects and materials.

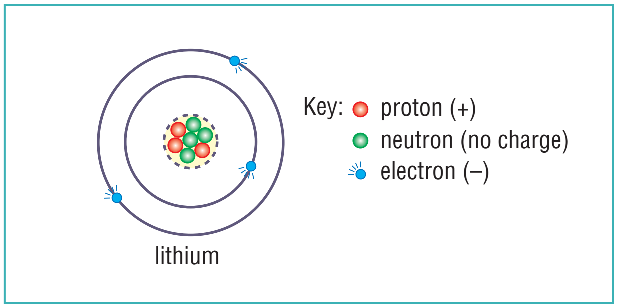


Fig 7.1.2 Atoms are neutral because they contain the same number of electrons and protons.

Everything is made of atoms—atoms make up water, bricks, clothes, pens, trees, humans and the gases of the air.

Atoms contain three types of particles:

- **protons**—are positively charged (+). They are located in the nucleus, which is the core of the atom.
- **electrons**—are negatively charged (–). The size of the negative charge on an electron is exactly the same as the size of the positive charge on a proton. Electrons travel around the nucleus in the atom's outer regions.
- **neutrons**—the nuclei of most atoms contain neutrons. As their name implies, neutrons are neutral, having no charge. As electricity is all about charge, neutrons can be ignored.

Atoms are neutral—they have the same number of positive protons and negative electrons, so their total charge is zero.

Go to Science Focus 2, Unit 2.3

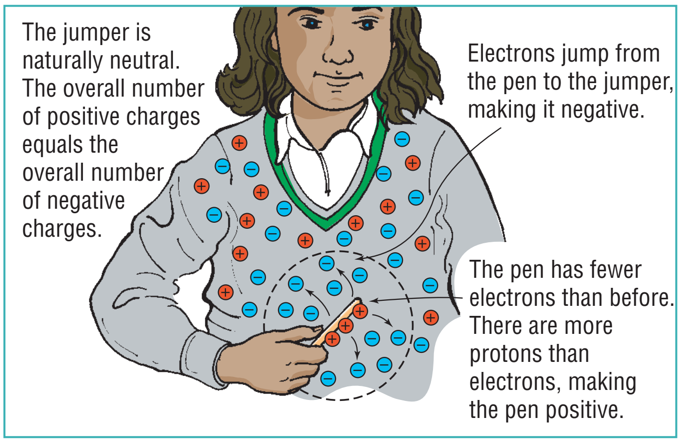


Fig 7.1.3 Negative charges (electrons) can be rubbed off a plastic pen and onto a woollen jumper. This leaves the pen positively charged and the jumper negatively charged.

Becoming charged

Rubbing often causes electrons to jump from one material or object to another. One object ends up with more electrons than protons, and the other ends up with more protons than electrons. Both objects are now said to be **charged**. Only electrons can move onto other materials because they are on the very outside of the atoms. Protons (and neutrons) are buried far too deep inside the atom's nucleus to be affected by rubbing. The charge on an object can be predicted by looking at the number of protons and electrons it has. Hence:

- If an object loses electrons to another material, then it will have more protons than electrons. The object is said to be **positively charged** (+).
- If an object gains electrons from the other material, then it will be **negatively charged** (–) because it has more electrons than protons.

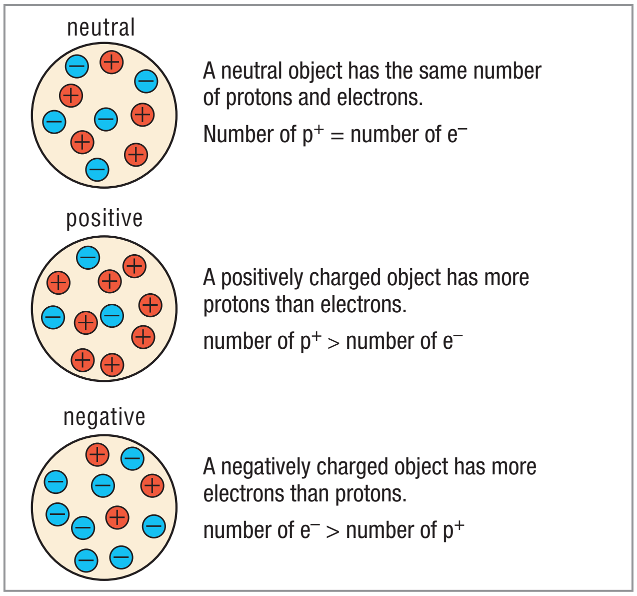


Fig 7.1.4 Objects are charged if the number of protons and electrons is not equal. The term *charge* can refer to a single proton or electron or a group of protons or electrons.

Attraction and repulsion

Prac 1 p. 216

Charges exert force on any other charges that happen to be nearby. This force is referred to as **electrostatic force**. The type of electrostatic force exerted depends on the charges that are interacting with each other. Note that:

- Charges that have the same sign (i.e. + and + or – and –) are referred to as like charges. **Like charges repel**, pushing away one another.
- Unlike charges have the opposite signs (i.e. + and –). **Unlike charges attract** one another, pulling them closer together.

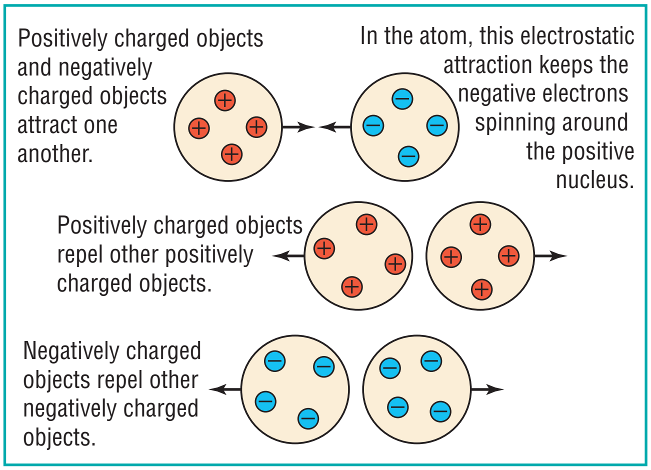


Fig 7.1.5 Electric charges exert a force of attraction or repulsion on each other. These forces are known as electrostatic forces.

PP Interactive

Induced charge

Prac 2 p. 216

Briskly rub a plastic pen on a woollen jumper and you will probably find it can attract small pieces of paper. The pen is charged and so is the jumper on which you rubbed it. The pieces of paper, however, are neutral—they have an equal number of protons and electrons and no *overall* charge. Therefore, you would not expect the paper to be attracted to the pen. **Induced charges** have formed (or induced) within the pieces of paper, and it is these charges that cause it to be attracted to the pen. The process happens via a number of steps.

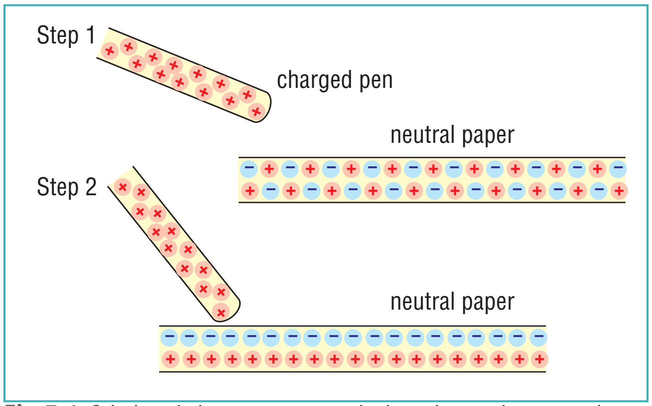


Fig 7.1.6 Induced charges are created when charges in a neutral object shift and separate.

Step 1: A negatively charged pen approaches neutral paper and repels the negative charges in the paper, forcing them to retreat as far away as they can. In this case, they move to the bottom side of the paper.

Step 2: The positive charges cannot move because they are tightly held in the nucleus of the atoms, and so are left at the top of the paper.

Step 3: These positive charges are attracted to the negatively charged pen, and so the paper sticks.

Step 4: After the pen and paper have been in contact for a short time, the charges spread out over both, leaving both with the same (negative) charge.

Step 5: The like (negative) charges repel each other and the paper falls off.

Electric fields

Prac 3 p. 217

The electrostatic forces that charges exert on one another arise because of invisible force-fields around each charge. These fields are called **electric fields**. Larger charges have stronger electric fields and the further the distance from the charge, then the weaker the electric field becomes. Scientists use electric field lines to represent an electric field—they show which direction a positive charge would move if it was placed in the field.

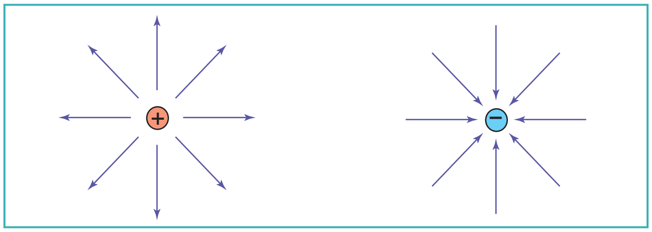


Fig 7.1.7 The field lines in an electric field points away from positive charges and towards negative charges. Electric field lines don't really exist but provide a convenient way of visualising what is happening around a charge.

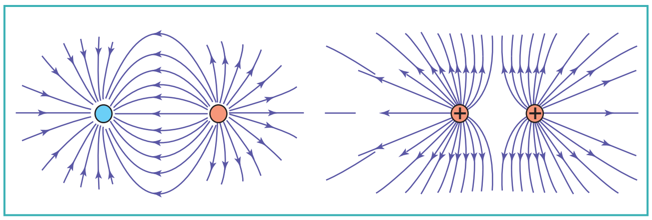


Fig 7.1.8 Each charge has its own electric field. If two charges are close to each other then their fields will interact, pulling the charges together or pushing them apart.

Electric fields are similar to gravitational fields in many ways. **Gravitational fields** are the invisible force-fields found around planets that make objects fall 'downwards', towards their centres. They also keep the planets in orbit around the Sun, and the Moon in orbit around Earth. Heavier planets have stronger gravitational fields than lighter planets. All gravitational fields weaken as the distance from the planet increases.

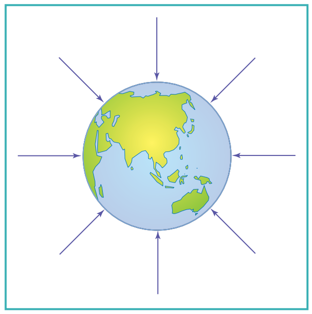


Fig 7.1.9 Earth's gravitational field exerts a force on all objects, towards its centre. Gravitational field lines are used to show the direction an object would fall.

What is static electricity?

Electricity is really just a collection of charges. **Static electricity** is a collection of charges. Sometimes there is so much charge that electrons will jump through the air, causing a spark. When someone touches a charged object, they may receive a severe shock as the charge jumps onto them and then passes through them to the earth. Most of the time, however, static electricity simply leaks, or **dissipates**, into the air, making the object neutral once again.

Good and bad static electricity

The sparks from static electricity can range from annoying to deadly, especially if the spark arrives in the form of lightning. Static electricity can also be used productively to make photocopies and to demonstrate some really hair-raising effects on the Van de Graaff generator.

The Van de Graaff generator

A Van de Graaff generator produces a large build-up of charge on its metal dome.

Carpet static

Static electricity often 'zaps' you after you have walked on certain types of carpet. Walking rubs your shoes against the carpet, causing a build-up of charge on your body. Usually, this charge would leak back out of your shoes, but sometimes rubber soles may insulate them enough to block this leakage. Gradually, you get more and more charged up as you walk across the carpet. All that excess charge is released when you touch an object, such as a doorknob, the charge jumping into that object and you become neutral once more. This causes a spark, which is felt as a small electric shock.

Charge tends to concentrate on sharp corners and spreads out more over flatter surfaces. One way of avoiding a shock is to touch any object that may be charged with an open palm instead of a finger. This spreads the charge and avoids a spark.

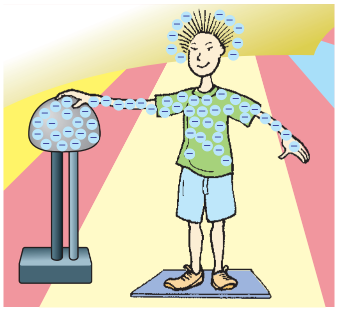


Fig 7.1.10 A Van de Graaff generator uses a belt to transfer negative charges to its metal dome.

Aircraft refuelling

An aircraft needs to be protected from the effects of static electricity during refuelling. Friction between the air and the aircraft creates a large charge on the outside of the aircraft. This charge stays on the aircraft after it has landed, and might jump as a spark from the aircraft to the fuel hose, causing a disastrous explosion. To prevent this, a wire is first connected between the aircraft and the ground, allowing any excess charge to safely leave the aircraft.

Worksheet 7.1 Static electricity

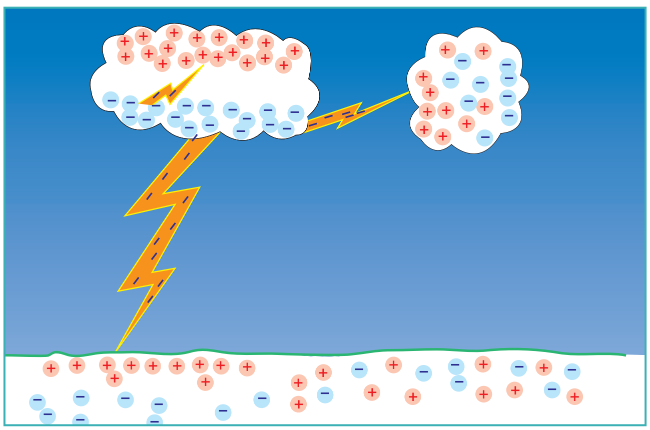


Fig 7.1.11 Lightning is just an enormous spark, caused by the separation of charge in clouds.

Photocopiers

Photocopiers use static electricity to produce images. A cylindrical drum is positively charged, and an image of the original page is projected onto it. Light areas of the image destroy the charge, whereas black regions leave the charge intact. A fine, negatively charged powder (called toner) drops onto the drum and sticks to the positive areas. The drum then rolls its powder image onto paper, which is then heated to melt the toner permanently onto it.

Thunder and lightning

Movement of water droplets and air molecules can cause charges to build up within storm clouds. If the build-up is great enough, then charges may flow suddenly from one part of a cloud to another, or to a separate cloud, or even to the ground. The sudden movement of charges causes the surrounding air to become super-heated and to expand rapidly. The temperatures can be as high as 30 000°C. This expansion causes shock waves to travel through the air, which we hear as thunder.

Science Clip

Unusual strikes!

In 1987, a lightning strike killed eleven soccer players and injured more than 30 players and spectators in Congo, Africa.

In 1970, ten European tourists sheltering under a tree were hit by a shock wave caused by the air surrounding a strike becoming super-heated and rapidly expanding. They emerged naked, but otherwise unhurt, their clothes having been blasted from them!

Science Fact File

Lightning

The Earth is hit by about one hundred lightning strikes every second. You should follow these safety tips if lightning is striking nearby.

- Shelter in a building or a car—electricity tends to flow around the outside of them, so you should be safe inside.
- Keep clear of anything tall, such as trees, umbrellas, fishing rods or even golf clubs—lightning tends to strike the tallest or pointiest object nearby.
- Keep clear of wire fences, railway tracks and cars (unless you are in one!)—lightning tends to strike metal objects.
- Drop to the ground immediately if you are outside and your hair stands on end or your skin tingles—these indicate that you are in a lightning strike zone and are in immediate danger.
- Crouch down if you are caught outside. Keep your feet close together with your hands on your knees. Keeping your feet together reduces the chances of the lightning travelling from foot to foot.
- Stay wet if you are outside—if you are hit, electricity will tend to flow through your wet clothes, rather than through your body.
- Keep away from water, such as the surf or lakes, and get to shore as soon as possible if you are on or in water.
- Do not to use a landline telephone (i.e. one with a cord)—electricity from lightning strikes can travel through phone cables to the telephone ear piece. Mobile and cordless phones are safe during a thunderstorm.

7.1 QUESTIONS

Remembering

1 **State** the charge and sign for:

a an electron b a proton.

2 **State** the direction in which the field lines point in an electric field.

3 **Name** the device often used in laboratories to demonstrate some of the effects of static electricity.

4 **State**:

a one practical use of static electricity in a school

b three ways in which static electricity is a nuisance or dangerous.

Understanding

5 **Describe** the relationship between the number of protons and electrons on: N

a a neutral object

b a positively charged object

c a negatively charged object.

6 **Define** the following terms:

a neutral

b electrostatic force

c induced charge

d electric field

e static electricity.

7 Copy these statements and **modify** any that are incorrect.

a A positively charged object contains only positive charges.

b A neutral object contains no charges.

c Induction is the 'coaxing' of charges in a neutral object to move to different positions within the object.

d An object may become charged only by rubbing electrons off it.

e Lightning is caused when a build-up of charge within a cloud jumps from the cloud to Earth.

8 **Calculate** whether the following particles would be neutral, positively charged or negatively charged: N

a 5 protons, 5 neutrons and 6 electrons

b 15 protons, 20 neutrons and 10 electrons

c 34 protons, 27 neutrons and 34 electrons.

9 If you tear a polythene shopping bag and try to put the pieces in the bin, they may stick to your fingers. **Explain** why.

10 **Explain** why:

a a Van de Graaff generator makes a person's hair stand on end

b the effect is even more dramatic if the person stands on a rubber mat.

11 A spark is more likely to jump to your finger than your forehead when you approach a charged Van de Graaff generator. **Explain** why.

Applying

12 **Use** the terms *attract*, *repel* and *no force* to **apply** what you know about force and charge to **describe** the interaction between each set of charges and complete the table below.

	Positive charge	Negative charge	Neutral charge
Positive charge		Attract	
Negative charge			no force
Neutral charge			

13 **Identify** two examples of how electric charge may be produced.

14 If a balloon is rubbed with wool, it will often stick to a wall. **Use** a diagram to **demonstrate** how this might happen.

15 **Use** '+' and '–' signs to **demonstrate** the position of various concentrations of charge within the metal sphere in Figure 7.1.12.

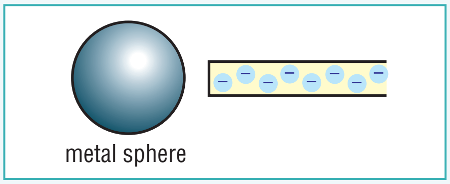


Fig 7.1.12

Analysing

16 **Compare** an electric field with a gravitational field.

17 Magnets also have a field around them. **Compare** an electric field with a magnetic field by listing their similarities and differences.

18 Figure 7.1.13 shows one type of Van de Graaff generator. **Use** the diagram to **explain** how:

a charge is formed

b charge is transferred to the dome.

>>

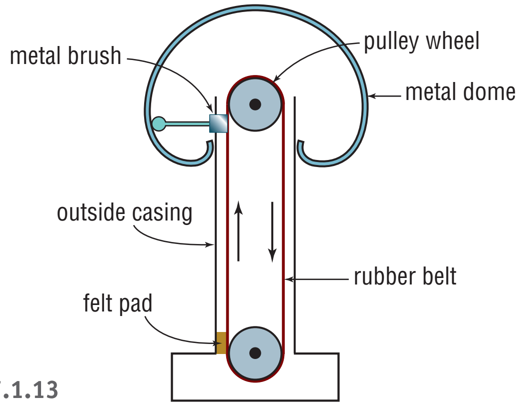


Fig 7.1.13

Evaluating

19 **Propose** a reason why:

- **a** cleaning and polishing a mirror might actually make it dustier
- **b** static electricity demonstrations using the Van de Graaf generator works better on dry days than on humid days
- **c** some people refer to photocopies as 'photostats'.

20 Animals such as sharks, echidnas and platypuses can detect the electric fields produced in the muscles of other animals. **Propose** ways in which they could use this ability.

Creating

21 **Construct** a diagram to show how a neutral object and charged object can attract each other.

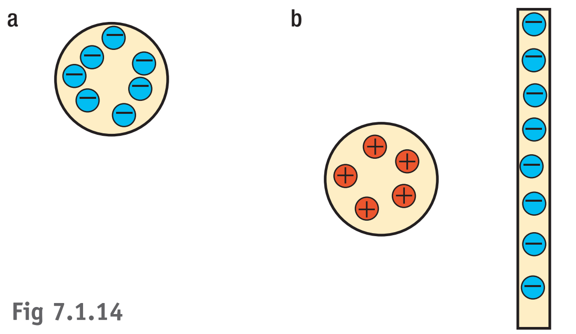


Fig 7.1.14

22 **Construct** diagrams to show the electric field near the charges in Figure 7.1.14.

23 **Construct** a cartoon that teaches a specific group of people how to avoid lightning strikes in a storm. The group might be people playing cricket, fishing on a pier or walking in a forest.

Fig 7.1.15 Frankenstein's monster, as he appeared in the 1931 film

24 In 1816, Mary Shelley wrote *Frankenstein*, a novel about a scientist who uses a 'spark' to bring life to a monster made from dead people's body parts. Most believe that this spark was electricity. **Construct** a short story, a cartoon or a short play showing the creation of a Frankenstein-like monster that used static electricity to bring it to life. In your story, include a device that will generate the large amounts of static electricity required.

7.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1. Construct a poster illustrating what a lightning rod is and how it works.
2. Research the story of Benjamin Franklin, who supposedly flew a kite with a key attached while in the middle of a thunderstorm. Summarise the information you found about the true story of Benjamin Franklin's experiment in the form of a newspaper article.
3. Find and read a copy of Mary Shelley's *Frankenstein*.

7.1 PRACTICAL ACTIVITIES

1 Positives and negatives

Aim

To investigate static electricity

Equipment

- two perspex (acetate) and two polythene rods or strips
- two dry woollen cloths
- watch-glass
- Blu Tack or plasticine

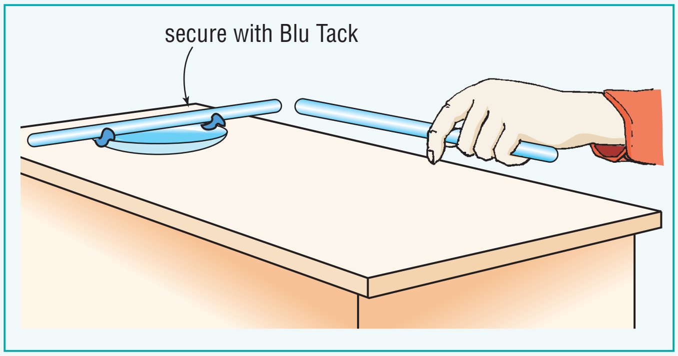


Fig 7.1.16

Method

1 Charge one perspex rod by rubbing it with a dry cloth and place it on a watch-glass, as shown. Quickly charge the other perspex rod and bring it near the one on the watch-glass. Note the direction of any movement.

2 Repeat step 1 for the polythene rods, but use the other cloth.

3 Now study the effect of a charged perspex rod on a charged polythene rod, using the same cloths that were rubbed on each previously.

Questions

1 **Explain** which combinations produced attraction, and which produced repulsion.

2 The charge produced on the perspex rod was positive. Use this information to **predict** the charge produced on:

   a the polythene rod

   b the cloth when rubbed on perspex

   c the cloth when rubbed on polythene.

3 **Account** for the use of a new cloth with the polythene rod in step 2.

2 Static magic

Aim

To charge up a balloon and a pen

Equipment

- a balloon
- a plastic pen

Method

1 Inflate a balloon and rub it on your jumper for a minute or so.

2 Hold the balloon against a smooth wall and let go.

3 Rub a pen on your jumper.

4 Hold the pen near (but not in) a thin stream of running water.

Questions

1 **Explain** in words what happened in each case.

2 **Construct** diagrams to support your explanations in Question 1.

Extension

A balloon becomes negatively charged when it is rubbed on a jumper. **Design** your own way of finding out whether the charge produced on a rubbed pen is positive or negative.

DYO

3 Making an electroscope

An electroscope is a device used to detect electric fields.

Aim

To construct an electroscope and use it to detect the presence of charges

DYO

Equipment

- glass jar
- aluminium foil
- thick wire
- card
- tape
- various rods (e.g. glass, polythene, ebonite) and cloths (e.g. wool, cotton, synthetic)

Method

1. **Design** your own electroscope, using Figure 7.1.17 as a guide.
2. Construct it so that it can detect the presence of an electric field.
3. Use the electroscope to compare the electric fields produced by various combinations of rods and cloths.
4. Record your results in a table.

Questions

1. **Explain** how the electroscope works. **Use** a diagram to support your answer.
2. **Identify** which rod and cloth produced the largest electric field.
3. **Propose** a use for an electroscope in an everyday situation.

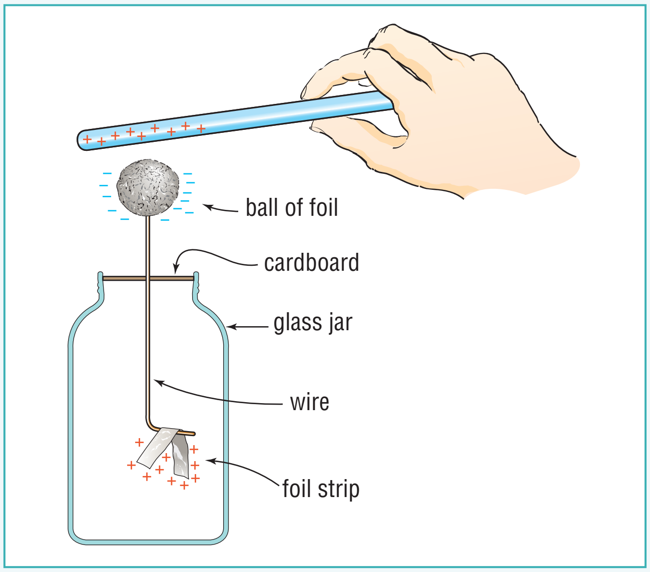


Fig 7.1.17

Unit 7.2 Current electricity

context

Electrical appliances such as iPods, hairdryers, electric toothbrushes, computer laptops and games consoles, like Wii, Xbox 360 and PS3, cannot work using static electricity because they need a constant flow of charges moving through them. This flow is called electric current or current electricity. Moving charges need an unbroken path to flow along. This path is called an electric circuit.

Fig 7.2.1 Current electricity is moving electricity. An ammeter measures how much current is flowing through it, whereas a voltmeter measures the energy used as the charges move through a component in the circuit.

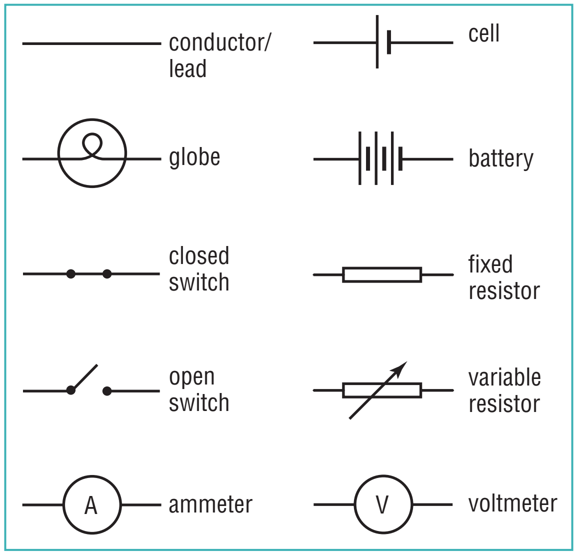


Fig 7.2.2 Symbols show which components are connected in a circuit.

Electric circuits

Whereas static electricity is made of charges that do not move, **current electricity** is made up of charges that move around an electric circuit. The path along which these charges flow must be complete. Any breaks in it will be enough to stop the current flowing.

The three basic parts of a simple circuit are:

- an energy source, such as a battery, power point or power pack
- something to use up the electrical energy, such as a globe, motor or heating element (resistance)
- wires (conductors) for the electric current to flow through.

Usually circuits also include a switch to turn the circuit on and off. The parts that make up a circuit are called its **components**.

Circuit diagrams

A **circuit diagram** is a shorthand way of showing the components that are connected in a circuit, how they are connected and in which order. Each component has its own easy-to-draw symbol and lines are used to represent the wires that connect them.

Current

Electric **current** measures the amount of charge flowing around the circuit every second. A large current involves more charge passing through a circuit each second than does a small current.

Most of the components in an electric circuit are made from metals, such as copper and tungsten. Like all materials, metals contain both positive protons and

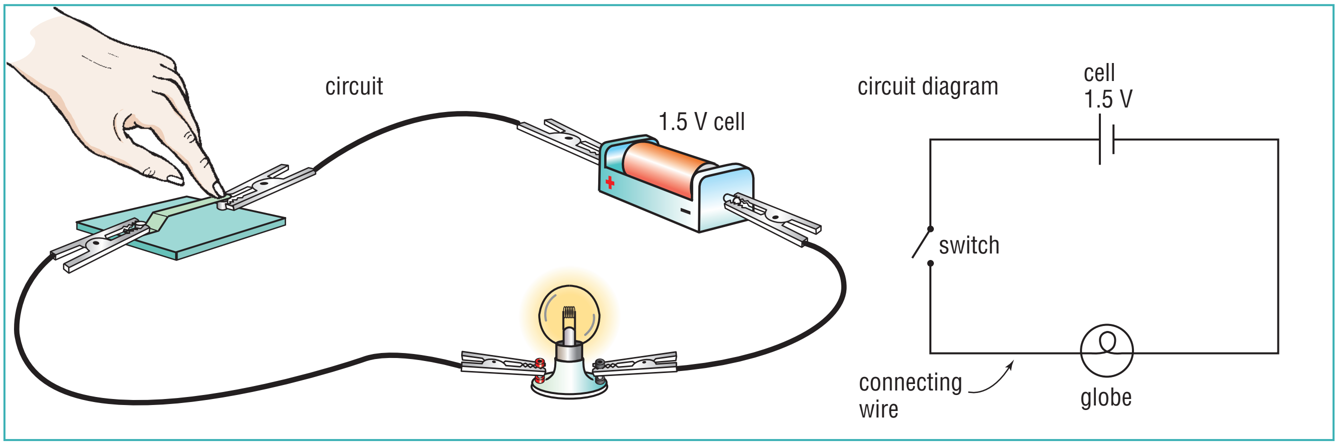


Fig 7.2.3 Two different versions of the same simple electric circuit. This circuit is similar to that found in a torch.

Worksheet 7.2 Circuit symbols

negative electrons. Although their protons and most of their electrons are not able to move far, a few electrons on each metal atom are free to move about. These free electrons form a negatively charged 'sea' that is able to flow from atom to atom and around the circuit. The more electrons that flow every second, the higher the current.

Current is measured in **amperes** (unit symbol A), which is sometimes shortened to 'amps'. Milliamps (mA) are used to measure extremely small currents and one milliamp is equal to one-thousandth of an ampere. An instrument called an **ammeter** measures current by being placed directly in its path. This involves 'breaking' the circuit and inserting the ammeter.

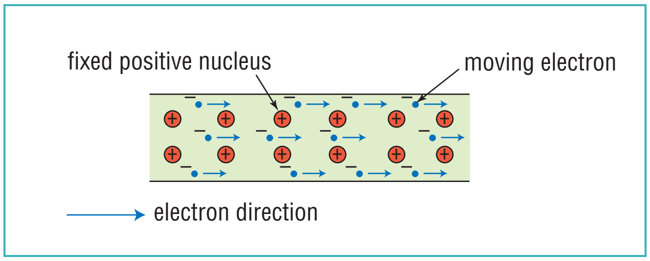


Fig 7.2.4 A current in a wire is made up of moving electrons, moving from the negative terminal of a battery or power pack to its positive terminal.

Voltage

Voltage is a measure of the amount of energy available to push charges around a circuit and is supplied by batteries, power points and power packs. Voltage is also used to measure the amount of energy released by an energy user, such as a globe, heating element or motor.

Voltage is measured in **volts** (unit symbol V) and is measured with an instrument called a **voltmeter**. Probes from the voltmeter are connected to each end of the component to be measured, 'piggybacking' it. In this way, the voltmeter measures the energy used by charges as they pass through the component.

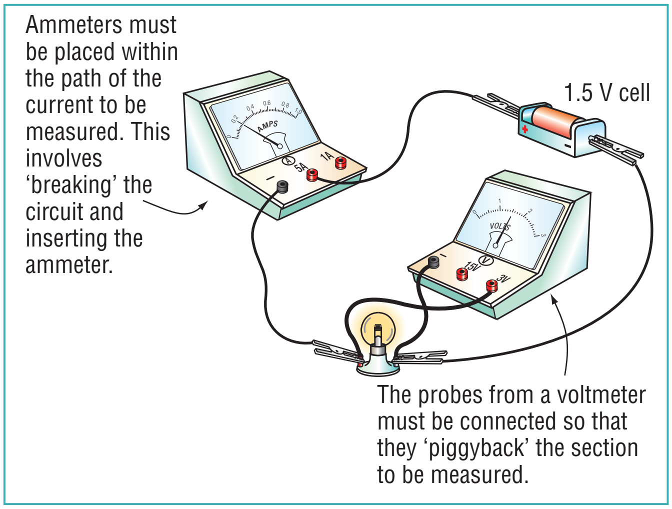


Fig 7.2.5 How to connect an ammeter and a voltmeter. The broken ammeter becomes part of the circuit and the voltmeter piggybacks part of it.

PP Interactive

Energy sources

Charge would never move around a circuit if it was not provided with the electrical energy and voltage to do so. At home, electrical energy and voltage usually come from a power point or from some type of cell or battery. Each energy supplier can be thought of as a charge 'pump'.

Science Clip

Living batteries

The electric eel is able to generate up to 600 volts, which it uses to stun small fish! The human body is full of small voltage generators, which are used to send messages via nerve cells.

Power points and power packs

Power points supply most of the electricity in the home. The 240 volts they supply can be deadly, so always make sure that the switch is off before connecting or disconnecting appliances.

Power packs are often used in school laboratories instead of batteries. Usually, their voltage can be altered from 1.5 volts up to 6 or 12 volts.

Cells and batteries

Batteries are used when a portable source of electricity is needed. Some are rechargeable, whereas others must be replaced when 'dead'. A typical small cell, such as an AA battery, provides 1.5 volts, whereas a car battery supplies 12 volts. A battery is made from a group of single cells, each of which uses chemical reactions to get electrons moving.

Wet cells

Prac 1 p. 225 Prac 2 p. 225

A **wet cell** consists of two different metal plates (known as **electrodes**) placed in a bath of acid.

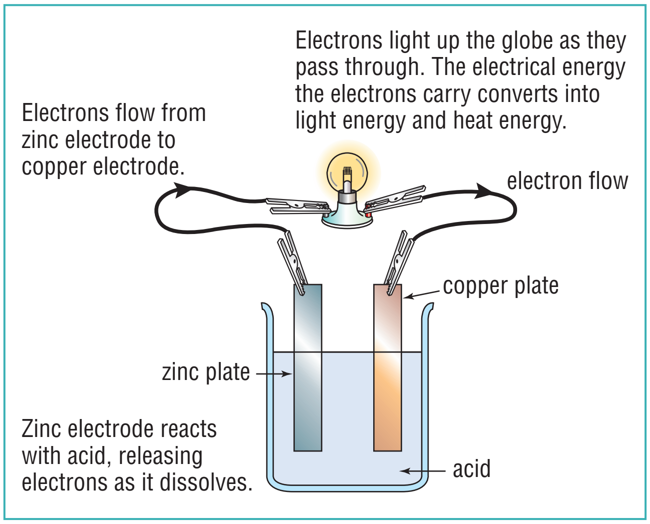


Fig 7.2.6 A typical wet cell. The acid slowly reacts with and dissolves the zinc plate, releasing electrons into the circuit. The electrons flow to the copper plate, lighting the globe as they pass through it.

A car battery is a collection of wet cells. The wet substance is sulfuric acid and the plates or electrodes are made of lead and lead oxide. When a car is running, chemical reactions in the battery are reversed, and help recharge the battery. Eventually, build-up of chemicals on the electrodes prevents recharging and the battery 'dies'.

Fig 7.2.7 A car battery uses a series of wet cells to generate its 12 volts.

Dry cells

Wet cells are usually large, heavy and can leak acid if tipped over. This makes them useless for torches, laptop computers or TV remote controls. These appliances need small, light and portable batteries that don't leak. They use a **dry cell** that contains a chemical paste instead of a liquid and their electrodes are shaped to make them compact.

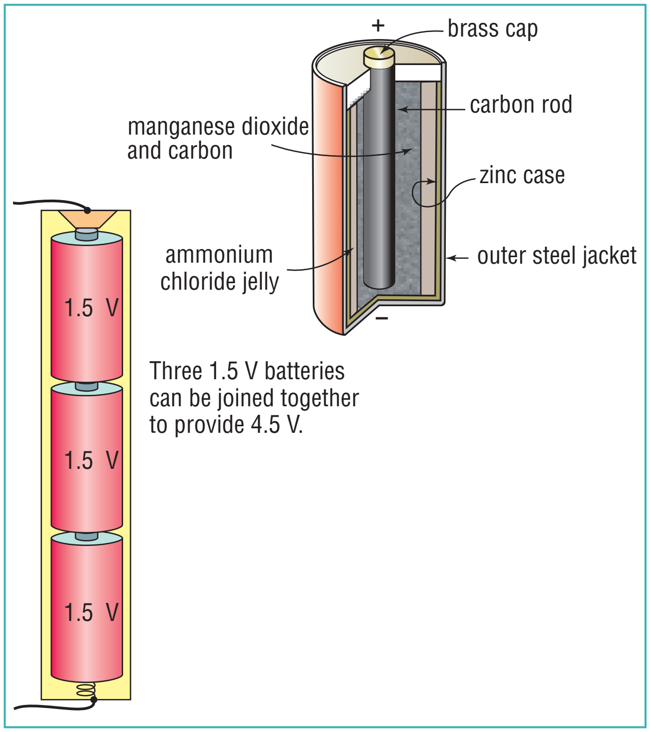


Fig 7.2.8 Dry cells are small, light and portable. If more voltage is needed then several cells can be connected together.

As in a wet cell, a chemical reaction generates charge that will flow when the cell is connected to a circuit. There are several types of dry cell:

- zinc–carbon cells are cheap
- alkaline–manganese cells are longer lasting, but more expensive
- lithium cells are compact, light and long-lasting
- nickel–cadmium cells (otherwise known as nicad) can be recharged using a recharger connected to a power point. The current it supplies reverses the chemical reactions within the cell, sending the electrons back to the electrode they originally came from.

Solar cells

A **photovoltaic cell** or **solar cell** is made of two layers of a substance called a **semiconductor**. When sunlight strikes the top layer, electrons are given energy to move from one layer to the other, creating an electric current. Several cells are used to make a solar panel.

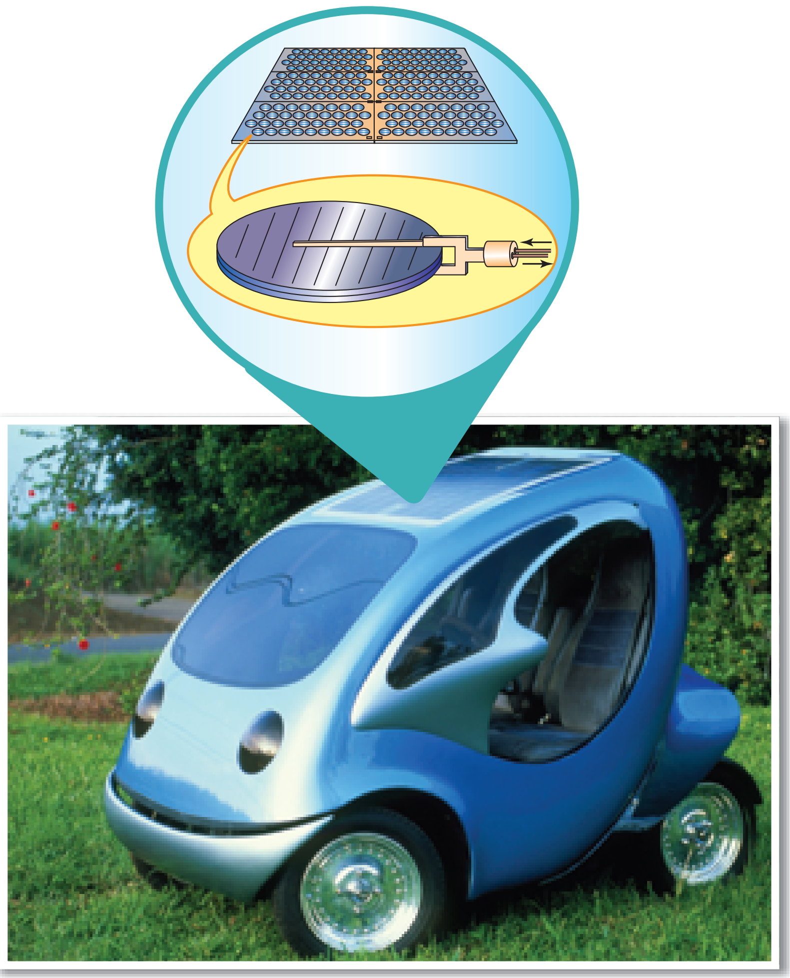


Fig 7.2.9 Sunlight falling on a photovoltaic cell forces electrons from one layer to the other, causing an electric current. This solar-powered car has a solar panel made from photovoltaic cells on its roof.

Conductors and insulators

Prac 3 p. 226

A **conductor** is a material that allows current to flow through it easily. Metals are good conductors of electricity. Copper wire is a low-cost and widely available conductor that is commonly used to connect the components in electric circuits around the house, in factories, in cars and in the ones you will build in the laboratory. Aluminium is more expensive but is used when copper would be too heavy, such as for high-voltage transmission lines that need to be strung between distant pylons.

Materials that do not normally allow current to pass through them are known as **insulators**. Plastic and rubber are two very effective insulators.

Fig 7.2.10 Household wires are made from three cables. Each cable contains a cluster of conducting copper wires wrapped in a sleeve of insulating plastic. They are then wrapped in another sleeve of insulating plastic.

Resistance

An old-fashioned incandescent light globe has a fine strand of tungsten called a **filament**. Electrons moving through the circuit have much more difficulty getting through this filament than they do getting through the much thicker and highly conductive copper wire. The energy the electrons give up trying to get through the filament is turned into heat and light.

A light globe is an example of **resistance**—something that restricts the flow of charge and 'robs' moving charges of energy. Resistance converts electrical energy into heat and light energy. Good conductors have very low resistance, whereas insulators have extremely high resistance.

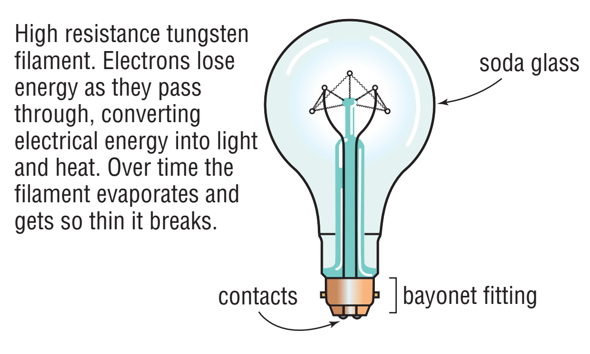


Fig 7.2.11 The resistance is obvious in an old-fashioned, energy-wasting incandescent light globe.

Fig 7.2.12 After 2010, only energy-saving, compact fluorescent light globes will be able to be purchased in Australia.

Science Clip

Saving the globe

Old-style, incandescent light globes are not very efficient as much of the energy they use is emitted as heat and not light. In an effort to increase efficiency and to reduce CO_2 emissions from electricity generation, in 2007 Australia began to phase out incandescent light globes. It was the first country to do so.

Thin nichrome wire is used as the heater in electric kettles, hairdryers, toasters, irons and electric hotplates. Nichrome has much greater resistance than the copper wire used in the rest of the circuit, and so it heats up when a current passes through it. Nichrome is ideal as it doesn't react with oxygen or water and does not become brittle when heated.

Prac 4 p. 226
Prac 5 p. 227

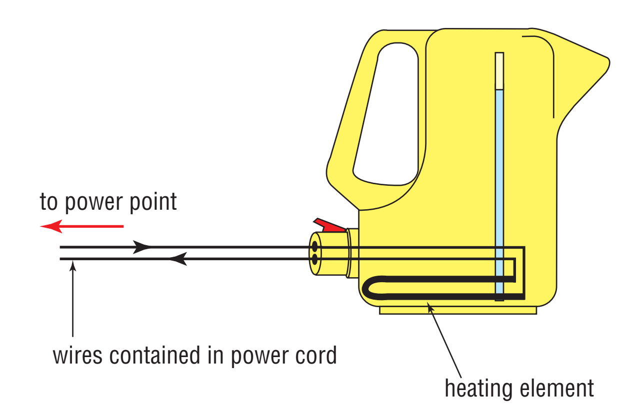


Fig 7.2.13 The heating element in an electric jug has a much higher resistance than the rest of the circuit it is part of. The element converts electrical energy into heat.

7.2 QUESTIONS

Remembering

1 **Recall** the basic parts of a simple circuit by matching the word with its best description.

a energy source	**i** wires
b conductors	**ii** heating element
c resistance	**iii** battery

2 **Recall** basic electrical components by drawing the symbol for:
- **a** a cell
- **b** a globe
- **c** a switch.

3 **Name** the device used to measure:
- **a** current
- **b** voltage.

4 **State** the units that are used to measure:
- **a** current
- **b** voltage.

5 **Specify** the voltage supplied by each of the following:
- **a** a AA torch battery
- **b** a household power point
- **c** a car battery.

>>

6 **List**:
a five electrical appliances that use dry cells.
b three appliances that use nichrome wires.

Understanding

7 **Define** the following terms: (L)
a current
b voltage
c conductor
d insulator
e resistance.

8 **Explain** why:
a ammeters need to be part of the circuit.
b voltmeters need to piggyback part of the circuit.

9 **Describe** how cells produce the charges that then travel around a circuit as a current.

10 **Explain** why:
a wet cells are fine in a car but not in a laptop computer
b car batteries are so heavy
c a car battery 'goes flat' if the car is not used often.

11 **Explain** why:
a tungsten heats and lights up but copper wires do not
b aluminium is used instead of copper for electric cables between distant pylons
c copper electrical wires need to be wrapped in plastic.

Applying

12 **Identify** which components in Figure 7.2.2:
a have almost no resistance
b have an almost infinite resistance
c would glow as electrons pass through
d would measure the number of electrons passing through each second
e would piggyback part of the circuit.

13 **Identify** whether a wet or dry cell would be best suited to power a heart pacemaker.

14 **Calculate** how many AA batteries would be needed to provide the same voltage as a car battery. (N)

Analysing

15 An electric motor is connected to a circuit. **Classify** the motor as either an energy source or an energy user.

16 **Distinguish** a cell from a battery.

17 An analogy is something that is used to help explain a difficult idea. One convenient analogy for electricity flowing around an electric circuit is water being pumped around a closed circuit (e.g. in a garden pond), as shown in Figure 7.2.14. Each of the components in the electric circuit has a matching component in the water 'circuit'.

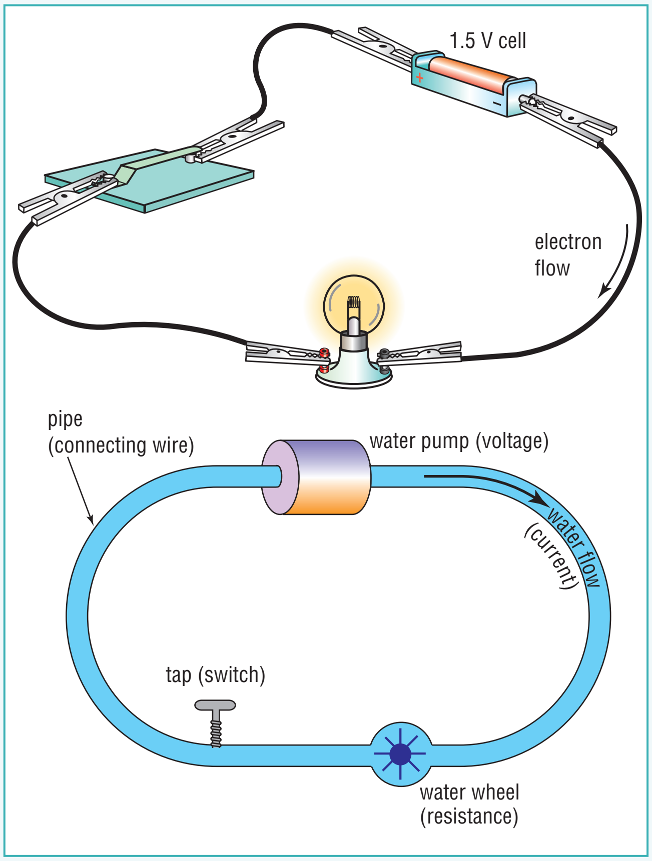


Fig 7.2.14

Compare this water 'circuit' with a simple electric circuit, and then complete the table.

Current electricity	Water
Charge	Water particles
Current	
	Pump
Connecting wire	
Globe	
	Tap

18 Complete the following unit conversions by **calculating** the missing numbers: (N)
a 1000 mA = _______ A
b 1500 mA = _______ A
c 1 A = _______ mA
d 2.3 A = _______ mA

>>

Evaluating

19 An electric eel has cells in its body that can produce a fraction of a volt each, but can produce up to 600 volts to kill or stun its prey. **Propose** a way in which the electric eel might build up such a high voltage from fractions of volts in its cells.

20 **Propose** a reason why electricians use screwdrivers with plastic or rubber handles.

21 **Evaluate** which of the circuits in Figure 7.2.15 are equivalent.

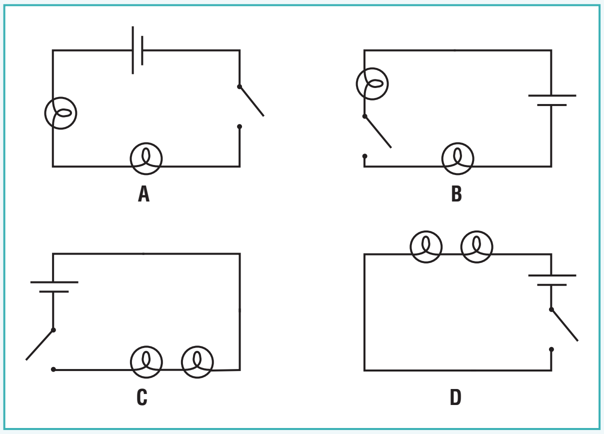


Fig 7.2.15

Creating

22 **a** **Construct** a circuit diagram (using correct symbols for each component) for the circuit shown in Figure 7.2.16.

b Add an ammeter to measure the current through the globe and a voltmeter to measure the voltage used by it.

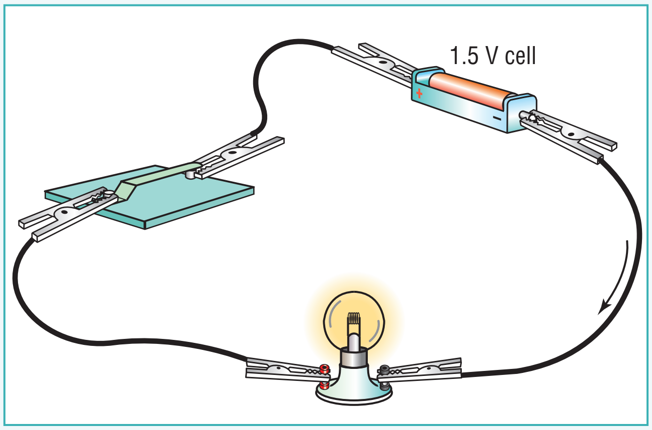


Fig 7.2.16

23 **Design** a simple circuit that activates an alarm when someone stands on a mat near your bedroom doorway.

24 An unexpected blast of powerful solar radiation has deactivated all cells and batteries on Earth. It will be several weeks until more cells can be manufactured. How will life be different without cells and batteries? What modifications will be needed to allow equipment to continue to function? Create a short story that describes how humans cope with this unexpected inconvenience. L

7.2 INVESTIGATING

e-xploring

Research one of the following scientists by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

PP Web Destination

Summarise your information in the form of a newspaper article announcing the scientist's discovery to the public.

- Research the invention of the light globe and other inventions by Thomas Edison.
- Research Luigi Galvani's contribution to the study of electricity.
- Alessandro Volta made the first battery, known as Volta's pile. Research how Volta's pile worked.

7.2 PRACTICAL ACTIVITIES

1 A lemon cell

Aim

To construct a battery using a lemon

Equipment

- a galvanometer or microammeter (for detecting small currents)
- copper and zinc plates (or a galvanised nail and uninsulated copper wire)
- a lemon
- two connecting wires

Method

1 Squeeze the lemon without breaking the skin to 'juice it up' inside.

2 Insert the plates (or the substitute items) into the lemon.

3 Connect to the current-measuring meter, ensuring the copper is connected to the positive terminal of the meter.

4 Predict and then investigate the effect of:

a pushing the copper and zinc plates further into the lemon

b increasing the distance between the copper and zinc plates

c squeezing the lemon.

Extension

5 Combine with another group and attempt to use two lemons to produce a larger current reading.

6 Make cells using other fruits and determine which produces the largest voltage.

Questions

1 Some chemical cells require acid. **Explain** where the acid comes from in this experiment and what sort of acid is involved.

2 **Discuss** the validity of your predictions in step 4 above.

3 **Explain** why the current increased or decreased in each case.

4 In step 5, lemons were linked together to produce a larger current. Was this a cell or a battery? **Justify** your answer.

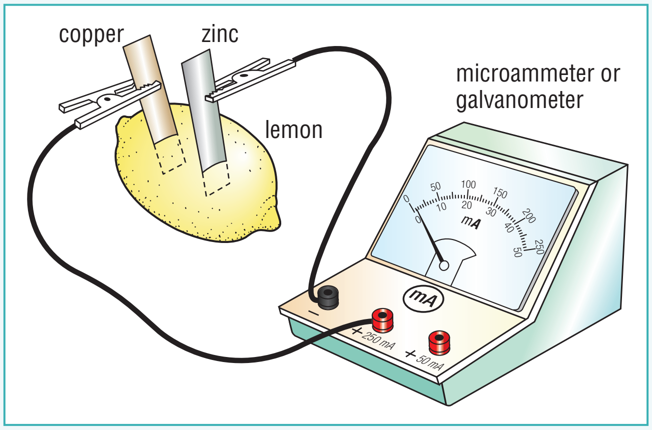


Fig 7.2.17

2 Battery life

Aim

To determine the life of different batteries

Equipment

- a range of different batteries (e.g. AA, AAA etc.)

Method

1 **Design** your own test to compare how long different brands and types of batteries last before they 'die'.

2 Present your findings as an experimental report that includes all the normal features such as aim, equipment, method, results, discussion and conclusion.

>>

3 Conductors and insulators

Aim

To test various materials and classify them as conductors or insulators

Equipment

- a 1.5 volt cell
- a 2.5 volt mounted globe
- three connecting wires
- various materials (e.g. a nail, coin, plastic, glass, wood, cloth, metal pieces, paper, rubber, steel wool)

Method

1. Assemble the circuit shown in Figure 7.2.18.
2. Test whether each material conducts well or not.

Questions

1. **Classify** the materials used as conductors or insulators.
2. If the light globe does not light up, **explain** whether this means the material is definitely an insulator.
3. Rubber is normally classified as an insulator, but will conduct electricity if an extreme voltage is connected across it. **Justify** the use of the term 'insulator' for rubber.

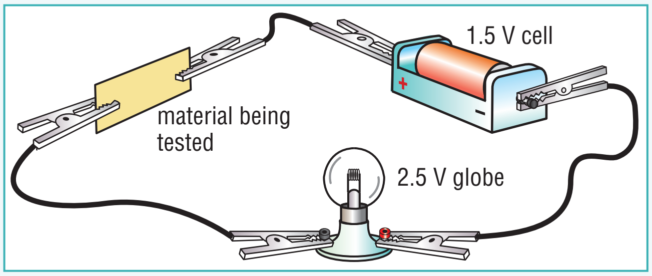


Fig 7.2.18

4 A mini water heater

Aim

To construct a mini water heater and observe the heating effect while varying the voltage

Equipment

- nichrome wire (20 cm)
- power pack capable of supplying 12 volts
- 250 mL beaker
- thermometer
- stopwatch or clock
- connecting wires

Method

1. Copy the table below into your workbook.
2. Connect the apparatus as shown in Figure 7.2.19. Leave the power pack turned off.
3. Take the temperature before any heating takes place.
4. Set the voltage knob on 6 volts. As you turn the power pack on, start the timer.
5. Record the temperature of the water every minute for 10 minutes.
6. Predict what would happen if you were to increase the voltage to 12 volts. Write down your prediction.
7. Repeat the steps above, but increase the voltage to 12 volts to test your prediction.

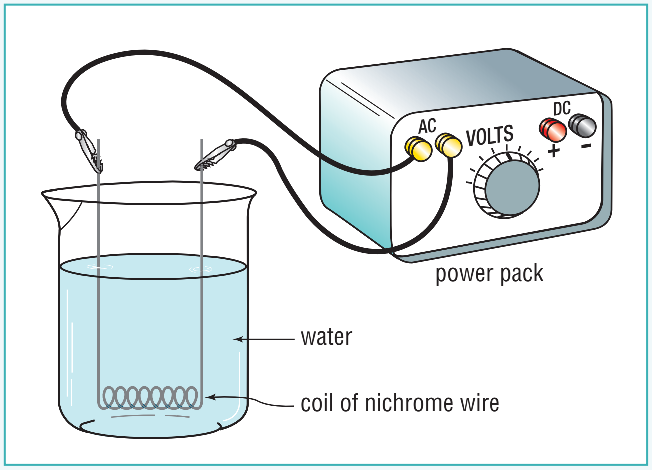


Fig 7.2.19

Questions

1. **Explain** where most of the energy supplied by the power pack is being transferred.
2. **Construct** a line graph showing the temperature variation over the 10 minutes. N
3. **Predict** what the temperature would have risen to if the water was heated another 10 minutes.
4. Would the temperature keep rising if the water was heated for a much longer time? **Justify** your answer.

Time (min)	0	1	2	3	4	5	6	7	8	9	10
Temperature (°C)											

5 Electric skill tester

Aim

To construct an electric skill-tester game

Equipment

- equipment, as shown in Figure 7.2.20

Method

Construct one of the skill-tester games shown in Figure 7.2.20.

Question

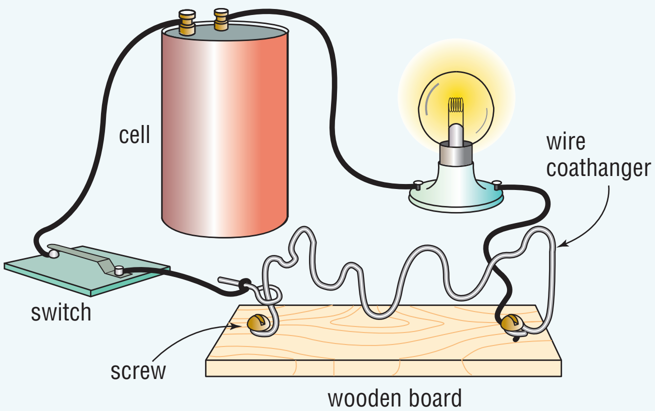
Whichever skill-tester you build, **identify** the:

a energy source

b energy user

c conductors.

DYO



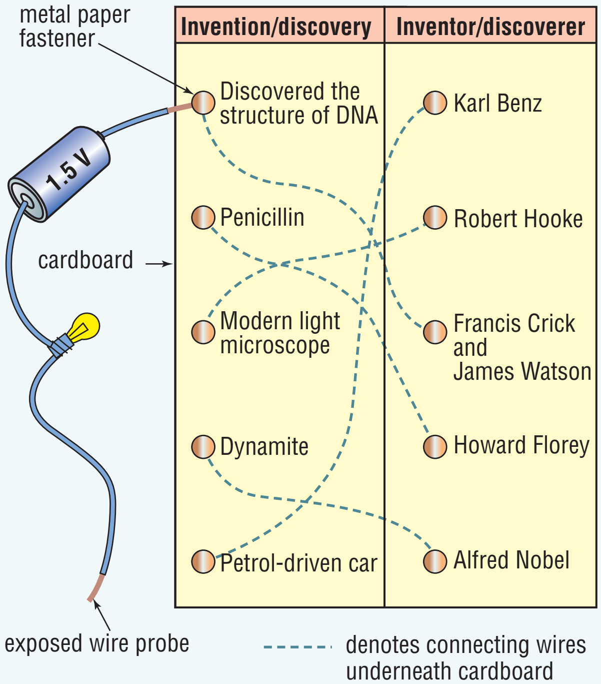


Fig 7.2.20

Unit 7.3 Using current electricity

context

Electric circuits are connected up in different ways, depending on how lights and other appliances are to operate. Imagine if you had to turn on the dishwasher, washing machine and all the other appliances around the house just to get the TV working! Or if you switched the bedroom light on and all the other lights in the house got dimmer! Some circuits will do exactly this—you need to pick the right type of circuit to do what you want it to do.

Fig 7.3.1 Many parallel circuits are working here.

Series circuits

If two globes are arranged one after the other, in a line with the battery, then the globes are said to be in **series**. Although the same current passes through each globe, the voltage supplied is shared between the globes. This makes each globe glow more dimly than if there was just one globe in the circuit.

The circuit is broken if any of the globes in a series circuit is removed or 'blows'. The current cannot jump over the break and so it cannot reach any of the other globes. They will not light up either.

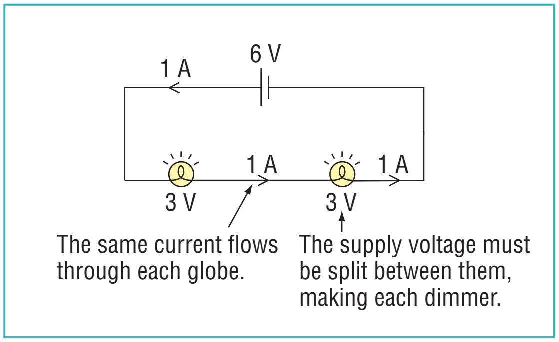


Fig 7.3.2 Globes that are in series are in a single line.

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Circuits

Two basic types of electric circuits are series and parallel circuits. Although series circuits are relatively simple, they have one big disadvantage—if the lights in a house were connected as a series circuit, then they would need to be all on or all off at the same time. Likewise, the air conditioner and dishwasher would turn on when you turned on the TV. Parallel circuits are a little more complex but allow a lot more flexibility. Each branch can be controlled separately. This makes them a far more practical way of wiring a house.

Parallel circuits

If two globes are arranged in separate branches, then they are said to be **parallel**. The voltage is the same for each globe in a parallel circuit and each will glow with equal brightness. At the branch point, the current splits. One globe will take half the total current and the other globe will take the other half.

If either globe in this circuit is removed or 'blows' then only that branch is broken. The other globe will stay alight because its branch is still intact.

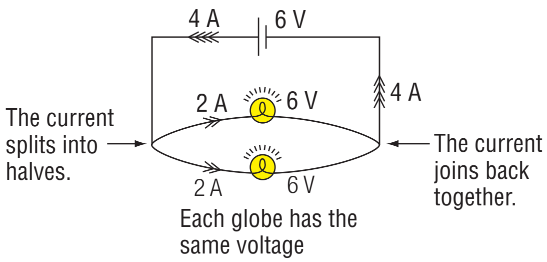

Fig 7.3.3 Globes that are in parallel are in different branches.

Worksheet 7.3 Electrical current

Fairy lights

Fairy lights and Christmas-tree lights can be wired in series or in parallel or sometimes a combination of both.

A series arrangement of 20 lights would share the 240 volts from the power point, giving each globe 12 volts. Globes come in different sizes (often 6 and 12 volts). For this circuit 12 volt globes would be ideal.

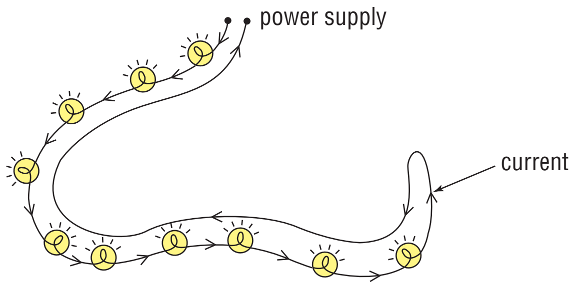

Fig 7.3.4 Fairy lights in series—they all carry the same current but share the supply voltage. If one globe blows, they all go out.

One disadvantage of a series circuit is that if one globe 'blows', they all go out. This makes it very difficult to find the failed globe.

The same 12 volt globes could also be arranged in parallel. All would have the same voltage (i.e. 12 volts). The advantage of a parallel circuit is that if one globe blows then all the others would continue to glow, making it easy to find the bad one. This circuit would need a power supply of only 12 volts and would 'blow' if it was connected directly into a 240 volt power point. A **transformer** is used to reduce the 240 volt supply to the 12 volts needed by the circuit.

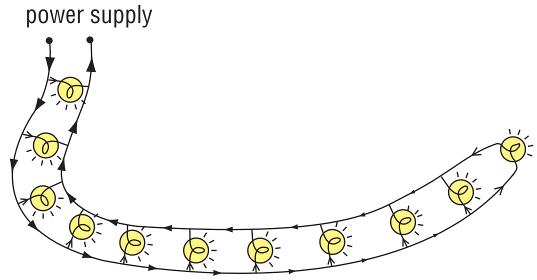

Fig 7.3.5 Fairy lights in parallel—they all have the same voltage and brightness, but the total current is split among them.

More complex circuits

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A circuit can combine series and parallel sections. Switches can then control current flow in each section, giving you some flexibility on what is 'on' and what is 'off'.

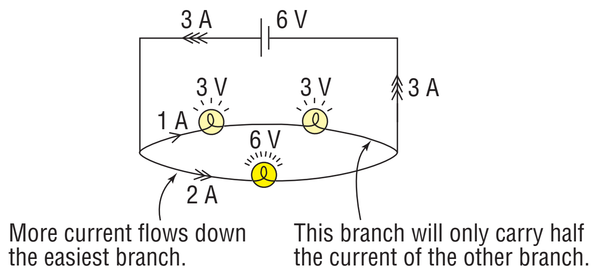

Fig 7.3.6 This circuit has two globes in series in one branch of a parallel circuit. The total current splits so that most current goes through the section with the lowest resistance.

Household circuits

The mains electricity wiring in your house is just one big parallel circuit. The big advantage of this arrangement is that each parallel branch can be controlled independently with a switch. Power points within the home allow extra parallel branches to be connected, where each branch gets the same 240 volts.

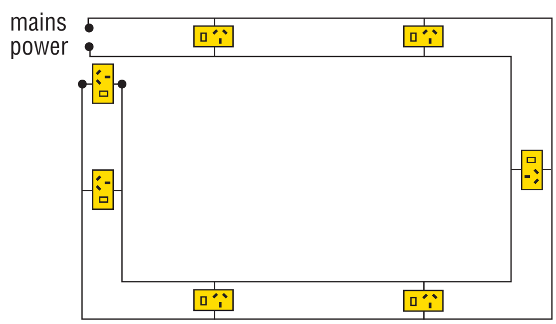

Fig 7.3.7 A house has a series of parallel circuits, each connected to the mains power at the switchboard. Each circuit and each power point receives 240 volts.

AC/DC

A battery pushes current in only one direction. Current that flows in only one direction around the circuit is known as **direct current** (**DC**). The current that comes from power points is **alternating current** (**AC**). This current is pulled back and forth 50 times every second, at a rate of 50 hertz (50 Hz). Household electricity is supplied as AC because it is easier to generate and transmit than DC.

Worksheet 7.4 Electricity costs   **Worksheet 7.5** Saving power

When things go wrong

A **short circuit** occurs when an easier path for current is created accidentally. This might happen if a wire becomes loose, say when a hairdryer is dropped, or if someone accidentally becomes part of the circuit themselves, say by sticking a knife into a toaster. A massive current then flows, causing the circuit to overheat, melt the surrounding insulation and possibly catch fire. Anyone who is part of the circuit will receive a nasty shock or will be electrocuted. To avoid this happening, home circuits have a **fuse** or **circuit breaker** that melts or 'trips' if too much current is flowing. A fuse is a short section of thin metal or a loop of thin wire. If the current in a circuit becomes too large the fuse will burn out, breaking the circuit and stopping the dangerous current from flowing.

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Science Clip

That's shocking!

The electric chair was invented to provide a quick and painless alternative to hanging, which often decapitated or strangled prisoners slowly. In 1860, William Kemmler was the first to die by electric chair. The first jolt of 1000 volts burnt his hair and skin and burst blood vessels, but he still lived! He eventually died after another 70 seconds of 1300 volts. Other prisoners convulsed so violently that they broke their own legs or broke the leather straps holding down their arms.

The electric chair gives short jolts of electrical current until the prisoner dies of a heart attack. A total of 4300 prisoners were executed by electric chair in the United States. Lethal injection has now replaced the electric chair as a method of execution.

Fig 7.3.9 The electric chair was designed to deliberately cause a heart attack.

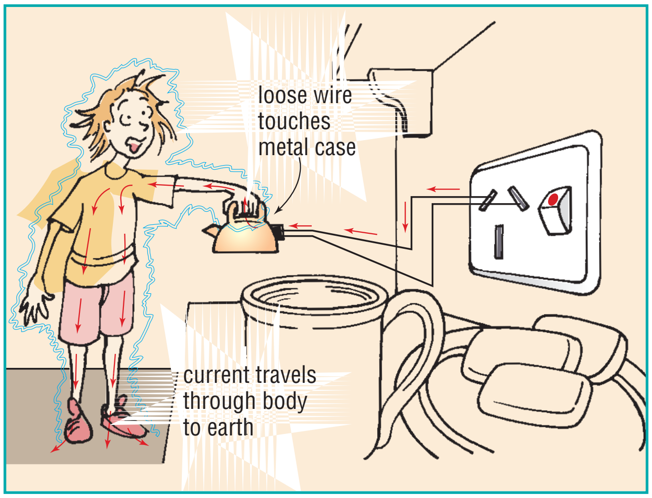


Fig 7.3.8 Electric shock occurs when current finds a path through the body.

A device called a safety switch or **residual current detector** (RCD) may also be connected to the household power supply to reduce the risk of electric shock. An RCD compares the current entering a home with that leaving via the correct circuit. If there is a difference caused by some current 'leaking out' (e.g. through a person's body), it switches off the main power switch within a few thousandths of a second. Serious electric shock is prevented.

Science Fact File

Safety

Electric shock or even electrocution (i.e. death by electricity) may occur if current finds a path through your body to the earth beneath you. A tiny current can cause death by damaging tissues and interfering with electrical signals driving the heart. For this reason, electricians wear rubber-soled shoes and use tools with insulated handles. Always follow these safety instructions when dealing with electricity.

- Never handle a plug without turning off the power point, and never interfere with circuits connected to mains power.
- If you do come across someone who has had an electric shock, first turn off the power, using the main switch at the fuse box if necessary.
- If this is not possible, do not touch the person directly, as you will be given a shock too. Sometimes, insulators such as a plastic rope or garden hose can be used to move them away from the source of electrocution.
- Then assistance and appropriate first aid can be given. Whatever happens, ring 000 (or 112 on a mobile if 000 doesn't connect).

7.3 QUESTIONS

Remembering

1 **State** whether the following statements are true or false:
  a Household wiring is like a big parallel circuit with many branches.
  b Current supplied to households goes in one direction only.
  c A large current is required to cause damage to your body.
  d Always ring 000 in case of emergency.

2 **List** two advantages of household circuits:
  a being wired in parallel
  b using AC.

3 **List** three ways of protecting a circuit and yourself from damage.

4 **List** what you should do if you find a person who has collapsed from electric shock.

Understanding

5 One globe 'blows' in a set of fairy lights. **Describe** what happens if the lights are wired in:
  a parallel
  b series.

6 The circuit diagram for a light at the bottom of a stairway is shown in Figure 7.3.10.

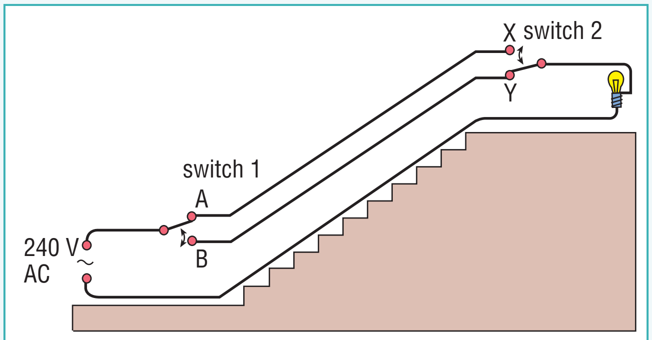


Fig 7.3.10

Copy and complete the table below into your workbook in order to **summarise** the operation of the circuit.

Switch 1 at position	Switch 2 at position	Light
A	X	on
B	X	
A	Y	
B	Y	

7 Carefully inspect the circuit shown in Figure 7.3.11 and **predict** which other globes would go out if:
  a globe A blows
  b globe B blows
  c globe C blows
  d globe D blows
  e globe E blows.

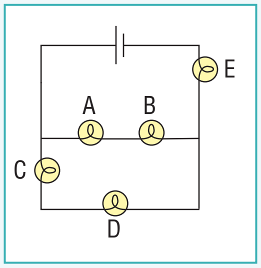


Fig 7.3.11

8 Copy the circuit in Figure 7.3.11 and **modify** it to include:
  a a switch that turns all globes on and off
  b an ammeter that measures the current through globe A
  c a voltmeter that measures the current through globe E.

9 **Predict** what would be the effect if a connecting wire was placed between points A and B to cause a short circuit in the circuits shown in Figure 7.3.12.

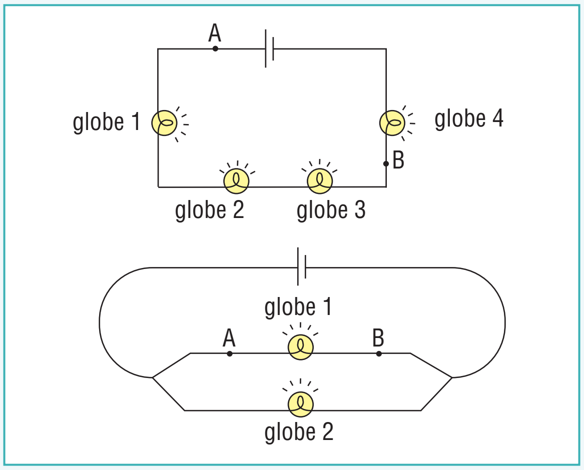


Fig 7.3.12

Applying

Use the following key to complete questions 10 to 13:
  A glow the same as before
  B glow brighter than before
  C glow dimmer than before
  D go out.

10 A globe in a series circuit blows. The other globes will…

11 Another globe is added in line with others in a series circuit. The other globes will…

12 A globe in a parallel circuit blows. The other globes will…

13 Another globe is added in parallel with others in a parallel circuit. The other globes will…

14 **Calculate** how many 6 volt globes can operate at full power in a 240 volt series circuit of fairy lights.

15 In Figure 7.3.13, identical globes and cells are used. **Identify** the circuit or circuits in which the globes glow:

a brightest

b most dimly.

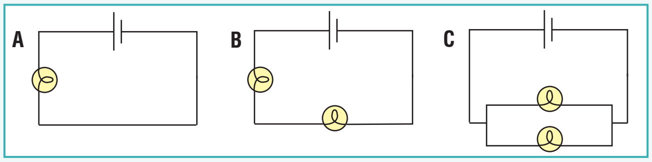


Fig 7.3.13

16 **Identify** the correct answer from the list below. The current that flows through point A in Figure 7.3.14 is:

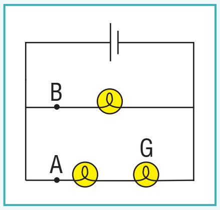


Fig 7.3.14

A the same as the current that flows through point B

B half the size of the current through point B

C twice the size of the current through point B

D three times the size of the current through point B.

17 **Identify** what fraction of the cell voltage would be used by globe G in Figure 7.3.14.

18 The diagrams in Figure 7.3.15 represent three safety switches. The numbers represent currents. **Identify** which safety switch would shut off the main power.

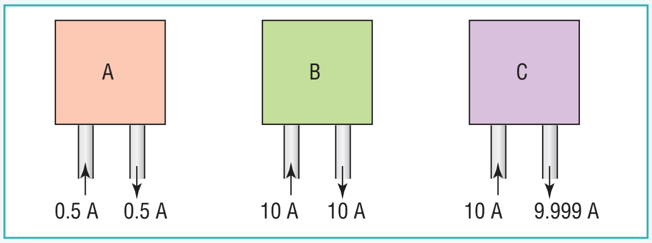


Fig 7.3.15

Evaluating

19 **Propose** what would happen if, rather than a number of parallel circuits, a household was set up as a single series circuit.

Creating

20 Use circuit symbols to **construct** a circuit with a cell and:

a three globes in series

b four globes in parallel

c two globes in series with three globes in parallel.

21 **Construct** a diagram showing the circuit in Question 20c and insert a single switch that controls the current in:

a the entire circuit

b one of the globes in parallel.

22 Greg notices that if one globe on his Christmas tree blows, four of its neighbours go out, but the other 45 stay lit. **Construct** the likely circuit diagram for Greg's fairy lights.

23 Imagine you are an electron who travels with several friends around a circuit containing two light globes in series followed by two globes in parallel, as shown in Figure 7.3.16.

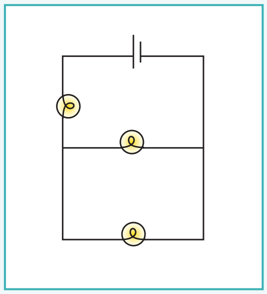


Fig 7.3.16

Construct an account of what you experience as you and your friends complete a circuit. Consider things such as:

- How do you get your energy?
- How do you lose energy?
- Was your movement restricted at any stage?
- What happens to your friends?
- Where were they as you were travelling?
- What happens to you all if the switch is suddenly opened? L

7.3 INVESTIGATING

Use circuit simulation software (e.g. Crocodile Clip) to construct circuits. Try to predict the current and voltage for various parts of each circuit you construct, then 'switch on' and check your predictions.

7.3 PRACTICAL ACTIVITIES

1 Series and parallel circuits

Aim

To construct a series and parallel circuit

Equipment

- two 2.5 volt globes
- four connecting wires (e.g. with alligator clip ends)
- two connection posts (e.g. nails in wooden blocks)
- 1.5 volt dry cell

Method

1 Connect and observe the brightness of a single globe, as in the first circuit shown in Figure 7.3.17.

2 Now insert an extra globe in series as shown. Note the brightness of each globe. Investigate what the effect is of removing a globe. Test if it depends on which globe is removed.

3 Now assemble the parallel circuit as shown in Figure 7.3.17. If you do not have connection posts, form the junction by piggybacking the alligator clips onto one another. Compare the brightness of the globes. Once again, investigate the effect of removing a globe. Does it depend on which globe you remove?

Questions

1 **Contrast** the brightness of globes in series with that of a single globe.

2 **Contrast** the brightness of globes in parallel with that of a single globe.

3 **Predict** the effect of removing a globe when they are:

a in series

b in parallel.

4 **Predict** the circuit in which the cell will go flat most quickly.

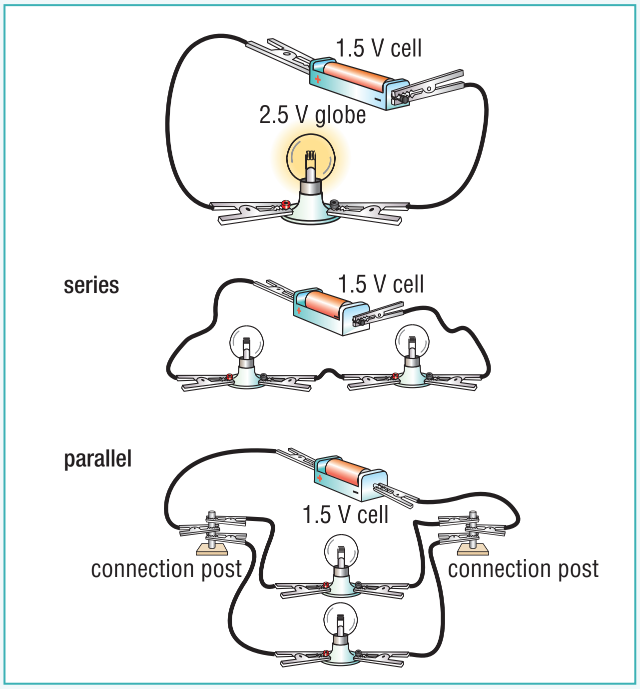


Fig 7.3.17

2 Connecting ammeters and voltmeters

Aim

To measure the voltage and current in series and parallel circuits

Equipment

- two 2.5 volt globes
- six connecting wires (e.g. with alligator clip ends)
- 1.5 volt dry cell
- ammeter
- voltmeter

Method

Part A

1 Assemble the circuit shown in Figure 7.3.18.

2 Record the current and voltage measurements as shown.

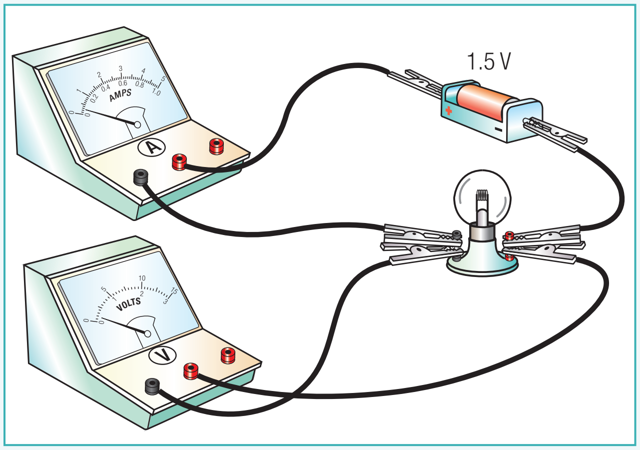


Fig 7.3.18

>>

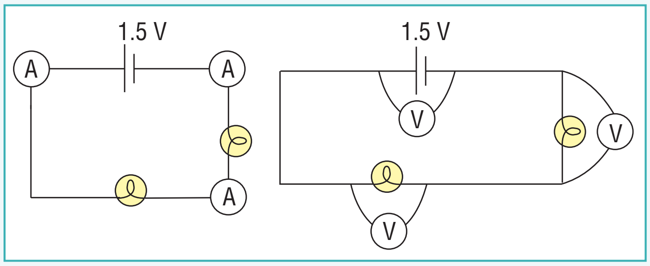


Fig 7.3.19

Part B: Series circuits

1. Copy each of the circuit diagrams in Figure 7.3.19 into your workbook. Use your copy to record all the current and voltage readings taken at each point as shown.
2. Construct the circuit as shown in Figure 7.3.19.
3. Use an ammeter to measure the current at each location indicated by the ammeter symbols in Figure 7.3.19.
4. Disconnect the ammeter and then piggyback a voltmeter across each location indicated by the voltmeter symbols in the second diagram in Figure 7.3.19.

   Note: The red or positive voltmeter terminal connects to the 'side' of the circuit closest to the positive of the cell or battery.

Part C: Parallel circuits

1. As before, copy the circuit diagrams shown in Figure 7.3.20 and use them to record all measurements taken.
2. Construct the parallel circuit shown in Figure 7.3.20 and measure the current and voltages at the locations shown in the circuit diagrams.

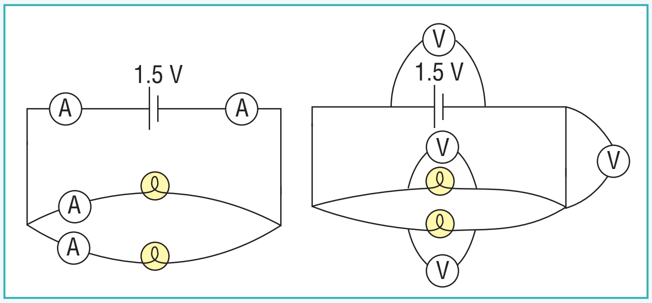


Fig 7.3.20

Questions

1. **Describe** the current at various points around the:
   - **a** series circuit
   - **b** parallel circuit.
2. **Describe** the voltages around the:
   - **a** series circuit
   - **b** parallel circuit.

3 A simple fuse

Aim

To observe how a fuse works

Equipment

- strands of steel wool
- cork
- two pins
- power supply
- connecting wires
- 2.5 volt globe

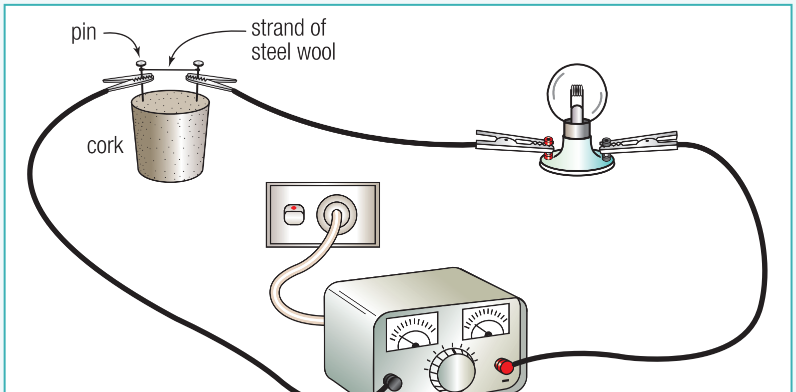


Fig 7.3.21

Method

1. Leaving the power pack turned off, construct the circuit in Figure 7.3.21.
2. Gradually increase the power supply voltage from zero, stopping when the fuse melts or the voltage reaches 3 volts, whichever comes first.

Questions

1. **State** the voltage at which the fuse melted.
2. **Explain** why a globe was included in the circuit.
3. **Describe** the role of a fuse in a circuit.
4. **Propose** ways in which this fuse could be modified to allow greater current before melting.

Solar challenge

Prescribed Focus Area:
The applications and uses of science

Electricity was first supplied by batteries and used only for scientific experiments. New ways to produce electricity were gradually developed, and more and more electrical devices were invented. Many of the activities in our everyday life now rely on the use of electrical energy. We produce huge amounts of electricity to meet society's needs.

Fig 7.3.22 We rely on electricity for many daily activities.

Unfortunately, we often produce this electricity in ways that cause pollution and have harmful effects on the environment. These include burning coal, oil or gas to turn the chemical energy into electrical energy. When supplies of fuel, such as coal, run low we will need new ways to produce electricity. These will also need to be less polluting. All life on Earth gets its energy from the sunlight that is trapped by plants during photosynthesis. Given this, many scientists have directed their attention to developing solar cells. **Solar cells** take the energy in sunlight and convert it into electrical energy.

Fig 7.3.23 Plants are nature's solar cells. They take the Sun's energy and turn it into a type of energy that is more useful, producing very little pollution.

Why solar cells?

The original materials used to manufacture solar cells were not very good at turning the energy from sunlight into electrical energy. They were also quite expensive to make. Time and money continue to be spent on research and the development of solar cells that will enable us to:

- provide a reliable source of electricity that can be used in space or hostile environments
- provide electricity to remote communities that are too far from power grids
- replace noisy, polluting diesel generators in office buildings, holiday venues and isolated research stations with a more environmentally friendly, non-polluting source of electricity
- provide small, portable power sources to reduce the need for batteries (e.g. in calculators)
- provide a totally renewable and sustainable source of electrical energy to overcome a reliance on fossil fuels and help to reduce global warming.

Fig 7.3.24 Solar panels are increasingly being used to provide electricity for homes in Australia.

How do solar cells work?

Solar cells (or photovoltaic cells) are made of **semi-conductors**. Semi-conductors are special materials, such as silicon, that are used in computers. They are called semi-conductors because they are not very good at conducting electricity compared with metals. However, they are much better at conducting electricity than insulators. A solar cell is made of two layers of semi-conductor. Each layer is made of silicon, but small amounts of phosphorus are added to one layer, and boron is added to the other layer to make them conduct a bit better.

When light hits the join between the layers, its energy knocks electrons off the atoms. These electrons are then free to move or flow. When a circuit is connected to the top and bottom metal conductors of the solar cell, the electrons flow out of the top metal conductor and around the circuit. The energy of these moving electrons can be used to make an appliance work. More electrons are released, and more electricity is generated, if more sunlight hits the cell.

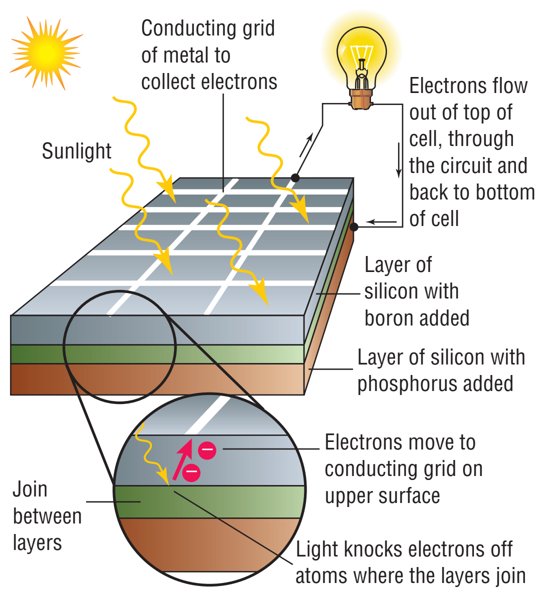


Fig 7.3.25 A solar cell works by the energy in sunlight causing electrons to migrate between layers of the solar cell.

The Solar Challenge

The Solar Challenge is an annual 3000 kilometre race from Darwin to Adelaide. The challenge is to design and build a car that is capable of crossing Australia powered only by sunlight.

To build a solar car requires many great minds and expertise from different areas of science, including physics, electrochemistry, engineering, mathematics and psychology. The Solar Challenge has grown over the years and attracts competitors from many countries. Competitors include nearly 100 of the world's top universities, companies such as Honda and organisations such as the Australian Aurora team. The competition is open to anyone whose vehicle meets the basic requirements. Some of the entries are constructed on very low budgets, and some secondary schools enter the competition.

The Solar Challenge is an adventure for people seeking to apply scientific knowledge to solar technology. It promotes a smarter, greener world, an awareness of environmental issues and the development of the best solar technology for the future. It also provides an opportunity for young minds to develop their potential. Maybe you could give it a go?

The vehicles are all powered by panels of solar cells. These provide electricity directly to motors that run the wheels or to storage batteries for use when light levels drop. Many entries use the most advanced technology and specially developed materials in their designs to make lightweight, strong and fast cars.

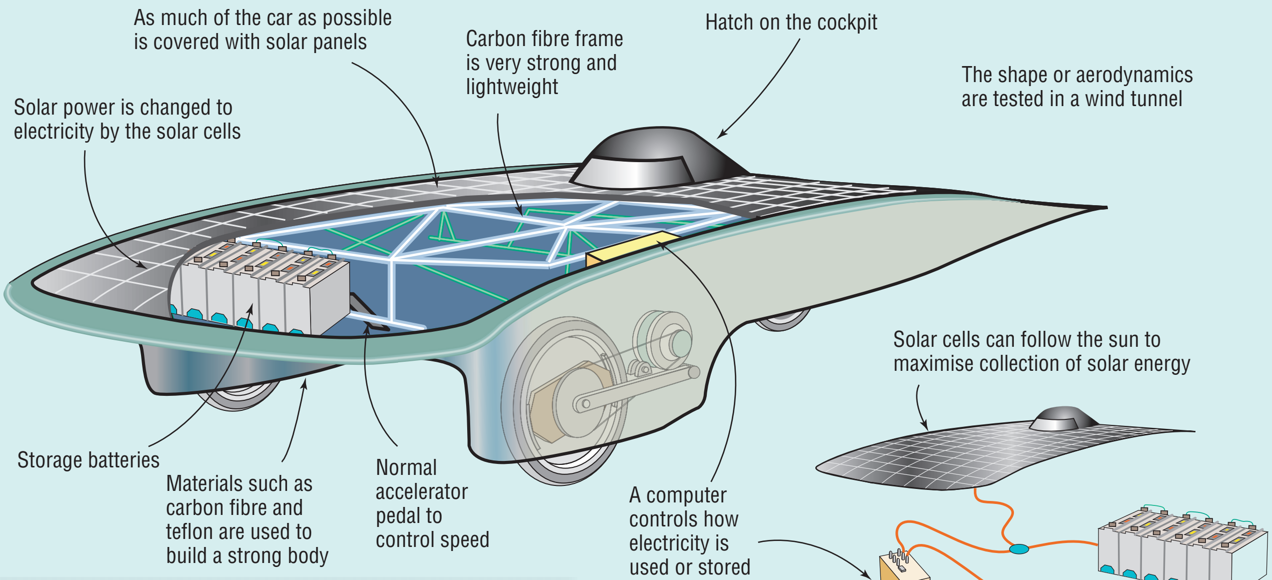


Fig 7.3.26 A solar car of the type used in the Solar Challenge

STUDENT ACTIVITIES

Learn more about the Solar Challenge and solar cars in general by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. The information on these links may help with the following activities.

PP Web Destination

1. **Outline** the energy changes that take place when using a solar cell to run a solar car.
2. **Summarise** the features that are designed to increase the efficiency of solar cars, and explain why each feature is important.
3. **a** **Investigate** solar cells further and make a list of the advantages and disadvantages in using solar power.
   b **Research** an answer to the question: Considering solar cells produce electricity from sunlight, why doesn't everybody use solar cells to produce the electricity they want?
   c **Assess** solar cells as an energy source for the future.
4. **Propose** some reasons why companies and universities invest so much money in their entry for the Solar Challenge.
5. Imagine that by the year 2030 solar cells have become so efficient and cheap that they are used to supply all societies' electricity. Produce an artwork to demonstrate what it would be like to live at this time.
6. In a team, **design** your own solar car. Try to make it as energy efficient and innovative as possible. Remember, you want to win the challenge!

CHAPTER REVIEW

Remembering

1 **State** whether the following statements are true or false:

- **a** Like charges attract each other.
- **b** A charged object may attract a neutral one.
- **c** An electron is a small negative charge.
- **d** Charge tends to concentrate on sharp corners.
- **e** Lightning can occur only when charge flows from a cloud to the ground.
- **f** A circuit contains a single globe glowing normally. It is possible to add 10 more globes to the circuit so that each glows just as brightly as did the single globe.
- **g** Voltage is shared in a series circuit.
- **h** Current always divides equally when it reaches several parallel branches in a circuit.
- **i** Current is measured with an ammeter.
- **j** The least energy is used in the resistance sections in a circuit.
- **k** A set of Christmas-tree lights is connected in series. If one globe blows, all will go out.

2 **Recall** the symbols used for circuit components by drawing the following:

- **a** an open switch
- **b** a globe
- **c** a cell
- **d** conducting wire
- **e** a resistor.

Understanding

3 **Describe** how a safety switch works.

4 **Use** Figure 7.2.13 to **describe** how the element in an electric jug heats the water.

5 **Explain** the purpose of a fuse in an electric circuit.

6 **Explain** how wearing rubber-soled shoes helps to protect electricians.

7 Draw a series of diagrams to **explain** the stages involved in producing a photocopy of a black square drawn on a white sheet of paper.

Applying

8 Copy each of these statements and complete them by **identifying** the correct word from the brackets.

- **a** Current is the flow of (electric/magnetic) charges.
- **b** Current is measured in (volts/amperes).
- **c** (A conductor/an insulator) does not allow charge to flow through it.
- **d** Most (plastics/metals) are good conductors.
- **e** (Voltage/current) is a measure of the energy available to push charges around a circuit.
- **f** A (wet/dry) cell contains a chemical paste and electrodes to produce free electrons.
- **g** It is usually (positive/negative) charges that flow in a circuit.

9 **Identify** which two surfaces rub together to produce charge in each of these situations.

- **a** You brush your hair and generate a spark.
- **b** A car moves along a road and becomes charged.
- **c** You rip off the thin plastic that seals the lid of a container, only to find that it sticks to your fingers.
- **d** The hairs on your arm are attracted to the surface of a plastic chair.

10 **Identify** which diagram in Figure 7.4.1 best illustrates:

- **a** a neutral object
- **b** a positively charged object
- **c** a negatively charged object.

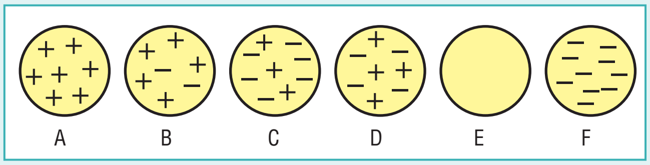


Fig 7.4.1

11 **Use** appropriate symbols to draw a simple circuit that could turn a globe on and off.

12 Copy Figure 7.4.2 and add appropriate devices to measure the energy used by globe G and the current that passes through it.

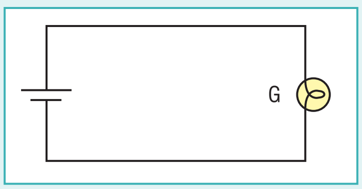


Fig 7.4.2

13 In Figure 7.4.3 a positive charge is being pulled in the direction shown by another charge. **Identify** which arrow gives the direction of the electric field acting on the charge.

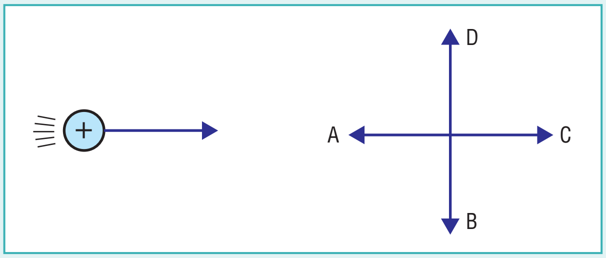


Fig 7.4.3

Analysing

14 **Contrast** a cell with a battery.

15 **Distinguish** a household power supply from a battery or cell.

16 **Contrast** static electricity with current.

Evaluating

17 **Propose** reasons why some cars dangle from their rear a rubber strip containing metal. The strip is long enough to touch the road surface.

Creating

18 **Construct** a circuit diagram for the circuit shown in Figure 7.4.4.

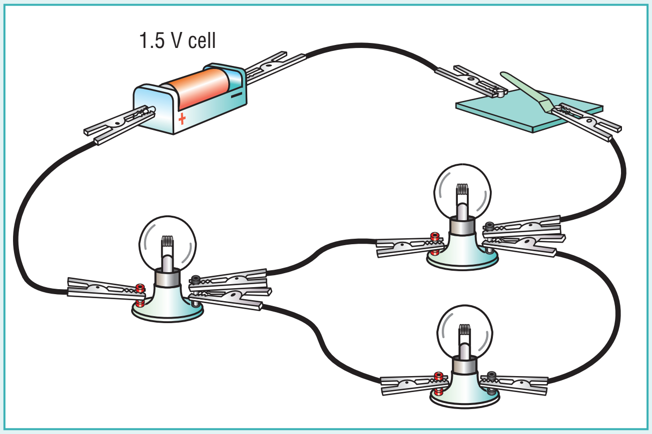


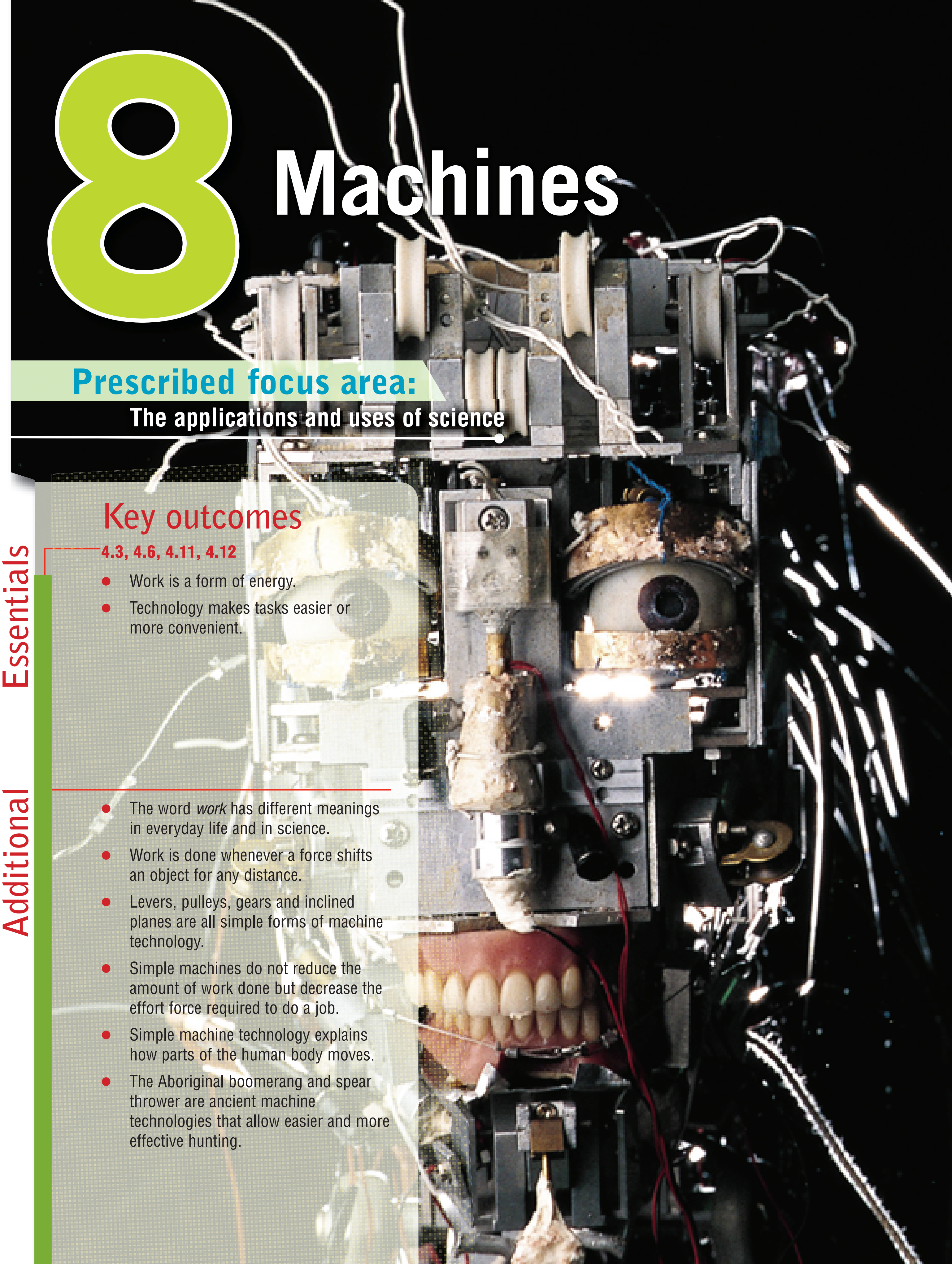
Fig 7.4.4

Worksheet 7.6 Crossword

Worksheet 7.7 Sci-words

PP Chapter Review Questions

PP Interactive



8 Machines

Prescribed focus area:
The applications and uses of science

Key outcomes

Essentials

4.3, 4.6, 4.11, 4.12

- Work is a form of energy.
- Technology makes tasks easier or more convenient.

Additional

- The word *work* has different meanings in everyday life and in science.
- Work is done whenever a force shifts an object for any distance.
- Levers, pulleys, gears and inclined planes are all simple forms of machine technology.
- Simple machines do not reduce the amount of work done but decrease the effort force required to do a job.
- Simple machine technology explains how parts of the human body moves.
- The Aboriginal boomerang and spear thrower are ancient machine technologies that allow easier and more effective hunting.

Unit 8.1 Simple machine technology

context Humans are weak creatures—even the strongest can lift only between 200 and 300 kilograms, and there's so much we can't do! Without help we can't fly or stay underwater for long or travel very fast.

Machine technology allows us to do all these things and much more. Machines make simple jobs easier and allow us to do things that we would otherwise find near impossible.

Fig 8.1.1 Simple machine technology helped build the ancient world.

Making tasks easier

PP Quick Quiz

Humans have been building machines since before written records began. Primitive machines helped humans hunt, cultivate and trap food, build protection from the weather, to glorify their gods, and to wage war against each other. Machines helped lift the huge pillars and blocks of stone to build the temples and pyramids of the ancient Egyptians, Romans and Greeks; helped them to draw water from wells; and allowed them to travel faster than ever before.

The ancient civilisations used **simple machines** like **ramps**, **wedges**, **screws**, **levers**, **wheels**, **gears** and **pulleys**. Although these might not seem to be machines, they all make some task easier.

Simple machines can be used by themselves or can be connected to **construct complex** machines. Eggbeaters, staplers, can openers, robots, the hinges on a garage door, bikes and cars are all complex machines that are made up from simple ones.

Effort and load forces

Machines are all about **force**. They generally reduce the amount of effort required, making the task much easier or allowing bigger loads to be lifted than would normally be possible. **Effort** is the force required to move an object. The object and its weight are called the **load**.

Go to Science Focus 1, Unit 7.1

Work in science

The word *work* is used in many ways. *Hard work*, *a lot of work* and *homework* are expressions we use and hear. Scientists mean something very different by the word work. To understand how machines make a job easier, you first need to understand the scientific meaning of work.

Scientifically, **work** is the energy needed to move something over a certain distance. Like all energy, work is measured in joules (abbreviated as the symbol J).

moved in doing the job ↓

Work = effort force × distance

↑ needed to get the job done

Simple machines and work

The work and energy needed to perform a job depends on the job itself and not how it is done. The same task can, however, be done in many different ways. Some ways might be difficult because a high effort force is needed. Other ways will be easier because they need only a small effort force.

Let's say a certain job takes 12 joules to do. You could do the job in a number of ways, as shown in the table below.

Energy needed to do the job (J)	Effort force needed to do the job (N)	Distance we need to move to do the job (m)	Proof that this will do the job
12	12	1	12 × 1 = 12
12	6	2	6 × 2 = 12
12	4	3	4 × 3 = 12
12	3	4	3 × 4 = 12
12	2	6	2 × 6 = 12
12	1	12	1 × 12 = 12

As the table shows, if the distance is increased, then the effort needed to do the job is decreased. Simple machines use this fact to make them effective—they increase the distance moved to reduce the effort force required to do the job.

The ramp

A **ramp** (sometimes called an **inclined plane**) is one of the oldest and simplest of machine technologies. Ramps are useful when shifting a heavy object up to a higher level.

If you want to lift a load, you need to do a certain amount of work regardless of how you go about it. This is because work depends on the weight of the object and the height you lift it—not on how you do it.

Imagine you're helping your family to move house and need to load the refrigerator onto a truck. The shortest path onto the truck is straight up, vertically. This is going to be very difficult (perhaps impossible) because it requires that you to put in an effort force at least equal to the weight of the fridge.

Yet, if you pull or push the refrigerator up a ramp, you will find the job easier. Although the work is the same, less effort is required because you are moving the fridge a greater distance.

Prac 1 p. 245

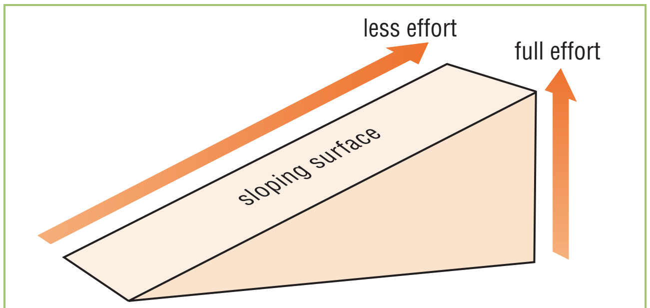


Fig 8.1.2 Ramps are effective because you have to travel further—effort is less when distance is more.

Type of ramps

Ramps are all around you, many of them not looking like a ramp at all. An escalator, for example, can be thought of as a moving ramp.

Wedges

A **wedge** is an inclined plane that passes through another object, splitting or slicing the object in two as it does so.

An axe or wood splitter is an obvious wedge. It reduces the effort needed to split a log by forcing the wood to travel up the long edge of the blade. The sharper the blade, the longer the edge and the less effort required to split the timber.

Saws, scissors, knives and your front teeth (i.e. the incisors) also act in this way, making it easier to cut and slice through wood, paper and food.

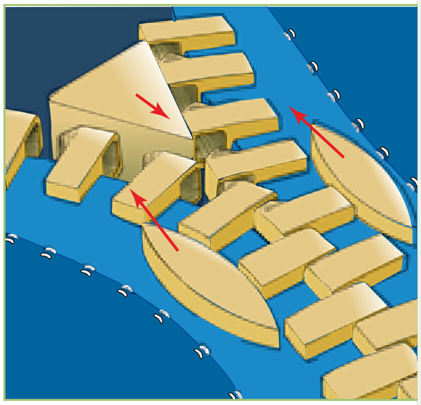


Fig 8.1.3 The zip fastener is an example of a twentieth-century technology that uses three wedges. The zipper's slide contains wedges that turn a little effort into a strong force that opens and closes the fastener. Without this assistance, the teeth of the zip are nearly impossible to join or part.

Science Clip

Zip!

Coincidence in science sometimes means that two people on opposite sides of the world have the same idea or invent the same contraption at exactly the same time. The modern, successful zipper was patented in 1913 by Catharina Kuhn-Moos in Europe *and* Gideon Sundback in the United States, neither of whom knew about the other or what they were working on. Sundback had been working on improving a clasp-fastener invented earlier by his boss, Whitcomb L. Judson, and Kuhn-Moos seems to have invented hers from scratch.

Screws, nuts and bolts

A **screw** is similar to a wedge in that it is also a ramp, this time spiralling around a metal cylinder. Screws penetrate materials such as:

- solids—woodscrews are screwed into timber
- liquids (e.g. water)—a propeller on a boat is a screw
- gases (e.g. air)—propellers on an aircraft, or an electric fan.

Fig 8.1.4 A propeller is a screw that cuts through air or water.

Try to hammer a woodscrew into a piece of timber and you won't get very far. It would need an extremely large force to do so. Yet, if the screw is turned, the timber is moved along the spiral ramp. Because of the great distance covered, a much smaller force is required (although a lot of turning has to be done). Once again, distance is increased, so the effort is less. A bolt and its nut work the same way, although in this case the nut is wound down the screw of the bolt.

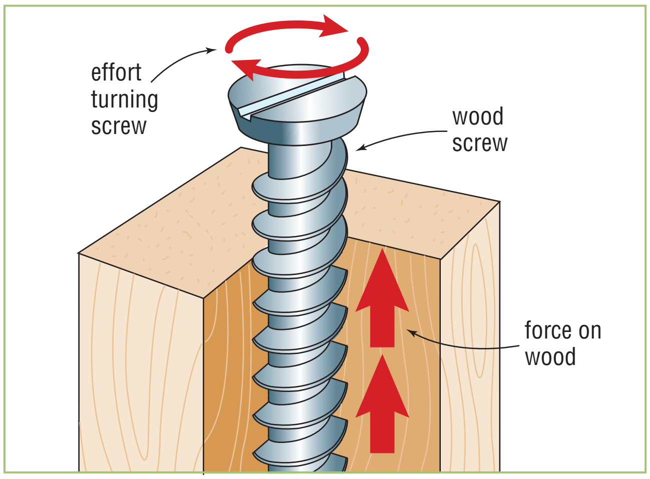


Fig 8.1.5 A woodscrew is really just a curved ramp. The screw needs to be turned a lot, but the effort needed is much reduced.

Mechanical advantage

Mechanical advantage measures how effective the technology or machine is. Mechanical advantage can be calculated by dividing the load you want to move by the effort needed.

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

Fig 8.1.6 Many villages in the Middle East use the Archimedes screw to raise water from dams and rivers. This water treatment plant in England also uses multiple screws to raise the water it treats.

Worksheet 8.1 Ramps

Prac 2 p. 246

Science Clip

The Archimedes screw

Archimedes (287–212 BCE) is usually remembered for his alleged naked dash from his bath and through the streets after he solved the problem of buoyancy. His fame in ancient Greece was, however, as a scientist, mathematician, philosopher and inventor. One of his inventions, the Archimedes screw, was a device to bail water out of the hulls of warships.

For example, if a simple machine lifted a weight of 60 newtons (this is about 6 kilograms) but needed an effort of only 20 newtons to do so, then the mechanical advantage would be:

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}} = \frac{60}{20} = 3$$

Better machines have higher mechanical advantages. A better machine than this one would be able to either:

- lift a bigger load (say, 600 N) with the same effort (i.e. 20 N). This would give a larger mechanical advantage:

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}} = \frac{600}{20} = 30$$

or

- lift the same load as before (60 N) but with a lot less effort than before (say, 2 N):

$$\text{Mechanical advantage} = \frac{60}{2} = 30$$

8.1 QUESTIONS

Remembering

1 **List**:

a seven simple machines

b five examples of ramps being used to make a job easier

c three examples in which wedges are used to separate or split or slice an object more easily.

2 **State** another name for a ramp.

3 **State** whether machines reduce the work or effort force required for a job.

4 **Name** the unit that is used to measure work.

5 **Name** a screw that cuts through:

a a solid

b a liquid

c a gas.

Understanding

6 **Define** the terms: L

a work

b mechanical advantage.

7 **a** **Describe** the advantage of using a ramp.

b **Describe** its disadvantage.

8 **Explain** how ramps assist in each of the following situations:

a getting wheelchair users and elderly people into a building

b getting a car over a gutter

c taking the escalator instead of the lift.

9 **Explain** why a path zig-zagging up a mountain is easier to walk than a track straight up to the top.

10 **Explain** how sharpening an axe makes it easier to use.

11 **Describe** how a screw is also a ramp.

Applying

12 Three machines do the same job in different ways. Their mechanical advantages are: Machine A = 2, Machine B = 0.5, Machine C = 10. **Identify** which is the better machine.

13 Bolt cutters easily slice through padlocks. **Identify** whether the load or effort is greater.

14 **Calculate** the mechanical advantage of the following machines: N

a load = 12 N, effort = 6 N

b load = 18 N, effort = 6 N

c effort = 3 N, load = 18 N

d load = 5 kg (about 50 N weight force), effort = 10 N

15 **Evaluate** which of **a**, **b**, **c** or **d** in Question 14 is the best machine.

Analysing

16 **Compare** a simple machine with a complex machine by listing their similarities and differences

17 **Contrast** effort and load. N

18 Sarah knew that 24 joules of work was needed to lift an object up to a certain height. She constructed the table below to help her decide which ramp would make the job easiest. Copy her table and **calculate** all her missing values. N

Work (J)	Ramp length (m)	Effort needed (N)	Proof that this will do the job	Mechanical advantage
24	1	24	1 × 24 = 24	24/24 = 1
24	2		2 × 12 = 24	
24		8		24/8 = 3
24	4			
24			6 × 4 = 24	24/4 = 6
24	8			
24				
24				

Evaluating

19 Which ramp in Question 18 would make the job easiest for Sarah? **Justify** your answer.

Creating

20 **Construct** a rule about how ramps make the job of lifting a load easier.

8.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find the design of the Archimedes water screw and construct a diagram or model to show how it works.

8.1 PRACTICAL ACTIVITIES

1 Ramps

Aim

To investigate the relationship between the slope of a ramp and effort

Equipment

- spring balance
- ramp
- dynamics cart and wooden block with a hook attached
- small masses
- sticky tape
- books
- protractor

Method

1 Make a pile of textbooks on your desk about 10 centimetres high.

2 Construct a table or spreadsheet as shown below.

Angle (°)	Distance along ramp (cm)	Effort to move cart (N)	Mechanical advantage	Effort to move block (N)	Mechanical advantage

3 Weigh the dynamics cart and the block of wood using a spring balance. Tape masses on them until both are about the same weight. Record their new weights.

4 Slowly lift up the cart vertically until it reaches the top of the stack. Record the effort required from the spring balance.

5 Repeat with the block.

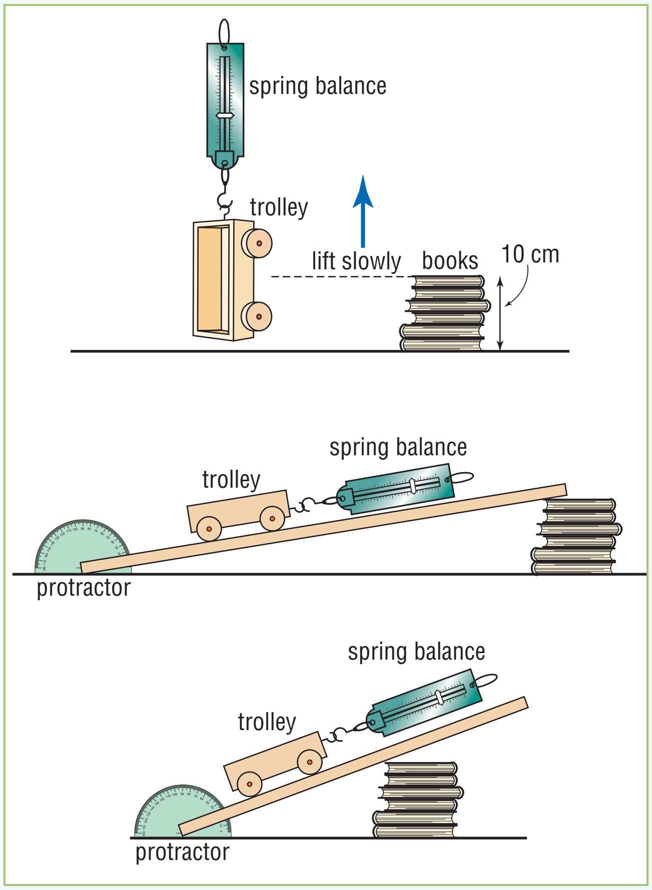


Fig 8.1.7

6 Now place the ramp on the books so that its angle with the desk is very small.

7 Measure the angle with a protractor and measure the distance along the ramp from the bottom to the top of the books. Record it.

8 Drag the cart up the slope with the spring balance until it reaches the top of the books once more. Record the effort needed, then repeat with the block.

>>

9 Try three different angles. You might need to overhang the books to do so. Take angle and effort measurements each time for both the cart and the block.

Questions

1 The work required to drag up the cart and block was the same in each case. **Explain** why.

2 **Describe** what happened to the effort force needed as the ramp got longer.

3 Which was the better ramp? **Explain**.

4 Which was easier to get up the slope—the block or the cart? **Propose** reasons for your answer.

2 Legal and illegal ramps

Australian building regulations state that ramps must be built with a slope of no more than:

- 1 : 8 for ramps shorter than 152 centimetres in length; that is, its horizontal distance must be more than eight times its height
- 1 : 14 for ramps longer than 152 centimetres in length; that is, its horizontal distance must be more than 14 times its height.

Aim

To test commonly used ramps to determine whether they meet Australian building regulations.

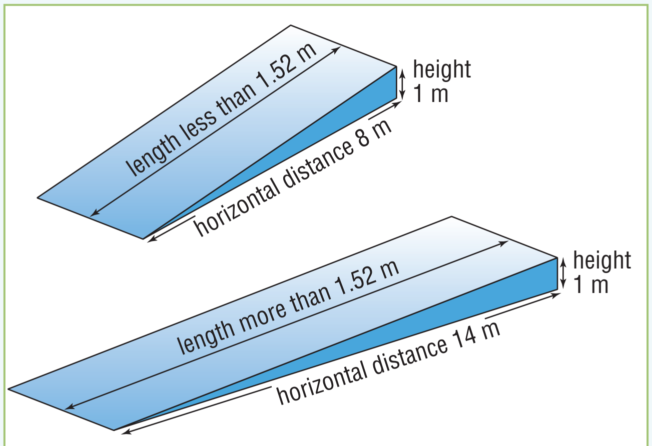


Fig 8.1.8

Method

1 Measure (or carefully estimate) the length, height and horizontal distance of ramps around school, at home or at the shops.

2 On a calculator, divide horizontal distance by height. Then use the guide below to assess if each ramp meets the law. N

3 Construct a table similar to that below. Enter your results and calculations.

For ramps	The ramp is legal if horizontal distance ÷ height is	The ramp is illegal if horizontal distance ÷ height is
Shorter than 152 cm	8 or more	less than 8
Longer than 152 cm	14 or more	less than 14

Questions

1 Ramps can be used by everyone, but are usually designed for a particular purpose. For example, factories might have ramps to make it easier to load trucks. **Identify** the main purpose for ramps:

a around school

b at an elderly person's home

c at the shops

d on a farm.

2 **Propose** a reason why shorter ramps are allowed to be steeper than longer ramps for the disabled.

3 **Propose** a reason why long ramps must have flat landings at regular intervals.

4 **List** the ramps that did not comply with the regulations.

Ramp location	Length (cm)	Horizontal distance (cm)	Height (cm)	Horizontal distance ÷ height	Legal or illegal
High Street shops	100	90	45	90 ÷ 45 = 2	illegal
School hall	1505	1500	100	1500 ÷ 100 = 15	legal

Unit 8.2 Levers

context The oldest diagrams of levers are found on 5000-year-old Egyptian sculptures. The ancient Greek philosopher Aristotle mentions them in his writings. Archimedes stated that 'With a lever long enough and a point to stand on, I could move the world.'

Fig 8.2.1 Seesaws are class 1 levers. They have the load and effort forces at either end, and the pivot somewhere in between.

What is a lever?

The lever is an old technology that can be dated back about 5000 years. You probably use a number of different forms of levers every day without even realising it. Shovels, spoons, scissors, tennis racquets and cricket bats are all levers, as are your arms, legs and jaws.

A **lever** is any solid object that is made to turn round a **pivot** or **fulcrum**. A load is placed somewhere along the lever and an effort causes it to turn.

Force multipliers: Class 1 and 2 levers

Prac 1 p. 252

Some levers are **force multipliers**—you put in a small effort and the lever system multiplies it so that you can lift much heavier loads. As with ramps, levers reduce the effort needed to lift a load. Once again, the disadvantage is distance—the more you wish to reduce effort, the further you need to move the lever.

Fig 8.2.2 Archimedes supposedly used levers to lift invading Roman ships out of the water of Syracuse harbour, smashing the ships onto rocks!

Science Clip

Ancient propaganda?

Archimedes is reputed to have built many machines to destroy invading Roman ships. As well as his lever-cranes, he supposedly built massive reflectors that burned the ships. He also had other machines that sat on the bottom of the harbour, grabbing ships from beneath and shaking them until all the soldiers fell off! However, it is possible that this was all just ancient propaganda designed to frighten the enemy.

Levers

Levers that act as force multipliers can be classified as either **class 1** or **class 2** levers. Both types are extremely useful when a heavy load must be moved. They can move heavy loads by putting in a little effort a long way from the pivot.

Where you apply the effort in these levers is just as important as the effort itself. The effort required depends on the distance of the load from the fulcrum and where on the lever we put our effort.

As with the ramp, these levers reduce the effort by increasing the distance the load must be moved.

Prac 2 p. 253

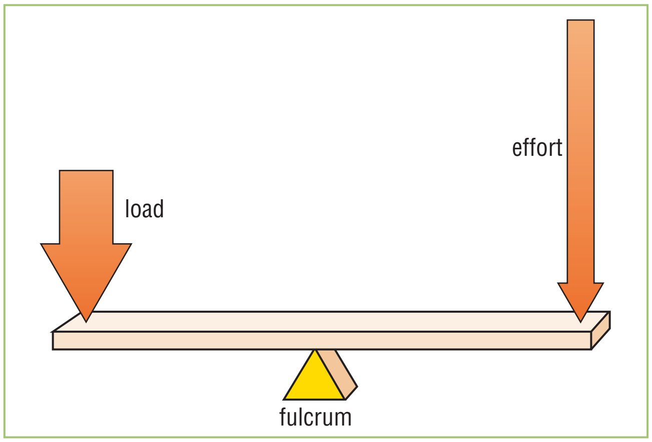


Fig 8.2.3 Class 1 levers (or first-order levers) have the load at one end, the effort force at the other and the fulcrum somewhere in between.

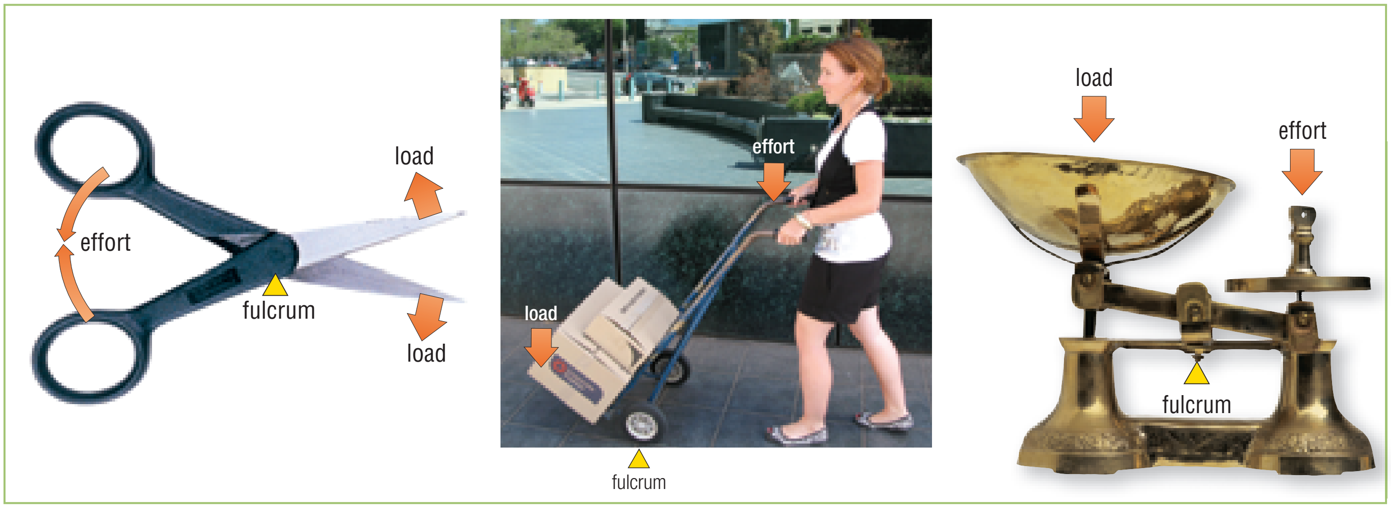


Fig 8.2.4 Class 1 levers resemble a seesaw, the fulcrum being somewhere in the middle of the lever.

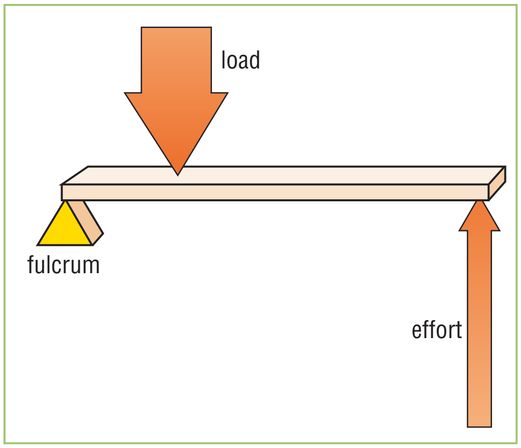


Fig 8.2.5 Class 2 levers (or second-order levers) have the fulcrum at one end, the effort at the other and the load somewhere in between.

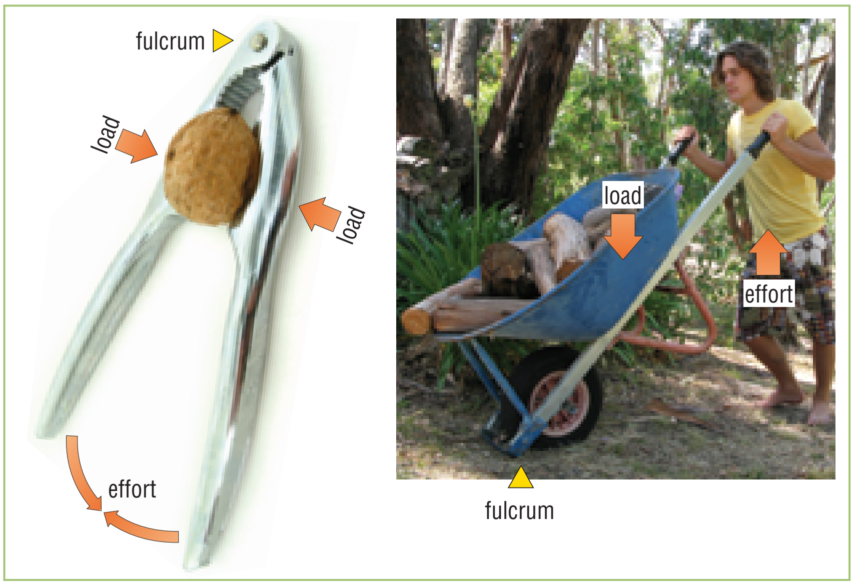


Fig 8.2.6 Class 2 levers always have their fulcrum at the end.

Principle of levers

Class 1 and 2 levers obey a rule called the **principle of levers**:

effort × distance = load × distance

(distance of effort from fulcrum; distance of load from fulcrum)

This means that a 60 kilogram student would need to sit 2 metres from the pivot of a seesaw to balance a 40 kilogram student who is sitting at the very end, 3 metres from the pivot. The principle of levers provides the proof:

60 kg student × 2 m = 40 kg student × 3 m

Speed multipliers: Class 3 levers

Class 3 levers (or third-order levers) are not used to decrease the required effort. Instead, they get the load (often a small one) moving at an increased speed.

Bats and racquets are all class 3 levers. We move our hands a short distance at high speed so the ball travels from the bat at an even higher speed—class 3 levers are **speed multipliers**. Because the distance the ball moves is large, the force on it is small. This requires your hand to move a small distance but with a large effort.

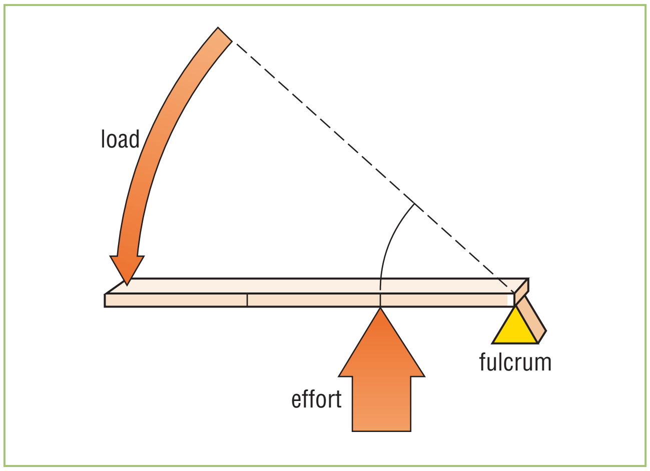
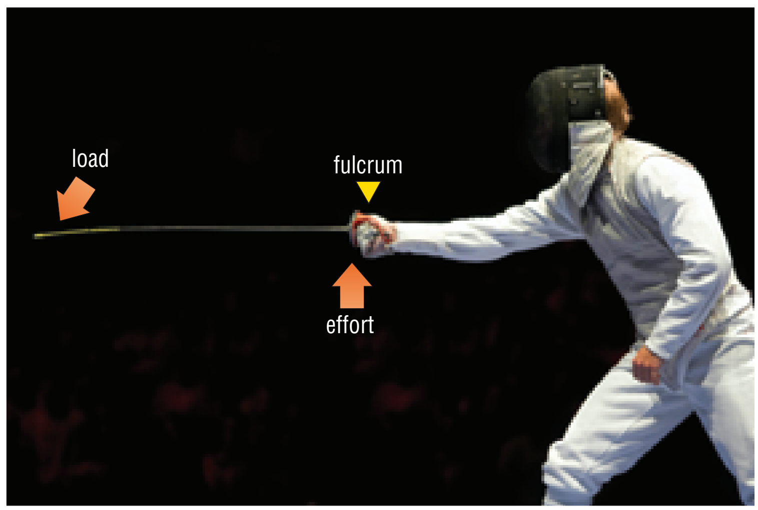


Fig 8.2.7 These levers have the fulcrum at one end, the load at the other end and the effort (usually from our hands) somewhere in between.

PP Drag-and-drop

Prac 3 p. 254 · Prac 4 p. 254 · Prac 5 p. 255



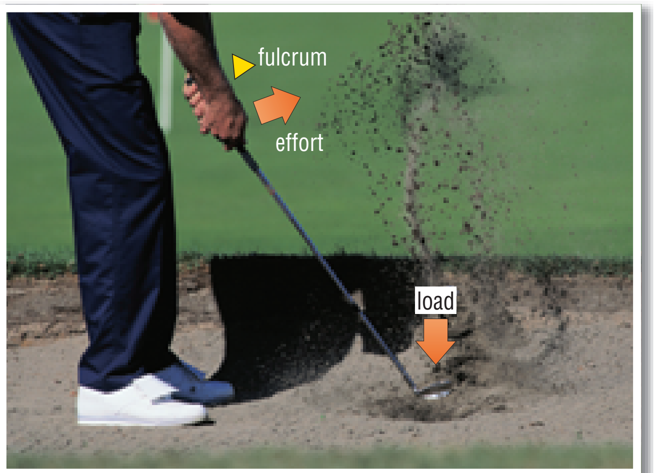


Fig 8.2.8 Bats and racquets are all class 3 levers. They act as speed multipliers, increasing the speed of the ball after it has been hit.

Worksheet 8.2 Levers

Mechanical advantage in levers

Mechanical advantage gives you an idea of the effectiveness of a machine or technology. The higher the mechanical advantage, the better the machine. For levers, mechanical advantage can be calculated in two ways:

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$$

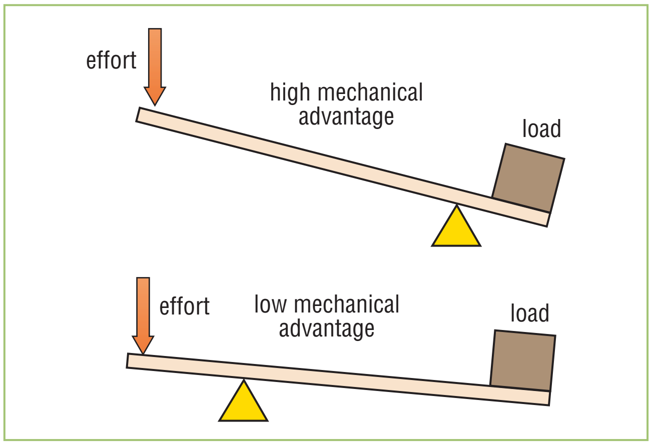


Fig 8.2.9 The further the effort is away from the fulcrum, the easier the job becomes.

8.2 QUESTIONS

Remembering

1 **List** three examples each of a class 1, class 2 and class 3 lever.

2 Use a mathematical equation to **state** the principle of levers.

3 **State** alternative names for a:

a fulcrum

b class 1 lever.

Understanding

4 **Define** the terms: Ⓛ

a lever

b fulcrum

c force multiplier

d speed multiplier.

5 Copy the following into your workbook and **modify** any incorrect statements to make them true:

a All levers are force multipliers.

b The fulcrum of a lever is always somewhere in the middle.

c A golf club is an example of a force multiplier.

d A pivot is the same as a fulcrum.

e A speed multiplier is needed in most ball sports.

6 **Explain** the advantage of using a class 3 lever in most ball sports.

7 Use a mathematical equation to **explain** how mechanical advantage is calculated for levers. Ⓝ

8 **Describe** how a greater mechanical advantage can be obtained when using a lever.

9 A sword is an example of a class 3 lever. **Explain** why.

10 You need to use a wheel brace to remove the nuts from a car wheel. A wheel brace is a spanner with a long arm. **Propose** a reason why the arm must be long.

Applying

11 A seesaw ruler was set up as shown in Figure 8.2.10. Different masses were added to each side so that the seesaw was *just* balanced. Copy and complete the table below by **calculating** the missing values. Ⓝ

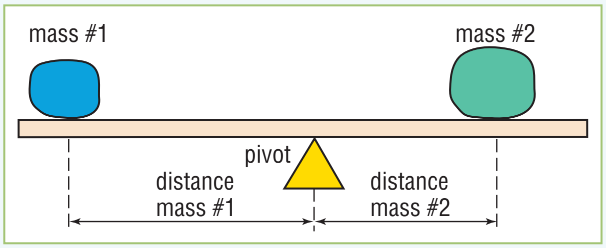


Fig 8.2.10

Mass #1 (g)	Distance of mass #1 from pivot (cm)	Mass #2 (g)	Distance of mass #2 from pivot (cm)
6	4	8	
6	4		12
1		12	2
10	1	5	
3	6		9
8		4	16

>>

Analysing

12 **Classify** the levers in Figure 8.2.11 as either class 1, 2 or 3 levers, and then **calculate** the mechanical advantage of each. Ⓝ

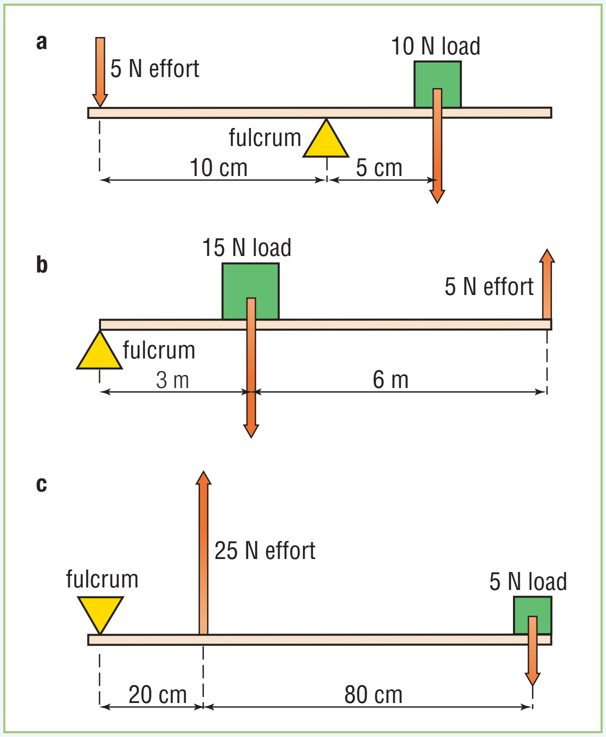


Fig 8.2.11

13 **Classify** the levers in Figure 8.2.12 as either class 1, 2 or 3 levers.

14 **Contrast**:

a a force multiplier with a speed multiplier

b class 1 and 2 levers with a class 3 lever.

Evaluating

15 Which class of levers is the most effective in lifting a load? **Justify** your answer.

Creating

16 A heavy rock is to be shifted, and all you have is a long metal bar and another smaller rock. **Construct** a diagram that shows how you would shift the rock. Label the load, fulcrum and effort.

17 **Construct** a sketch of a playground seesaw. Draw where you would place a heavy person to balance a light person sitting on the very end of one side. On your diagram, mark the fulcrum, effort and load.

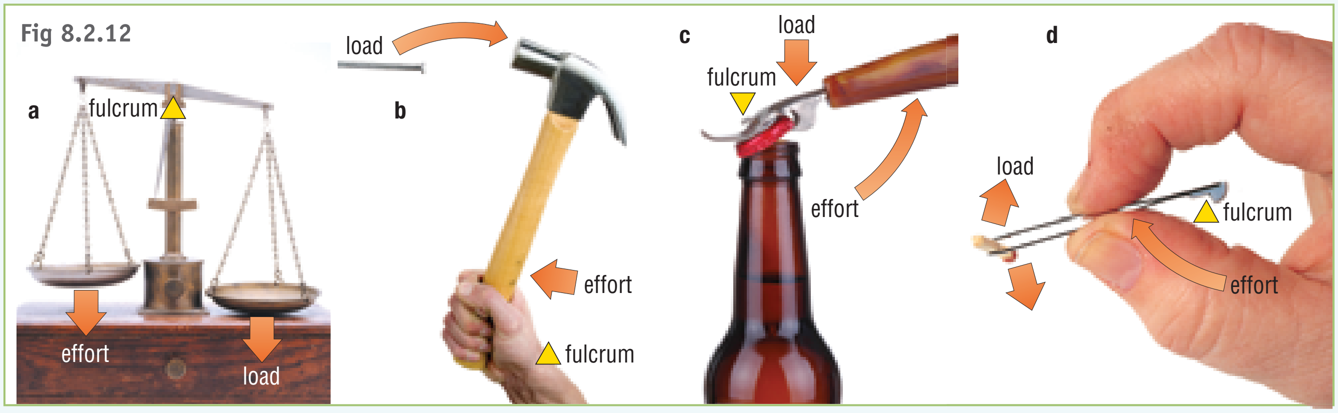
18 **Construct** a poster to demonstrate how different levers are used in sport.

19 **a** **Construct** a collage of photos of levers from magazines, advertising brochures and newspapers.

b **Classify** each lever as either class 1, 2 or 3 levers.

c **Identify** and label the effort, fulcrum and load on each lever.

Fig 8.2.12



8.2 INVESTIGATING

Muscles can only contract (i.e. get shorter and thicker) or relax (i.e. get longer and thinner), pulling the bone up or letting it down. Muscles provide the effort force that controls bone levers.

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find a diagram of the muscles of the body. Use this diagram to identify the names of the muscles used to flex your arm and to straighten it.

>>

e-xploring

Web Destination

Investigate the following information about levers by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

- Recall how levers work by watching the animations.
- Archimedes used machines to invent many different machines. **Investigate** your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find out about Archimedes and his work, and then write a short biography of his life. L

8.2 PRACTICAL ACTIVITIES

1 The seesaw

Aim

To investigate the seesaw as a lever

Equipment

- seven small masses (such as 5 cent coins)
- a ruler
- a fulcrum or pivot (a pencil is ideal)
- an elastic band

Method

1. Set up a seesaw as shown in Figure 8.2.13.
2. Use the elastic band to hold the ruler in place on the pencil.
3. Copy the results table below into your workbook.
4. Place four of the small masses on the left side of the ruler and another four on the right, and arrange them until the seesaw is balanced.
5. In the table, record the distance of each pile of masses from the pencil fulcrum. Repeat with two masses on the left and three on the right.
6. Repeat for all the other masses shown.

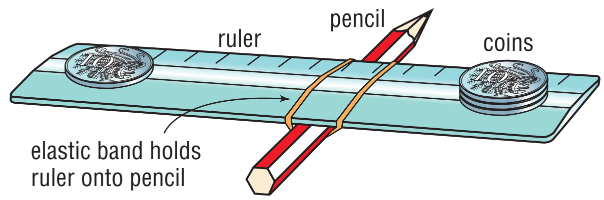


Fig 8.2.13

Questions

1. What do you notice about your answers in columns 3 and 6? **Analyse** what you notice.
2. You have just discovered the principle of levers. Use it to **predict** where you would place a 2 g mass to balance:
   a. another 2 g mass placed 4 cm from the pivot
   b. a 10 g mass, 2 cm from the pivot
   c. a 6 g mass, 6 cm from the pivot
   d. a 1 g mass, 2 cm from the pivot.
3. **Identify** the class of lever used in this activity.

Left-hand side			Right-hand side		
Number of masses	Distance from pivot	Number of masses × distance from pivot	Number of masses	Distance from pivot	Number of masses × distance from pivot
4			4		
3			2		
4			3		
5			2		
6			1		

2 Lifting books

Aim

To investigate the relationship between fulcrum position and effort on a class 1 lever

Equipment

- metre ruler
- rubber stopper
- textbook

Method

1 Set up the lever as shown in Figure 8.2.14.

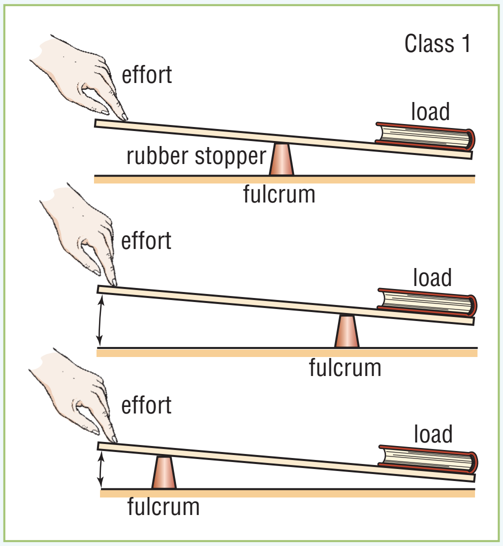


Fig 8.2.14

2 Lift the book by pushing down on the ruler with your finger.

3 Now place the stopper close to the book and repeat the experiment.

4 Repeat once more, but with the stopper placed at the far end away from the book.

5 Copy the table below. Complete it using the words 'high', 'medium' or 'low'.

Position of stopper	Effort required to lift the book
Far away from book	
Midway	
Close to book	

6 Now try lifting the book using the class 2 and 3 levers shown in Figure 8.2.15.

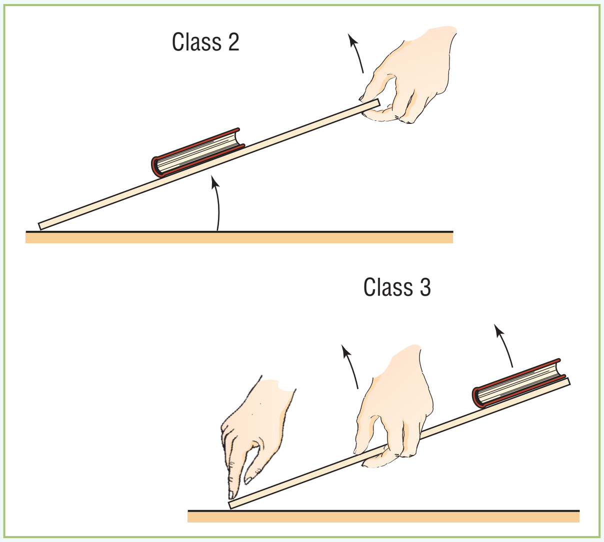


Fig 8.2.15

Questions

1 Copy the three diagrams (i.e. class 1, 2 and 3 levers) into your workbook. Add arrows to show the effort and load forces. **Identify** the fulcrum.

2 The force needed to lift the book using the class 1 lever changed as the stopper moved away from the book and towards your finger. **Analyse** what happened.

3 Use the principle of levers to **explain** why, in a class 1 lever, it is easier to lift the book if the fulcrum is close to it and far away from your finger.

4 **Assess** which class of lever made it most difficult to lift the book.

3 Class 3 levers

Aim

To investigate a class 3 lever

Equipment

- metre ruler
- one kilogram mass
- spring balance
- brick or block to act as the fulcrum

Method

1 Copy the table below into your workbook and then set up the class 3 lever shown in Figure 8.2.16.

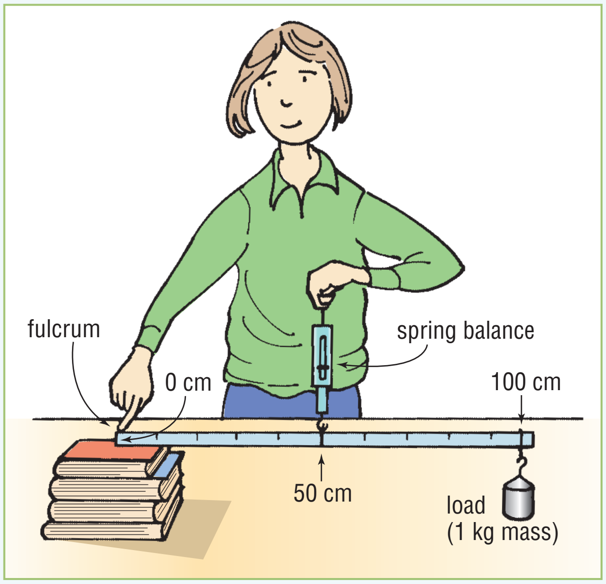


Fig 8.2.16

2 Use the spring balance to measure the effort force needed to raise the load slowly.

3 Record your measurements in the table. You might need to convert the newton readings of your spring balance to kilograms by dividing your measurements by 10.

4 Calculate the mechanical advantage for each measurement.

Load (kg)	Distance of load from fulcrum (cm)	Spring balance reading (N)	Spring balance reading (kg)	Distance of spring balance from fulcrum (cm)	Mechanical advantage
1	100			30	
1	100			40	
1	100			50	
1	100			60	
1	100			70	

Questions

1 **Identify** which was bigger—the load or the effort required to lift it.

2 **Identify** which was the most effective lever. **Justify** your answer.

4 Levers at work

Aim

To examine various common machines to determine which class of lever is being used

Equipment

- stapler
- nail clippers
- scissors
- pruning shears
- nutcracker or bulldog clip

Method

1 Accurately draw each machine.

2 Label the fulcrum, load and where the effort needs to be applied.

3 Identify the purpose of other parts of each machine.

Questions

1 **Classify** each lever as either a class 1, 2 or 3 lever.

2 **State** whether each one is a force or speed multiplier.

5 Body levers

Aim

To model levers that are used in the body

Equipment

- cardboard
- paperclip
- three balloons
- string
- hinge and screws
- wood strips

Method

1 Using cardboard, make a larger version of the skull shown in Figure 8.2.17. Use a paperclip to hinge the jaw to the skull and a deflated balloon for the muscle that controls it.

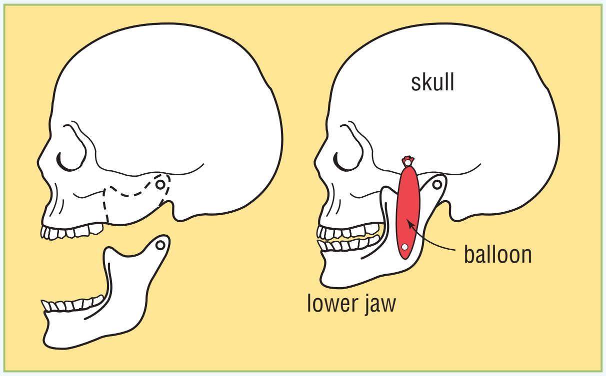


Fig 8.2.17

2 Use the diagram shown in Figure 8.2.18 to construct a model of the human arm, its bones and muscles.

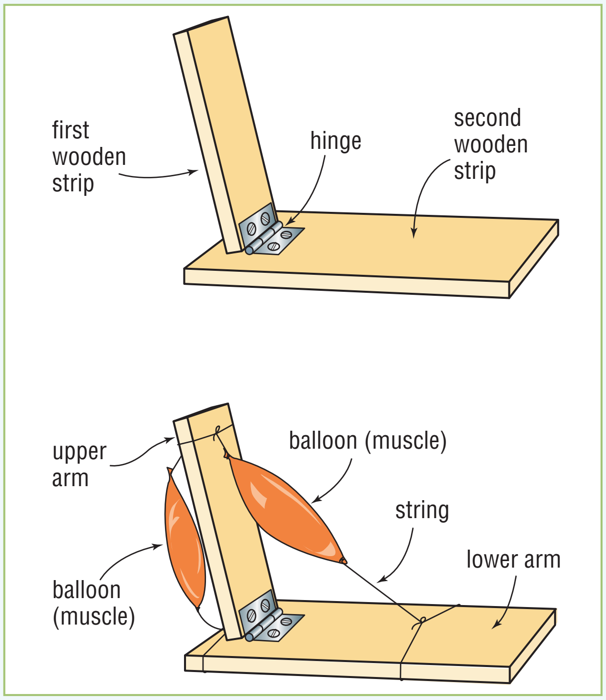


Fig 8.2.18

Questions

1 **Explain** what happens to the 'balloon muscles' as the model jaw opens and closes or the model arm is flexed or straightened.

2 **Compare** this with the real muscles that control a real jaw or arm.

Unit 8.3 Wheels, axles and gears

context

Most machines do not use the simple up-and-down movement that ramps and levers produce. They use a spinning or rotary motion instead. Wheels, axles and gears apply the principle of levers to our everyday lives. Although they might not look like it, some taps and doorknobs are really wheels. Gears are used in many applications—from bicycles to corkscrews.

Fig 8.3.1 Wheels can multiply either force or speed.

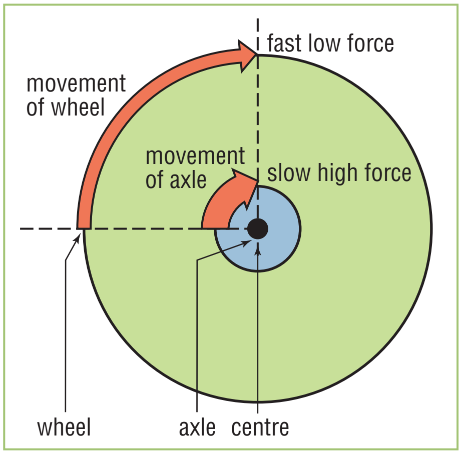


Fig 8.3.2 In a wheel, the strongest force is felt at its axle because it moves the least. The rim experiences the least force because it moves the furthest. The further you move, the less force is needed.

Wheels

Located at the centre of every wheel is an **axle**. Around the outside of the wheel is its **rim**. The wheel acts just like a lever. Its axle acts as a fulcrum and its rim is the other end of the lever. The rim of a rotating wheel moves a larger distance and at a higher speed than the axle, which simply turns on the spot.

Wheels as force multipliers

Prac 1 p. 260

As with a lever, a wheel can be used to reduce the force needed to carry out a task. The **spindle** (axle) of a doorknob or tap is nearly impossible to turn with bare fingers. A doorknob or a tap can be either a simple lever or a 'wheel'. A small force moving the end of the handle or the edge of the

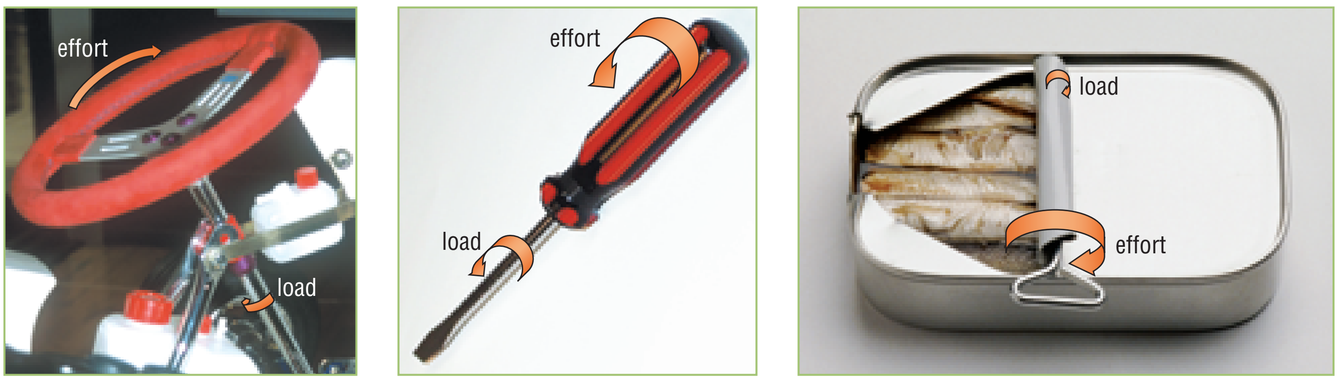


Fig 8.3.3 Wheels often don't look like wheels—a steering wheel, a screwdriver and the key used to open a can of sardines are all examples of wheels and axles.

Science Clip

The wheel, invented in 2001!

A patent acknowledges the inventor, who can then claim money from anyone using their invention or manufacturing it. Although the wheel has been used for thousands of years, its inventor is unknown. No-one had ever registered a patent for the wheel. In 2001, as a protest against changes to Australian patent laws, John Keogh registered his patent for a 'circular transportation device'. He did not get his patent.

knob or tap will turn the spindle easily enough to unlock the door or turn on the tap. The wheel acts as a **force multiplier**—a small effort applied to the rim has produced a large turning force at its axle. The force has been multiplied.

The turning effect of a force on an object is called **torque**. Torque is calculated by multiplying the applied force by its perpendicular distance from the turning point. Torque is measured in newton metres (N.m).

Changing the motion

Once a spinning motion has started, its direction, speed or location often needs to be changed.

Belts, ropes and chains

The simplest way to change the speed, direction or location of a spinning motion is to connect wheels of different diameters together with ropes, belts or chains. A wheel of smaller diameter will spin faster and with greater force if it is connected by a belt to a larger wheel.

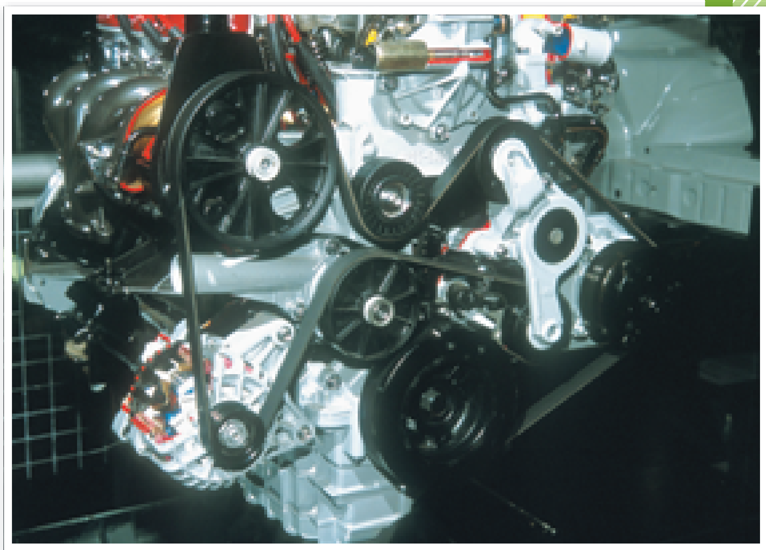


Fig 8.3.6 Fanbelts in a car engine rope together wheels of different sizes.

Gears

A gear (sometimes called a cog or sprocket) is a wheel with identical teeth around its edge. **Gears** can be connected together by a chain or they can **mesh** directly together.

Gears can be used to change speed, torque (i.e. spinning force) or the direction of rotation. If the axle turns it, it is called the **driving gear**. If the teeth of another gear (called the **driven gear**) mesh together with the driving gear, it too will turn, but in the opposite direction. The speed of the driven gear, and the torque it can apply, depends on how big it is compared with the driving gear.

Fig 8.3.4 Some taps and door handles are levers. Others act as wheels.

Wheels as speed multipliers

Wheels can also be used as **speed multipliers**. A slowly spinning axle turns the rim at a higher speed.

The blades of a fan or a propeller must spin very fast to move the quantities of air needed to cool or to move an aircraft along. The motor turns the axle relatively slowly. The bigger the propeller, the faster the blade tips will go and the more air is moved.

Prac 2 p. 261

Fig 8.3.5 Fans and propellers are speed multipliers.

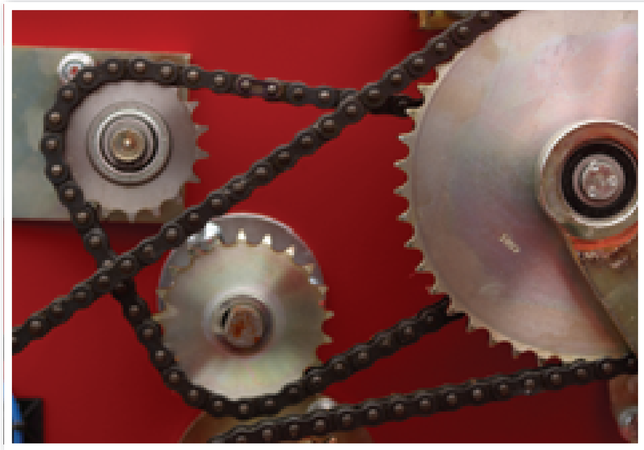


Fig 8.3.7 Gears can be connected by chain. Bikes use this method of meshing gears together.

Gear trains

A gear train is a series of two or more connected gears. If the gears are identical, they both turn at the same speed but in different directions. These are called **parallel gears**.

If the driven gear is smaller than the driving gear, it will rotate faster—the gears act as a speed multiplier. This is called **gearing up** and is useful when high-speed rotation is needed, say, in a power drill, kitchen blender or the coarse focus knob on a microscope.

Gearing down is when a small driving gear rotates a larger one, which turns at a slower speed. The torque applied is multiplied, making it useful in situations where a strong turning force is required. Gears on bikes use this to make the hard job of climbing hills easier and to allow swift acceleration at traffic lights.

Types of gears you will commonly find are **rack and pinion**, **idler**, **worm** and **bevel** gears. They do different jobs but all work in much the same way.

Science Clip

Ancient gears

The first-ever calculator seems to be a machine built by the ancient Greeks in the first century BCE. It was built to predict the timing of eclipes and contained 32 bronze gears. When it was discovered in 1901 in the wreckage of an ancient ship sunk in the Aegean Sea, it looked like a lump of metal covered in barnacles. The gears and its function didn't become obvious until it was X-rayed in 1972.

PP Interactive

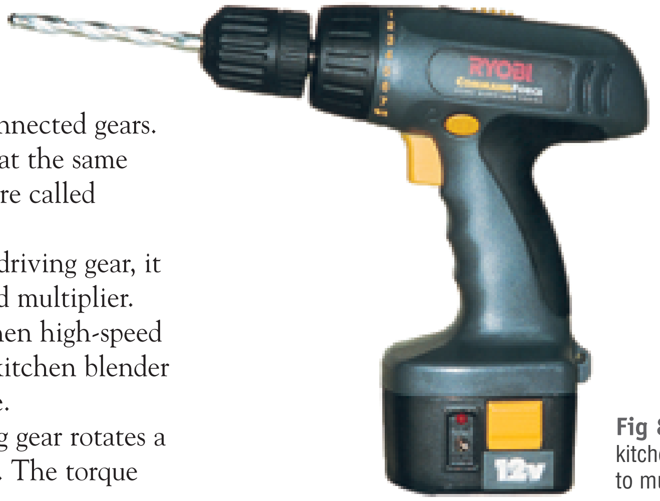


Fig 8.3.9 Power drills and kitchen blenders use gears to multiply their speed.

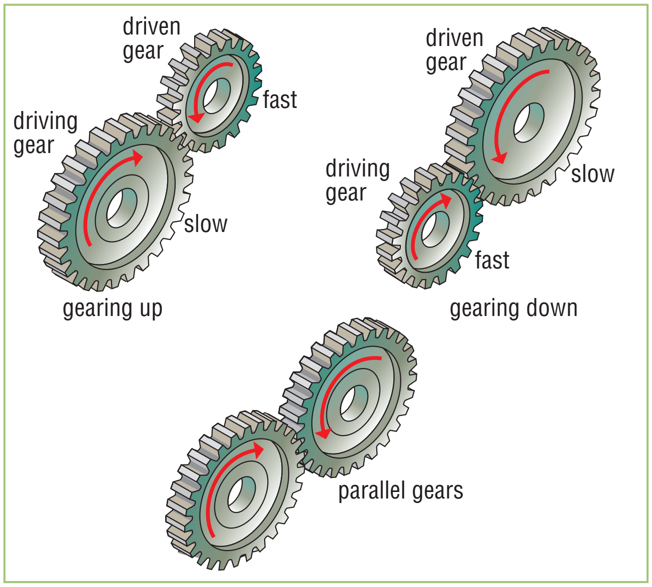


Fig 8.3.8 Gear trains are groups of gears meshing together.

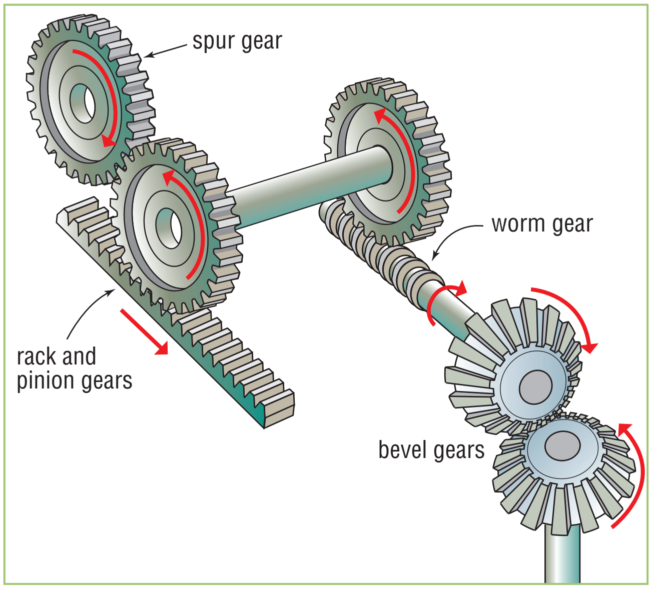


Fig 8.3.10 Different gears might do different jobs in a machine but all work by meshing together and changing the direction and speed of the motion.

Prac 3 p. 262
Prac 4 p. 262
Prac 5 p. 263
Worksheet 8.3 Gears

8.3 QUESTIONS

Remembering

1 **List** two examples of a wheel acting as a:

  a speed multiplier

  b force multiplier.

2 **State** another name for the:

  a fulcrum of a wheel

  b fulcrum of a doorknob or tap.

3 **List** four different types of gears.

4 **State** what the speed and torque of a driven gear depends on.

5 **Specify** what is acting as the effort and load in a:

  a wheel acting as a force multiplier

  b wheel acting as a speed multiplier.

Understanding

6 Copy these statements into your workbook and **modify** any that are incorrect.

  a Rotary motion is up–down motion.

  b The axle and the rim of a wheel are the same thing.

  c The driving wheel of a bicycle is an example of a speed multiplier.

  d Parallel gears turn in the same direction.

  e The steering wheel of a car is an example of a speed multiplier.

  f Gearing up is used when high-speed rotation is needed.

  g Gearing down is used in drills and kitchen blenders.

7 **Define** the following terms: L

  a spindle

  b torque

  c gear

  d gearing down

  e gear train.

8 **Explain** two different ways in which the direction of a spinning wheel can be changed.

9 **Explain** when gearing up and gearing down are used.

10 **Predict** the direction of rotation and the speed of the wheels shown in Figure 8.3.11.

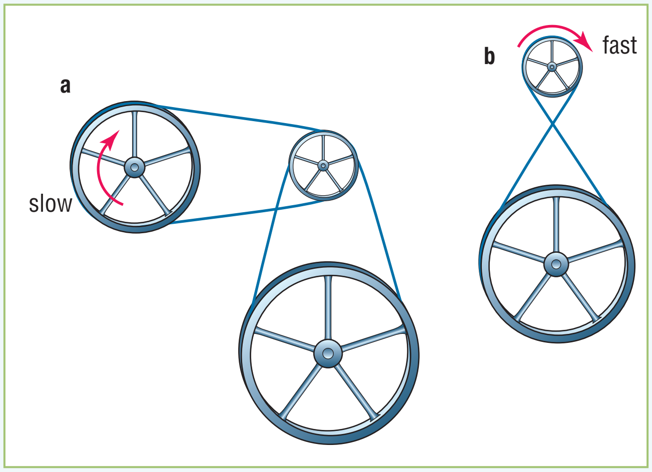


Fig 8.3.11

11 **Predict** the direction of rotation and the speed of the gears shown in Figure 8.3.12.

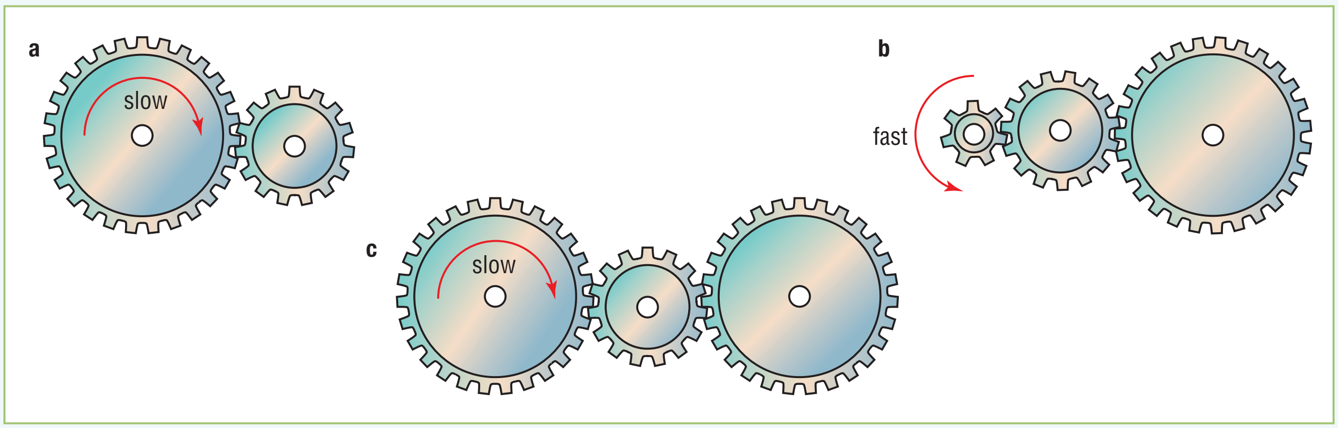


Fig 8.3.12

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Applying

12 **Identify** which is spun first—the driving or the driven gear?

Analysing

13 **Compare** a wheel with a lever by listing their similarities and differences.

14 **Distinguish** between:

- **a** gearing up and gearing down
- **b** a driving gear and a driven gear.

Creating

15 **Construct** a labelled diagram to **demonstrate** how a wheel can act as a speed multiplier.

16 **Construct** or trace diagrams of rack and pinion, idler, worm and bevel gears.

17 **Construct** a diagram of a bicycle wheel. **Identify** and label its axle and rim. Show where the wheel would move the fastest/slowest and where the torque that could be applied would be the greatest/smallest.

18 **a** **Construct** a diagram of two gears that would act as a speed multiplier, and another two acting as a force multiplier.

b **Identify** and label the driving and driven gears in your diagram.

8.3 INVESTIGATING

e-xploring

Research how gears work by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

PP Web Destination

8.3 PRACTICAL ACTIVITIES

1 A simple wheel and axle

Aim

To construct a simple wheel and axle

Equipment

- 250 mL beaker or tin can
- 100 gram mass
- two paperclips
- flexible drinking straw or a satay stick
- cotton thread
- sticky tape

Method

1. Set up the apparatus as shown in Figure 8.3.13.
2. Try to lift the 100 g mass by turning the straw or satay stick.
3. Bend the straw or satay stick without breaking it, and try again.

Questions

1 **State** whether you were able to lift the 100 g mass without bending the straw or stick.

2 **Propose** a way of making the job even easier.

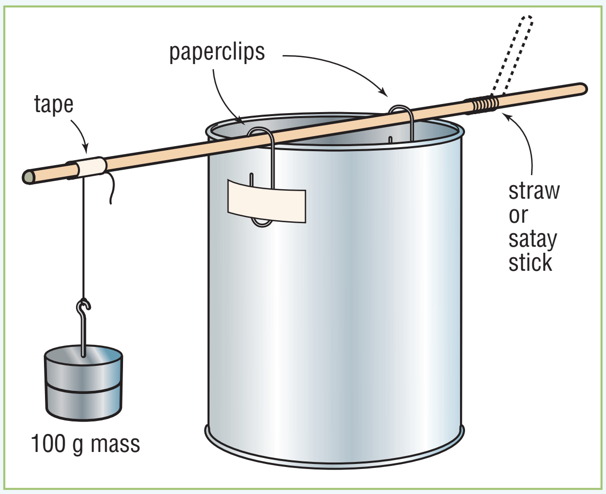

Fig 8.3.13

2 Roping them together

Aim

To investigate speed changes by connecting wheels of different sizes

Equipment

- a variety of circular lids of different sizes from jam jars etc. (serrated edges are ideal)
- elastic bands
- a piece of wood
- a small sheet of thin cardboard
- pins
- small nails or tacks (they must have a circular cross-section)
- marking pen
- hammer

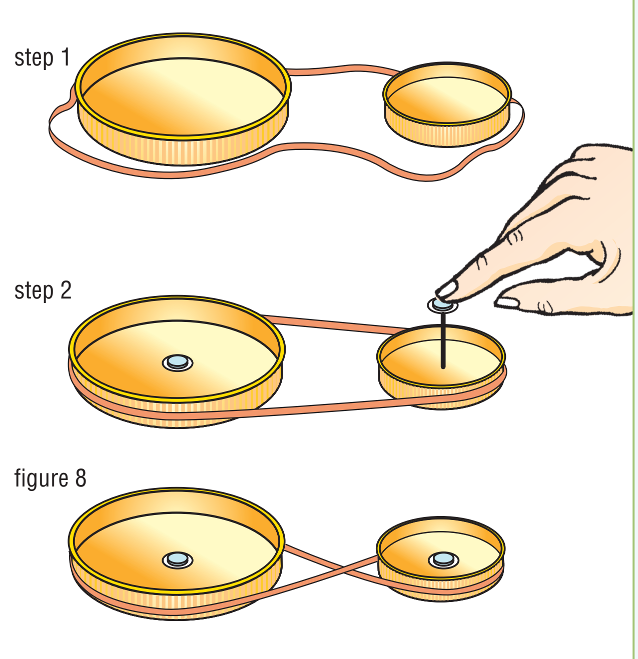

Fig 8.3.14

Method

1 Put small holes in the exact centre of two lids.

2 Cut several elastic bands and tie them together so that they go right around two lids.

3 Cut out small circular 'washers' from the thin cardboard.

4 Assemble your wheels as shown in Figure 8.3.14. The elastic band should be stretched just a little.

5 Use the marker to draw an obvious line on each of the lids.

6 Measure the diameter of each lid.

7 Start one wheel spinning. Note which direction the wheels turn and use the line you have drawn to count how many times each lid turns in one minute. You have just measured the r.p.m. (i.e. revolutions per minute) of each wheel.

8 Record your results in a table like this:

Diameter wheel #1	Clockwise/ anticlockwise?	Speed (r.p.m.) wheel #1	Diameter wheel #2	Clockwise/ anticlockwise?	Speed (r.p.m.) wheel #2

9 How does the size of the wheel affect the force needed to do a job?

10 Try different combinations of lids.

11 Change the elastic band to look like a figure 8, and repeat the experiment.

Questions

1 **Examine** how the r.p.m. of a small wheel compared with the r.p.m. of the larger wheel it was connected to.

2 **Analyse** whether there is a link between wheel diameter and r.p.m.

3 **State** whether the wheels spun in the same or different directions.

4 **Describe** what happened when the elastic band was changed to a figure 8.

3 Geared machines

Aim
To investigate common implements that use gears

Equipment
- eggbeater
- hand-drill
- corkscrew
- adjustable spanner

Fig 8.3.15

Method
1. Carefully draw the gear arrangements in the machine you have been given, labelling each type of gear (e.g. rack and pinion, worm etc.).
2. Label which gear is driving and which is driven, and the directions they move.
3. Label any levers or wedges that might also be there.
4. Count how many teeth are on each gear. Put these numbers on your diagram.
5. Make a small mark on the side of the driving gear and another on the driven gear.
6. Turn the driving gear slowly and count the number of times each gear turns. Stop when one of the gears has turned 10 times. Write the number of turns on the gears on your diagram.

Questions
1. **Identify** which gear was the largest—the driving or the driven gear?
2. **Explain** what the job is of your machine.
3. Does your machine need to be a force multiplier or a speed multiplier? **Justify** your answer.
4. **Calculate** the gear ratio by dividing the number of teeth of the biggest gear by the number of teeth of the smallest. N
5. **Calculate** the turning ratio by dividing the biggest number of turns (i.e. 10) by the smallest number of turns. N
6. **Describe** what you notice about the two ratios.

4 Model building

Aim
To build various models using gears, levers and wheels

Equipment
- model building set, such as Lego

Method
1. Use two gears to make a gear train that gears up, and another that gears down.
2. Connect an arrangement to turn the driving gear of each, and something that will be spun by the driven gear.
3. Draw your machines.
4. Rotate the driving gear slowly, adding to your diagram the direction the gears move.
5. Count how many teeth each gear has and the number of times the driving gear must be turned to rotate the driven gear 10 times.
6. Record all numbers and ratios on your diagram.
7. Construct a machine like the one in the previous experiment.

Question
1. Use the numbers of teeth to **calculate** the gear ratio, and the number of turns to **calculate** the turn ratio of each. N

5 Investigating bicycles

Bikes have gears to make pedalling easier for the rider.

Aim

To investigate the relationship between gear ratio and speed in a bike

Equipment

- access to a bike with gears

Method

1 Count how many gears there are at the pedal and at the back in a 10-speed bicycle.

2 Look carefully to see how the front and back gears are meshed together.

3 Identify the arrangements of gears at the pedal and the rear that a cyclist would use to:

   a travel at high speed

   b climb a steep hill

   c ride downhill.

4 Identify these arrangements as either gearing up, parallel or gearing down.

5 **Gear ratio** is the number of teeth on the pedal gear divided by the number of teeth of the gear at the back. Count the number of teeth on each gear used in Question 2 and then calculate the gear ratio for each situation. Record all counts and calculations in a table like that shown below.

Situation	Number of teeth on pedal gear	Number of teeth on rear gear	Gear ratio calculation
Example	40	32	40 ÷ 32 = 1.25
High speed			
Steep hill			
Downhill			

Questions

1 **State** what the gears are called in a bicycle.

2 **Explain** how gears are connected front and back.

Fig 8.3.16

Unit 8.4 Pulleys

context

Humans usually find pulling an object down a lot easier than lifting it up. Your bodyweight is acting as a downwards force already and helps in pulling a load down. A pulley can be used to convert a lifting force into a pulling down force.

Fig 8.4.1 A pulley is a wheel with a grooved edge inside which a string, rope or chain can run.

Multiple pulleys

Prac 1 p. 266

Bigger loads can be lifted with little effort if a system of two or more pulleys is strung together. The pulleys become a **force multiplier**—we put in an effort and the pulley multiplies it, so we can lift heavier loads.

A multiple pulley system is often called a **block and tackle** or sometimes a **chain hoist**.

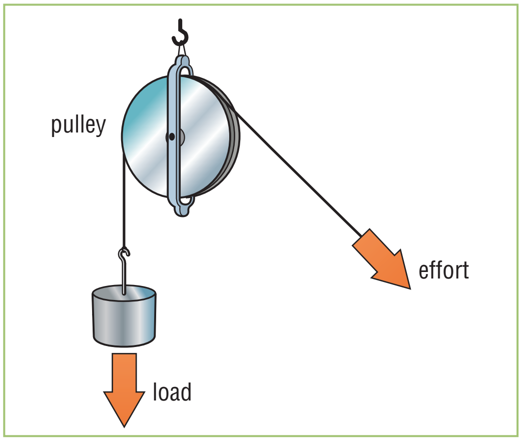

Fig 8.4.2 A single pulley makes the job easier by changing the direction of the effort.

Single pulleys

A **pulley** is a wheel with a grooved edge inside which a string, rope or chain can run. A **single pulley** makes the job of lifting an object easier, but only because it changes the direction of the effort force. You still need to put in the same effort as that if you were lifting the object—the mechanical advantage should be equal to one. Yet, you probably need to put in more effort because you need to overcome the load *and* some **friction** in the pulley.

Friction always makes work harder. It does so by reducing the effectiveness or **efficiency** of machines.

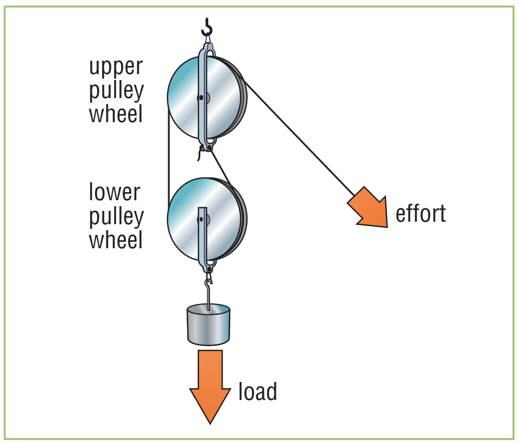

Fig 8.4.3 A double pulley system halves the effort required. Double the load can be lifted, but the distance needed to pull the rope is also doubled.

How do pulleys reduce effort?

Imagine that you need to lift a refrigerator 2 metres onto a truck. With a single pulley you need to pull the rope down the same distance (i.e. 2 metres). If you use a double pulley, however, the distance that the rope needs to be pulled is doubled, making it 4 metres. The advantage is that you need to use only half the effort.

Work is the energy needed to move something:

Work = effort force × distance moved

If the distance moved is greater, then the effort required is less. This is how multiple pulleys work—you need to pull further but you put in less effort.

The effort needed reduces if more pulleys are added to the system—the mechanical advantage equals the number of pulleys used.

Once again, friction unfortunately makes work harder by reducing the efficiency of a pulley system.

Prac 2 p. 267
Prac 3 p. 268
Prac 4 p. 269
Prac 5 p. 269
Worksheet 8.4 Pulleys

Science Clip

Whoops!

Thomas Midgley (born 1889) discovered in 1921 that tetra-ethyl lead could be added to petrol to stop 'knocking' in car engines. In 1928 he realised that chlorofluorocarbons (or CFCs) would be perfect as a refrigerant—they couldn't catch fire, were non-toxic and odourless if they leaked, and they wouldn't rust the fridge. When stricken by polio in 1940, he became partially paralysed and he invented a system of pulleys and ropes that could lift him from bed to wheelchair. Unfortunately, all his discoveries and inventions proved to be harmful—lead from car exhausts slowly pollutes the air in busy cities, poisoning their inhabitants; CFCs cause depletion of the ozone layer; and Thomas himself was strangled to death when he became tangled in his own pulley and rope contraption in 1944.

Science Clip

Archimedes ...again!

Archimedes also used pulleys to make machines. Using levers and a primitive pulley system, he enabled his king to drag a fully loaded warship out of the water.

8.4 QUESTIONS

Remembering

1 **List** the main components of a pulley.

2 **State** the main advantage of using a single pulley to lift a load.

Understanding

3 **Explain** why humans naturally find pulling an object down easier than lifting it up.

4 **Define** the term *block and tackle.* (L)

5 Using the formula for work, **describe** how a pulley reduces effort.

6 If you use two pulleys instead of one, **describe** what happens to the effort and distance you must pull.

7 Friction is a nuisance in a pulley. **Explain** why.

8 Are pulleys force or speed multipliers? **Justify** your answer.

9 **Outline** the advantages and disadvantages of using multiple pulleys.

Applying

10 A hoist does not use rope over a pulley. **Identify** what it does use.

11 **Identify** how many pulleys are in each arrangement in Figure 8.4.4.

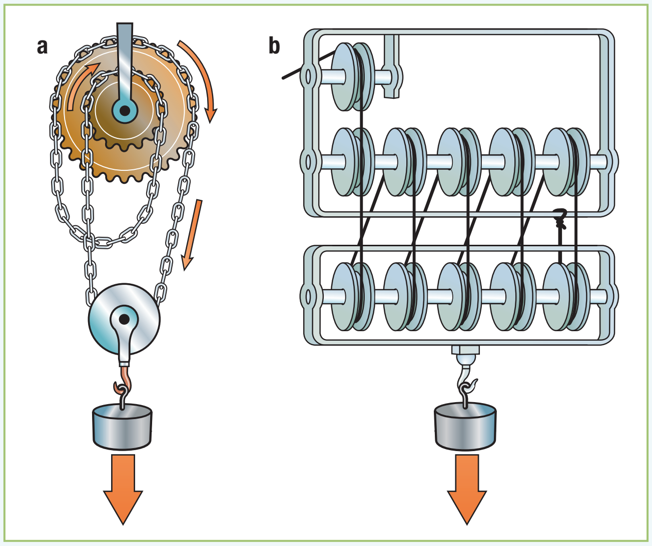

Fig 8.4.4

12 **Determine** what force multiplication each pulley arrangement in Question 11 would give.

Use the key below to **identify** the correct mechanical advantage.

A 0 **B** 1

C more than 1 **D** less than 1.

>>

13 A single pulley would have a mechanical advantage of ______.

14 The mechanical advantage of a double-pulley arrangement would be ______.

Analysing

15 **Compare** a pulley with a gear by listing their similarities and differences.

Evaluating

16 **Propose** a reason why clamps are often used with a pulley.

Creating

17 Use Figure 8.4.5 to **design** a tug-of-war competition that you cannot lose. Continue adding more opponents until you find the maximum number of people you can defeat.

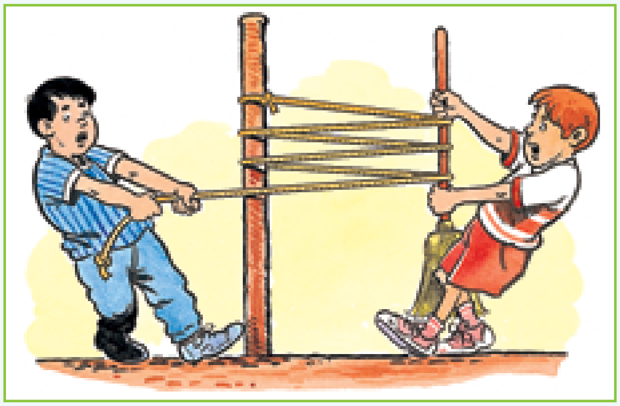

Fig 8.4.5

18 Use junk materials or materials from your pencil case to **construct** a model that shows how ramps, wedges, wheels, pulleys (and any other machines) may have been used in constructing the pyramids of ancient Egypt.

8.4 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to find out how pulley arrangements are used in car repair shops, on yachts and in simple cranes. Construct models of each pulley arrangement, using weights to mimic the real thing.

8.4 PRACTICAL ACTIVITIES

1 Fixed and moveable pulleys

Aim

To investigate the mechanical advantage of various pulley configurations

Equipment

- 100 gram mass
- spring balance
- retort stand
- strong cotton thread

Method

1 Use a spring balance to measure the effort force needed to *hold* a 100 g mass in each of the situations shown in Figure 8.4.6.

2 Record your readings in a table similar to the one shown below.

3 Now use the fixed pulley (part **b**) and moveable pulley (part **c**) in Figure 8.4.6 to gently *lift* the 100 g mass. What are the spring balance readings now?

Question

Did the fixed or moveable pulley require less effort to hold and lift a mass? **Propose** a reason why.

>>

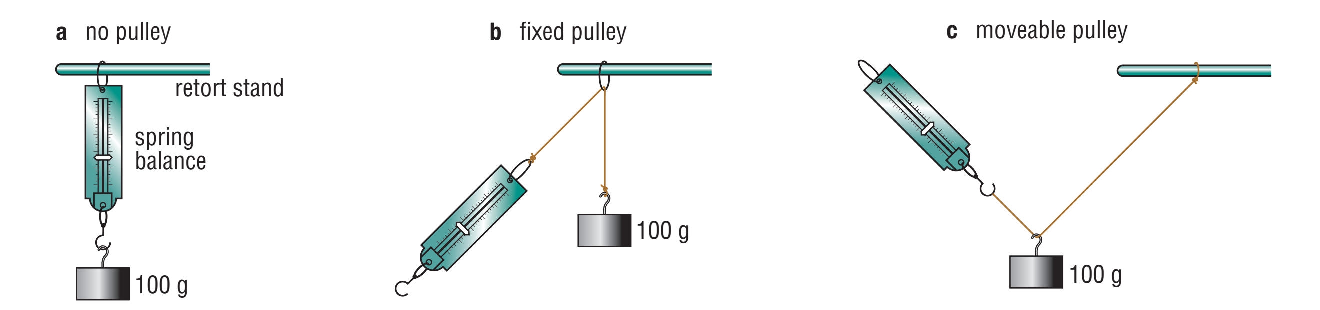

Fig 8.4.6 Pulley arrangements to try

	Pulley	Effort needed to hold the mass (N)	Effort needed to lift the mass (N)	Mechanical advantage
A	No pulley			
B	Fixed pulley			
C	Moveable pulley			

2 Paperclip pulleys

Aim

To compare single and double pulleys made from paperclips

Equipment

- 100 gram mass
- spring balance
- retort stand
- strong cotton thread
- paperclips

Method

1. Use a spring balance to measure the effort needed to hold a 100 g mass. Record its reading.
2. Twist the two paperclips apart, as shown in Figure 8.4.7, and construct the double-paperclip pulley as shown.
3. Now use the paperclip pulley to gently lift the 100 g mass. Record the new spring balance reading.
4. Measure the effort required to hold the 100 g mass, and then the effort required to gently lift it.

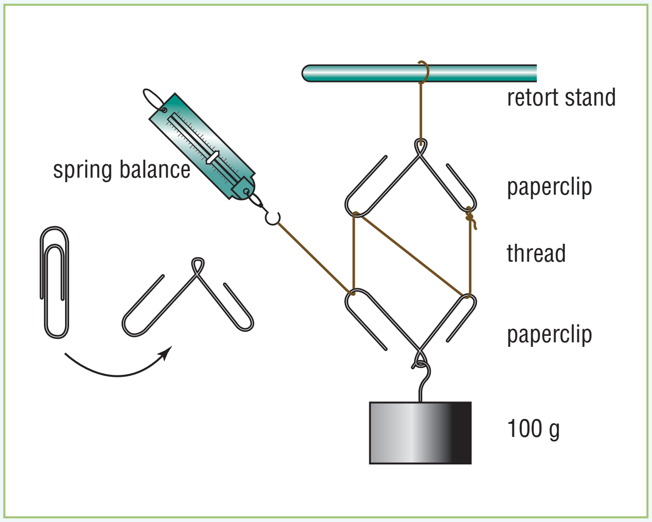

Fig 8.4.7

Questions

1. **State** whether the double-paperclip pulley made the jobs of holding and lifting easier or harder.
2. These paperclip pulleys are not as good as pulleys with moving wheels. **Assess** why.
3. **Calculate** the mechanical advantage of the single- and double-paperclip pulleys.

3 Using pulleys

Aim

To construct pulley systems to lift various masses

Equipment

- two single pulleys
- two double pulleys
- string of length 1 metre
- a set of 50 gram masses
- a spring balance
- a ruler

Method

1. Construct a table or spreadsheet as shown below.
2. Use the spring balance to measure the effort needed to hold a 500 g mass. This is its weight force.
3. Pile some textbooks on your desk to about 5–10 cm high, and measure the exact height.
4. Place the 500 g mass (i.e. the load) on the desk next to the books and lift it slowly to the top with the spring balance.
5. Read the effort force required and record it in your table.
6. Also measure the distance your hand had to move to lift the load to the top of the books.
7. Repeat, but with the spring balance upside down.
8. Pass a string over a single pulley and use it to lift the 500 g to the top of the books. Once again, measure the effort required and the distance your hand had to move.
9. Repeat with the other combinations shown in Figure 8.4.8 or some of your own designs.
10. Calculate the mechanical advantage for each arrangement.

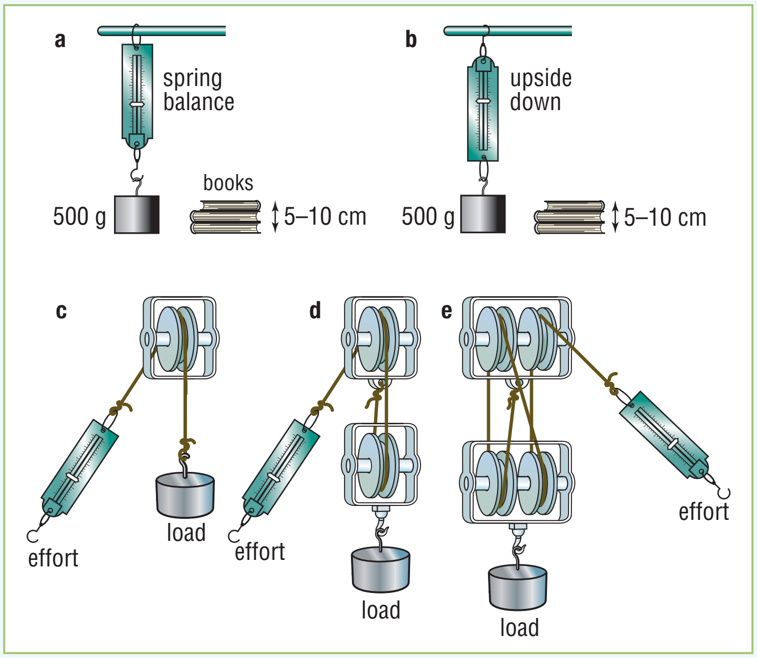

Fig 8.4.8

Questions

1. Was there any difference in the reading of the spring balance when it was upside down? If yes, **propose** why.
2. **Identify** any advantage in using a single pulley.
3. **Describe** what happened to the effort force as more pulleys were added.
4. **Describe** what happened to the distance your hand moved when lifting the mass.
5. Write a conclusion for your findings.

	Arrangement	Mass used (g)	Weight force (N)	Effort force required (N)	Distance mass lifted (cm)	Distance hand moved (cm)	Mechanical advantage
A	No pulley	500					
B	Spring balance upside down	500					
C	One pulley	500					
D	Two single pulleys	500					
E	Two double pulleys	500					

4 Rope sections

Aim

To construct a pulley system using common materials

Equipment

- strong wire that can be bent (Coat hangers are ideal.)
- retort stand and clamp with ring
- strong cotton thread or string
- 100 gram mass

Method

1 Construct a table like the one shown here.

Number of sections of thread	Distance mass moved (cm)	How far hand moved (cm)
2	5	
4	5	
6	5	
8	5	

2 Build the 'pulley' arrangement as shown in Figure 8.4.9.

3 Pass the cotton thread or string over the 'pulley' so that there are two sections of string supporting the mass.

4 Use the 'pulley' to lift the 100 g mass a distance of 5 cm. Measure how far you needed to move your hand to do so.

5 Repeat, but with four, then six, then eight sections of thread.

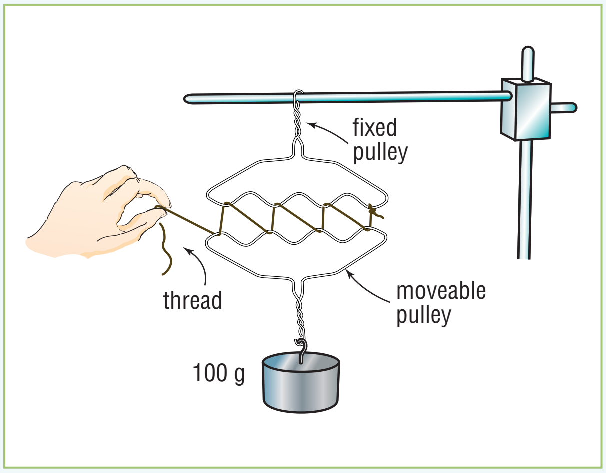

Fig 8.4.9

Questions

1 **Describe** what happened to the distance your hand moved to lift the mass when the number of sections of thread increased.

2 **Evaluate** what this suggests about the effort required.

3 Use your knowledge of the formula Work = effort × distance to **explain** your answer.

5 Constructing a complex machine

DYO

Aim

To build a machine

Equipment

- junk materials
- sand

Method

1 **Design** your own machine that will lift a small quantity of sand (i.e. the load) to a height of 10 cm. Your machine must use *two or more* simple machines, such as ramps, levers, wheels, gears or pulleys.

2 The machine must use less effort than would be required to lift the load directly. Only simple materials such as wood, cardboard, nails, pins, straws, elastic bands, string and cotton reels can be used. Commercial equipment like Meccano or Lego cannot be used.

3 Construct your machine and test it.

4 Write a one-page report that includes:
- a labelled diagram of your machine
- a list of the simple machines that you used
- a description of how each machine reduced the effort required to lift the sand.

Science Focus

Aboriginal technology

Prescribed Focus Area:

The applications and uses of science

The ancient world used the technology of their times to build their monuments, many of which still stand today. Wedges were used to split stone for their temples and tombs, the stone then being transported on sleds or on simple wheels made from logs. The stone was then lifted into place by human-powered cranes that consisted of levers or, in the case of the pyramids, dragged up massive ramps.

Fig 8.4.10 Spear throwers and boomerangs are simple technologies developed by the ancient Aboriginals in Australia that helped them hunt more effectively. The skills involved in making them are passed down through careful observation and practice.

The Aboriginal people of Australia also used simple machines to their advantage, but not for building grand monuments—they used their knowledge of forces and simple machines to help them hunt.

The spear thrower

Prac 6 p. 273

Although many different Indigenous groups used similar designs for their spear throwers, the shape and name for this tool varied in different areas. Known as the *woomera* (*wommera/wamarr*) in New South Wales or *mirr* in Western Australia, the spear thrower was a very effective device for increasing the speed of a spear. It did this by increasing the time that the throwing force was applied to the spear. The shape of the spear thrower varies depending on where it was developed. Modifying the shape allows the spear thrower to be used for other purposes also, such as a water scoop, a digging stick or a simple axe.

Spear throwers usually consisted of a piece of wood that was carefully shaped to be held at one end. The other end had a hook-like peg, sometimes made from a bone or stone. This hook-like peg fitted into a hole at the end of the spear. The spear thrower then acted as an extension of the thrower's arm.

The spear thrower uses two levers to launch the spear. Both levers act as speed multipliers, producing an increase in the speed of the spear compared with the speed of the thrower's arm and hand.

An added bonus of the spear thrower is that the force on the spear is applied directly along the shaft, allowing a skilled thrower to be extremely accurate.

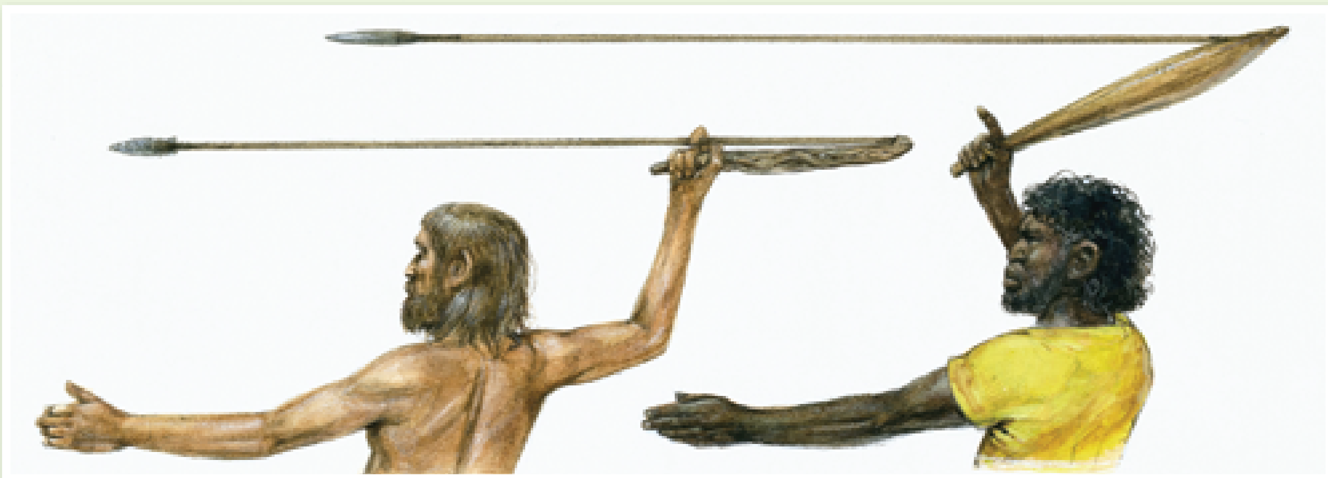

Fig 8.4.11 Spear throwers were used by Aboriginals to increase the speed of a spear when hunting.

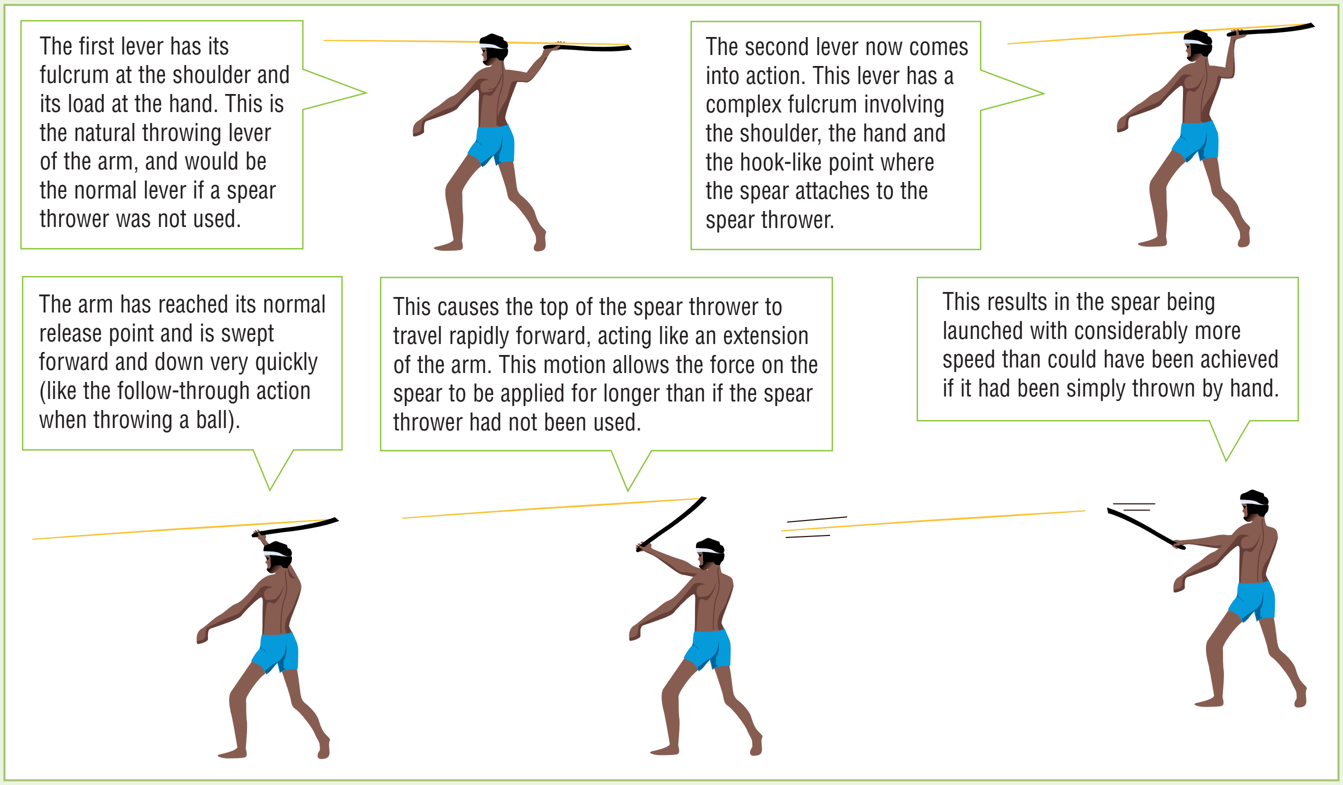

Fig 8.4.12 The spear thrower is a lever that acts as an extension of the arm. It acts as a speed multiplier.

The boomerang—throwing sticks

Although the returning boomerang is usually thought of as a form of recreation, it originated from specially shaped sticks that were used for hunting.

Several forms of boomerang-like throwing sticks were used by different Indigenous tribes.

Fig 8.4.13 Hunting boomerangs/throwing sticks were carefully shaped according to the type of prey they were to be used to hunt.

Why do boomerangs return?

Different returning boomerangs have different shapes and different curved upper surfaces. This causes them to have different flight paths when thrown. One surface of the boomerang is usually flat, whereas the other is curved. This combination of surfaces is known as an **airfoil**.

Go to Science Focus 1, Unit 7.4

As an airfoil cuts through the air it generates a lift force, which pushes the boomerang in the direction that the curved surface is facing. In this way, a boomerang is similar to a wing on an aircraft—as the wings move through the air, lift is generated, pushing the wings in the direction that their upper curved surfaces are pointing. This pushes the aircraft upwards, into the air.

The boomerang also acts similar to a helicopter. The throwing action causes the boomerang to spin rapidly just like the rotor of a helicopter. This causes the lift on either side of the boomerang to be different, which in turn causes it to change its angle in the air. This gyroscopic effect allows the boomerang to 'hover' in the air and travel in a circle, returning to its thrower.

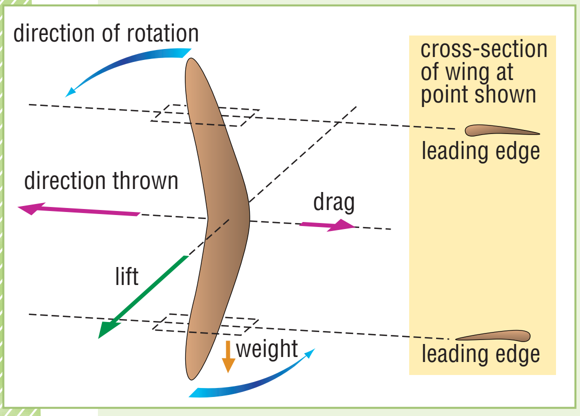

Fig 8.4.14 The boomerang acts as a wing with two leading edges. The forces shown here are those acting just after the boomerang is launched.

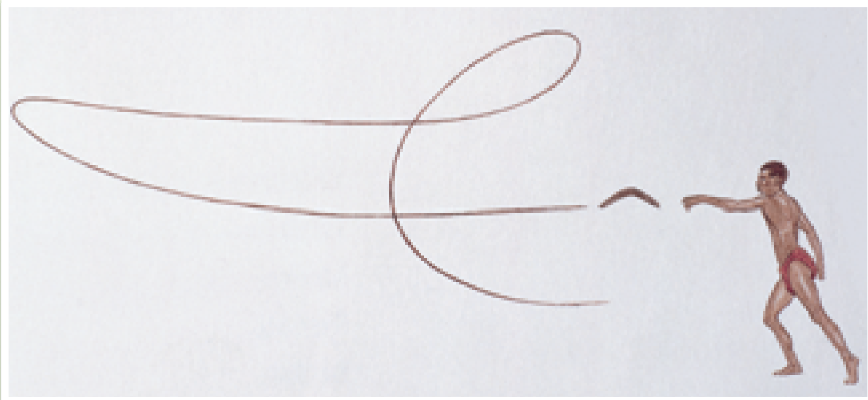

Fig 8.4.15 A typical flight path for a returning boomerang.

STUDENT ACTIVITIES

1. The spear thrower relies on two levers to act as speed multipliers in order to increase the speed of the spear when it is thrown. **Describe** some important things that would have to be considered when designing spears to be thrown.
2. **a** Figure 8.4.16 shows how a returning boomerang should be released when thrown. In the sketch, the boomerang is being thrown straight into the page by a right-handed person. The curved surface is to the left and the top of the boomerang is pointed in the direction it will be thrown. Construct a diagram to show the forces on the boomerang when it is first released.

   b **Explain** what would be likely to happen if a left-handed person threw the boomerang in the same way as described for the right-handed person.

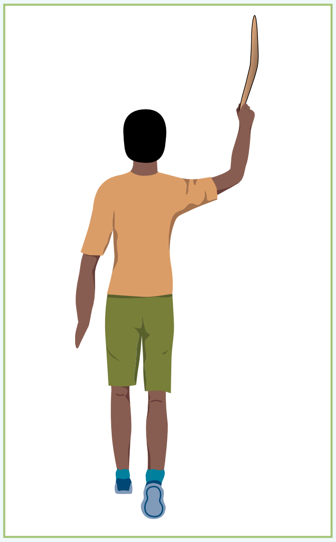

Fig 8.4.16

INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1. Research more about boomerangs that are shaped differently for each different type of prey.
2. Find a pattern for making boomerangs and construct your own.

e-xploring

PP Web Destination

As well as the spear thrower and the boomerang, Indigenous Australians used many other technologies to make life easier. These include fire, medicines, stone tools, glues, baskets, fish traps and string. Explore information about these technologies by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. From your investigation, construct a poster that could be used to demonstrate some of the clever innovations developed by the earliest Australians.

PRACTICAL ACTIVITY

6 Spear thrower

Aim

To build a spear thrower

Method

DYO

1 **Design** and construct your own spear thrower. Then construct a spear that locks into it.

2 Compare throwing the spear with and without the spear thrower. Which is more effective?

CHAPTER REVIEW

Remembering

1 **State** whether each of the following are true or false:

- a Machines make less work.
- b Machines reduce the effort required to do a job.
- c A ramp is the same as an inclined plane.
- d Ramps reduce effort because the distance travelled is less.
- e A screw is an example of a ramp.
- f A machine that gives a high mechanical advantage is a good one.
- g A pivot and a fulcrum are different things.
- h Ramps and levers use rotary motion.
- i Wheels can never act as speed multipliers.
- j Two connected gears always turn in opposite directions.
- k Gearing up is when the driven gear turns faster than the driving gear.
- l Single pulleys reduce the effort needed to lift something.

2 **List** six simple machines.

3 **Recall** what work is by completing its equation:

Work = effort force × _______

4 **State** whether it is best for a machine to have a high or low mechanical advantage.

Understanding

5 **Explain** what a simple machine does.

6 **Describe** what a complex machine is.

7 A ramp is to be used to help you get a fridge loaded onto a truck.

- a **Describe** the best ramp for the job.
- b **Explain** why it is the best.

8 **Predict** the direction and speed of the wheels and gears shown in Figure 8.5.1.

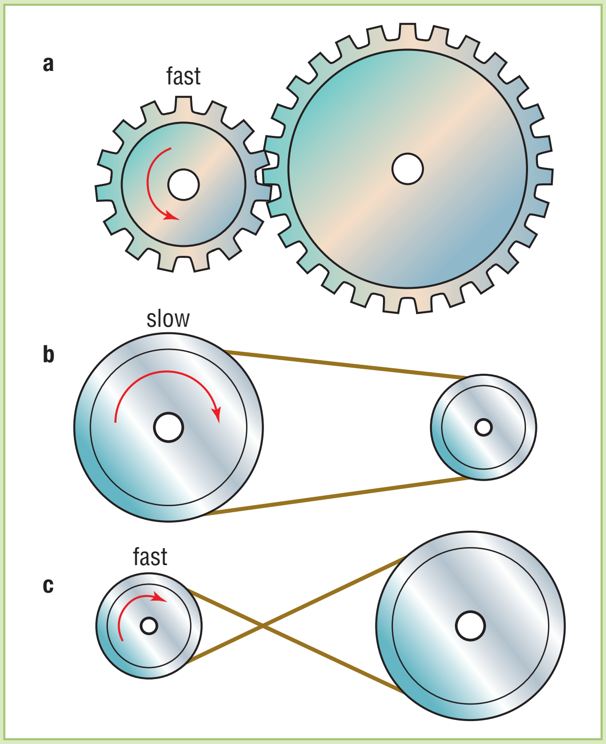

Fig 8.5.1

9 **Explain** what parallel gears are and what they do.

10 **Discuss** the advantages and disadvantages of a single pulley.

>>

Applying

11 **Use** the principle of levers to **predict** where a 20 g mass should be located to exactly balance each of the seesaws in Figure 8.5.2. Ⓝ

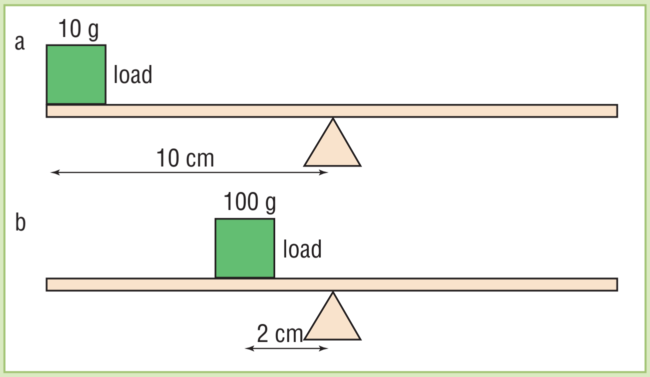

Fig 8.5.2

12 **Calculate** the mechanical advantage for the levers in Question 11. Ⓝ

13 **Identify** what idler, worm and bevel are each examples of.

14 A double pulley can lift twice the load of a single pulley. **Determine** what distance the rope must be pulled in order to do so.

15 Use examples to **demonstrate** a wheel acting as a:

- **a** force multiplier
- **b** speed multiplier.

16 **Examine** the pictures of common kitchen appliances shown in Figure 8.5.3.

- **a** **Identify** the simple machines that are used in each appliance.
- **b** **Describe** how each one uses machines to make life easier.

Analysing

17 **Distinguish** between the effort and the load on a machine.

Creating

18 **Construct** diagrams of class 1, 2 and 3 levers and **state** three examples of each.

19 **Construct** diagrams to **demonstrate** how gears could be connected to:

- **a** gear down
- **b** gear up
- **c** rotate in the same direction
- **d** increase the speed of rotation
- **e** decrease the speed of rotation
- **f** change the direction of rotation by 90°.

PP Chapter Review Questions

Worksheet 8.6 Crossword

Worksheet 8.7 Sci-words

Fig 8.5.3

9 Astronomy

Prescribed focus area:

Current issues, research and developments in science

Key outcomes

4.5, 4.9.2, 4.12

Essentials

- Space is so large that light years are needed to describe distances.
- Individual stars are grouped in constellations in the night sky.
- Earth is a planet in our solar system that is found in the galaxy called the Milky Way.
- The Milky Way is one of millions of galaxies in the universe.
- Galaxies are classified according to their shape.
- Optical and radio telescopes are used to create images of space from the light and radio waves that reach the surface of Earth.

Additional

- Scientists collect information about asteroids, meteoroids and comets that can be a risk to Earth.
- Different cultures have interpreted constellations in different ways.

Unit 9.1 Space rocks

context

Astronomy is the study of all the objects that are in space and everything that happens there. Look up at the night sky and you will see the Moon, stars and even some planets like Venus and perhaps Mercury.

If you're lucky you might also glimpse some fast-moving and rarer objects, such as comets, meteors, 'shooting or falling stars' and asteroids.

Fig 9.1.1 An asteroid is thought to have hit Earth 65 million years ago, wiping out the last of the dinosaurs.

PP Quick Quiz

Meteors

Watch a clear night sky for about 20 minutes and you'll probably see a sudden streak of light commonly known as a 'shooting star' or 'falling star'. Despite these names, what you see is not a star at all, but a meteoroid.

A **meteoroid** is a chunk of rock that has been pulled into the atmosphere at speeds of around 256 000 kilometres per hour by Earth's gravitational pull. Friction with atmospheric gases burns them up from the outside, releasing the bright light that you see as a falling star. Meteoroids are classified according to whether they burn up completely in the atmosphere or whether a chunk is left to hit the ground.

- **Meteors** are meteoroids that burn up completely, leaving nothing to hit the ground. Earth's atmosphere 'harvests' about one million kilograms of meteoroids every day, the vast majority burning up soon after entry into the atmosphere.

Fig 9.1.2 Mars has only a thin atmosphere, so meteoroids are far more likely to make it to its surface than on Earth. This iron–nickel meteorite is about the size of a basketball and was the first-ever meteoroid found on another planet. The image was taken by the unmanned Martian exploration rover *Opportunity*.

- **Meteorites** are larger chunks of space rock that have made it to the ground without burning up completely. Meteorites hit the ground at speeds of between 40 000 and 47 000 kilometres per hour, and so it's not surprising that the larger ones form craters when they hit.

Science Clip

Aussie craters

Australia has one of the biggest impact craters discovered so far. About 570 million years ago, a 4.7 kilometre-wide meteorite slammed into what is now desert, west of Port Augusta, South Australia. It caused a crater 90 kilometres wide and rocks from its impact have been found over 300 kilometres away. Evidence suggests that it triggered a tsunami and a cosmic winter, and that primitive plankton, algae and seaweeds evolved differently because of it. The eroded impact crater now forms the saltpan, Lake Acraman.

The Henbury crater field in the Northern Territory consists of several craters spread over an area of one square kilometre, and is thought to have been made after a single meteorite exploded before hitting the ground. Wolf Creek Meteorite Crater in far northern Western Australia is a perfectly formed impact crater, measuring 850 metres wide and 50 metres deep.

Sometimes several appear at once in what is called a **meteor shower**. A meteor shower occurs when the Earth passes through a region of space containing a cloud of dust particles associated with a comet. Meteors in a meteor shower appear to come from one point, called the **radiant**. Meteor showers are named after the constellation in which the radiant is located. The Leonid meteor shower, for example, appears to fall from the constellation Leo.

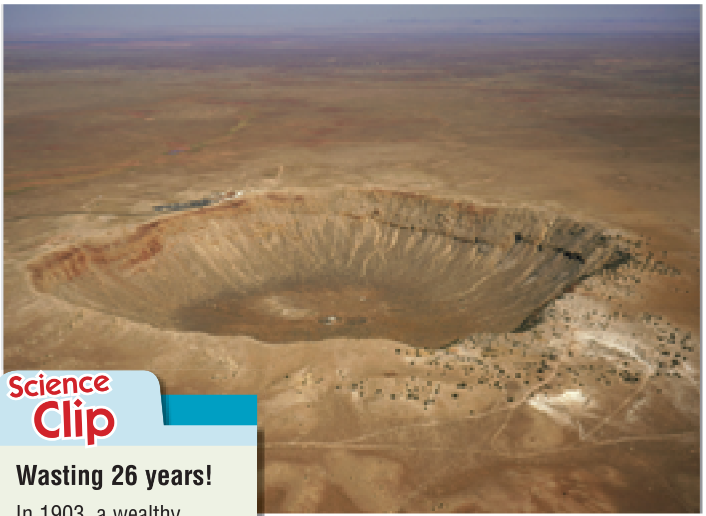

Fig 9.1.3 Meteor Crater in Arizona, USA, is 275 metres deep and 1.26 kilometres in diameter. The meteorite that caused it was around 60 metres in diameter and had a mass of more than 10 000 tonnes.

Science Clip

Wasting 26 years!

In 1903, a wealthy miner named Daniel M. Barringer thought he could increase his fortune by digging out the iron and nickel left behind by the meteorite that formed Meteor Crater. Over the next 26 years, he mined and mined, but never found anything. Unfortunately for Barringer, the heat of impact completely vaporised the meteorite. Nothing would have been left behind except for the hole!

Asteroids

Asteroids are irregularly shaped rocky objects left over from the formation of the solar system. Although over 26 000 of the bigger asteroids have been named, billions of smaller ones orbit the Sun in a 345 million kilometre-wide **asteroid belt** located between Mars and Jupiter. Asteroids range in diameter from one metre to many hundreds of kilometres, the largest being Ceres, which has a diameter of around 975 kilometres. Giuseppe Piazzi, a Sicilian astronomer, discovered it in 1801. Another asteroid, Vesta, is big enough to be visible without a telescope.

Annual meteor showers	
Meteor shower	**Main date**
Quadrantids	3–4 January
Eta Aquarids	4–6 May
Delta Aquarids	29 July – 6 August
Persids	12 August
Orionids	21 October
Geminids	13–14 December

Science Clip

Trojan asteroids

Not all asteroids that orbit the Sun are in the asteroid belt. So-called Trojan asteroids are in two groups in the same orbit as Jupiter, with one group ahead and one behind the gas giant.

Comets

Comets are dirty snowballs of ice mixed with dust, frozen carbon dioxide and carbon-containing (organic) matter. Comets come from the **Oort cloud**, a region beyond Pluto that contains many billions of them. They swing in long and narrow elliptical orbits towards the Sun and then back into space. Most are never seen again because they can take thousands or millions of years to complete their orbits. Comet Hale–Bopp, for example, takes more than 4000 years to travel around the Sun and was last seen in 1997. Some comets appear more regularly—Halley's Comet appears every 76 years, its last appearance being in 1986.

Science Clip

Dead flat craters

Some of the biggest craters in the world cannot be seen because they have been eroded away to nothing. A crater in Iowa, USA, measuring 5 kilometres deep and 33 kilometres wide, is completely filled and flat. The small town of Manson sits in its middle.

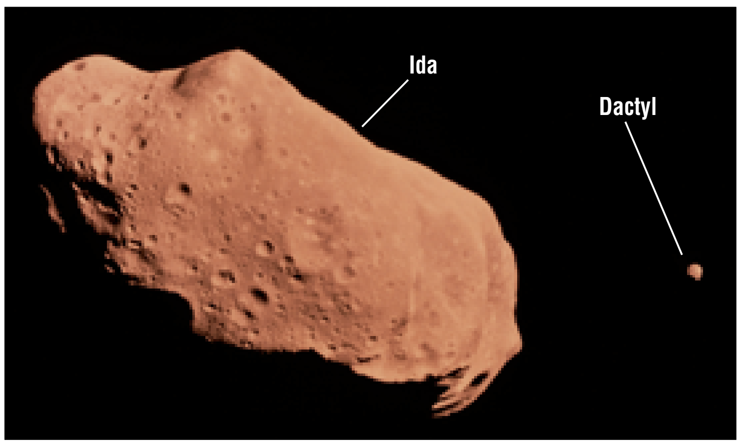

Fig 9.1.4 The asteroid Ida is 56 kilometres long and has its own moon, Dactyl, which is 1.6 kilometres across.

Worksheet 9.1 The asteroid belt

A comet can be a spectacular sight as it nears the Sun. Its frozen nucleus begins to evaporate, releasing dust particles and gas to form a **coma** (head) and two tails—one formed of gas, the other dust. A stream of particles from the Sun form the solar wind that affects the dust and gas slightly differently, causing them to separate and always point away from the Sun. Each tail can stream out 100 million kilometres from the comet's core.

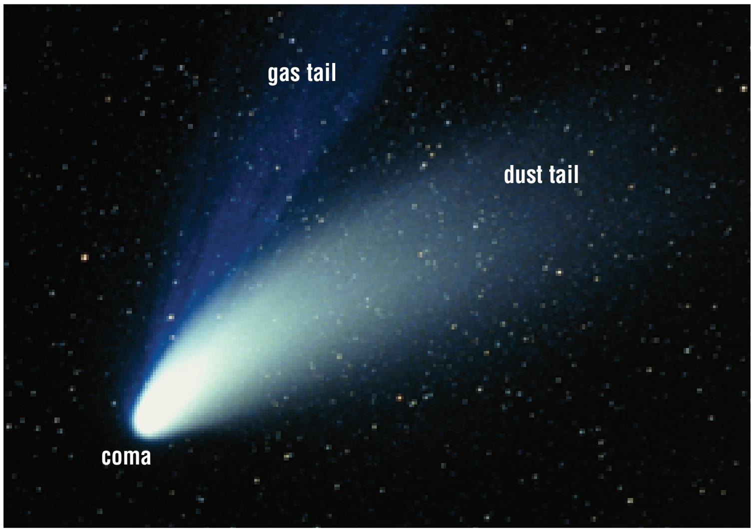

Fig 9.1.5 Comet Hale–Bopp, as seen from Earth in 1997. Two tails are formed because the solar wind affects the comet's dust and gas slightly differently.

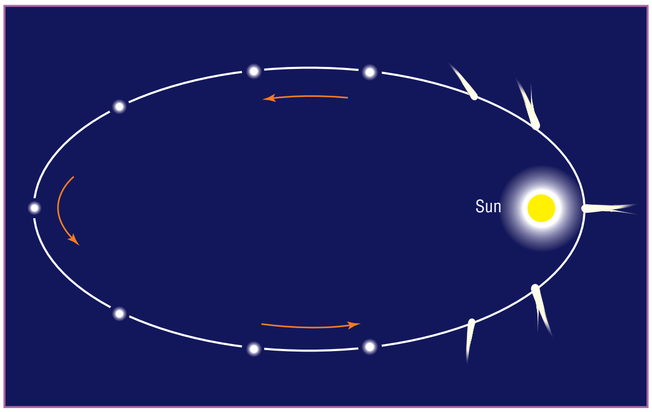

Fig 9.1.7 A comet develops two tails as it approaches the Sun. These always point away from the Sun.

Fig 9.1.6 Dark brown impact sites on Jupiter caused by fragments of the comet Shoemaker–Levy 9 colliding with Jupiter in 1994.

Science Clip

Shoemaker collisions

In 1993, Eugene Shoemaker, his wife Carolyn and fellow scientist David Levy discovered a comet orbiting Jupiter, apparently trapped by its strong gravity (probably protecting Earth in the process). The comet, named Shoemaker–Levy 9, broke up and began to hit the planet on 16 July 1994, finishing a week later. Jupiter's atmosphere flashed brightly and huge clouds were thrown up. The biggest fragment left scars the size of Earth! In 1997, Shoemaker was killed in a collision of his own—a head-on car accident on a lonely dirt track in the Tanami Desert in the Northern Territory. After cremation, some of his ashes were sprinkled around Meteor Crater in the USA and some were sent to the Moon on the *Lunar Prospector* spacecraft.

Missions to space rocks

There have been a number of unmanned missions during which space probes have flown past asteroids and comets. Two have actually made physical contact.

Asteroid missions

In 2001, the *NEAR-Shoemaker* spacecraft made a successful landing on Eros, an asteroid measuring 33 kilometres long and 13 kilometres wide that is almost 320 million kilometres from Earth. The spacecraft had taken five years and had been orbiting it for a year, transmitting 160 000 images of its surface. As it was nearly out of fuel and had collected more data than expected, scientists decided to try and land it. This mission has given scientists valuable information about the elements that make up the asteroid and about how its surface has been shaped.

1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001

- 1991: Flyby of the asteroid Gaspra.
- 1993: Flyby of the asteroid Ida and the discovery of its moon Dactyl by the *Galileo* space probe on its way to Jupiter.
- 1995: *Clementine* spacecraft heads towards asteroid 1620, but failed en route.
- 1997: *NEAR-Shoemaker* space probe flies by asteroid Mathilde on its way to Eros.
- 1999: *Deep Space 1* probe flies by Braille asteroid.
- 2001: *Deep Space 1* probe flies by the comet Borrelly.
- 2001: *NEAR-Shoemaker* lands on asteroid Eros.

The space probe *Dawn* was launched in 2007 on a journey that will take eight years and travel five billion kilometres to the solar system's asteroid belt. *Dawn* will reach the asteroids Vesta in 2011 and Ceres in 2015, the purpose of the mission being to provide information on how the solar system formed.

Science Clip

Changing names

The space probe that landed on Eros was known only as *NEAR* (*Near Earth Asteroid Rendezvous*) when launched, but was renamed *NEAR-Shoemaker* after Eugene Shoemaker's death in 1997.

Fig 9.1.8 An artist's impression of the *NEAR-Shoemaker* spacecraft orbiting the asteroid Eros before landing.

Crashing into a comet

Before 2005 space probes had successfully passed through the tails of comets, but had never gone too close to the coma or head. In January 2005, the space probe *Deep Impact* was launched to rendezvous with Comet 9P/Tempel, 140 million kilometres from Earth. Comet 9P/Tempel orbits the Sun every 5.5 years and was first seen by Ernst Tempel in 1867. On reaching its target, *Deep Impact* split in two—one half (i.e. the 'impactor') guiding itself into the path of the comet's head, crashing into it on 4 July 2005. Images were transmitted by the 'impactor' just before hitting and by the other half of the spacecraft (the 'flyby') that did not hit. About the size of a small car, the 'impactor' is thought to have produced a crater several storeys deep and as long as a football field. Despite this, the orbit of the comet is not expected to change. The purpose of this mission was to study material exposed by the impact from deep below the surface of the comet. Scientists found that the material was dustier and less icy than first expected.

Global killers

Killer asteroids

Asteroids normally stay in their asteroid belt, but occasionally one may stray closer to Earth, as did asteroids in 1991 (missing Earth by a mere 170 000 kilometres) and 1993 (145 000 kilometres). In 1994, an asteroid measuring 10 metres wide, XM1, missed Earth by only 104 000 kilometres, and the 30 metre-wide asteroid 2004 FH passed within 43 000 kilometres of Earth in 2004. All these asteroids were too small to cause widespread damage since scientists estimate that an asteroid would need to be one kilometre or more in diameter to be catastrophic. At that size, it would cause firestorms, earthquakes and tsunamis. A gigantic dust cloud would envelop the

Science Clip

Ceres the dwarf

After much discussion and debate, in 2006 the International Astronomical Union created the category of dwarf planets to cover those objects in space that had enough gravity to pull themselves into a roughly spherical shape, but not enough gravity to clear debris out of their orbit. Under this new definition, Ceres is considered to be both an asteroid and a dwarf planet. The new definition also caused Pluto to be downgraded from a 'proper' planet to a dwarf planet.

Fig 9.1.9 An artist's impression of *Deep Impact* about to strike the comet 9P/Tempel in 2005.

planet and last for several months or possibly years, blocking the Sun, cooling the atmosphere and wiping out many forms of life. A crater, with a diameter of at least 180 kilometres, was discovered off the coast of the Yucatan Peninsula in Mexico. The most commonly accepted theory is that the asteroid that made this crater possibly caused the extinction of the dinosaurs.

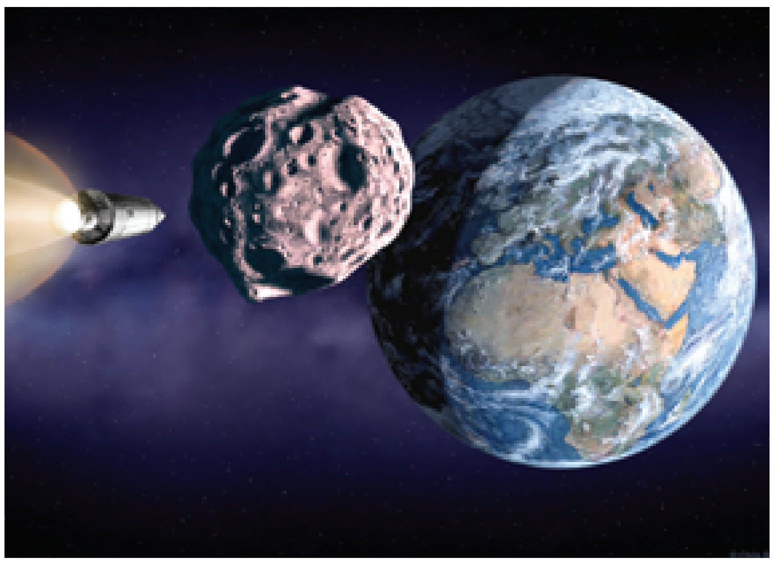

Fig 9.1.10 An artist's impression of a rocket nearing an asteroid in an attempt to divert it away from Earth.

Killer comets

As with asteroids, a comet colliding with the Earth has the potential to be devastating to life. Comets, however, are the greater threat because they:

- originate in the outer reaches of the solar system, where they can't be seen
- are coated with a dark outer layer that makes them difficult to observe until they near the Sun.

Science Clip

No warning

Earth would have only a couple of days' warning if a 100 metre-wide asteroid was heading straight for us. Anything smaller would be seen only when it began to burn up in the atmosphere, giving us no more than two or three seconds to run!

Global protection

One proposal to safeguard Earth from life-threatening impact involves remote-sensing satellites (called sentries) and 'soldier' spacecraft armed with nuclear explosives, directed from an Earth-based control centre.

Blowing up an asteroid or a comet would be too dangerous, however, as many smaller pieces from the explosion could still strike Earth. A better idea would be to deflect the threatening comet by exploding a nuclear device near it. In order to deflect a global killer measuring one kilometre in diameter, the explosion would need to occur when the object was still one year away from us. Obviously, early detection is essential.

9.1 QUESTIONS

Remembering

1 **State** whether the following statements are true or false:
  - **a** A shooting star forms when a streak of light travels across the sky.
  - **b** A meteoroid is a burning meteor.
  - **c** Meteorites burn on impact with the Earth.
  - **d** Most comets are seen regularly every few years.
  - **e** A comet has two tails.
  - **f** A comet's tail appears only when it nears the Sun.
  - **g** A comet's tail may be millions of kilometres long.

2 **Specify** where the following are normally found:
  - **a** asteroids
  - **b** Trojan asteroids
  - **c** comets.

3 **Specify** how often the following comets reappear:
  - **a** Halley's Comet
  - **b** Hale–Bopp.

4 **List** seven facts each about the:
  - **a** *NEAR-Shoemaker* landing on Eros
  - **b** *Deep Impact* crash on 9P/Tempel.

5 **a** **Specify** the size range of asteroids.
  - **b** **State** the size of an asteroid that would threaten Earth.

6 **List** three possible consequences of a large asteroid entering Earth's atmosphere.

Understanding

7 **Describe** what makes shooting stars visible at night.

8 **Define** the term *meteor shower*. L

9 **Outline** how meteor showers are named.

10 **a** **Explain** what is meant by a 'global killer'.
  - **b** **Outline** one suggestion for avoiding destruction due to a 'global killer'.

>>

11 **Account** for the fact that Ceres was the first asteroid to be discovered.

12 **Predict** what would happen to Jupiter if it sped up, or slowed down, in its orbit around the Sun.

Applying

13 You see a 'star' suddenly shoot across the night sky. It then 'dies' well above the horizon. **Identify** what type of space rock the 'star' is.

14 **Calculate**: (N)

- **a** the year in which Halley's Comet is due to appear again
- **b** the years of the last four sightings of Halley's Comet
- **c** the year in which comet Hale–Bopp is expected to reappear.

15 The dust in a comet's tail is affected more by the Sun's gravity than the gas in the tail. Use this information to **explain** how this may cause a comet to have two tails.

Analysing

16 **Distinguish** between:

- **a** a shooting star and a real star, such as the Sun
- **b** a meteorite and a meteor.

17 **a** **Contrast** the size of the crater in Figure 9.1.3 with the size of the meteorite that caused it.

- **b** **Explain** why nothing of the meteorite is left.

18 **Contrast** what would happen if:

- **a** a small and a large meteoroid hit Earth's atmosphere
- **b** a large and a small asteroid hit Earth.

19 **a** **State** how close the asteroid named 2004 FH came to Earth.

- **b** **Contrast** this distance with the distance between the Earth and the Moon (which is 384 000 kilometres). (N)

Evaluating

20 Meteor Crater is an incorrect name. **Propose** a reason why.

21 **Propose** a reason why 9P/Tempel was:

- **a** a better choice than either comet Hale–Bopp or Halley's Comet on which to crash land a space probe
- **b** not expected to change direction after the impact of *Deep Impact*.

22 It is thought that Jupiter has helped to protect the Earth from impacts, particularly from comets. **Propose** how it might do this.

23 New meteorites are often found in Antarctica. **Propose** a reason for this.

Creating

24 You are a leading astronomer and you calculate that a major asteroid impact with Earth is likely in the next 20 years. **Construct** a plan that answers these questions.

- What can you do to protect the Earth and to provide sufficient warning for a course of action?
- How will you convince politicians, who are reluctant to believe you and unwilling to fund your proposal?
- How can you muster support for your plan?
- How can you convince those people who believe your calculations are wrong?

9.1 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1. Find the location of the world's major meteorite craters. Construct a map showing their location, labelling each one with important information (e.g. name, year of impact if known, size etc.).
2. Find out how Jupiter came to have a great red spot, stripes and strange swirls. Explain whether Jupiter's surface changes over time or always stays the same.
3. Research comets such as Hale–Bopp, Borrelly and Encke, and construct a short information card on each.
4. Identify what was found within meteorites from Mars crashing onto Earth in 1997, which some thought indicated that they contained the fossilised remains of life on Mars! Evaluate evidence that indicated the meteorites came from Mars, what the 'life' was and why the excitement about it died down quickly.

Reviewing

Deep Impact (1998) and *Armageddon* (also 1998) were two blockbuster films made about Earth's impact with an object from space. Watch either movie and prepare a film review about it. In your review, assess the accuracy of the science shown. (L)

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Unit 9.2 The night sky

context

Over one thousand stars may be visible on a clear night in the country. In the city, this number will be greatly reduced due to light pollution or glare from artificial lighting. In daylight, too, there are over one thousand stars in the sky. Nevertheless, we see only one—the nearest star to us, called the Sun. The Sun is so bright it makes it impossible to see the others. People have looked to the stars for guidance throughout history. The stars have allowed sailors to navigate the globe, provided us with information about the seasons and allowed astrologers to think they could predict the future.

Science Clip

Twinkle, twinkle

Twinkle, twinkle, little star,
How I wonder what you are!
Up above the world so high,
Like a diamond in the sky.

Jane Taylor (circa 1806)

Looking up at the stars from Earth, they appear to twinkle. The density of air affects how light is bent as it passes through our atmosphere. When patches of air that vary in density come between a star and our eyes, we see different rays of light that appear to come from slightly different parts of the star. The constant movement of air in the atmosphere causes the stars to appear to twinkle.

Fig 9.2.1 Time lapse photography produces 'star trails'. From Australia, these are centred on the South Celestial Pole. Some stars never set, whereas others only dip under the horizon for a short time.

Light years

Alpha Centauri is the brightest and closest star system to our solar system. It is situated about 42 trillion kilometres (i.e. 42 000 000 000 000 kilometres) from Earth. To avoid using such long numbers when describing distances in space, astronomers talk about light years instead.

A **light year** is the distance light travels in a year. Light travels at 300 000 kilometres every second or 9.45 trillion kilometres (i.e. 9 450 000 000 000 kilometres) in a year. Albert Einstein described it as the natural speed limit of the universe.

To calculate the distance of Alpha Centauri from Earth in light years, divide the distance by the speed of light to get 4.3 light years. This also means that it takes 4.3 years for the light from Alpha Centauri to reach Earth. Only eight stars are within 10 light years of Earth. As a comparison, Pluto is 0.0006 light years or 5.5 light hours away.

Distances in light years from Earth

Object	Type	Distance (light years) from Earth	Time light takes to reach Earth
Proxima Centauri	star	4.3	4.3 years
Sirius	star	9.1	9.1 years
Alpha Crucis	star	230	230 years
The Pleiades	set of 7 stars	400	400 years
Rigel	star	900	900 years
Great Nebula	nebula	1600	1600 years
Dorado	large cloud of stars	170 000	170 000 years
Sombrero	galaxy	50 million	50 million years
The Sun	star	0.000 015	8 minutes
Pluto	dwarf planet	0.0006	5.5 hours

Science Clip

The zodiac

Although there are many constellations, the Sun appears to move through only 12 of them in one year. These are the constellations of the **zodiac**. The word *zodiac* comes from the Greek word meaning 'wheel of life'. The 12 signs of the zodiac are: Aries, Taurus, Cancer, Gemini, Sagittarius, Libra, Virgo, Leo, Scorpio, Capricorn, Aquarius and Pisces.

Career Profile — Astronomer

Astronomers study planets, galaxies and other objects in the universe. An astronomer can be involved in:

- observing objects in space, from Earth and via orbiting satellites, using a wide range of telescopes
- designing and attaching special equipment to telescopes or spacecraft
- recording, analysing and comparing results and observations, using electronic and computer systems
- developing theories and making predictions to explain observations
- attempting to understand the nature and origin of the universe
- using computers to produce star maps, catalogues and tables of measurements for use in navigation, and surveying.

A good astronomer will have:

- imagination and patience
- an inquiring mind
- an interest in and good skills in maths, computing and physics
- good oral and written communication skills
- good team skills
- a willingness to work at night.

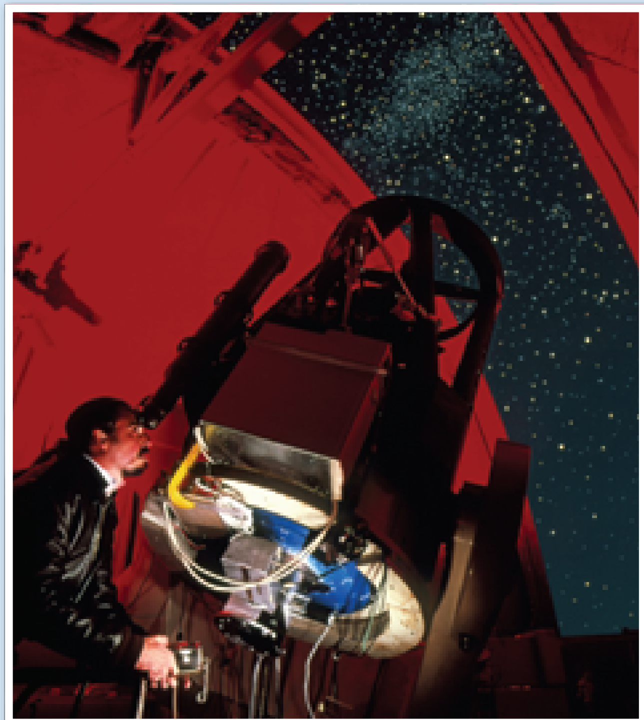

Fig 9.2.2 An astronomer using an optical telescope

Celestial street directory

The word *celestial* means 'of the sky'. Astronomers imagine the sky and its stars to be on an invisible globe with the Earth at the centre. Although this is not true, it provides a convenient way of describing the position of objects in the sky. This imaginary globe is called the **celestial sphere**. The Earth rotates from west to east and so the celestial sphere appears to rotate the opposite way, making the stars 'rise' in the east and 'set' in the west.

Latitude and **longitude** are used to describe a position on the Earth's surface—lines of latitude run around the Earth's surface from east to west, whereas lines of longitude run north to south. On the celestial sphere, similar measurements are used—**right ascension (RA)** is the celestial equivalent of longitude and **declination (DEC)** is the equivalent of latitude.

Sometimes a line called the **ecliptic** is marked on the celestial sphere. This is the line followed by the Sun as it moves across the sky, and makes an angle of 23.5° to the celestial equator. The stars that are visible depend on your position on Earth and which part of the celestial sphere you are under. For example, the Southern Hemisphere sky (i.e. the sky viewed from Australia) appears very different to that in the Northern Hemisphere (i.e. viewed from North America).

Constellations

Five thousand years ago there were no streetlights, no air pollution to 'hide' the stars and no TV to entertain you at night. Instead, the early civilisations looked up into the heavens and saw patterns in the stars. To aid their memory, they imagined that they saw likenesses to mythical beings, animals and monsters, and named the groups of stars after them. These star groupings are now known as **constellations**.

Science Clip

Who's the closest?

Although Alpha Centauri appears as a single star, a telescope shows that it is actually a cluster of three stars—one of which is Proxima Centauri. Proxima Centauri is actually the closest star to Earth but, since you can't normally see it on its own, the label 'closest' usually goes to the whole cluster Alpha Centauri.

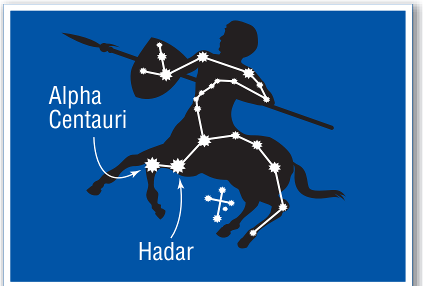

Fig 9.2.3 The two pointers, Alpha Centauri and Hadar, form part of the Centaurus constellation. A centaur is a mythical creature made up of half man and half horse.

The most observed constellation in the southern skies is the Southern Cross, also known as Crux Australis with its two pointers, Alpha Centauri and Hadar. Some Australian Aboriginal tribes call the two pointers 'The Two Men that once were Lions', whereas others refer to them as the twins that created the world. The Southern Cross is the smallest constellation and is very close to the Centaurus constellation, which is 10 times larger.

Prac 1 p. 288

Worksheet 9.2 Constellations

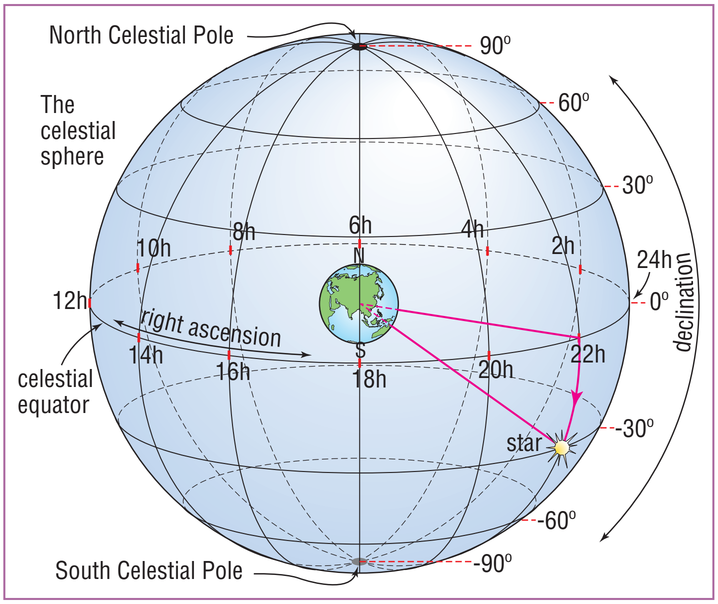

Fig 9.2.4 A celestial sphere. Right ascension is measured in hours, and describes how far a star is around the celestial equator. Declination is the angle (in degrees) we then move (north = +, south = –) to locate a star. The star in the diagram has RA = 22 hours and DEC = –30°.

Fig 9.2.5 The Southern Cross (Crux Australis) is seen from most of the Southern Hemisphere—the four bright stars are just right of centre.

Science Clip

So colourful!

When you look up at the stars on a clear night some stars flash blue, and others are white or red. The temperature of the star affects what colour you see. Stars that appear blue are the hottest and red stars are the coolest.

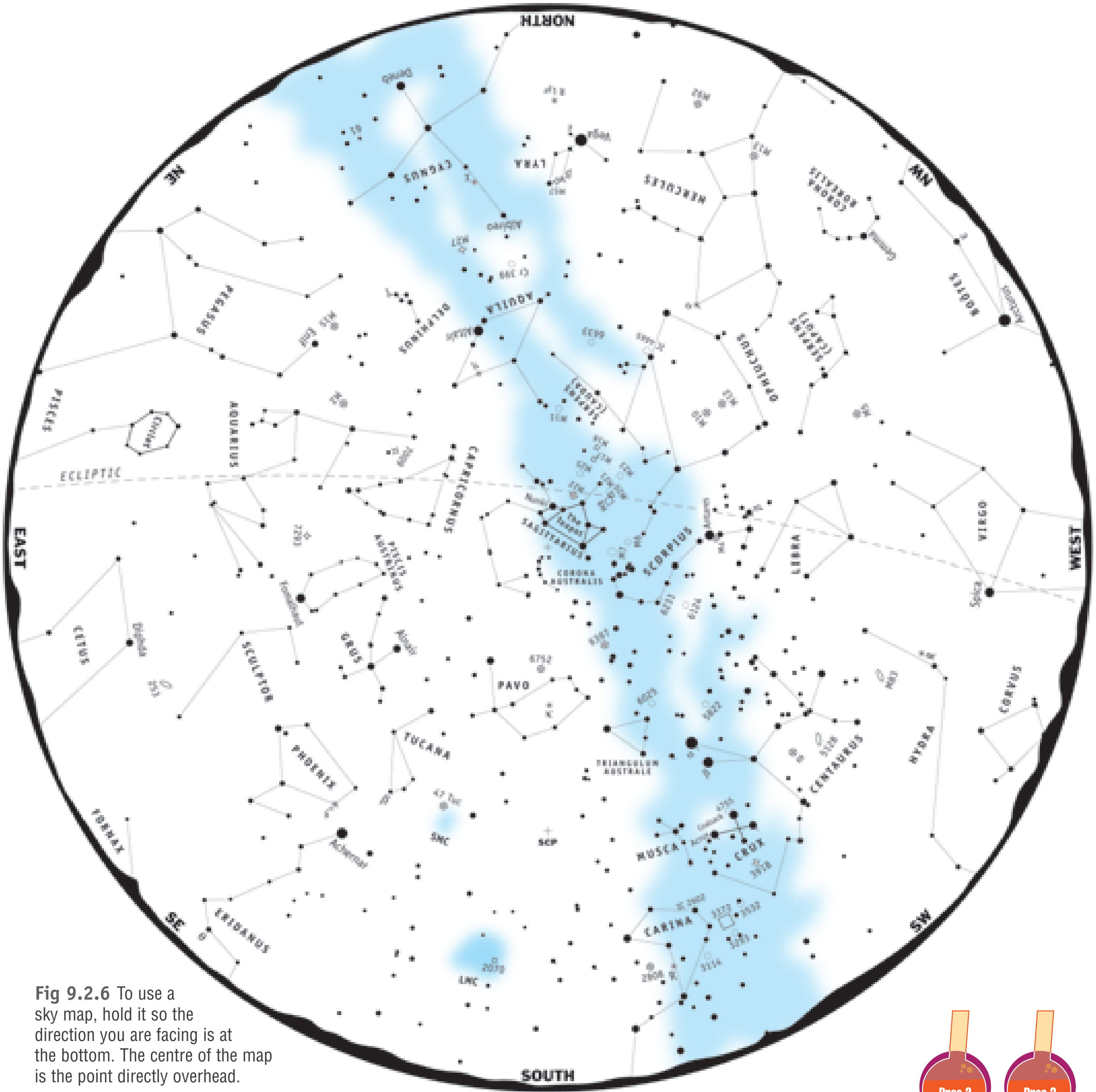

Fig 9.2.6 To use a sky map, hold it so the direction you are facing is at the bottom. The centre of the map is the point directly overhead.

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Prac 3 p. 289

Sky maps

A **sky map** shows the entire sky as viewed from a given location at a specified date and time. Sky maps are used to locate stars and other objects in the sky, just like a world map is used to locate countries, states and cities.

Sky maps for the current month can be found on the Internet. Excellent software programs for viewing the sky at any time from any location are available as shareware from several Internet sites. You can search using the keywords CyberSky, SkyGlobe or sky maps.

A measure of the brightness of stars is called magnitude. Star magnitudes are found in the corner of the sky map. The lower the number, the brighter the star and the larger the dot symbol on the map. The pointer farthest from the Southern Cross has a magnitude of 0, whereas brighter stars may have magnitudes of –0.5 to –1.0. The faintest visible stars to the naked eye have a magnitude of +6.

9.2 QUESTIONS

Remembering

1 **State** the distance:
  a that light is able to travel in a year (in kilometres)
  b from Earth to the nearest star outside our solar system (in light years).

2 **State** how long it takes light to travel from the following objects in space to Earth:
  a the Sun
  b Proxima Centauri
  c Great Nebula
  d Sombrero galaxy.

3 **State** another name for the Southern Cross.

4 **List** the following star magnitudes in order from dimmest to brightest:
0, –1, +2, –0.5

Understanding

5 **Define** the following terms: (L)
  a light year
  b celestial
  c right ascension
  d declination
  e ecliptic.

6 **Explain** why distances in space are measured in light years and not in kilometres.

7 **Explain** how the Sun, Alpha Centauri and Proxima Centauri can all be legitimately called the closest star to Earth.

8 If the stars that make up the Pleiades 'died' today, **predict** when we on Earth would find out about it.

9 **Explain** why you cannot see all the stars on the celestial sphere from Australia.

10 **Explain** why stars leave 'trails' across the night sky in time-lapse photography.

11 Use an example to **clarify** what is meant by a constellation.

12 The Southern Cross and the pointers can be used to find the South Celestial Pole. Use a diagram to **describe** how this is done.

Applying

13 From the list below **identify** which objects are the most visible in the night sky.
  A planets
  B orbiting artificial satellites
  C suns
  D galaxies.

14 **Use** the sky map in Figure 9.2.6 to complete the names of the following constellations: (L)
  a Scor ___
  b Triangulum _____
  c Peg ___
  d Her ___.

15 **Use** the sky map in Figure 9.2.6 to **name** a constellation near:
  a Centaurus
  b Grus.

16 **Identify** the symbol used on the sky map for:
  a a galaxy
  b a diffuse (i.e. fuzzy) nebula.

17 Achernar is one of the brightest stars in the sky and is 1400 trillion kilometres from Earth. **Calculate** how many light years this is. (N)

Analysing

18 **Calculate** how long it would take to reach Alpha Centauri travelling at the speed of: (N)
  a a bicycle (i.e. 10 kilometres per hour)
  b a car on the highway (i.e. 100 kilometres per hour)
  c a passenger jet (i.e. 1000 kilometres per hour)
  d an orbiting space shuttle (i.e. 30 000 kilometres per hour).

19 A light year is the distance travelled by light in a year. If the speed of sound is 330 metres per second, **calculate** what distance could be called a 'sound year'. (N)

Evaluating

20 Some 'stars' appear to move across the night sky much faster than the other stars. **Propose** what these 'stars' may be.

21 You are travelling back in time whenever you look at the stars in the night sky. **Propose** a reason why.

>>

22 **a** **Describe** what the North Celestial Pole is.

b **Propose** a reason why it is not important to us in Australia.

23 **Assess** whether it is safe to look at all the stars in the sky.

24 Astrologers claim to tell the future by observing the stars and constellations of the zodiac. They also sometimes claim to be scientists.

a **List** points supporting their claim and points that reject their claim.

b Use your lists to **assess** whether they are scientists or not.

Creating

25 **Construct** a diagram of a celestial sphere similar to that shown in Figure 9.2.4 and **identify** the approximate position of a star having right ascension 12 hours and declination 45°. N

9.2 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1. Find national flags that include the Southern Cross (e.g. Australia, New Zealand, Western Samoa, Papua New Guinea, Solomon Islands) or stars (e.g. Brazil, China, Tuvalu, Iraq, Venezuela, USA, Singapore etc.). Design a new national flag for Australia that incorporates the Southern Cross and other national icons. Present your work in one of the following ways:
   - a flag made from fabric or paper
   - a poster the shape and size of your flag
   - a nationalistic TV advertisement for the new flag.
2. **Investigate** which constellation contains the 'saucepan'. Draw the constellation, marking out the 'saucepan' in it.
3. List bright stars that can be identified in an Australian night sky. Include their distance from Earth.
4. Explain what the North star is and how it relates to the North Celestial Pole.
5. Construct a poster to demonstrate the finer details of a particular constellation, such as Orion or Triangulum Australe.

Fig 9.2.7 The Southern Cross is the basis of many flags of the Southern Hemisphere.

e-xploring

Find out more about sky maps by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations. Once there, obtain a sky map or planisphere (i.e. a device for locating stars at various times of the year). Construct a diagram to demonstrate the stars or constellations you can name using the planisphere. (Hint: Use a torch covered with red cellophane to view your star map at night.)

PP Web Destination

Fig 9.2.8 A planisphere

9.2 PRACTICAL ACTIVITIES

1 Model constellations

Aim

To construct a model of a constellation and try to identify what it represents

Equipment

- A3 black paper or cardboard
- aluminium foil
- sticky tape or glue
- white chalk

Method

1 Choose one of the constellations shown in the sky map in Figure 9.2.6 and accurately mark a larger version on the A3 black paper or cardboard.

2 Scrunch up little balls of aluminium foil to make enough 'stars'.

3 Carefully stick or paste the 'stars' into the correct positions for your constellation.

4 Draw lines between the stars with the white chalk to make the constellation shape clear.

5 Use more foil to cut out the name of your constellation.

6 Review all the constellations built by the class.

Questions

1 Try and **identify** what each constellation is meant to represent.

2 **Propose** some other possibilities.

2 Finding south

Aim

To locate the South Celestial Pole

Equipment

- compass

Method

1 Look for the Southern Cross on a clear night. You should be able to see it even if you live in the city.

2 Draw an imaginary line in the sky so that the long line of the Southern Cross is extended by about four times its length. See line A on Figure 9.2.9.

3 Draw another imaginary line to join the pointers. See line B.

4 Draw another imaginary line that bisects line B joining the pointers. See line C.

5 Check that line A and line C intersect.

6 Draw a line down to the horizon from where lines A and C intersect. This is geographic south.

7 Use a compass to check how correct you have been.

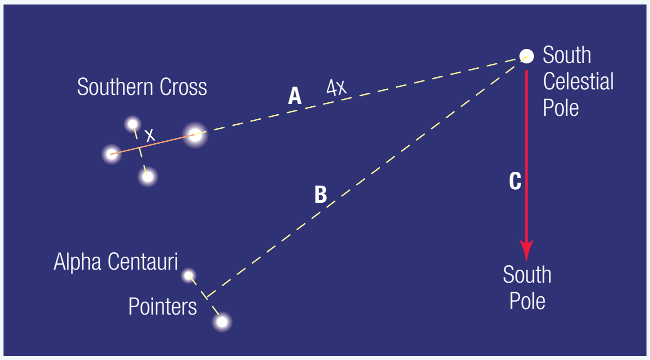


Fig 9.2.9 Alpha Centauri is one of the pointers of the Southern Cross. The pointers and the cross can be used to locate the South Celestial Pole and the South Pole.

Questions

1 **Explain** why the South Celestial Pole never moves in the night sky.

2 **Explain** why the Southern Cross shifts across the night sky.

3 The Southern Cross is higher in the sky in Tasmania than in Queensland. **Propose** a reason why.

4 **Assess** how accurate you were at finding south.

3 Exploring the stars

Aim

To use a sky map to locate stars and constellations

Equipment

- The program SkyGlobe (available as shareware—enter SkyGlobe in an Internet search engine to find a download site) installed on a computer running Windows

Method

1. Double-click the SkyGlobe.exe file to begin SkyGlobe.
2. Set the location to the major city nearest you (e.g. Sydney) by typing L and selecting a location. (You may need to first select 'More locations'.)
3. Use the mouse (move to an edge of the screen) or arrow keys to change the view.
4. Type S to obtain a southerly view.
5. Position the cursor over a star to find its name. Note some of the brightest stars' names. Also take note of some constellations and where they appear.
6. Type M or H to advance the view by a minute or hour, respectively. Type Shift M or Shift H to go back. Try repeatedly pressing M or H (or Shift M or Shift H).
7. Type Z to zoom in, or Shift Z to zoom out.
8. Investigate the other commands shown at the top left of the screen.
9. Another shareware program is CyberSky. Search for the program and compare it with SkyGlobe.

Questions

1. **List** some of the brightest stars.
2. **List** some constellations that are visible at the current time of year.
3. **Identify** the direction that the stars appear to move when you advance the minute or hour.
4. **Describe** another interesting SkyGlobe command.

Unit 9.3 Galaxies

context The night sky is full of stars, but look carefully and you will also see cloud-like blurs of faint light. The most obvious is the Milky Way—a band of light that stretches right across the sky. The Milky Way is the galaxy in which we live.

Fig 9.3.1 Billions and billions of stars fill the night sky, the vast majority of them invisible to the naked eye. 'Clouds' in the sky are really collections of countless stars that we can see only as a blur.

Stars

Our Sun is a **star** and is the closest one to Earth. It is the centre of our solar system and its gravitational pull keeps eight planets (i.e. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune) and an assortment of asteroids and dwarf planets orbiting around it.

Like all stars, the Sun is a huge ball of gas, most of it being hydrogen. The Sun is so large that its own gravity is constantly trying to collapse it. This creates intense pressure and heat—temperatures at the core can be as high as 15 000 000°C. Under this heat and pressure hydrogen atoms are forced together until they fuse, forming a new atom, helium. This is a type of **nuclear reaction** called a **fusion reaction** and produces incredible amounts of heat and light energy, as well as a range of other radiations, such as visible light, infra-red, ultraviolet (UV), X-rays, radio waves and gamma rays. The visible light from the Sun shines on Earth, giving us daylight, and the visible light from more distant stars is what you see as a twinkling dot of light in the night sky. Optical telescopes detect this visible light too, and other types of telescopes detect their radio waves.

Galaxies

A **galaxy** is an enormous collection of gas, dust and stars spinning in space, held together by gravitational forces. In 1926, the astronomer Edmund **Hubble** (1889–1953) classified the numerous galaxies according to their shape, designating a letter to each of the four main types:

- E—elliptical galaxy
- S—spiral galaxy
- BS—barred spiral galaxy
- Irr—irregular galaxy.

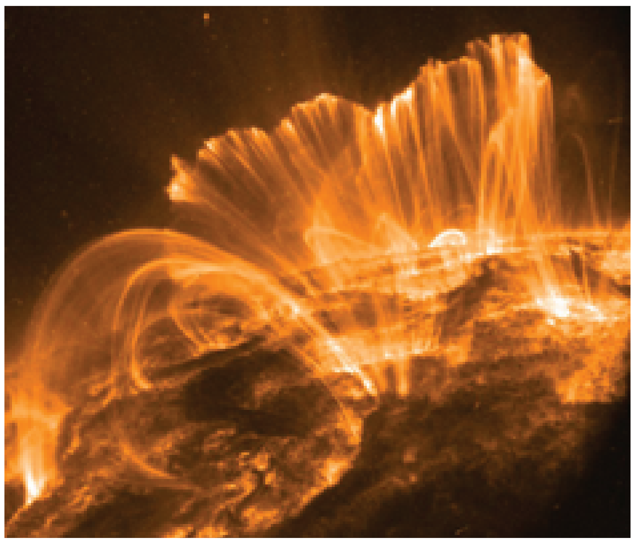
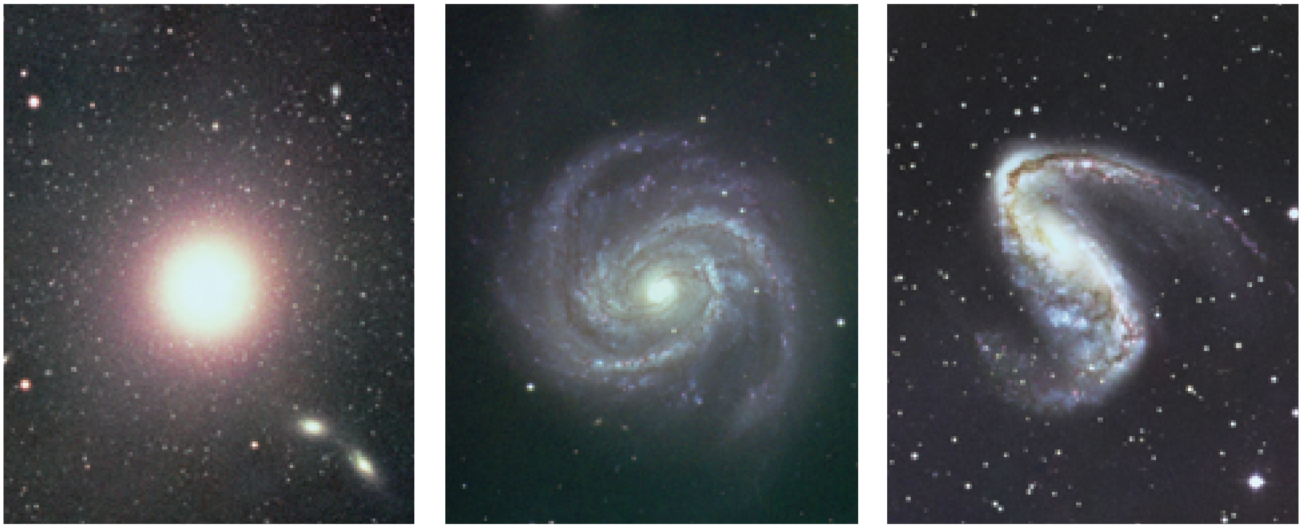


Fig 9.3.2 The Sun is a typical, ordinary-sized star.



E—**elliptical galaxy:** round or oval with no arms

S—**spiral galaxy:** arms form a pinwheel-shape

BS—**barred spiral galaxy:** similar to a spiral but with a solid bar across the middle

Fig 9.3.3 Three of the main types of galaxies. A fourth type, an irregular galaxy, appears as a random collection of stars with no obvious order.

Science Clip

Messier objects

In 1784, a French astronomer called Charles Messier compiled a list of fuzzy-looking celestial objects, including star clusters, nebulae and galaxies. He assigned M numbers to these objects, many of which are still used today.

Active galaxies

An active galaxy is one that exhibits unusual activity in its centre, such as a quasar or a radio galaxy.

A **quasar** is a galaxy whose centre is so bright that it obscures the outer regions. It is as though a quasar has at its centre a black hole that causes gas and dust to spiral around it, heating up as they near the centre. Some of this matter escapes in jets along the axis of the black hole.

A **radio galaxy** gives off energy in the form of radio waves from clouds of matter that have been blasted to either side of the galaxy.

The Milky Way

Earth and our Sun are part of a galaxy known as the **Milky Way**.

From Earth, the Milky Way looks like a milky band of light stretching across the night sky. If you could see the Milky Way from the outside, however, it would appear as a **spiral galaxy**, 100 000 light years in diameter and containing over one hundred billion stars. It has a bright central bulge, which is 10 000 light years thick, and several arms. Our solar system sits out near the end of one of these arms at about 30 000 light years from the centre. Along the spiral arms of the Milky Way are **open clusters** containing a few hundred stars. Surrounding the outer regions are more dense groups called **globular clusters**, consisting of up to one million stars. Omega Centauri is a globular cluster that can be seen with the naked eye—it looks like a fuzzy, bright star.

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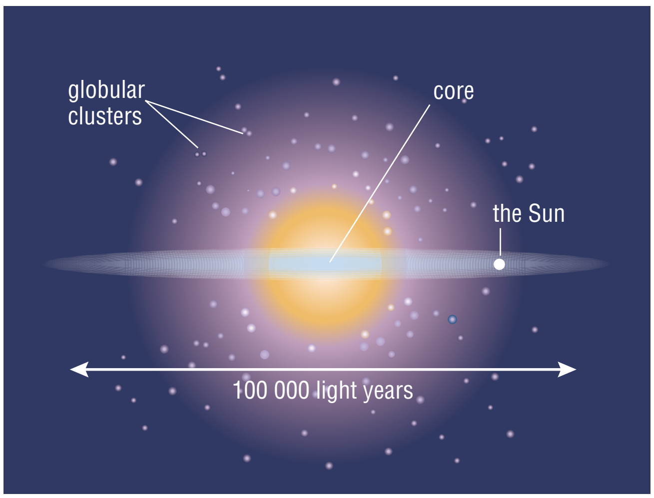


Fig 9.3.4 A side view of the Milky Way

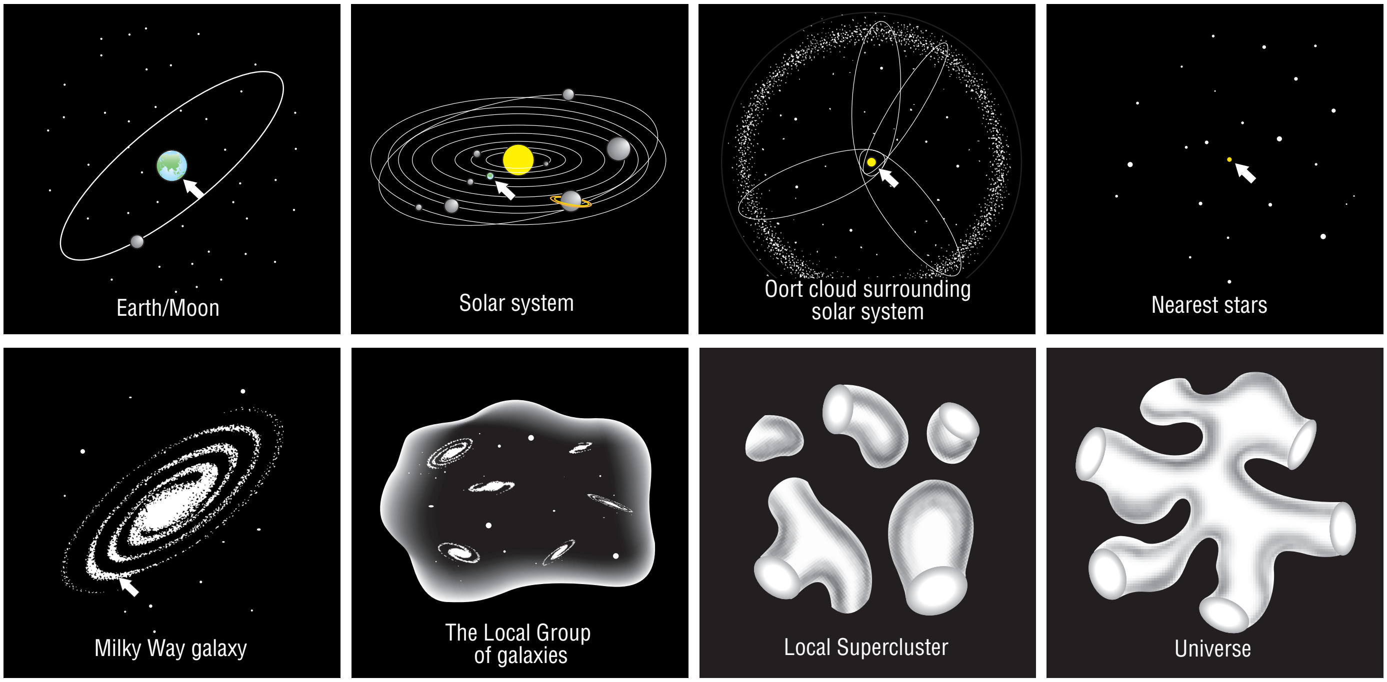


Fig 9.3.5 Earth's place in the solar system, galaxy and universe

Science Clip

Watercourse in the sky

The Kaurna, an Indigenous tribe from South Australia, see the sky as *Womma*, the celestial plains, and the Milky Way as *Wodliparri*, a watercourse winding through its stars.

Bigger and bigger

The Milky Way galaxy is part of a group of more than 30 galaxies, which are referred to as the **Local Group**. Only one of these, the Andromeda galaxy, is bigger than the Milky Way. The Local Group, in turn, is part of the **Local Supercluster**. Superclusters combine to form part of the Universe.

Worksheet 9.3 Parts of a galaxy

PP Drag-and-drop

The Earth's atmosphere absorbs and distorts light coming from objects in space, therefore limiting the usefulness of Earth-based telescopes. Any telescope stationed in outer space, however, is entirely above the atmosphere and will receive images of much greater brightness and detail than the images formed by identical ground-based telescopes.

Since 1990, the **Hubble Space Telescope (HST)** has taken un-obscured images of objects in space with more detail than any ever obtained before.

Telescopes

Some objects in the universe can be seen because they emit electromagnetic radiation in the form of visible light waves. However, many objects, such as neutron stars, radio galaxies and pulsars, give out their energy as non-visible forms of electromagnetic radiation, such as infra-red, microwaves and radio waves. Only visible light and radio waves make it to Earth, and so there are two types of large Earth-based telescopes:

- **optical telescopes**—these use large mirrors to collect and focus visible light
- **radio telescopes**—these use large parabolic dishes to collect radio waves.

Both types of telescopes provide valuable information about the size, composition and movement of stars and galaxies.

Fig 9.3.6 The Australian telescope compact array near Narrabri in New South Wales detects radio waves from objects such as pulsars. Several telescopes are placed together so that they form the equivalent of a much larger single telescope.

Career Profile

Astronaut

An **astronaut** can be involved in:

- commanding space missions
- working while on a mission, performing experiments, repairs or other tasks
- piloting the space shuttle (or vehicle) through ascent, on-orbit, re-entry and landing phases of flight
- planning, testing, training and preparing for space missions.

A good astronaut will be able to:

- work with a large team of people
- maintain physical fitness and health in preparation for the demands placed on their bodies during missions
- perform experiments and tasks in difficult environments
- be a good leader and be able to make decisions under pressure.

Science Clip

Hubble trouble!

Shortly after the Hubble Space Telescope was launched in 1990, scientists feared it would become a billion dollar dud, as an error in its mirror, one-fiftieth of the width of a human hair, caused blurred images. In 1993 the space shuttle *Endeavor* undertook a mission to fit a series of small corrective mirrors. The mission was successful, and now Hubble produces breathtaking, crystal-clear astronomical images.

Fig 9.3.7 Astronauts carry out mirror repairs on the Hubble Space Telescope (HST) from the space shuttle *Endeavor*.

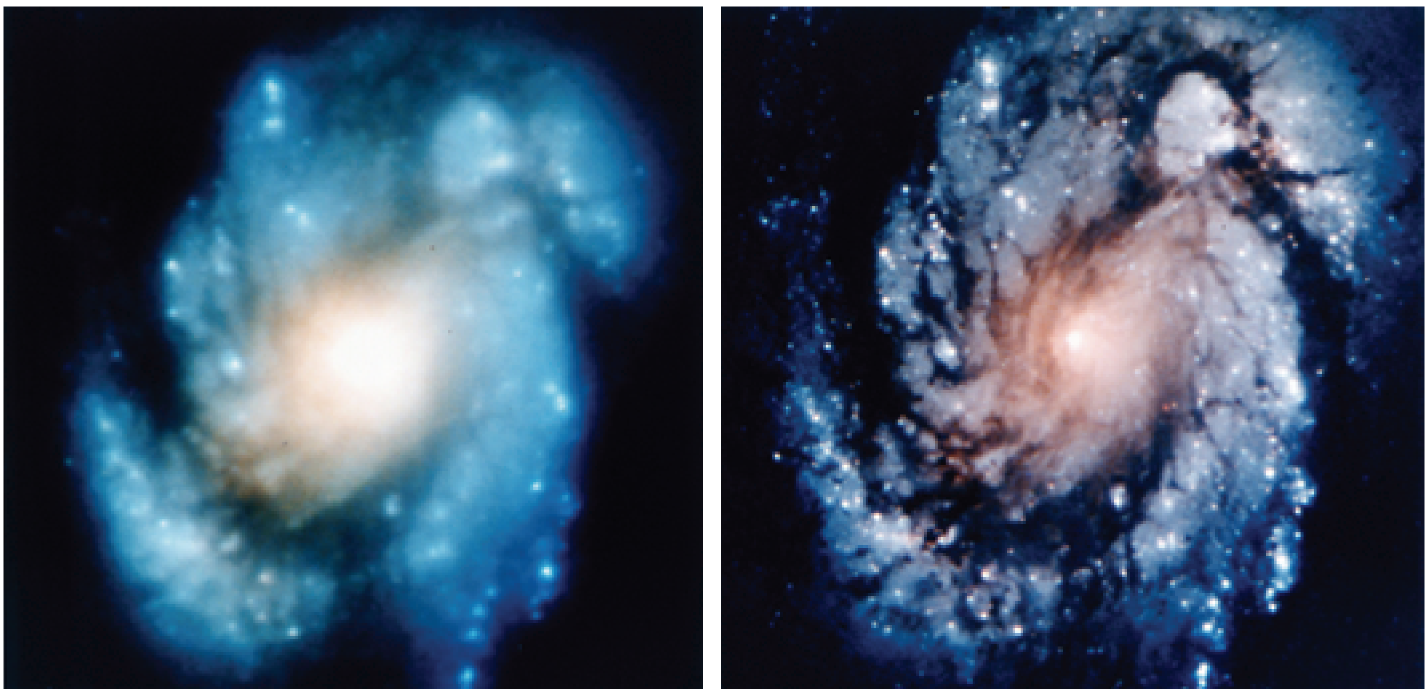


Fig 9.3.8 Comparison images of galaxy M100 before and after the Hubble Space Telescope mirror repairs.

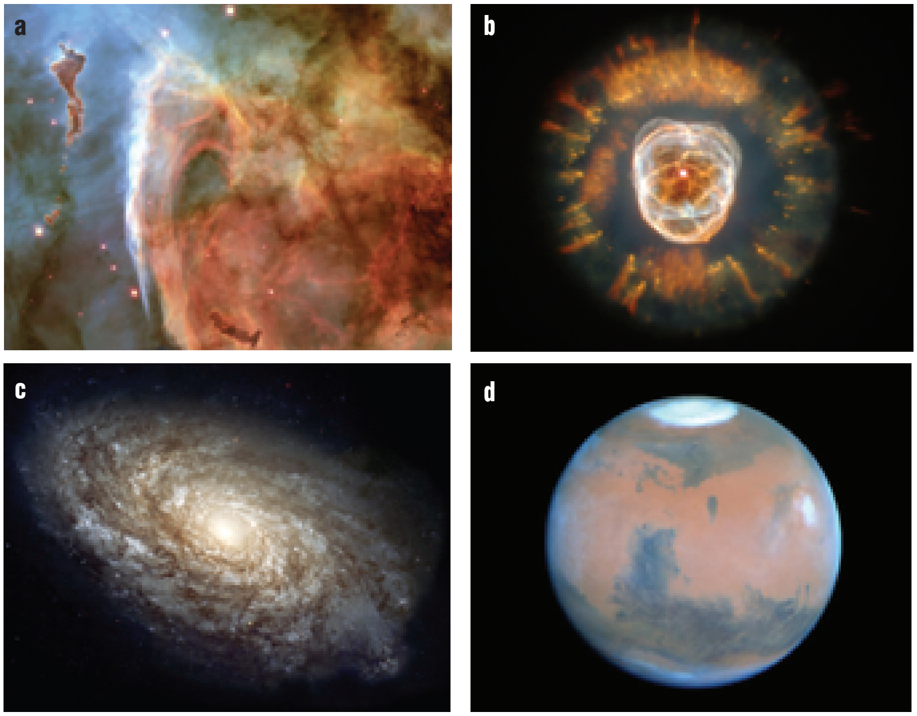


Fig 9.3.9 These pictures were taken by the Hubble Space Telescope. **a** The Carina nebula shows many new stars forming in enormous gas clouds. **b** The Eskimo nebula looks like a face surrounded by a furry parka when viewed from Earth-based telescopes. The Hubble shows much more detail. **c** This spiral galaxy shows older yellow stars in the centre. The arms are blue due to the ongoing formation of young blue stars. Interstellar dust is seen as dark patches in the arms. **d** This image of Mars is considered the 'best ever'.

9.3 QUESTIONS

Remembering

1 **List** the four main types of galaxies.

2 a **State** the distinguishing feature of an active galaxy.

b **List** two examples of active galaxies.

3 **List** the following component of the universe in order from smallest to largest:
Solar system, Local supercluster, the Sun, Universe, Earth, the Moon, Oort cloud, Local group, Milky Way

Understanding

4 **Define** the term *galaxy*. L

5 Copy these statements and **modify** any that are incorrect so that they become true.

a The Milky Way galaxy is a cluster galaxy.

b The Milky Way galaxy contains less than 100 billion stars.

c Earth is located in the centre of the Milky Way galaxy.

d Omega Centauri is a globular cluster that cannot be seen with the naked eye.

6 **Describe** the shape of the Milky Way galaxy when viewed from the side.

7 The Hubble Space Telescope has expanded our knowledge of the Universe. **Outline** three ways it has achieved this.

8 **Outline** how the Milky Way relates to the 'local group'.

Applying

9 **Identify** the following galaxy types:

a a galaxy whose centre is very bright

b a galaxy that emits radio waves.

10 **Identify** the galaxies shown in Figure 9.3.10 as elliptical, spiral, barred spiral or irregular.

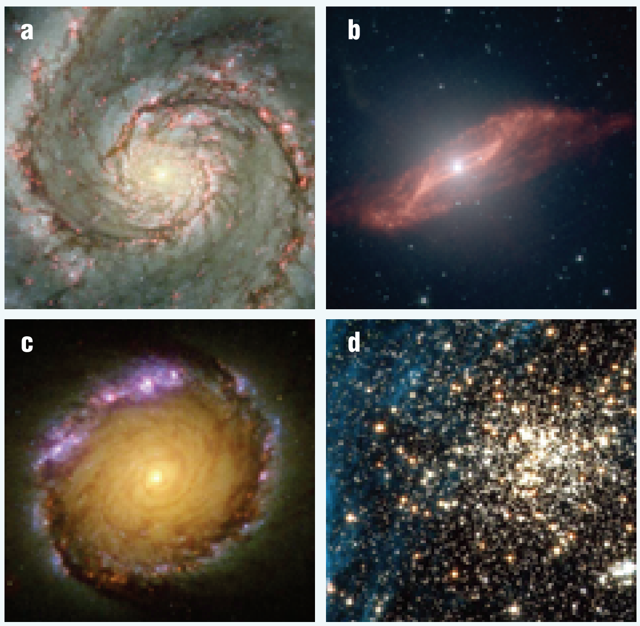


Fig 9.3.10

>>

Analysing

11 **Contrast**:

- **a** an elliptical galaxy with a spiral galaxy
- **b** a space telescope with an Earth-based one
- **c** a radio telescope with an optical telescope
- **d** images from the Hubble Space Telescope before and after the correction.

Evaluating

12 **Predict** whether the spiral galaxy shown in Figure 9.3.3 is spinning clockwise or anticlockwise.

13 **Propose** a reason for why telescopes are often built on the top of mountains.

Creating

14 **Construct** a diagram of the Milky Way galaxy when viewed:

- **a** from above
- **b** from the side.

15 **Identify** where Earth is located in each of the diagrams you have constructed in Question 14.

16 One type of galaxy has no regular shape and so is called an 'irregular galaxy'. **Construct** a diagram of what this might look like.

17 In the 1960s there was a luxury car called the Ford *Galaxy*. Imagine that Ford wants to reintroduce the *Galaxy* model and has employed you to design a badge for the new car.

- **a** **Design** a *Galaxy* badge, but be careful because Subaru already uses a set of stars for their car badge and yours must look very different to it.
- **b** **Explain** what your badge means and how it relates to a galaxy.

9.3 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1 Gather information on major Earth-based telescopes, such as the Australian telescope array, the Keck optical telescope in Hawaii, USA, and the Arecibo telescope in Puerto Rico.

2 Research information on the Parkes radio telescope in New South Wales. Specifically:

- **a** State what its main purpose is.
- **b** Outline what type of research is performed by this telescope.
- **c** Describe some of the major achievements that have been made by this telescope.
- **d** Present your information as a tourist information brochure for people who visit the Parkes telescope. L

3 Find information on the work of Edwin Hubble and give an account of his life. Include: L

- **a** personal details, such as date of birth, country of origin etc.
- **b** his education, type of work performed and his major contributions to scientific knowledge
- **c** important events in his life.

e-xploring

PP Web Destination

Connect to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations and take a trip from the far reaches of the Universe, into the Milky Way, into the solar system to eventually land on Earth. Alternatively, use 'Power of ten' as keywords in an Internet search.

9.3 PRACTICAL ACTIVITY

1 Globular clusters

Aim

To locate globular clusters on a sky map

Equipment

- The program SkyGlobe installed on a computer that runs Windows

Method

1. Double-click the SkyGlobe.exe file to begin SkyGlobe.
2. Set the location to the city nearest you by typing L and selecting a location. (You may need to first select 'More locations'.)
3. Find one of the following globular clusters by typing F, then selecting 'Messiers'.
4. Describe the position of each globular cluster, and the constellation it is part of: globular clusters M2, M3, M4, M5, M15.

Unit 9.4 Satellites

context

The Moon, the International Space Station, the Hubble Space Telescope and Halley's Comet are all **satellites** that orbit a much larger object. Apart from the Moon, all other satellites orbiting around Earth are artificial—they were put into orbit by humans. Each artificial satellite is specialised for its specific purpose. This might be sending and receiving communication and navigation signals, watching the weather, surveying the land surface, studying space or even for spying on what is happening in other countries.

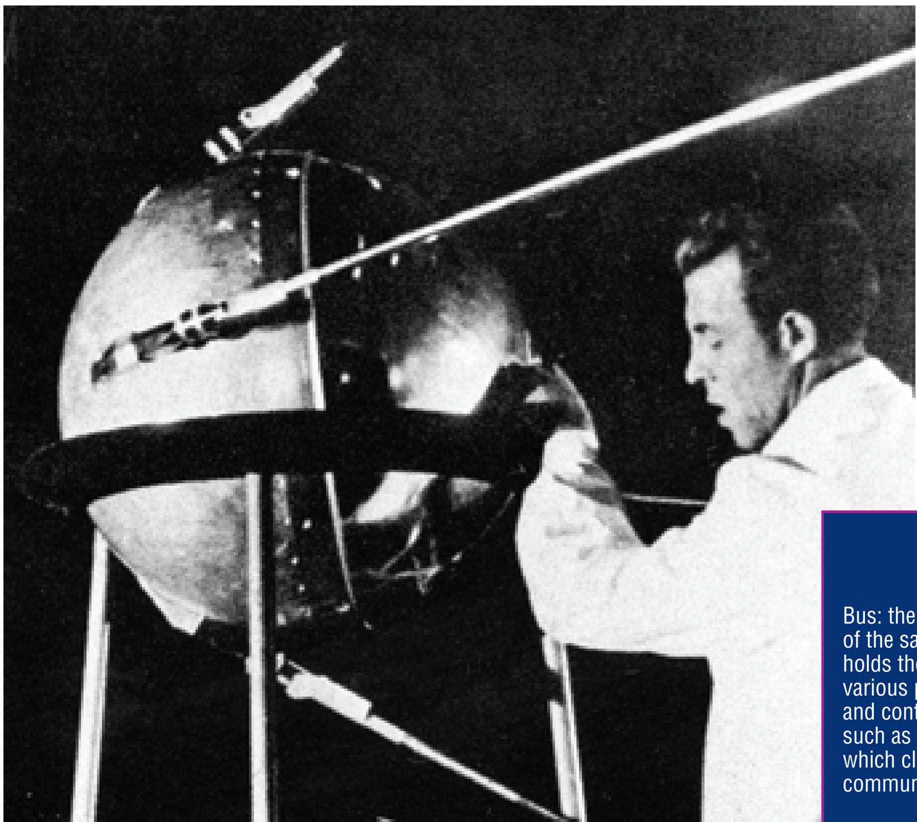


Fig 9.4.1 The Russian *Sputnik 1* was the first artificial satellite ever to be placed in orbit. It orbited Earth for 21 days in 1953.

Science Clip

Science fiction becomes fact

The first person to suggest that satellites could be used for communication was science fiction writer Sir Arthur C. Clarke (1917–2008) in 1945. Over 20 years later, the first geostationary communications satellite was launched into what is known as the Clarke Orbit. This was the beginning of satellite TV.

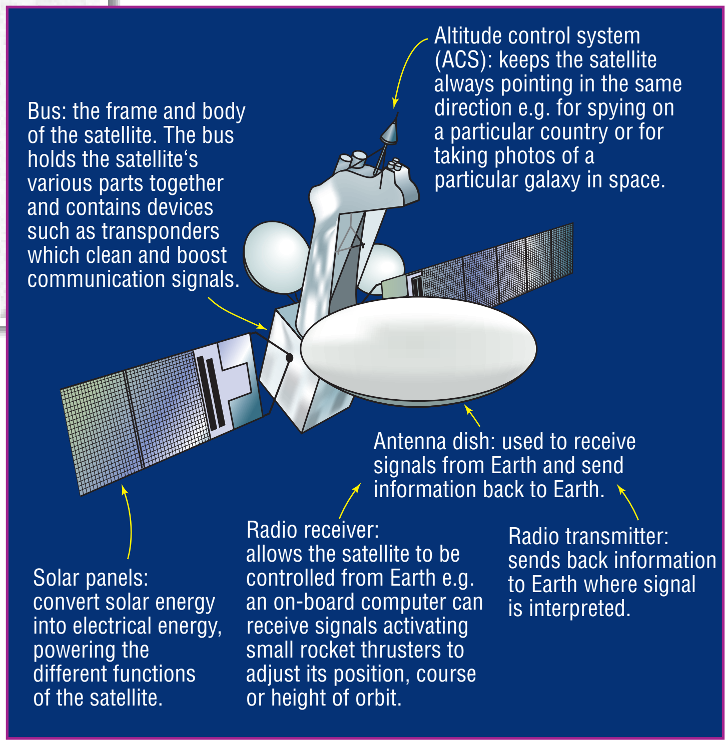
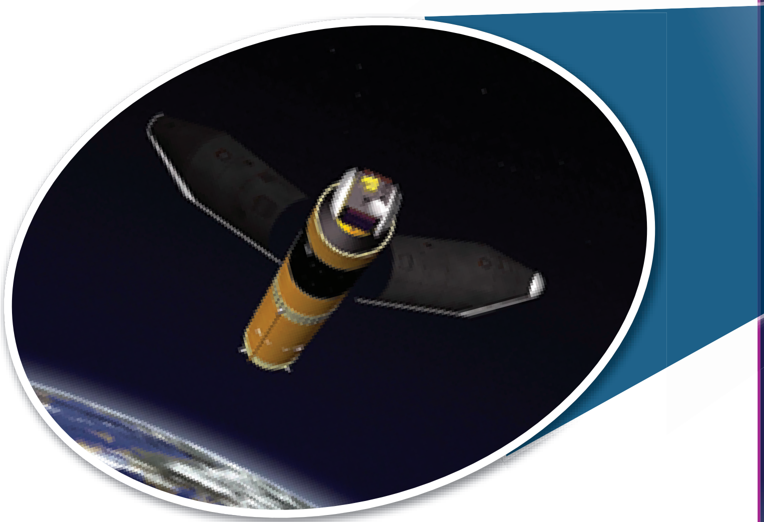


Fig 9.4.2 The *Galaxy-25* (*G-25*) communications satellite, known until 2007 as *Intelsat 5*.

Artificial satellites

A satellite is any object in space that travels around a larger object. The planets of our solar system are **natural satellites** that orbit around the Sun and so are the various moons that are in orbit around the planets.

Artificial satellites are sent into space on board spacecraft or rockets. Once they are in the right position they are detached from the spacecraft and most continue to orbit Earth without any assistance. Most satellites use solar energy to carry out their functions.



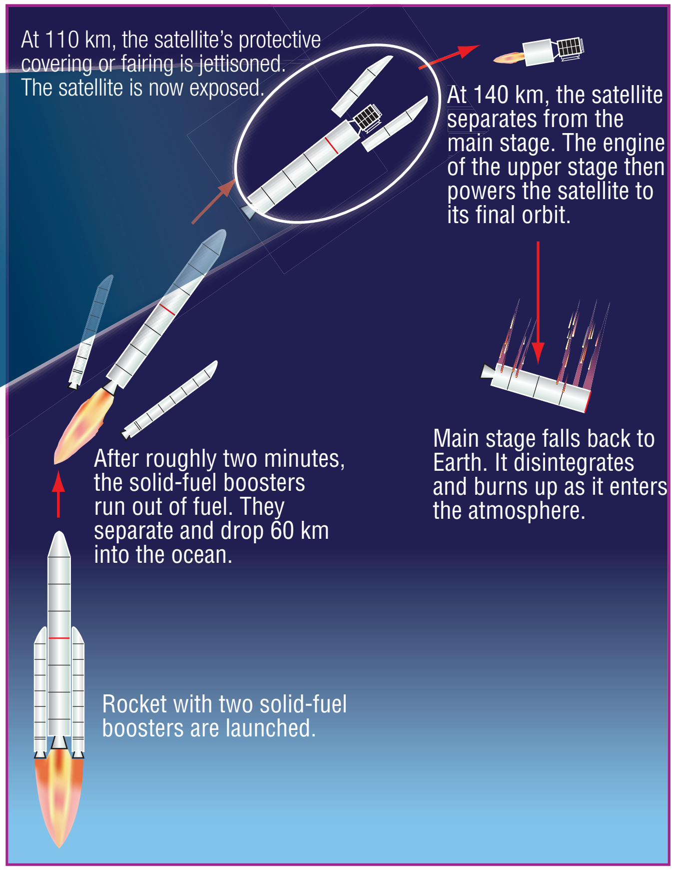


Fig 9.4.3 Deployment of a satellite from an *Ariane 5* rocket.

Science Clip

How many satellites?

It is estimated that there are about 3100 artificial satellites in orbit around Earth. Most, however, are not operational. Only 600 to 1000 of these satellites are actually working.

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Satellite orbits

Satellites are placed into several different types of orbits, depending on their function. The three main orbits are:

- **geostationary orbit**—Satellites in this orbit take 24 hours to revolve around Earth and are always above the same point on the Earth's surface. Most communications satellites are in geostationary orbits.
- **asynchronous orbit**—Observation satellites are placed into this orbit. They move in the same rotational direction as the Earth but more quickly, so they pass over different parts of the Earth's surface.
- **polar orbit**—Satellites in this orbit move in a path at right angles to the rotation of the Earth, ensuring complete coverage of the planet over time as it rotates under them.

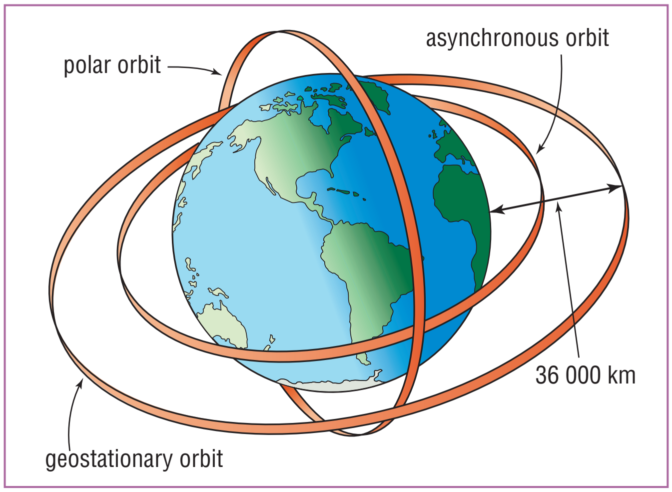


Fig 9.4.4 Types of orbit (Note that the scale of orbit is shown much larger for the sake of clarity.)

Communications satellites

Communications satellites relay information, such as telephone calls, television signals and Internet data, over long distances and around the curvature of the Earth. Communications satellites operate from geostationary orbits that are 35 900 kilometres above the Earth.

Satellites

Nearly all international phone calls get to their destination (e.g. Tokyo, Japan) via a communications satellite in orbit around Earth. An international phone call is first directed to a nearby Earth station containing an antenna. This then sends the call up to a communications satellite, such as Australia's *Optus D2*, in the form of an electromagnetic wave. By now the signal has probably been distorted and weakened by its journey through the atmosphere and it is the job for one of the many **transponders** in the satellite to 'clean' it and boost it. The satellite then relays the boosted signal back to another Earth station at a distant location (e.g. near Tokyo), which will then send the call via the telephone system to their destination. Although electromagnetic waves carry information at the speed of light, the large distances involved via satellite can add a delay of up to half a second in conversations.

Fig 9.4.6 The *Optus D2* communications satellite

Fig 9.4.5 Most communications satellites (for telephone, TV etc.) orbit so that they are always located over the same point on Earth. This allows satellite dishes to be fixed in the direction of the satellite. If the satellite was in some other orbit, the dish would need to 'track' the satellite to keep in contact with it.

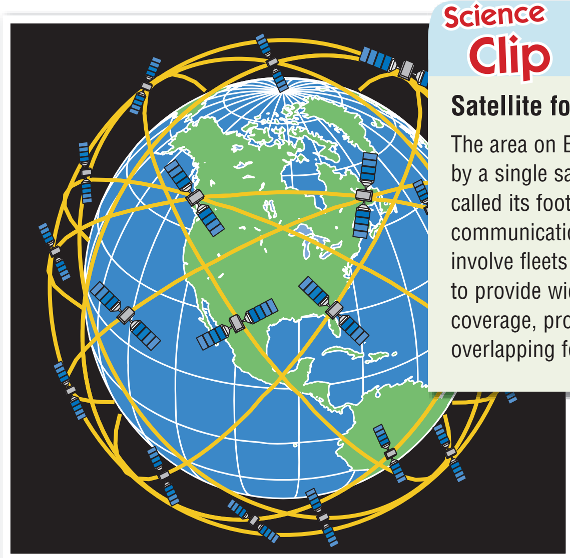


Fig 9.4.7 Overlapping satellite footprints ensure that there is always excellent coverage wherever you go on Earth.

Science Clip

Satellite footprints

The area on Earth reached by a single satellite is called its footprint. Many communications systems involve fleets of satellites to provide wider coverage, produced by overlapping footprints.

Remote-sensing satellites

Many different sensors are now mounted onto satellites. The information from the satellite allows scientists to research and monitor the Earth's features without going to space themselves or waiting for photographs taken on space missions. This is called **remote sensing** and is now commonly used for studying and monitoring:

- weather patterns
- the temperature of the Earth and oceans
- the shape of the land surface
- the sea floor by penetrating the oceans and ice
- natural phenomena, such as bushfires and volcanoes
- vegetation and crop types in farming and forestry
- features of the atmosphere, including the size of the ozone hole
- the movement of animals and pests

- pollution, algal blooms and oil spills in lakes and the oceans
- the activities of other countries (i.e. spying or espionage).

The information obtained from remote sensing is used for navigation, weather forecasting, scientific research and military purposes.

Fig 9.4.8 A satellite image of Sydney.

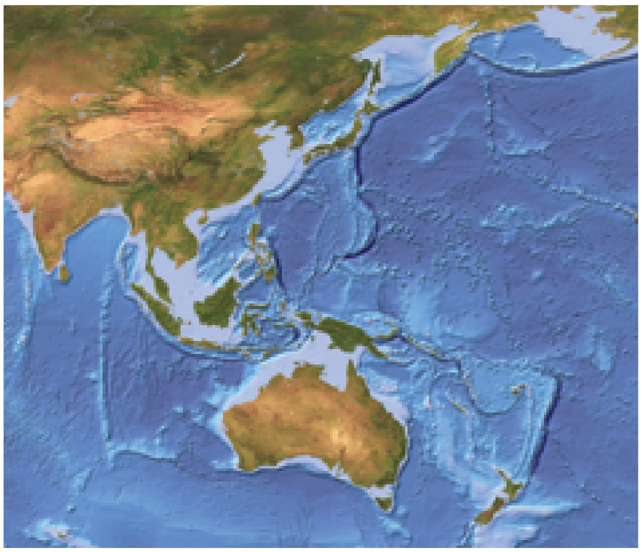


Fig 9.4.9 This remotely sensed computer-generated image of the Earth is based on satellite data. It shows water (blue) bare land (brown) and vegetation (green). The shape of the ocean floor is shown by different shades of blue.

Fig 9.4.10 A satellite image of the bushfires in Victoria on 7 February 2009, the day when Australia suffered its worst natural disaster. Nearly 180 people died on this day, 2000 homes and buildings were burnt down and nearly 10 000 people were left homeless.

How remote sensing works

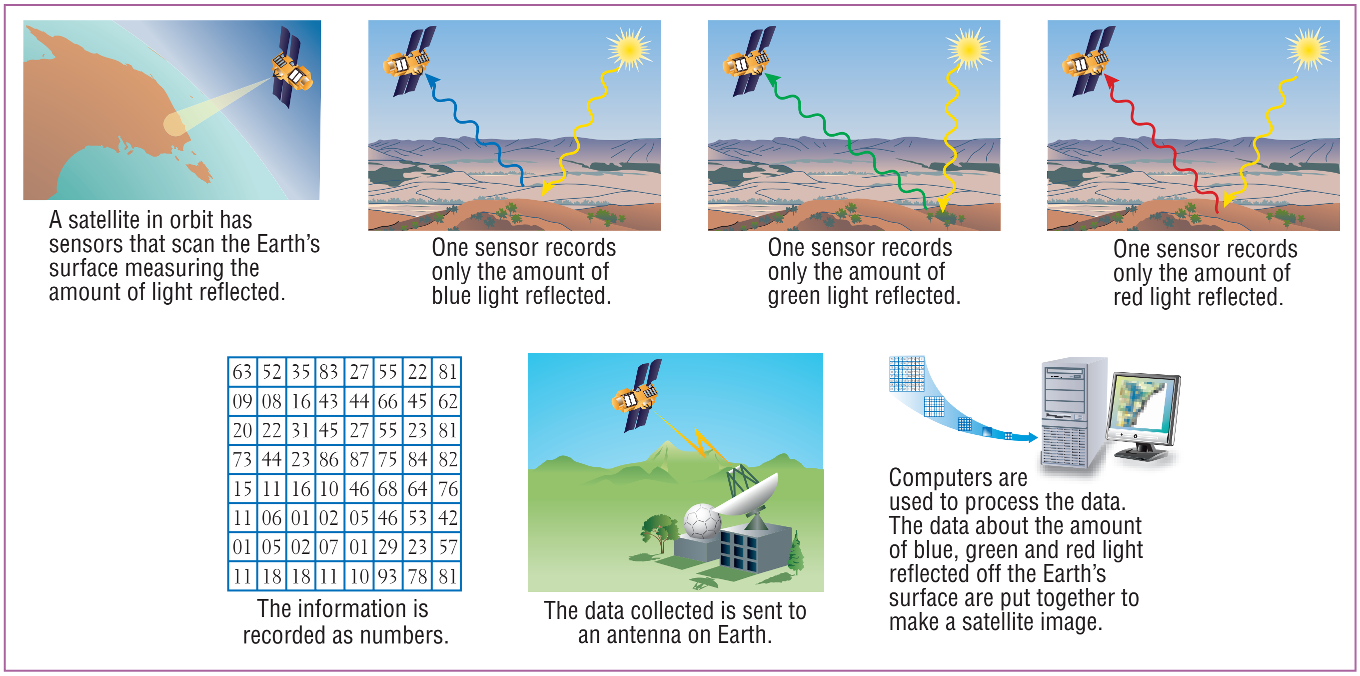
Light and other forms of energy, such as radioactivity and heat, are reflected from the surface of the Earth and can be analysed to reveal a great deal about what is happening. Remote sensing can be used to take 'normal' photographs, but special images can also be produced using special sensors and computers. These images often have **false colour** added to various parts to make information clearer. Examples are 'heat photos' that record the infra-red radiation emitted or reflected from the Earth's surface.

Weather

Weather or **meteorology** satellites are found in both geostationary and polar orbits. They record images and measure temperature, pressure and humidity using specialised sensors. Combined with data collected on Earth, they help forecasters with their predictions and can provide better advance warning of many life-threatening phenomena, such as cyclones or severe storms. Unfortunately, some phenomena such as tornadoes form so quickly that remote sensing is still too slow to give much warning.

Navigation

The **Global Positioning System**, or **GPS**, is probably the best example of a navigation satellite system. The GPS consists of 24 satellites spread among six different orbits 20 000 kilometres above the Earth. The GPS satellites contain solar panels for power, and atomic clocks.



63	52	35	83	27	55	22	81
09	08	16	43	44	66	45	62
20	22	31	45	27	55	23	81
73	44	23	86	87	75	84	82
15	11	16	10	46	68	64	76
11	06	01	02	05	46	53	42
01	05	02	07	01	29	23	57
11	18	18	11	10	93	78	81

Fig 9.4.11 How remote sensing works

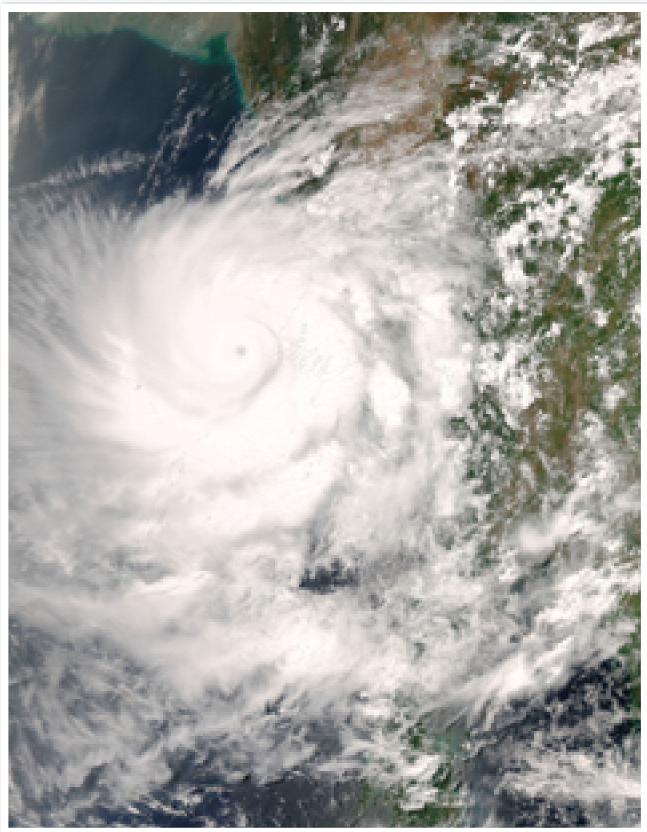


Fig 9.4.12 A satellite photograph of cyclone Nargis, which wiped out much of southern Myanmar (Burma) on 2 May 2008.

Tracking stations on Earth send information about each satellite's position to a master control centre. This, in turn, sends information to the satellites, so that the satellites 'know' their position relative to the Earth. A GPS receiver on Earth can receive signals from at least four GPS satellites and use them to calculate your position on Earth.

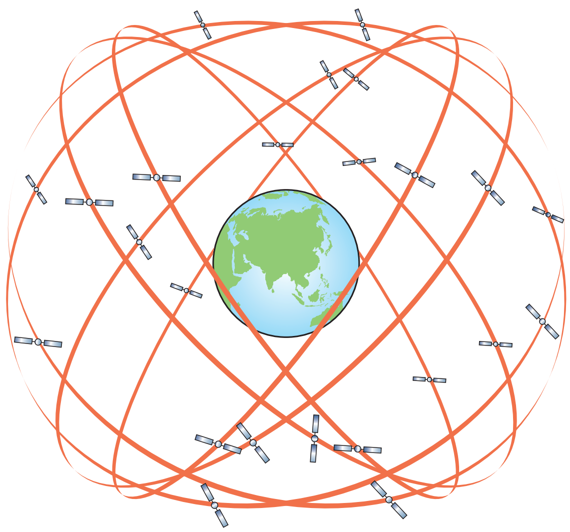


Fig 9.4.13 Twenty-four Navstar satellites in different orbital planes provide global coverage for the GPS.

Career Profile

Geoscience technician

Geoscience technicians assist scientists in finding and developing mineral and fuel resources hidden in the earth. They also look after the practical tasks involved in servicing a remote field operation.

Geoscience technicians can be involved in:

- undertaking geophysical surveys
- using GPS to establish ore deposit locations
- operating geophysical instruments to complete surveys that outline hidden rock features. This may involve measuring magnetism or gravity
- collecting, recording and transporting samples of rock, soil, drill cuttings and water
- analysing information collected from a range of sources and carrying out computer processing of the data
- using digital technology to produce geological and geophysical maps
- surveying the Earth's surface and rocks using satellite remote sensing.

A good geoscience technician will be able to:

- participate in scientific activities and use high-tech instruments
- prepare accurate records and reports
- work as part of a team
- have an interest in rocks, fossils and minerals
- stay physically fit
- work in remote locations.

Fig 9.4.14 A geoscience technician finding his location using a hand-held GPS receiver.

Some GPS receivers contain electronic maps on which they display your position. Many bushwalkers now use hand-held GPS receivers instead of maps, and car makers now commonly include dash-mounted GPS receivers as a standard feature.

Worksheet 9.4 Using GPS

Remote-sensing spacecraft

Exploration of the planets is one of the major achievements of science. The solar system is huge. Sending remote-sensing spacecraft to explore it is far safer and more cost-effective than sending humans. Remote-sensing spacecraft can be smaller; there is no need to provide food, air or accommodation; and the spacecraft do not need to return to Earth. Huge amounts of information have already been gathered using remote-

Fig 9.4.15 The Mars rovers are robots that act as remote sensors. Information collected is sent back to Earth via satellites that orbit Mars.

sensing techniques. Observing the bodies of our solar system is commonly done with orbiting spacecraft, flyby, probe and lander missions. Most of the instruments that survey the Earth have been adapted for the exploration of the surfaces and atmospheres of the other planets.

NASA's twin robot geologists, *Spirit* and *Opportunity*, landed on Mars in 2004. They were equipped with state-of-the-art sensors and tools designed to collect information about the Martian environment. They include panoramic cameras, spectrometers, magnets, a microscope and a rock abrasion tool.

The Phoenix Mars mission launched in 2007 was designed to study the history of water in the Martian arctic's ice-rich soil.

Fig 9.4.16 NASA's Phoenix Mars Lander in 2008—the extended arm of the robot holding scientific instruments can be seen.

9.4 QUESTIONS

Remembering

1 **List** three naturally occurring satellites of the Sun.

2 **List** three types of information relayed by communication satellites.

3 **State** two possible uses for a hand-held GPS receiver.

4 **List** the equipment on *Spirit* and *Opportunity*.

5 **Recall** the three types of satellite orbits around Earth by drawing a diagram of each.

Understanding

6 **Outline** the usefulness of *Optus D2* to communication.

7 **Clarify** the purpose of remote sensors.

8 False colour is added to some satellite images. **Explain** why.

9 **Outline** the information gathered by:

- **a** a weather satellite
- **b** an Earth resource satellite.

10 **Outline** the main task of remote-sensing spacecraft.

11 **Explain** why remote-sensing spacecraft are being used to explore the solar system rather than manned spacecraft.

12 **Describe** the advantages of using a geostationary satellite for communication.

13 Imagine that an Ariane rocket is delivering a satellite into orbit. **Outline** what happens to each of the following when they are no longer needed after the launch:

- **a** solid fuel booster rockets
- **b** main stage rocket.

14 **Predict** what would happen to a satellite orbiting the Earth if the Earth's atmosphere suddenly extended beyond its orbit.

15 Satellites rotate so that their transmitters always face the same point on the Earth's surface. **Discuss** the reasons for this.

Applying

16 A satellite dish used for TV or entertainment always points in the same direction. **Identify** the type of satellite from which it receives its signals.

Analysing

17 By listing their similarities and differences, **compare**:

- **a** a natural satellite with an artificial satellite
- **b** a geostationary orbit with a polar orbit
- **c** a remote-sensing satellite with a remote-sensing spacecraft.

>>

Evaluating

18 **Propose** how the information from remote sensing could be misused by the military.

Creating

19 Figure 9.4.17 shows the footprint of a single satellite. Copy the diagram and **explain** how, by adding two more satellites, the entire Earth may be covered by footprints from a three-satellite system.

20 **Construct** a crossword to **summarise** remote sensing and its uses. Ⓛ

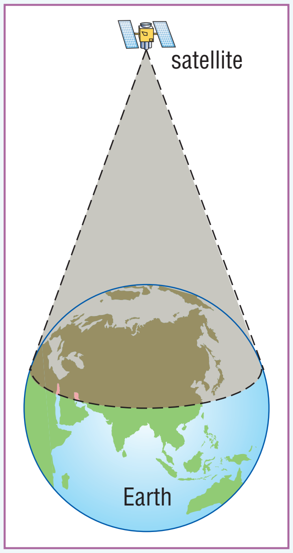


Fig 9.4.17

9.4 INVESTIGATING

Investigate your available resources (e.g. textbooks, encyclopaedias, Internet etc.) to:

1. State the names and functions of several current satellites. Include one or more Australian satellites (e.g. *Optus Sat*, *ARIES-1*, *FedSat 1*).
2. Research the USA Strategic Defense Initiative (nicknamed the Star Wars program) that was introduced by former US president Ronald Reagan in 1983.
   - **a** Outline the aims of the project.
   - **b** Describe any current scientific research into the Star Wars project.
   - **c** Assess the advantages and disadvantages of the Star Wars project.
   - **d** Evaluate the attitudes of some governments to the Star Wars project. (e.g. Why does Russia object to it?) Include the Australian government's position on the matter.
   - **e** Assess the Star Wars project and present your own opinion as to whether it should be completed.
   - **f** Present your information in a manner discussed previously with your teacher.

e-xploring

Complete the following activities by connecting to the ***Science Focus 2 Second Edition Student Lounge*** for a list of web destinations.

PP Web Destination

- Research more about the Phoenix Mars mission, and its work in collecting information on Mars. Imagine you are an education officer from NASA. Construct a Powerpoint presentation or website to summarise information for people wanting to know more about the Phoenix Mars Lander. Your website should be concise and clear, containing no more than 10 pages. Start your research using the NASA website. Ⓝ
- Construct a model of a remote-sensing space probe or satellite. You will find many examples on the Internet. Search the NASA site for 'models' or 'model'.
- Go to Google Maps and use the search function to find a map and satellite view of where you live and your school.
- Google Maps has a navigation function. Use it to find the best directions from home to school. Assess if this is the route you actually take and explain why it might be different.
- For fun, use the navigation function to find directions from your home to somewhere overseas (say Los Angeles City Hall). Be prepared for a lot of kayaking!

9.4 PRACTICAL ACTIVITY

1 Satellite speed

Aim

To investigate the relationship between satellite speed and orbit radius

Equipment

- a smooth hollow tube (e.g. the body of a pen)
- cotton or thin string (50 cm)
- four small rubber stoppers with holes
- stopwatch
- scissors

Method

1. Construct the apparatus shown in Figure 9.4.18.
2. Spin the top stopper (the 'satellite') so it orbits at a steady speed about 15 cm from the top end of the tube (the 'Earth'). Adjust the speed of orbit until the orbital radius remains steady at about 15 cm. Once you have achieved a steady orbit, find the time taken for 10 revolutions.
3. Reduce the force of 'gravity' by cutting off one of the lower stoppers.
4. Orbit the 'satellite' once more at a steady speed, but at a distance of 20 cm from the 'Earth'. Again, find the time taken for 10 revolutions.
5. Reduce the force of 'gravity' even more by cutting off another stopper, and orbit the 'satellite' steadily at a distance of 25 cm from 'Earth'.
6. Try spinning the 'satellite' slower or faster than that required for a steady orbit. Note what happens.

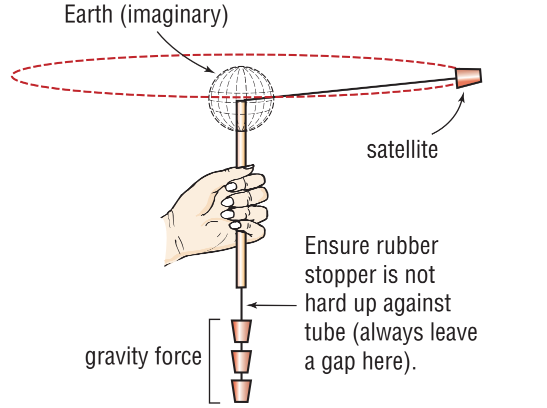


Fig 9.4.18

Questions

1. A satellite is placed in a steady orbit around the Earth. **Explain** the effect of its distance from the Earth on its speed in orbit.
2. **Predict** what may happen to a satellite in a steady orbit if it suddenly:
   - **a** speeds up
   - **b** slows down.
3. **Explain** why you needed to increase the radius of orbit when each stopper was removed.

> **Safety**
> Wear eye-protecting goggles and carry out this experiment in an open space where no obstacles can be hit.

CHAPTER REVIEW

Remembering

1. **Name** the space rocks that pose a threat to Earth.
2. Alpha Centauri is about 42 trillion kilometres from Earth. **Name** the unit of measurement used in astronomy to avoid having to deal with such large numbers.
3. **List** four different types of galaxies.
4. **Name** the type of galaxy that has a black hole near its centre.
5. **Name** the two forms of radiation that reach the surface of Earth and which telescopes can collect.
6. **Specify** what the initials GPS stand for.
7. **Recall** three distinguishing features of a comet.

Understanding

8. **Define** a shooting star. L
9. **Outline** the features of an asteroid.

>>

10 The right ascension and declination are two measurements used on the celestial sphere. **Outline** the meanings of these terms.

11 **Outline** how the stars can be used to find which direction is south.

12 **Outline** the origin of the twelve constellations of the zodiac.

13 **Outline** four types of work carried out by astronomers.

14 Satellites can be placed into three different types of orbits. **Identify** these orbits.

15 **Outline** four uses for remote satellites.

16 The Global Positioning System is used for navigation. **Outline** its main advantage.

17 **Describe** what *Spirit* and *Opportunity* are and what they have done.

18 The North Star is almost directly above the North Celestial Pole on the celestial sphere. **Describe** what observers in the Northern Hemisphere would notice about its position over time.

19 **Explain** what type of celestial object is known as a 'star nursery'.

Applying

20 **Identify** the type of space rock that is:

a a dirty snowball that orbits the Sun

b a burning piece of dust or rock that hits the ground

c an irregularly shaped, rocky object also known as a minor planet

d a shooting star that burns out before it strikes the ground.

21 From the following list, **identify** the satellites: the Moon, the International Space Station, Mars, Halley's Comet, Titan (a moon of Jupiter) *Optus D2*, the space shuttle in orbit.

22 Copy the diagram of the comet below and **use** your knowledge of comets to add the two tails.

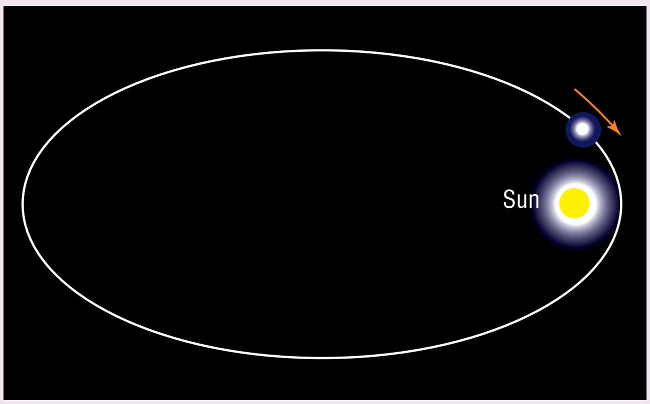


Fig 9.5.1

23 **Identify** the right ascension and declination of the star labelled S in Figure 9.5.2.

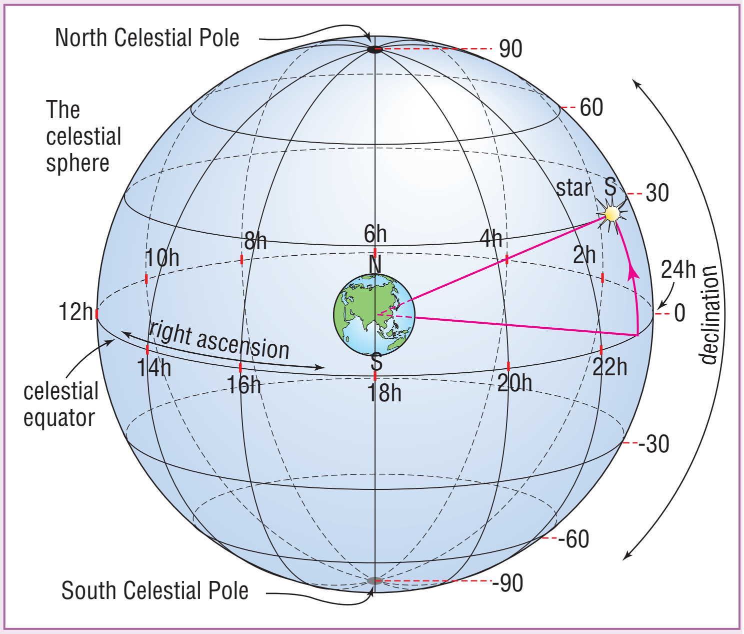


Fig 9.5.2

24 **Identify** the type of constellations that are close to the ecliptic on the star map on page 285.

Analysing

25 **Contrast** a meteor with a meteorite.

26 a **Contrast** the number of stars visible on a clear night in the country with the number visible in the city.

b **Propose** reasons for any differences.

27 **Distinguish** a pulsar from a quasar.

Evaluating

28 Australia was the fourth nation to build and launch a satellite in 1967. It is now almost completely reliant on satellites owned by other countries. **Assess** the following statement: *It's time for Australia to rejoin the space race.*

29 There are stars in the sky both day and night. **Justify** this statement.

Creating

30 **Construct** a diagram of:

a a spiral galaxy

b a barred spiral galaxy

c an elliptical galaxy.

PP Interactive

PP Chapter Review Questions

Worksheet 9.5 Crossword

Worksheet 9.6 Sci-words

Sci Q Busters

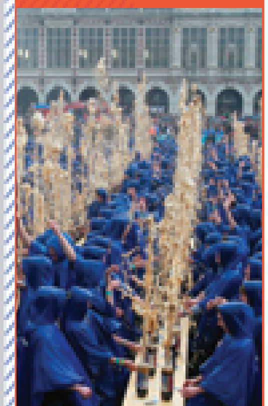
Ask Sci Q Busters team | Mentos madness | Cicadas' wee

Mentos madness

Cicadas' wee

Spider webs

Body bugs!



Mentos madness

Hi Q Busters,

The other day I was on YouTube and came across a reaction between Mentos mints and Diet Coke. Have you seen it? A couple of classmates came over to my place on the weekend and we did it too. It was not as good as the one on YouTube, but it still shot up a long way. We then tried it with regular Coke, but it didn't work as well. It only shot up half the height. Can you tell us how this works and why there was a difference between the two drinks?

Thanks,

Peter

REPLY

Hi Peter,

We have done the experiment a number of times together. The first time we ended up covered in sticky Coke. At first, we thought it was a chemical reaction between the mints and the acid in the drink, mainly because of the fast generation of the bubbles and the difference between diet drinks with other drinks.

We also thought that maybe the caffeine level might affect it. We repeated the experiments with caffeine-free Diet Coke and it worked just as well. So, we concluded that it wasn't the caffeine at all.

You may find this hard to believe but there appears to have been some research on this. A study in the United States actually found that it relates to the surface of the mint and how fast it sinks to the bottom of the bottle.

Here are some of their findings.

- They tested the pH before and after the reactions and found no change.
- It appears that it depends on the factors that affect the growth rate of carbon dioxide bubbles. The rough, dimply surfaces of the mints make excellent bubble growth sites.
- Bubbles grow more quickly when there is low surface tension. The sweetener in Diet Coke is aspartame (or sweetener 951) and it lowers surface tension better than sugar. This explains why diet drinks are better than regular ones.
- Another factor is that the mint is coated with something that contains gum arabic, and this reduces surface tension in the liquid even more.
- Luckily the mints are fairly dense and sink quickly in the drink. This allows for quick bubble creation and these make more bubbles as they rise. We guess this is why it starts out slowly and then we get the final rush to maximum height.

Happy experimenting!

The Q Busters team

Cicadas' wee

Hi Q Busters,

The other day it was 38°C in the shade of this great big gum tree I was under. The noise the cicadas were making was deafening, and then something really weird happened. It started to rain. Not a cloud in the sky and it started to rain. Only very small drops but it was rain! Is it global warming or what?

Regards,

Indya

REPLY

Hi Indya,

We don't think you're going to like the answer to this. It wasn't raining. It was 'cicada wee', which is more commonly known as 'honey dew'.

The cicadas stab into the tree's phloem with their mouth stylets. Stylets are needle-like appendages, so they easily pierce the surface of plants. They then drink the sugar-rich sap from the tree and get rid of the excess water as urine. They probably did it while you were under the tree as a warning to you to go away.

Here is some more information on cicadas that you may not know.

- Australian cicadas are the loudest insects in the world. Large species, such as the greengrocer and double drummer, produce a noise intensity in excess of 120 dB at close range. A rock concert is only as loud as about 110 dB!
- Cicadas spend most of their life underground. Some of the large, common Australian species may live underground as nymphs for around six to seven years. This explains why adult cicadas are much more abundant during some seasons than others.

Good luck dodging wee!

The Q Busters team

Sci Q Busters

Ask Sci Q Busters team | Spider webs | Body bugs!

Mentos madness

Cicadas' wee

Spider webs

Body bugs!

Spider webs

Hi Q Busters,

Why don't spiders get stuck in their own web but other insects do?

From Tannya

REPLY

Hi Tannya,

Insects are not the only things that stick to spiders' webs. The scariest experience is when you walk into a big web at night. Your imagination runs wild as you imagine an enormous spider on your face! Has that ever happened to you?

To answer your question, some spiders do get stuck in their own webs, mainly by accident. To remove themselves, they actually lay down two types of silk threads—one sticky and the other non-sticky. They travel around the web on the non-sticky threads. These are the first to be laid down when making a web.

Web building actually happens in several phases. Here are the steps.

1. The spider begins by attaching a single strand horizontally between two supports, such as twigs or branches. As you can imagine, this is the hardest part. It's done by releasing a sticky thread that is blown away on the breeze with the hope that it will stick somewhere across the gap. This forms the first bridge line which the spider carefully crosses, and reinforces it until it is very strong.
2. It then builds an outside rim—almost like a bike wheel—and attaches spokes and a spiral from the centre to the outer edge of the web. These parts of the web are all non-sticky silk.
3. Now the spider adds the sticky threads or catching threads, again in a spiral pattern. This spiral is connected to the non-sticky spokes. This lets the spider run across from the centre of the web to grab its stuck prey. It goes along a spoke, stepping on the bits that aren't sticky.

So what is the difference between the two types of threads you ask? The sticky thread has small glue-like globules along its length, as you can see in the photo above.

Regards,

The Q Busters team

Body bugs!

Hi Q Busters,

We are studying microbes at school in Science, and our teacher told us that there are 60 different species of microbes that live inside our mouth and heaps of others in our stomach and all over our body. I can't see how this could be true.

Please help!

Leo

REPLY

Hi Leo,

The bad news is that it's not 60 but approximately 600 different species that live in a healthy mouth.

These microbes include viruses, fungi, protozoa and bacteria, with bacteria being the most numerous. Can you believe there are 100 million bacteria in every millilitre of saliva? But keep flossing and scrubbing those teeth and gums or some nasty ones might start to take over.

There are about 500 species of bacteria, weighing about 2 kilograms, living inside the digestive system. There are two main ones that break down carbohydrates and make essential nutrients like vitamins K and B12.

It is estimated that the number of microbes that live on and in your body exceeds the number of cells in the body by up to one hundred times. In scientific terms, you are a walking, talking ecosystem.

The Q Busters team

Head louse with egg

Two bed bugs

Subject

Got a question? Email the Sci Q Busters team at

http://SciQBusters@pearson.com.au

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Page numbers in **bold** refer to key terms in **bold** type in the text

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